PANIMALAR INSTITUTE OF TECHNOLOGY
(JAISAKTHI EDUCATIONAL TRUST)

EC8451
ELECTROMAGNETIC FIELDS
(FOR IV SEMESTER ECE)

Course Name: Electromagnetic Fields (EC-8451) **Year of Study: 2021–2022(R-2017)**

CO1	Apply vector calculus to static electric-magnetic fields in different engineering situations
CO2	Analyze field potentials due to charges & Explain how materials affect electric fields.
CO3	Analyze field potentials due to static magnetic fields & Explain how materials affect electric fields.
CO4	Analyze Maxwell's equation in different forms and apply them to diverse engineering problems.
CO5	Examine the phenomena of wave propagation in different media and its interfaces
CO6	Analyze the nature of Electromagnetic wave propagation in guided medium and Applications of Electromagnetic Fields

UNIT I
INTRODUCTION

Electromagnetic model, Units and constants, Review of vector algebra, Rectangular, cylindrical and spherical coordinate systems, Line, surface and volume integrals, Gradient of a scalar field, Divergence of a vector field, Divergence theorem, Curl of a vector field, Stoke's theorem, Null identities, Helmholtz's theorem.

1. State Stoke's theorem. **[Remember]**(**May 21**,**May 19 17R**, **Nov 17N** ,**May 15**,**Nov 14**,**May 2010,Nov 2009,Nov 2007,May 2007)**

   The line integral of a vector around a closed path is equal to the surface integral of the normal component of its curl over any surface bounded by the path.

$$\oint \vec{H}.\vec{dl} = \int_S (\nabla \times \vec{A}).\vec{ds}$$

2. State Helmholtz's theorem. **[Remember]**(**May 21)**

   Mathematically the Helmholtz's theorem is written as,

$$\therefore \qquad \boxed{\bar{\mathbf{B}} = -\nabla U + \nabla \times \bar{\mathbf{A}}}$$

   where U is a scalar field while $\bar{\mathbf{A}}$ is a vector field.

   Any vector field $\bar{\mathbf{B}}$ can be divided into two components,

   1. Gradient of a scalar field U
   2. Curl of a vector field $\bar{\mathbf{A}}$

3. Define Infinitesimal volume element in spherical polar coordinates. **[Remember]**(**May 19 17R)**

   In spherical polar coordinates, however, the infinitesimal volume element is $r^2 \sin\theta \, dr d\theta d\phi$.

4. State Divergence Theorem. **(May 18N, May 2017N, May 2016N,Nov 2015,May 2013,Nov 2012,May 2011,Nov 2009,May 2009, May 2007,Nov 2006)** **[Remember]**

   Divergence theorem states that the volume integral of the divergence of a vector field is equal to the surface integral of that vector field.

$$\int_V (\nabla.\vec{D}) dv = \oint_S \vec{D}.\vec{ds}$$

5. Write the different coordinate systems. **(May 18N)** **[Remember]**

   Three different coordinate systems, known as Cartesian, cylindrical and spherical.

6. Define gradient of a Scalar field. **[Remember]** **(May 2017N,May 2014,Nov 2013)**

   Gradient is the concept of rate of change of a scalar in the given field. Thus the rate of change of temperature can be given as the example of gradient. The gradient of a scalar field V is a vector that represents both the magnitude and direction of maximum space rate of increase of V.

7. Determine the gradient of the scalar field $F = 5r^2 + r\sin\theta$. **[Apply]** **(May 2016,May 2012)**

$$\nabla F = \frac{\partial F}{\partial r}a_r + \frac{1}{r}\frac{\partial F}{\partial \theta}a_\theta + \frac{1}{r\sin\theta}\frac{\partial F}{\partial \phi}a_\phi$$

$$\nabla F = (10r + \sin\theta)a_\theta + a_\phi$$

8. Convert the given rectangular coordinate A(x=2,y=3,z=1)into the corresponding cylindrical cocordinate. **[Apply]** **(Nov 2010)**

$$\rho = \sqrt{x^2 + y^2} = 3.6$$

$$\phi = \tan^{-1}\frac{y}{x} = \tan^{-1}\frac{3}{2} = 56.3^0$$

$$z = z = 1$$

9. What is the physical meaning of curl of a vector? **[Remember]** **(Nov 2009)**

   Curl gives the rate of rotation Curl of vector $\vec{F}$ Gives work done per unit area.

10. What are irrotational vectors? **[Remember]** **(May 2009)**

    A vector F is said to be irrotational if, $\nabla \times F = 0$

11. What is the physical meaning of divergence of a vector? **[Remember]** **(May 2009)**

    $\nabla . D = -\rho_v$. The divergence of a vector flux density is electric flux per unit volume leaving a small volume. This is equal to the volume charge density.

12. Find the gradient of scalar system $t=x^2y+e^z$ at point P(1,5,-2). **[Remember]** **(May 2008)**

$$\nabla t = \frac{\partial t}{\partial x}a_x + \frac{\partial t}{\partial y}a_y + \frac{\partial t}{\partial z}a_z$$

$$\nabla t = 2xya_x + x^2a_y + e^z a_z$$

$$(\nabla t) atP = 10a_x + a_y + 0.1353a_z$$

13. Convert the point P(3,4,5) from Cartesian to spherical coordinates. **[Remember]** **(Nov 2006)**

$$r = \sqrt{x^2 + y^2 + z^2} = \sqrt{3^2 + 4^2 + 5^2} = 7.07$$

$$\cos ¯ = \frac{z}{r} = \frac{5}{7.07} = 0.707$$

$$¯ = \cos^{-1}(0.707) = 45^0$$

$$\tan ¤ = \frac{y}{x} = \frac{4}{3} = 1.33$$

$$¤ = \tan^{-1}(1.33) = 53.13^0$$

14. What is volume charge density? **[Remember]** **(Nov 2006)**

It is the charge per volume(C/m^3) at a point on the volume of the charge.It is denoted by ρ_v.

15. State the condition for the vector F to solenoidal. **[Remember]** **(Nov 2005)**

$$\nabla . F = 0$$

16. Define scalar product. **[Remember]**

Scalar product of two vectors $\vec{A}$ and $\vec{B}$ is defines as $\vec{A} . \vec{B} = |\vec{A}||\vec{B}|Cos\theta$

17. Define Vector product. **[Remember]**

Vector product of two vectors $\vec{A}$ and $\vec{B}$ is defines as $\vec{A} \times \vec{B} = |\vec{A}||\vec{B}|\sin\theta\, \vec{a}_n$

18. Define the curl of a vector. **[Remember]**

The curl of $\vec{A}$ is an axial (or rotational) vector whose magnitude is the maximum circulation of the $\vec{A}$ per unit area as the area tends to zero and whose direction is the normal direction of the area when the area is oriented to make the circulation maximum.

19. Find the divergence of $\vec{A}$ where $\vec{A} = e^{-y}(\cos x\, ax - \sin x\, ay)$

$$\nabla . \vec{A} = \frac{\partial}{\partial x}(e^{-y}\cos x) + \frac{\partial}{\partial y}(-e^{-y}\sin x)$$

$$= -e^{-y}\sin x + e^{-y}\sin x = 0$$

20. Name few applications of Gauss law in electrostatics. **[Remember]**

Gauss law is applied to find the electric field intensity from a closed surface. Examples - Electric field can be determined for shell, two concentric shell or cylinders etc.

21. Write expressions for differential length in cylindrical and spherical co-ordinates. [Remember]

For cylindrical co-ordinates

$dl = \sqrt{(d\rho)^2 + (\rho d\Phi)^2 + (dz)^2}$

For spherical co-ordinates

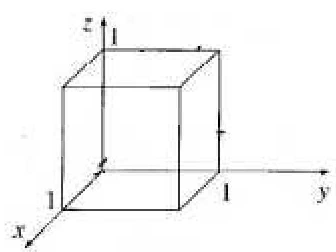
$dl = \sqrt{(dr)^2 + (rdc)^2 + (r\sin\theta d\Phi)^2}$

22. What is a point charge? **[Remember]**

Point charge is one whose maximum dimension is very small in comparison with any other length.

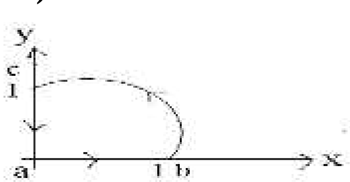
PART-B

1. Give the Cartesian coordinates of the point C(ρ = 4, ϕ = –650, z = 2). (4) [Apply]**(May 21)**
   Give the cylindrical coordinates of the point D(x = –3.1, y = 2.6, z = 3). (4) [Apply]**(May 21)**
   Specify the distance from C to D(5).
2. i) Find the div D at the Point P(2, 3, –1) if D = $(2xy - y^2)az + (^{x2z} - 2xy)ay + x^2 yaz$ C/m^2. (6) [Apply]**(May 21)**
   ii) Given vectors M = –10ax + 4ay – 8az and N = 8ax + 7ay + –2az. Find (a) Unit vector in direction –M + 2N (b) Magnitude of 5az + N – 3M. (7) [Apply]**(May 21)**
3. Check the divergence theorem using the function V = y^2 I + (2xy+z2) j + (2yz) k and the unit cube situated at the origin. [Apply] **13(May 19, 17R)**



4. Write the infinite small displacement, surface and volume elements is spherical and cylindrical coordinates. [Remember] **13(May 19, 17R)**
5. Define D= $2rz^2\, a_r + r\cos^2\theta\, a_z$. Prove Divergence theorem. [Apply] **(13)(May 17N)**
6. State and prove Stokes Theorem. [Remember] **(8)(Apr 18N,Nov 16N, Nov 2013, Nov 2008)**
7. Given two vectors $\bar{A} = 3\hat{a}_x + 4\hat{a}_y - 5\hat{a}_z$ and $B = -6\hat{a}_x + 2\hat{a}_y + 45\hat{a}_z$, determine the unit vector normal to the plane containing the vectors $\bar{A}$ and B.[Apply] **(8)(May 2016N)**

8. Given that $D = \left[\frac{5r^2}{4}\right]\overrightarrow{a_r}$ (C/m$^{2)}$ in spherical coordinates, evaluate both sides of divergence theorem for the volume enclosed by r = 4 m and $\theta = \frac{\pi}{4}$. [Analyze] **(8)(May 2012,May 2016**)
9. State and Explain Divergence Theorem. [Remember] **(8)** (**Nov 2015N, Nov 2013, Nov 2008,Nov 2007,Nov 2005**)
10. Define Curl, Divergence and Gradient and state their meanings. [Understand] **(6)**(**Nov 2015**)
11. Transform A = y a_x +x a_y + x^2 / √ (x^2 +y^2) a_z from Cartesian to cylindrical coordinates. **(8) (May 15N)**
12. Define divergence and curl. [Understand] **(4) (May 15)**
13. Define Curl, Divergence and Gradient and state their meanings. [Understand] **(6) (Nov 14)**
14. State and explain the fundamentals of Divergence and curl. [Understand] **(8)(May 2014)**
15. Determine the divergence and curl of the given field F= 30 a_x+2xya_y+5x$z^2$$a_z$ at (1,1,-0.2).[Apply] **(6)(Nov 2012,Nov 2010)**
16. State and prove Gauss's law for electric field. Also give differential form of Gauss law. [Understand] **(8)(Nov 2011,May 2009,Nov 2006)**
17. Given two points A(x=2,y=3,z=-1) and B$(r=4,\bar{\ } =25^0,\Phi=120^0)$.Find the spherical coordinates of A and Cartesian coordinates of B.[Apply] **(8)(May 2010)**
18. Find curl $\vec{H}, \vec{H} = 2°COS\text{¤}\vec{a}_\circ - 4°\sin\text{¤}\vec{a}_\text{¤} + 3\vec{a}_z$.[Understand] **(8)(May 2010)**
19. Verify Stoke's theorem for a vector field, $\vec{F} = r^2 COS\ \text{¤}\vec{a}_r + z\sin\ \text{¤}\vec{a}_z$ around the path L defined by $0 \le r \le 3, 0 \le \text{¤} \le 45^0, z = 0$.[Analyse] **(8)(May 2009)**
20. Determine the constant c such that the vector F = (x + ay)i + (y + bz)j + (x + cz)k will be solenoidal. [Understand] **(4)(Nov 2005)**
21. Given $\overline{A} = 2r\cos\ddot{\ }\overline{I_r} + r\overline{I_{\cdot\cdot}}$ in cylindrical co-ordinate. For the contour shown in Fig., verify Stoke's theorm. [Understand] **(12)(Nov 2005)**



22. Using the Divergence theorem, evaluate ∬ E.ds = 4xz a_x – y^2 a_y + yz a_z over the cube bounded by x = 0; x = 1; y = 0; y = 1; z = 0; z = 1. [Apply]
23. Obtain the spherical coordinates of 10a_x at the point P (x = -3, y = 2, z = 4).
24. Given A = a_x + a_y, B = a_x + 2a_z and C = 2 a_y + a_z . Find (A X B) X C and compare it with A X (B X C). Using the above vectors, find A.B X C and compare it with A X B.C.[Apply]

ASSIGNMENT

1. Transform A = y a_x +x a_y + x^2 / √ (x^2 +y^2)a_z from Cartesian to cylindrical coordinates. [Apply]
2. Find the divergence of $\vec{A}$ where $\vec{A} = e^{-y}(\cos x\, ax - \sin x\, ay)$[Apply]
3. Given that $D = \left[\frac{5r^2}{4}\right]\overrightarrow{a_r}$ (C/m^{2}) in spherical coordinates, evaluate both sides of divergence theorem for the volume enclosed by $r = 4$ m and $\theta = \frac{\pi}{4}$. [Apply]
4. Determine the gradient of the scalar field $F = 5r^2 + r\,\sin\theta$. [Understand]
5. Determine the divergence and curl of the given field F= 30 a_x+2xya_y+5x$z^2$$a_z$ at (1,1,-0.2). [Apply]
6. Two point charges
7. Given two points A(x=2,y=3,z=-1) and B$(r=4, \bar{} = 25^0, \Phi = 120^0)$.Find the spherical coordinates of A and Cartesian coordinates of B.Verify Stoke's theorem for a vector field, $\vec{F} = r^2 COS\, ¤\, \vec{a}_r + z \sin ¤\, \vec{a}_z$ around the path L defined by $0 \le r \le 3, 0 \le ¤ \le 45^0, z = 0$. [Apply]
8. Determine the gradient of the scalar field $F = 5r^2 + r\,\sin\theta$.
9. Determine the constant c such that the vector F = (x + ay)i + (y + bz)j + (x + cz)k will be solenoid. [Apply]
10. If $V = \frac{60\sin \bar{}}{r^2} Volts$ find V and E atP(3,60^0,25^0) where V =electric potential and E=electric field intensity. [Apply]
11. Find curl $\vec{H}, \vec{H} = 2°COS¤\vec{a}_{◦} - 4° \sin ¤\vec{a}_{¤} + 3\vec{a}_z$.[Understand]

UNIT II
ELECTROSTATICS

Electric field, Coulomb's law, Gauss's law and applications, Electric potential, Conductors in static electric field, Dielectrics in static electric field, Electric flux density and dielectric constant, Boundary conditions, Capacitance, Parallel, cylindrical and spherical capacitors, Electrostatic energy, Poisson's and Laplace's equations, Uniqueness of electrostatic solutions, Current density and Ohm's law, Electromotive force and Kirchhoff's voltage law, Equation of continuity and Kirchhoff's current law

1. State coulomb's law for electric field. **[Remember]** **(May 21)**

   State Coulomb's law of electrostatic charges. **[Remember]** **(May 19 17R,Nov 2016N,Nov 2011,Nov 2009,May 2008,May 2006)**

   Coulomb's law states that force between two point charges is

   (i)Directly proportional to product of two charges

   (ii)Inversely proportional to square of the distance between them

   $$F \propto \frac{Q_1 Q_2}{r^2} = \frac{Q_1\, Q_2}{4\pi\varepsilon r^2}$$

   Coulombs law states that the force between any two point charges is directly proportional to the product of their magnitudes and inversely proportional to the square of the distance between them. It is directed along the line joining the two charges.

   $$F = \frac{Q_1 Q_2}{4\pi\epsilon_0 R^2}\overrightarrow{a_R} \text{ Newton's}$$

2. Two point charges –1nCand 3nCare located at (0, 0, 0), and (1, 0, 0) respectively. Find the Electric Field Intensity of the system. **[Apply]** **(May 21)**

   $$E = \frac{Q_P}{4\pi\varepsilon_0 R_1^2}\bar{a}_{R1} + \frac{Q_Q}{4\pi\varepsilon_0 R_2^2}\bar{a}_{R2}$$

3. Find the energy of a uniformly charged spherical shell of total charge q with a radius R. **[Remember]** **(May 19 17R)**

$$W = \frac{1}{2}\int \sigma V \, da$$
$$= \frac{1}{8\pi\epsilon_0}\frac{q}{R}\int \sigma \, da = \frac{1}{8\pi\epsilon_0}\frac{q^2}{R}.$$

4. Two Capacitance C1 & C2 are connected in series. Find the equivalent total capacitance. [Remember] (**May 18N**)

$$C_{Tot} = \frac{C_1 C_2}{C_1 + C_2}$$

5. Define Current density at a given point. [Remember] (**May 18N, May 15N**)

Current density is defined as the current per unit area.

$J = \frac{I}{A}\ A/m^2$ & $I = \int_s \mathbf{J}.ds$

6. Define polarization. [Remember] **(Nov 2017N)**

Polarization is defined as the dipole moment per unit volume as volume shrinks to zero.

$$\vec{P} = \frac{\vec{p}}{V}$$

7. State Gauss law and write its applications. **[Remember]** (**Nov 2015N, May2015 N, Nov 2006**)

The total electric flux passing through any closed surface is equal to the total charge enclosed by that surface.

$\Psi = Q \quad Q = \oint D.ds$

Application of Gauss's law in electric field.

Gauss's law is useful to find the field due to (a) point charge (b) Line charge (c) Surface charge and (d) Spherical charge.

8. What is an Electric Potential? Write the expression for potential due to electric dipole. **(Nov 2016N) [Remember]**

Potential at any point is defined as the work done in moving a unit positive charge from infinity to that point in an electric field.

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

Electric dipole is nothing but two equal and opposite point charges separated by a small distance.

$$V = \frac{Qd\cos\theta}{4\pi\varepsilon r^2} = \frac{m\cos\theta}{4\pi\varepsilon r^2}$$

9. What is an electric dipole? Write down the potential due to an electric dipole. **[Remember]**

(May 2016N ,May 2016,May 2012, Nov 2010)

Electric dipole is nothing but two equal and opposite point charges separated by a small distance.

$$V = \frac{Qd\cos\theta}{4\pi\varepsilon r^2} = \frac{m\cos\theta}{4\pi\varepsilon r^2}$$

10. Find the electric field intensity E at (111) if the potential is $V=xyz^2+x^2yz+xy^2z$(V). (**Nov 2015N**)

$$\vec{E} = -\nabla V$$

$= - (yz^2+2xyz+y^2z)\, a_x + (xz^2+x^2z+2xyz)\, a_y + (2xyz+x^2y+xy^2)\, a_z$

$= - (4a_x + 4a_y + 4a_z)$

11. Define electric field and electric potential. **[Remember]** **(Nov 2015, May 15, Nov 2013, May 2013,May 2010, Nov 2007,May 2007)**

Electric field intensity is defined as the electric force per unit positive charge.

$$E = \frac{F}{Q} = \frac{Q}{4\pi\epsilon_0 R^2}\overrightarrow{a_R} \text{ V/m}$$

Potential at any point is defined as the work done in moving a unit positive charge from infinity to that point in an electric field.

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

$$\vec{E} = -\nabla V$$

12. Define linear charge density. Write its unit. **[Remember](May 2015N)**

It is the charge per unit length. It is represented by ρ_l. Its unit is Columb /meter.

13. A 15 nC point charge is at the origin in free space. Calculate V_1 if point P_1 is located at P_1(-2,3,1) and V=0 at (6,5,4). **[Apply]** **(Nov 2014)**

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

14. Define potential and potential difference.**[Remember]** **(Nov 2007)**

Potential at any point is defined as the work done in moving a unit positive charge from infinity to that point in an electric field.

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

Potential difference is defined as the work done in moving a unit positive charge from one point to another point in an electric field. It is denoted by V_{AB}.

$$V_{AB} = Q/4\pi\epsilon_o[\frac{1}{r_A} - \frac{1}{r_B}] \text{ Volts or J/C}$$

15. What is the significance of electric flux density? **[Remember]** **(Nov 2012)**

The total number of lines of electric force is electric flux. Electric flux density is defined as electric flux per unit area.

$$D = \frac{\psi}{A}$$

16. State the principle of superposition of fields. **[Remember]**

The total electric field at a point is the algebraic sum of the individual electric field at that point.

17. Define electric flux. **[Remember]**

The total number of lines of electric force is electric flux.

18. Define electric flux density. **[Remember]**

Electric flux density is defined as electric flux per unit area.

$$D = \frac{\psi}{A}$$

19. Why is electric field zero inside a conductor? **[Understand]**

Always the charge tends to distribute over the surface of a conductor, so the charge inside the conductor is zero and hence the electric field inside the conductor is also zero.

20. Should the potential at a point always have a reference? Justify. [Understand]

Yes. As potential is defined as the total work done in bringing unit positive charge from infinite distance to the point, where the potential is to be found, so always to measure the total work done there should be one reference.

21. State electric displacement. **[Remember]**

The electric flux or electric displacement through a closed surface is equal to the charge enclosed by the surface.

22. What is displacement flux density? **[Remember]**

The electric displacement per unit area is known as electric displacement density or electric flux density.

23. What is electrostatic force? **[Remember]**

The force between any two particles due to existing charges is known as electrostatic force, repulsive for like and attractive for unlike.

24. Give the relation between electric field intensity and electric flux density. **[Remember]**

$$D = \epsilon E \text{ C/m}^2$$

25. Indicate the application of Gauss's law in electric field. **[Remember]**

Gauss's law is useful to find the field due to (a) point charge (b) Line charge (c) Surface charge and (d) Spherical charge.

26. What is the limitation of Gauss's law? **[Remember]**

Gauss's law can be applied for finding electric field or flux density if symmetry conditions exist.

27. Find E at the origin due to a point charge of 64.4 nC located (4, -3, 2) m in Cartesian coordinates. **[Apply]**

The Electric field intensity due to a point charge Q at the origin in Spherical coordinates is

$$E = \frac{Q}{4\pi\varepsilon_o r^2} a_r$$

The distance is √29 m and the vector from the charge to the origin, where E is to be evaluated is $R = 4a_x - 3a_y - 2a_z$

$$E = \frac{64.4 \times 10^{-9}}{4\pi (10^{-9} / 36\pi)\, 29} \; \frac{4a_x-3a_y-2a_z}{\sqrt{29}}$$

$$E = 20\, \frac{4ax-3a_y-2a_z}{\sqrt{29}} \quad V/m$$

28. Write the equation for energy stored in electrostatic field in terms of the field quantities. [Remember] (**May 17N)**

$$W = \frac{C\,V^2}{2} = \frac{\epsilon_0\, A\, E^2\, d^2}{2\, d} = \frac{\epsilon_0\, E^2\, Ad}{2},$$

29. Define Capacitance and capacitors? [Remember] (**May 17N)**

Capacitance is defined as the ratio of charge and voltage (or) capacity of a capacitor to hold a charge.

$$C = \frac{Q}{V}$$

A capacitor is an electrical device composed of two conductors which are separated through a dielectric medium and which can store equal and opposite charges ,independent of whether other conductors in the system are charged or not.

30. What is the practical application of method of images? [Remember] (**Nov 16N)**

Method of images practical application is acting as problem-solving tool in electrostatics.

31. State the Poisson's equation and Laplace's equation. .[Remember] (**Nov 16N, May 15,Nov 2010,May 2009,Nov 2007,May 2007))**

Poisson 's eqn:

$$\nabla^2 V = \frac{-\rho_v}{\epsilon}$$

Laplace' s eqn:

$$\nabla^2 V = 0$$

Poisson's and laplace's equations are useful for determining the electrostatic potential V in regions whose boundaries are known. When the region of interest contains charges poisson's equation can be used to find the potential. When the region is free from charge laplace's equation is used to find the potential.

32. Define resistance of a conductor.

Resistance of a conductor is defined as ratio of potential difference across the conductor to current flowing through it.

The resistance of an electrical conductor is the opposition to the passage of an electric current through that conductor.

33. Write the Laplace’s equation in all the three coordinates .[Remember] (**May 2016N**)

$$\nabla^2 V = \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = 0$$

$$\nabla^2 V = \frac{1}{\circ}\frac{\partial}{\partial \circ}(\circ \frac{\partial V}{\partial \circ}) + \frac{1}{\circ^2}\frac{\partial^2 V}{\partial \text{¤}^2} + \frac{\partial^2 V}{\partial z^2} = 0$$

$$\nabla^2 V = \frac{1}{r^2}\frac{\partial}{\partial r}(r^2 \frac{\partial V}{\partial r}) + \frac{1}{r^2 \sin -}\frac{\partial}{\partial -}(\sin - \frac{\partial V}{\partial -}) + \frac{1}{r^2 \sin^2 -}\frac{\partial^2 V}{\partial \text{¤}^2} = 0$$

34. What is dielectric polarization? .[Remember] (**May 2016N**)

When a dielectric is placed in an electric field, electric charges do not flow through the material as they do in a conductor, but only slightly shift from their average equilibrium positions causing dielectric polarization.

35. Determine the capacitance of the parallel plate capacitor composed of tin foil sheets, 25 cm square for plates separated through a glass dielectric 0.5 cm thick with relative permittivity of 6. .[Remember] (**May 2016**)

C= ε A / d

36. State point form of Ohm’s law. .[Remember] (**May 2016, Nov2014**)

Electric field strength within a conductor is proportional to the current density.

J∞E J=σE

37. What are the boundary conditions for electric field at the perfect dielectric conductor interface? .[Remember] (**Nov 2015N, Nov 2015**,**May,2014Nov 2007,May 2007**)

i)The tangential component of electric field is continuous i.e)$E_{t1}=E_{t2}$

ii)The normal component of electric flux density is continuous i.e)$D_{n1}=D_{n2}$

38. Find the energy stored in the 20pF parallel plate capacitor with plate separation of 2 cm. The magnitude of electric field in the capacitor is 1000 V/m. .[Remember] (**Nov 2015N**)

39. What is displacement current? .[Remember] (**May 15)**

Displacement current:It is the current through a capacitor.

$$I_D = \frac{dQ}{dt}$$

40. Write the equation of continuity. [Remember] **(Nov 2013,May 2011,Nov 2009,Nov 2008)**

Current density is defined as the current per unit area.

$$J = \frac{I}{A}\ A/m^2 \qquad \& \quad I = \int_s \mathbf{J}.ds$$

Point form of continuity equation:

$$\nabla.J = \frac{-\partial \rho_V}{\partial t}$$

41. Express Laplace equation in spherical coordinates. .[Remember] **(May 2012,Nov 2011)**

$$\nabla^2 V = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial V}{\partial r}\right) + \frac{1}{r^2\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial V}{\partial\theta}\right) + \frac{1}{r^2\sin^2\theta}\frac{\partial^2 V}{\partial\phi^2} = 0$$

42. Define dielectric strength of material and give its unit. .[Remember]**(May 2010)**

The dielectric strength of a dielectric is defined as the maximum value of electric field that can be applied to the dielectric without its electric breakdown.No unit.

43. State the Laplace’s equations in Cartesian,cylindrical and spherical coordinates. .[Remember] **(Nov 2009)**

$$\nabla^2 V = \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = 0$$

$$\nabla^2 V = \frac{1}{\circ}\frac{\partial}{\partial \circ}\left(\circ\frac{\partial V}{\partial \circ}\right) + \frac{1}{\circ^2}\frac{\partial^2 V}{\partial \text{¤}^2} + \frac{\partial^2 V}{\partial z^2} = 0$$

$$\nabla^2 V = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial V}{\partial r}\right) + \frac{1}{r^2 \sin -}\frac{\partial}{\partial -}\left(\sin - \frac{\partial V}{\partial -}\right) + \frac{1}{r^2 \sin^2 -}\frac{\partial^2 V}{\partial \text{¤}^2} = 0$$

44. What are the basic properties of conductors? .[Remember] **(Nov 2009)**

- It has excellent conductivity
- The ratio of conduction current to displacement current $\frac{\pm}{\mu \text{£}} > 1$.

45. Write down the capacitance of a parallel plate capacitor. .[Remember] **(May 2008)**

$$C = \frac{\varepsilon A}{d}\ Farads$$

46. What is the significance of energy density? It depends on what factors? .[Remember] **(May 2006)**

It is defined as energy per unit volume.

$$\frac{W}{V} = \frac{\epsilon E^2}{2}$$

47. Obtain Poisson's equ ation from Gauss's law. [Remember]

Gauss's law in point form is given by

$\nabla_{.} D = \rho_v$, where 'D' is the electric flux density, ρ_v is the volume charge density.

But D = εE

$\varepsilon \nabla_{.} E = \rho_v$ -> $\nabla\ E = \rho_v / \varepsilon$

But $E = -\nabla\ V, \nabla\ .\nabla\ V = -\rho_v/\varepsilon$

$\nabla\ ^2V = -\rho_v / \varepsilon$. This is Laplace equation.

48. Define ohms law at a point. .[Remember]

Ohms law at a point states that the field strength within a conductor is proportional to current density.

49. Find the total current in a circular conductor of radius 4mm if the current density varies according to $J = 10^4 / r\ \ A/m^2$.[Apply]

$J = 10^4 / r$, current $I = \int J.ds$

$$= \int_{\Phi=0}^{2\pi} \int_{r=0}^{0.004} 10^4 / r \ rdrd\Phi = 80\pi$$

50. How is electric energy stored in a capacitor? [Understand]

In a capacitor, the work done in charging a capacitor is stored in the form of electric energy.

51. What are dielectrics? .[Remember]

Dielectrics are materials that may not conduct electricity through it but on applying electric field induced charges are produced on its faces .The valence electron in atoms of a dielectric are tightly bound to their nucleus.

52. State the properties of dielectric materials. .[Remember]

- It has bound charges. So there is no effect on external electric field.
- External electric field causes polarization of dielectric material and electrical dipoles are created.
- Induced electric dipoles modify the electric field both inside and outside of the dielectric material.
- Polarized dielectric gives rise to an equivalent volume charge density.

53. What meaning would you give to the capacitance of a single conductor? .[Remember]

A single conductor also possesses capacitance. It is a capacitor whose one plate is at infinity.

54. Why water has much greater dielectric constant than mica? [Understand]

Water has a much greater dielectric constant than mica because water has a permanent dipole moment, while mica does not have.

Part-B

1. Find the electrostatic field intensity E produced at the point P(1, 5, 4) in free space due to the following static charge distributions : **May 21**[Apply]

   i) A uniform line charge with a charge density of 150 nC/m is located along X-axis. (6)

   ii) A uniformly charged sheet with a charge density of 25 nC/m2 is located in the plane z = –1. (7)

2. Derive the boundary conditions of the normal and tangential components of electric field at the interface of dielectric and free space. **May 21,** (**Nov 2016N**) **(10)** (**May 2016N**) **13 (Apr 18N)**
3. Two grounded conducting planes (y=0 and x=0) are intersecting at 90 degree. A charge of 100 nC is placed at (3,4,0). Find the electric potential and electric field intensity at (3,5,0). [Apply]**15 (May 19, 17R)**
4. Find the electric field a distance Z above the center of a square loop of side 'a' carrying uniform line charge λ. [Understand]**13 (May 19, 17R)**
5. Derive the expression for the energy of a (1) point charge distribution, ii) continuous charge distributions. [Understand]**13 (May 19, 17R)**
6. Derive the expression for energy stored in an electrostatic field section of coaxial cable. **(13)**(**Apr 2018N**) [Understand]
7. Find the electric field due to infinite long conductor and infinite sheet of charge using Gauss law. [Understand] **(13)(Apr 18N,Nov 17N)]**
8. Derive the expression for potential due to an electric dipole at any point P. Also find electric field intensity at the same point. [Understand] **(10)(May 2012) (8)(Apr 18N, May 2016)**
9. Derive the energy stored in electrostatic field in terms of field quantities/ [Understand] **(13)(Nov 17N)] (10)**(**Nov 2015N**)
10. A cylindrical capacitor consists of an inner conductor of radius'a' and an outer conductor whose inner radius is'b'. The space between the conductors is filled with a dialectric permittivity €r and length of the capacitor is L. Find the value of the capacitance. **[Analyse] (13)(Nov 17N)]**
11. Write down the general procedure for solving Poisson's and Laplace's equation. **[Remember] (6)(Nov 17N)]**
12. Using gauss law find the electric field intensity for the uniformly charged sphere of radius a find the E everywhere. [Understand] **(8)(May 16N)**
13. Derive the equation for scalar electric potential**.** [Remember] **(5)(May 16N)**
14. State and prove Gauss law and explain any one of applications of Gauss law. [Understand] **(8)(May 2016N, Nov 2006, Nov 2006)**
15. Derive the expression for energy and energy density in static electric fields. [Understand] **(8)(Nov 16N)**

16. A circular disc of radius a meter is charged uniformly with a charge r c/m.Find the electric field intensity at a point h meter from the disc along its axis. [Understand] **(8)(Nov 16N)**
17. Explain the concept of superposition principle of electric field intensity. [Understand] **(8)(Nov 16N)**
18. Define the potential difference and electric field. Give the relation between potential and field intensity. Also Derive an expression for potential due to infinite uniformly charged line and also derive potential due to electric dipole. [Understand] **(16)(May 2016N)**
19. A point charge Q_1 = 300 µC located at (1,-1,-3) m experiences a force F1 = $8a_x$ $-8a_y$ $+a_z$ (N) due to point charge Q_2 at (3,-3,-2) m. Find charge Q_2. [Apply] **(8)(May 2012)** (**May 2016**)
20. Two point charges, 1.5 nC at (0,0,0.1) and -1.5 nC at (0,0,-0.1) are in free space. Treat the two charges as a dipole at the origin and find potential at P(0.3,0,0.4). **(6)(May 2012) (8)(May 2016)**
21. Determine the electric flux density D at (1,0,5) and if there is a point charge 10mC at (1,0,0) and a line charge of 50 mC/m along y axis. .[Apply] **(8)**(**Nov 2015N**)
22. The two point charges 10 µC and 2µC are located at (1,0,5) and (1,1,0) respectively. Find the potential at (1,0,1), assuming zero potential at infinity. .[Apply] **(6)** (**Nov 2015N**)
23. State Gauss law and explain its applications. [Understand] **(6)(Nov 14)** (**Nov 2015**)
24. Three infinite uniform sheets of charge are located in free space as follows: 3 nC/m^2 at z= -4, 6 nC/m^2 at z=1 and -8 nC/m^2 at z=4. Find E at the points P_A (2,5,-5), P_B (4,2,-3), P_C (-1,-5,2) and P_D (-2,4,5). [Apply] **(4)**(**Nov 2015**)
25. Point charges of 50 nC each are located at A (1,0,0), B (-1,0,0), C (0,1,0) and D (0,-1,0) in free space. Find the total force on the charge at A. .[Apply]**(4)**(**Nov 2015**)
26. Find the potential due to an electric dipole. [Understand]**(6)** (**Nov 2015**)
27. Two uniform line charges, 8 nC/m each, are located at x=1, z=2 and at x=-1, y=2 in free space. If the potential at the origin is 100 V, find V at P(4,1,3). .[Apply] **(4)** (**Nov 2015**)
28. A charge +Q located at A (- a ,0,0) and another charge -2 Q is located at B(a,0,0).Show that the neutral point also lies on the x axis , where x = -5.83 a. .[Apply] **(8) (May 15N)**
29. Derive coulombs law starting from guass theorem. State any reasonable assumptions which you think are necessary for the derivations. **[Understand] (10) (May 15N)**
30. What maximum charge can be put on sphere of radius 1m, if the breakdown of air is to be avoided? For breakdown of air, E=$3x10^6$ V/m. **[Analyse](6) (May 15N)**

31. A charge $Q_1 = 3x10^{-4}$ C is at a point M(1,2,4) and a second charge $Q_2 = -10^{-4}$ C located at a point N(2,0,10) in vacuum. Find the force exerted on Q_2 by Q_1.[Apply].**(4) (May 15)**
32. Infinite uniform line charges of 5nC/m lie along the x and y axes in free space. Find E at $P_a(0,0,4)$ and at $P_b(0,3,4)$.[Apply] **(4) (May 15)**
33. Derive an expression for electric field on the axis of a uniformly charged circular disc. **(8) (May 15)**
34. Derive an expression for potential due to electric dipole. [Understand] **(6) (May 15)**
35. State Guass law and prove it. [Understand] **(6) (May 15)**
36. Three infinite uniform sheets of charge are located in free space as follows : 3nC/m^2 at Z= -4, 6 nC/m^2 at Z=1 and -8 nC/m^2 at Z = 4. Find E at the points PA(4,2,-3), Pc (-1,-5,2) and PD(-2,4,5). **(6)** .[Apply] **(Nov 14)**
37. Point charges of 50 nC each are located at A(1,0,0), B(-1,0,0), C(0,1,0) and D(0,-1,0) in free space. Find the total force on the charge at A. .[Apply] **(4) (Nov 14)**
38. Find the potential due to an electric dipole. [Understand]**(6) (Nov 14)**
39. Two uniform line charges, 8 nC/m each, are located at x=1, z=2 and at x=-1, y=2 in free space. If the potential at the origin is 100 V, find V at P(4,1,3).[Apply] **(4) (Nov 14)**
40. Find the electric field at a distance Z above the center of a flat circular disc of radius R , which carries a uniform surface charge $\pm$.[Apply] **(8)(May 2014)**
41. Get the relationship between potential and electric field. A (physical) dipole consists of two equal and opposite charges separated by a distance d. Find the approximate potential at points far from the dipole.[Understand] **(6)(May 2014)**
42. Find the electric field at a distance Z above the center of a circular loop of radius r which carries a uniform line charge λ. [Understand] **(5)(May 2014)**
43. Apply Gauss law to find charge Enclosed in a hollow sphere whose surface is uniformly charged. Derive the equation for potential due to a system of point charges. [Understand] **(Nov 2013)**
44. Derive an expression for the electric field due to a straight and infinite uniformly charged wire of length L meters and with a charge density of + ρ C/m at appoint P which lies along the perpendicular bisector of wire. [Understand] **(May 2013)**
45. A uniform line charge of ρ_L= 25 nC/m parallel to z axis at x=3m,y=4m.Find the electric field intensity at the point P(2,3,15)m. [Apply]**(8) (May 2013)**

46. Given the potential V=10sin θ cos Φ /r2 find the electric flux density D at (2,π/2,0). **(8)(May2013)**
47. Find the electric field intensity at a point P located at (0,0,h)m due to charge of surface charge density $\pm$ C/m^2 uniformly distributed over the circular disc $r \le a, z = 0$ m. .[Apply] **(10)(Nov 2012,Nov 2010)**

48. Point charges Q and –Q are located at (0,0,d/2) and (0,0,-d/2).Show that the potential at point P($r, ^{-}, \Phi$) is inversely proportional to r^2 noting that r >>d. .[Analyse] **(8)(Nov 2012,May 2011)**
49. Given a field $E = \frac{-6y}{x^2} a_x + \frac{6}{x} a_y + 5a_z V/m$,find the potential difference V_{AB} between A(-7,2,1) and B(4,1,2). .[Apply] **(8)(Nov 2012,May 2011)**
50. Assume a straight line charge extending along the z axis in a cylindrical coordinate system from - ∞ to ∞**.**Determine the electric field intensity E at every point resulting from an uniform line charge density ρ_l C/m..[Apply] **(8)(Nov 2011)**
51. Consider an infinite uniform line charge of 5 nC/m parallel to z axis at x=4,y=6.Find the electric field intensity at the point P(0,0,5) in free space. .[Apply] **(8)(Nov 2011)**
52. The flux density within the cylindrical volume bounded by r=2 m,z=0 and z= 5 m is given by D= $30e^{-r}$ a_r – 2z a_z C/m^2.What is the outward flux crossing the surface of the cylinder? [Understand] **(8)(Nov 2011)**
53. Find the total electric field at the origin due to 10^{-8} C charge located at point P(0,4,4) m and a -0.5X10^{-8} C charge at P(4,0,2) m. .[Apply] **(8)(May 2011)**
54. Derive an expression for the electric field intensity at any point due to a uniformly charged sheet with density ρ_s C/m^2. [Understand] **(8)(May 2011)**
55. Point charges Q and –Q are located at (0,0,d/2) and (0,0,-d/2).Show that the potential at point P($r, ^{-}, \Phi$) is inversely proportional to r^2 noting that r >>d. [Analyse] **(8)(May 2011)**
56. Given a field $E = \frac{-6y}{x^2} a_x + \frac{6}{x} a_y + 5a_z V/m$,find the potential difference V_{AB} between A(-7,2,1) and B(4,1,2). [Apply] **(8)(May 2011)**

57. Find the electric field intensity at a point P located at (0,0,h)m due to charge of surface charge density $\pm$ C/m^2 uniformly distributed over the circular disc $r \le a, z = 0$ m.**(10)(Nov 2010)**

58. Derive the expression for potential due to an electric dipole at any point P.Also find the electric field intensity at the same point. [Understand] **(10)(Nov 2010,Nov 2009)**

59. Two point charges 1.5 nC at (0,0,0.1) and -1.5 nC at (0,0,-0.1)are in free space.Treat the two charges as a dipole at the origin and find the potential at P(0.3,0,0.4). [Analyse] **(6)(Nov 2010)**

60. A circular disc of radius 'a' m is charged uniformly with a charge of $\pm$ C/m^2.Find the electric field intensity at a point 'h' m from the disc along its axis. [Understand] **(8)(May 2010,May 2009 ,Nov 2007,May 2007,Nov 2005)**

61. If $V = [2x^2 y + 20z - \frac{4}{x^2 + y^2}] volts$, find E and D at P(6,-2.5,3) .[Apply] **(8)(May 2010,May 2009)**

62. State and explain Coulomb's law and deduce the equation of force between two point charges stating the units of quantities in the equation of force**.** [Understand] **(10)(Nov 2009)**

63. Three identical point charges of 2 Coulombs are placed at the vertices of an equilateral triangle 10 cm apart. Calculate the force on each charge.[Understand] (**6)(Nov 2009)**

64. What is dipole and its moment? [Understand] **(4)(Nov 2009)**

65. A circular disc of 10 cm radius is charged uniformly with a total charge of 2 coulombs.Find the electric field intensity at a point 20 cm away from the disc along the axis. **(10)(May 2009)**

66. Find the electric field due to n charges**.** [Understand] **(8)(Nov 2009,May 2008)**

67. Establish the relation between potential and electric field. [Understand] **(8)(Nov 2009)**

68. Find the electric field due to infinite long straight line. [Understand] **(16)(Nov 2009)**

69. Explain the potential due to charged disc. [Understand] **(8)(May 2008)**

70. Prove Div D = ρ using Gauss law**.** [Understand] **(8)(May 2008)**

71. The electric flux density is given by $D = \frac{r}{4} a_r nC/m^2$ in free space. Calculate

(i)the electric field intensity at r= 0.25 m

(ii)the total charge within a sphere of r = 0.25 m

(iii)the total flux leaving the sphere of r = 0.35 m [Understand] **(8)(Nov 2008)**

72. If $V = \frac{60\sin\bar{}}{r^2} Volts$ find V and E at P(3,60^0,25^0) where V =electric potential and E=electric field intensity.[Understand]**(8)**(**Nov 2007)**

73. Given field intensity $E = 40xyu_x + 20x^2u_y + 2u_z$,calculate the potential difference between two points P(1,-1,0) and Q(1,2,3).[Apply] **(8)(May 2007)**

74. A circular disc of 10 cm radius is charged uniformly with a total charge of 10^{-6}c. Find the electric intensity at a point 30 cm away from the disc along the axis. .[Apply]

75. Find the value of the constant a, b, c so that the vector E = (x + 2y + az) a_x + (bx – 3y –2) a_y + (4x + cy + 2z) a_z is irrotational. [Understand]

76. Two point charges Q_1 = 4nC, Q = 2nC are kept at (2, 0, 0) and (6, 0, 0).Express the electric field at (4, -1, 2) .[Apply]

77. Define the potential difference and absolute potential. Give the relation between potential and field intensity. [Understand]

78. Two point charges of +1C each are situated at (1, 0, 0) m and (-1, 0, 0) m. At what point along Y axis should a charge of -0.5 C be placed in order that the electric field E = 0 at (0, 1, 0) m? .[Apply]

79. Let A= 5a_x and B = 4 a_x + $B_y a_y$, find B_y such that, angle between A and B is 45^0. If B also has a term $B_z a_z$, What relationship must exist between by B_y and B_z**.** .[Analyze]

75. Find the capacitance for a coaxial capacitor with inner radius a and outer radius b with length L. (Apply) **(7)** (**May 2017N**)

76. Derive the expression for capacitance of coaxial cable. [Understand] **(16)** (**Nov 2016N**)

77. Derive an expression for Polarization P. [Understand] **(4)** (**Nov 2016N**)

78. Derive the relationship between polarization and electric field intensity. [Understand] **(8)** (**May 2016N**)

79. Derive the capacitance of a spherical capacitor. [Understand] **(8)** (**May 2016N**)

80. If two parallel plates of area 4 m^2 are separated by a distance 6 mm, find the capacitance between these 2 plates. If a rubber sheet of 4 mm thick with ε_r = 2.4 is introduced in between

the plates leaving a bap of 1 mm on both sides, determine the capacitance. (Analyze) **(6)** (**May 2016N**)

81. Derive the expression for relaxation time by solving the continuity equation. [Understand] **(10)**(**Nov 2015N**) (Apply)
82. Calculate the relaxation time of mica ($\sigma = 10^{-15}$ S/ m, $\varepsilon_r = 6$) and paper ($\sigma = 10^{-11}$ S/ m, $\varepsilon_r = 7$). **(10)** (**Nov 2015N**) (Apply)
83. Derive the Poisson's equation. [Understand]**(6)** (**Nov 2015N**)
84. A spherical capacitor consists of an inner conducting sphere of radius 'a' and an outer conductor with spherical inner wall of radius is 'b'. The space between the conductors is field with a dielectric of permittivity 'ε'. Determine the capacitance.(Apply) **(10)** (**Nov 2015N**)
85. Write down the Poisson's and Laplace's equations. State their significance in electrostatic problems. [Understand] (**Nov 2015**)
86. Two parallel conducting plates are separated by distance 'd' apart and filled with dielectric medium having 'ε_r' as relative permittivity. Using Laplace's equation, derive an expression for capacitance per unit length of parallel plate capacitor, if it is connected to a DC source supplying 'V' volts. [Understand] (**Nov 2015**)
87. Each of two dielectrics (of relative permittivity ε r1 and ε r2 respectively) occupies one-half the volume of the annular space between the electrodes of a cylindrical capacitor such that the interface plane between the dielectric is a rz plane. Show that the two dielectric act like a single dielectric having the average relative permittivity. [Understand] **(8) (May 15N)**
88. If J= $1/r^3$ (2 cos θ a_r + sin θ a_r) A/m^2, calculate the current through **(8) (May 15N)**
    1) A hemisphere shell of radius 20 cm. (Apply)
    2) A spherical shell of radius 10 cm.
90. A capacitor of capacitance C is charged to a voltage V. At a particular time this capacitor is connected to a second capacitor also of value C, but containing no charge. What will be the final voltage?[Understand] **(10) (May 15N)**
91. A wire of dia 1mm and conductivity $5x10^7$ s/m has 10^{29} free electronics/m^3 when an E-field of 10 mV/m is applied. Find charge density of free electronics current density and current in the wire**.** (Apply)**(6) (May 15N)**
92. Derive the boundary conditions for the electic fields**.** [Understand]**(8) (May 15)**
93. Derive the expressions for electrostatic energy and energy density**.** [Understand]**(8) (May 15)**

94. State continuity equation for current and point form of ohms law[Understand] **(4) (May 15)**
95. Derive the expression for electrostatic energy density. [Understand] **(6) (Nov 14)**
96. Derive the Capacitance of a parallel plate capacitor. [Understand] **(4) (Nov 14)**
97. Derive the expression for the energy of a point charge distribution. Three point charges -1 nC, 4 nC and 3 nC are located at (0,0,0),(0,0,1)and (1,0,0) respectively. Find the energy in the system. (Apply) **(May 2014)**
98. Write the poisson's and laplace equations. **(4)(May2014,MAY 2010)**
99. Two concentric metal spherical shells of radii a and b are separated by weakly conducting material of conductivity. If they are maintained at a potential difference V , what current flows from one to the other? What is the resistance between the shells? Find the resistance if b>> a. (Apply) **(6)(May2014)**
100. Derive the boundary relations for E field & H field. [Understand] **(Nov 2013)**
101. A composite conductor of cylindrical cross section used in overhead line is made of a steel inner wire of radius a and an annular outer conductor of radius b , the two having electrical contact, Evaluate the H field within the conductors and the internal self inductance per unit length of the composite conductor. [Understand] **(Nov 2013)**
102. The capacitance of the conductor formed by the two parallel metal sheets each $100cm^2$ in area separated by a dielectric 2mm thick is $2 * 10^{-4}$μF.A potential of 20kv is applied to it .find (1) electric flux,(2) potential gradient in kv/m,(3) the relative (Apply) Permeability of the material, (4) electric flux density. **(16)(May 2013) (8)(May 2007)**
103. Derive the boundary conditions of the normal and tangential components of electric field at the interface of two media with different dielectrics. [Understand] **(16)(May 2013)**
104. Determine whether or not the following potential fields satisfy the Laplace's equation. (i)$V= x^2-y^2+z^2$ (ii)$V=r \cos\Phi+z$ (iii)$V=r \cos\theta +\Phi$ [Understand] **(8)(Nov 2012,May 2011)**
105. Write down the Poisson's and Laplace's equations. State their significance in electrostatic problems. [Understand]**(4)(May 2012, Nov 2010)**
106. Two parallel conducting plates are separated by distance'd' apart and filled with dielectric medium having 'ε_r ' as relative permittivity. Using Laplace's equation, derive an expression for capacitance per unit length of parallel plate capacitor, if it is connected to a DC source supplying 'V' volts. [Understand] **(12)(May 2012)**

107. A metallic sphere of radius 10 cm has a surface charge density of 10 nC/m^2.Calculate the energy stored in the system. (Apply)**(4)(Nov 2011)**

108. State and explain the electric boundary conditions between two dielectrics. [Understand] **(8)(Nov 2011,May 2009)**

109. Derive the expression for continuity equation of current in differential form. [Understand] **(8)(Nov 2011,Nov 2008)**

110. Solve the Laplace's equation for the potential field in the homogeneous region between two concentric conducting spheres with radius 'a' and 'b' where b>a,V=0 at r=b and $V=V_0$ at r=a.Find the capacitance between the two concentric spheres. [Understand] **(8)(May 2011)**

111. Using Laplace's equation, derive an expression for capacitance per unit length of parallel plate capacitor. [Understand] **(12)(Nov 2010,Nov 2007)**

112. A parallel plate capacitor has an area of 0.8 m^2,separation of 0.1 mm with a dielectric for which $\P_r = 1000$ and a field of 10^6 V/m.Calculate C and V. (Apply) **(8)(May 2010)**

113. Discuss about the amount of energy stored in a capacitor and energy density of it. [Understand] **(10)(May 2009,Nov 2006)**

114. Find the expression for cylindrical capacitance using Laplace's equation. [Understand] **(16)(Nov 2009)** (Apply)

115. Derive an expression for spherical capacitance of a spherical capacitor with conducting shells of radius 'a' and 'b'. [Understand] **(16)(May 2009,Nov 2006)**

116. Parallel plate capacitor is of area 1 m^2 and has a separation of 1 mm.The space between the plates is filled with dielectric of ξ =25.If 1000 V is applied,find the force squeezing the plates together. (Apply) **(8)(May 2008)**

117. Discuss briefly about nature of dielectric materials.[Understand] **(8)(May 2007)**

118. Given the potential field, $V = \frac{50 Sin\,\overline{\ }}{r^2} Volts$ in free space,determine whether V satisfies Laplace's equation. [Analyse] **(8)(May 2007)**

119. The plates of a parallel plate capacitor are separated by a distance'd' along the z-axis. The lower and upper plates are maintained at potential 0 volts and v0 volts respectively. Assume negligible fringing affects at the edges. Determine (1) the potential at any point

between the plates (2) the surface charge densities on the plates and (3) the capacitance. [Analyse] **(16)(May 2006)**

120. Obtain the capacitance of a conducting sphere of 2cm in diameter, which is covered by an another medium with $\varepsilon_r = 2.26$ and 3 cm thick. [Analyse] **(8)(May 2007)**

121. List out the properties of dielectric materials. [Understand] **(8)(May 2007)**

122. The capacitance of the conductor formed by the two parallel metal sheets each $100cm^2$ in area separated by a dielectric 2mm thick is $2 * 10^{-4}$μF.A potential of 20kv is applied to it .find (1) electric flux,(2) potential gradient in kv/m,(3) the relative permeability of the material, (4) electric flux density. [Apply] **(8)(May 2007)**

123. Derive an expression for energy density in electrostatic fields. [Understand] **(8)(Nov 2006)**

124. A capacitor consists of squared two metal plates each 100 cm side placed parallel and 2 mm apart. The space between the plates is filled with a dielectric having a relative permittivity of 3.5. A potential drop of 500 V is maintained between the plates. Calculate the capacitance, the charge of capacitor, the electric flux density, the potential gradient [Understand] **(8)(Nov 2006)**

ASSIGNMENT

1. When a bird perches on a dc high-voltage power line and then flies away, it does so carrying a net charge. .[Analyze]

(a) Why?

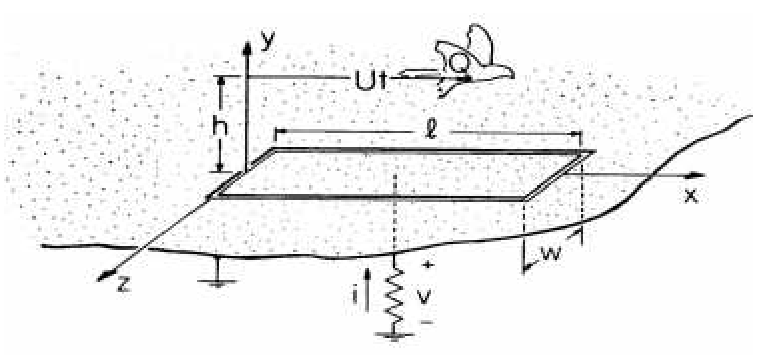
(b) For the purpose of measuring this net charge Q carried by the bird, we have the apparatus pictured below. Flush with the ground, a strip electrode having width w and length l is mounted so that it is insulated from ground. The resistance, R, connecting the electrode to ground is small enough that the potential of the electrode (like that of the surrounding ground) can be approximated as zero. The bird flies in the x direction at a height h above the ground with a velocity U. Thus, its position is taken as $y=h$ and $x=Ut$. At time t, what is the effective charge distribution that will allow easy calculation of the electric scalar potential?

(c) The bird flies at an altitude h sufficiently large to make it appear as a point charge. What is the potential distribution as a function of time and position (x, y, z)?

(d) Determine the surface charge density (x, y 0, z, t) on the ground plane at $y=0$ as as function of time.

(e) At time t, what is the net charge, q, on the electrode? (Assume that the width w is small compared to h so that in an integration over the electrode surface, the integration in the z direction is simply a multiplication by w.)

(f) The current through the resistor is dq/dt. Find an expression for the voltage, v, that would be measured across the resistance, R.



"Bird on Powerline" diagram from:

(a) Two point charges are a distance d apart along the y-axis. Find the electric field (magnitude and direction) at any point in the $y=0$ plane when the charges are:

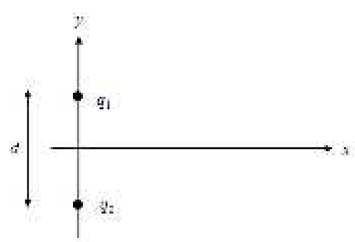
i) $q_1 = q, \quad q_2 = 0$

ii) both equal $q_1 = q_2 = q$

iii) of opposite polarity but equal magnitude $q_1 = \quad q_2 = q$.

This configuration is called an electric dipole with dipole moment

(b) For each of the 3 cases in (a) find the force on q_1 .



2. In a spherically symmetric configuration, the region $r < b$ has the non-uniform charge density $_b r/b$ and is surrounded by a region $b < r < a$ having the uniform charge density

   At $r = b$ there is no surface charge density, while at $r = a$ there is perfectly conducting sheet with surface charge density that assures $E = 0$ for $r > a$.

   a) What is the total charge in the regions $0 < r < b$ *and* $b < r < a$?

   b) Determine $\boldsymbol{E}$ in the two regions $r < b$ and $b < r < a$.

   c) What is the surface charge density at $r = a$?

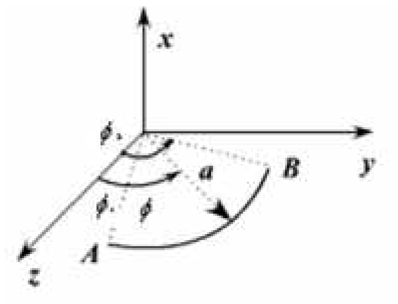
   d) What is the total charge in the system for $0 < r \quad a$.

3. Two point charges Q_1 and Q_2 are located at (3,0,0) and (1,2,0). Find the relation between Q_1 and Q_2 such that x and y component of the total force on a test charge q_i placed at (1,-1,0) are equal. [Apply]

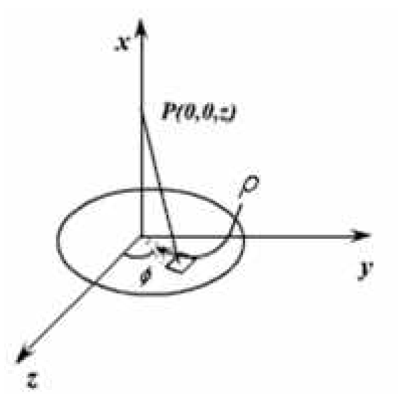
4. A line charge of charge density $\rho_\lambda = \frac{1}{24} C/m$ lies along z -axis and a point charge Q_0 lies at (0,9,0). Find Q_0 so that net force on a test charge located at (0,3,0) is zero. [Apply]

(a) The figure Figure P2.1shows an arc AB of radius 'a' and carrying uniform charge density ρ_l C/m lies on the xy plane. Calculate the electric field intensity at point P(0,0,h).[Apply]

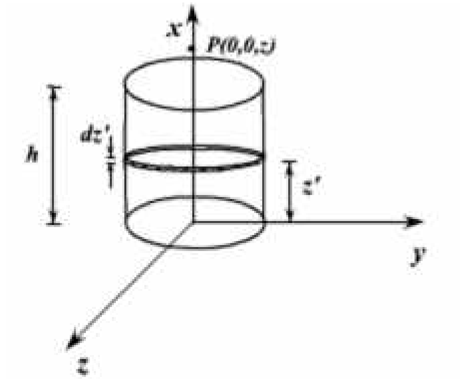
(b) What is the electric field at P due to a ring of radius 'a' carrying ρ_l C/m if the ring lies on the x y plane with its centre at the origin. [Analyze]



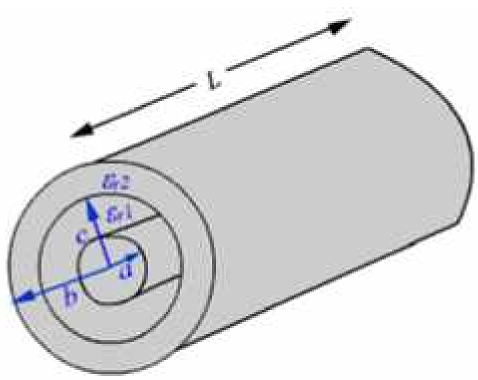
5. A circular disc of radius 'a' carries a uniform surface charge density ρ_s as shown in Figure P2.3. Determine the potential and electric field at a point P(0,0,z) on the axis (z > 0) . [Analyze]



6. Determine the work done in carrying $-1\mu C$ charge from P_1((1,1,-3) to P_2(4,2,-3) in an electric field $E = ya_x + xa_y$.[Apply]
7. Assume that a circular tube of radius 'a' and height 'h' is placed on the xy plane with its axis coinciding with z axis. A total charge Q is uniformly distributed on the tube. Determine V and E at a point z>h on the z axis. [Apply]



8. Dipole moment $p = 3\hat{a}_x - 5\hat{a}_4$ is located at the point (1, 1,-2). Determine the potential at a point (3, 4, 2). [Apply]
9. The interface between a dielectric medium having relative permittivity 4 and free space is marked the y = 0 plane. If the electric field next to the interface in the free space region is given by $E = 5\hat{a}_x + 12\hat{a}_y + \hat{a}_z \ V/m$, determine *E* field on the other side of the interface. [Apply]
10. A parallel plate capacitor has a plate area of 1 cm^2 and 2mm separation between the plates. The space between the plates is filled with a dielectric whose relative permittivity varies linearly from 2 to 4. Neglecting the fringing effect, what would be the capacitance? [Apply]
11. Consider a cylindrical capacitor as shown in the Figure P2.5. Determine the capacitance neglecting the fringing given that a dielectric material of dielectric constant fills the region and another dielectric material of dielectric constant fills the region [Apply].



12. Define dipole moment &Convert the point P(3,4,5) from Cartesian to spherical coordinates. [Apply]
13. Find E at the origin due to a point charge of 64.4 nC located (4, -3, 2) m in Cartesian coordinates[Apply]
14. Infinite uniform line charges of 5nC/m lie along the x and y axes in free space. Find E atP_a(0,0,4) and at P_b(0,3,4). [Apply]
15. Three infinite uniform sheets of charge are located in free space as follows : 3nC/m^2 at Z= -4, 6 nC/m^2 at Z=1 and -8 nC/m^2 at Z = 4. Find E at the points PA(4,2,-3), Pc (-1,-5,2) and PD(-2,4,5). [Apply]
16. Point charges of 50 nC each are located at A(1,0,0), B(-1,0,0), C(0,1,0) and D(0,-1,0) in free space. Find the total force on the charge at A. [Apply]
17. Given the potential V=10sin θ cos Φ /r2 find the electric flux density D at (2,π/2,0). [Apply]
18. Determine the divergence and curl of the given field F= 30 a_x+2xya_y+5x$z^2$$a_z$ at (1,1,-0.2). [Apply]

19. Define Guass Law.&Find the gradient of scalar system t=x^2y+e^z at point P(1,5,-2). [Apply]
20. Two uniform line charges, 8 nC/m each, are located at x=1, z=2 and at x=-1, y=2 in free space. If the potential at the origin is 100 V, find V at P(4,1,3). [Apply]
21. A uniform line charge of ρ_L= 25 nC/m parallel to z axis at x=3m,y=4m.Find the electric field intensity at the point P(2,3,15)m. [Apply]
22. Given a field $E = \frac{-6y}{x^2} a_x + \frac{6}{x} a_y + 5a_z V/m$,find the potential difference V_{AB} between A(-7,2,1) and B(4,1,2). [Apply]
23. A point charge $Q_1 = 300\ \mu C$ located at (1,-1,-3) m experiences a force $F_1 = 8\vec{a}_x - 8\vec{a}_y + \vec{a}_z$ (N) due to point charge (3,-3,-2) m.Find the charge Q_2. [Apply]
24. Two point charges 1.5 nC at (0, 0, 0.1) and -1.5 nC at (0, 0,-0.1) are in free space. Treat the two charges as a dipole at the origin and find potential at P (0.3, 0, 0.4). [Apply]

25. What is the relationship between electric field and potential [Understand]

26. Consider an infinite uniform line charge of 5 nC/m parallel to z axis at x=4,y=6.Find the electric field intensity at the point P(0,0,5) in free space. [Apply]
27. The flux density within the cylindrical volume bounded by r=2 m,z=0 and z= 5 m is given by D= $30e^{-r}a_r - 2z\ a_z C/m^2$.What is the outward flux crossing the surface of the cylinder[Apply]
28. Find the total electric field at the origin due to 10^{-8} C charge located at point P(0,4,4) m and a -0.5X10^{-8} C charge at P(4,0,2) m. [Apply]
29. 1.5 nC at (0,0,0.1) and -1.5 nC at (0,0,-0.1)are in free space.Treat the two charges as a dipole at the origin and find the potential at P(0.3,0,0.4). [Apply]
30. Define Columbs Law.
31. Given field intensity $E = 40xyu_x + 20x^2u_y + 2u_z$,calculate the potential difference between two points P(1,-1,0) and Q(1,2,3). [Apply]
32. The electric flux density is given by $D = \frac{r}{4}a_r nC/m^2$ in free space.Calculate[Understand]

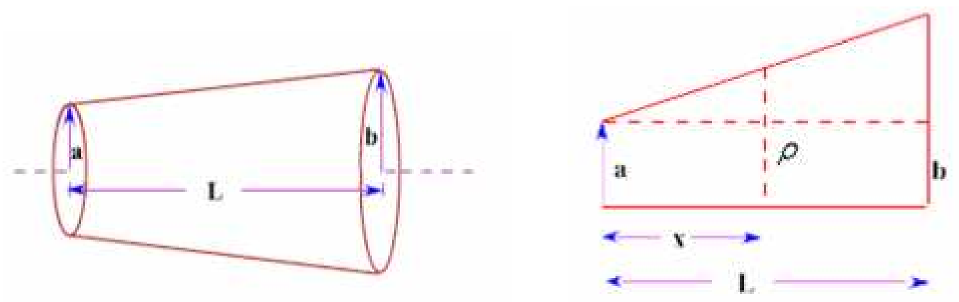
    (i)the electric field intensity at r= 0.25 m

    (ii)the total charge within a sphere of r = 0.25 m

    (iii)the total flux leaving the sphere of r = 0.35 m
33. A circular disc of 10 cm radius is charged uniformly with a total charge of 2 coulombs.Find the electric field intensity at a point 20 cm away from the disc along the axis. [Understand]

35. A dc voltage of 10 V is applied to the ends of a conducting wire of length 100m and diameter 2mm. The resulting current is 0.1A. What is the conductivity of the wire? What is the power dissipation in the wire ? Assuming the electron mobility to be $1.4\times10^{-3}\ m^2/V\cdot s$. Calculate the drift velocity. [Apply]
36. A disc of thickness 't' has radius 'b' and conductivity of the disc material is 'a' . A central hole of radius $a = \frac{b}{2}$ is drilled.By what percentage the resistance between the two flat sides of the disv changes? What is the resistance between the hole and the rim of the disc. [Apply]

37. A truncated circular cone of as shown in the Figure P3.1 below is made up of a material having conductivity σ .What is the resistance of the cone between the flat faces? [Analyze]



38. The current density in a cylindrical conductor of radius 'a' is given by $\vec{J} = I_0 e^{-(1-\rho/a)} \hat{a}_z$ A/m^2 . If and the total current through the cross section of the wire is 10 A. Calculate the radius of the wire. [Apply]

39. A long round wire of radius *'a'* and conductivity σ is coated with material of conductivity σ' .the thickness of the coating is *'a'* . If the resistance per unit length of the coated wire is 50 % of that of the uncoated wire, determine σ' in terms of *a* .Also determine the ratio of the current densities in the core and the coating and verifies that the electric field is same in the two parts. [Apply]

40. Write the relation between perfect conductor and electrostatic field. [Understand]

41. Define Current density at a given point. [Understand]

42. The capacitance of the conductor formed by the two parallel metal sheets each 100cm^2 in area separated by a dielectric 2mm thick is 2 * 10^{-4}μF.A potential of 20kv is applied to it .find (1) electric flux,(2) potential gradient in kv/m,(3) the relative Permeability of the material, (4) electric flux density. [Apply]

43. Determine whether or not the following potential fields satisfy the Laplace's equation. [Apply]

    (i)$V= x^2-y^2+z^2$ (ii)$V=r \cos\Phi+z$ (iii)$V=r \cos\theta +\Phi$

44. A metallic sphere of radius 10 cm has a surface charge density of 10 nC/m^2.Calculate the energy stored in the system. [Understand]

45. What is displacement current? [Understand]

46. State the Poisson's equation and Laplace's equation. [Understand]

47. A parallel plate capacitor has an area of 0.8 m^2,separation of 0.1 mm with a dielectric for which $\P_r = 1000$ and a field of 10^6 V/m. Calculate C and V. [Apply]

48. Given the potential field, $V = \frac{50 Sin^{-}}{r^2} Volts$ in free space, determine whether V satisfies Laplace's equation. [Apply]

49. Derive the boundary conditions of the normal and tangential components of electric field at the interface of two media with different dielectrics. [Understand]

50. State point form of ohms law. [Understand]

51. Write the boundary condition for electric field. [Understand]

52. The plates of a parallel plate capacitor are separated by a distance'd' along the z-axis. The lower and upper plates are maintained at potential 0 volts and v0 volts respectively. Assume negligible fringing affects at the edges. Determine (1) the potential at any point between the plates (2) the surface charge densities on the plates and (3) the capacitance.

53. Two parallel conducting plates are separated by distance'd' apart and filled with dielectric medium having 'ε_r ' as relative permittivity. Using Laplace's equation, derive an expression for capacitance per unit length of parallel plate capacitor, if it is connected to a DC source supplying 'V' volts.

54. Parallel plate capacitor is of area 1 m^2 and has a separation of 1 mm. The space between the plates is filled with dielectric of ξ =25.If 1000 V is applied, find the force squeezing the plates together.

55. Write the equation of continuity. [Understand]

56. State the difference between Poisson's equation and Laplace's equation. [Understand]

57. Derive the expressions for electrostatic energy and energy density**.** [Understand]

58. Solve the Laplace's equation for the potential field in the homogeneous region between two concentric conducting spheres with radius 'a' and 'b' where b>a, V=0 at r=b and $V=V_0$ at r=a. Find the capacitance between the two concentric spheres. [Apply]

59. Obtain the capacitance of a conducting sphere of 2cm in diameter, which is covered by an another medium with ε_r= 2.26 and 3 cm thick. [Apply]

UNIT III

MAGNETOSTATICS

Lorentz force equation, Law of no magnetic monopoles, Ampere's law, Vector magnetic potential, Biot-Savart law and applications, Magnetic field intensity and idea of relative permeability, Magnetic circuits, Behavior of magnetic materials, Boundary conditions, Inductance and inductors, Magnetic energy, Magnetic forces and torques

PART A

1. A current density K = 20a^x A/m flows in the y = 0 plane through the region –5 < z < 5 m and – ∞ < x < ∞. Find ˆH at P(0, 10, 0) in free space. . [Apply] **(May 21)**

   K = 20a^x
   –5 < z < 5 m and – ∞ < x < ∞
   P(0, 10, 0)

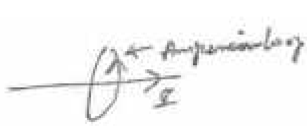
   $H = \frac{1}{2}(20\, a_z \times a_y) = -10\, a_y$

2. State Biot – Savarts law. [Understand] **(May 21), (May 2016,Nov 2015N,May 2014,May 2013,May 2010,Nov 2009,May 2009,Nov 2006)**

   It states that the magnetic flux density at any point due to current element is proportional to the current element , sine of the angle between the elemental length and the line joining and inversely proportional to the square of the distance between them. In vector form it is expressed as,

   $$\overrightarrow{dH} = \frac{I\,\overrightarrow{dl}\,\sin\theta}{4\pi R^2} \qquad \overrightarrow{dH} = \frac{I\,\overrightarrow{dl} \times \overrightarrow{a_R}}{4\pi R^2} = \frac{I\,\overrightarrow{dl} \times \vec{R}}{4\pi R^2}$$

3. Find the magnetic field a distance s from a long straight wire carrying a steady current I. [Understand] **(May 19 R17)**
   Magnetic field a distance s from a long straight wire carrying a steady current I



$$B = \frac{\mu_0 I}{2\pi r}$$

4. Write Lorent'z force equation for a moving charge. [Understand] **(May 19 R17, Nov 2016N, Nov2015, May 15,Nov 2013,Nov 2012,Nov 2011,Nov 2009,Nov 2008)**

   Lorentz force equation gives the force experienced by the test charge in the magnetic flux density and electric field intensity .It is maximum if the direction of movement of charge is perpendicular to the orientation of field lines.

   $$\vec{F} = q(\vec{E} + \vec{V} \times \vec{B})$$

5. What is vector magnetic potential? [Remember] **(May18N)**
   It is defined as the vector quantity whose curl gives the magnetic flux density.

   $$\vec{B} = \nabla \times \vec{A}$$

   $$\nabla \bullet \bar{B} = 0$$
   $$\nabla \bullet (\nabla \times \bar{A}) = 0 \Rightarrow \bar{B} = \nabla \times \bar{A} \ (T)$$

   A - vector magnetic potential (Wb/m)

6. What is ferro Magnetic Materials? [Remember] **(May18N)**
   Ferromagnetic material has the magnetic moment, intensity of magnetisation and magnetic susceptibility are all positive and quite large and magnetic permeability is of the order of hundreds and thousands.
   The magnetic susceptibility decreases with rise of temperature.

7. An infinitesimal length of wire is located at (1,0,0) and carries a current 2A in the direction of unit vector az. Find the magnetic flux density B due to the current element at the field point (0,2,2) . [Apply] **(Nov 17N)**

   B = µ H $\oint \vec{H} \cdot \vec{dl} = I_{enc}$

8. State Ampere's circuital law. [Remember] **(May17N, May 2011,May 2009,Nov2009,Nov 2007,May 2007)**

   Magnetic field intensity around a closed path is equal to the current enclosed by that path.

   $$\oint \vec{H} \cdot \vec{dl} = I_{enc}$$

9. Define magnetic vector potential. [Understand] **(Nov 17N, Mat 15,Nov 14,May 2013,May 2009)**
   It is defined as the vector quantity whose curl gives the magnetic flux density.

$$\vec{B} = \nabla \times \vec{A}$$
$$\vec{A} = Magnetic\ vector\ potential$$

10. Define magnetic vector and scalar potential. [Understand] (**May 2016N**)

It is defined as scalar quantity whose negative gradient gives the magnetic intensity if there is no current source present. V_m = Magnetic scalar potential

$$\vec{H} = -\nabla V_m$$

It is defined as the vector quantity whose curl gives the magnetic flux density.

$$\vec{B} = \nabla \times \vec{A}$$
$$\vec{A} = Magnetic\ vector\ potential$$

11. A current of 3A flowing through an inductor of 100mH. What is the energy stored in inductor? [Apply] (**May 2016N**)

Energy stored in inductor $=1/2 \ \ L I^2$

$=1/2 \ \ 100*10^{-3} \ \ 3^2$

$= 0.45$

12. If the magnetic field $B = 25x\hat{\imath} + 12y\hat{\jmath} + \alpha z \hat{k}\ (T)$, Find α. [Understand] (**May 2016**)

$$\oint \vec{B}.\vec{ds} = 0 \quad or \quad \nabla.\vec{B} = 0$$

$25+12+\alpha = 0$

$\alpha = -37$

13. Derive point form of Ampere’s circuital law. [Understand] (**Nov 2015N**)

Ampere's circuital law states that the line integral of the magnetic field $\vec{H}$ (circulation of H) around a closed path is the net current enclosed by this path. Mathematically,

$$\oint \vec{H}.\vec{dl} = I_{enc}$$

The total current I enc can be written as,

$$I_{enc} = \int_S \vec{J}.\vec{ds}$$

By applying Stoke's theorem, we can write

$$\oint \vec{H}.d\vec{l} = \int_S \nabla \times \vec{H}.d\vec{s}$$

$$\therefore \int_S \nabla \times \vec{H}.d\vec{s} = \int_S \vec{J}.d\vec{s}$$

$$\therefore \nabla \times \vec{H} = \vec{J}$$

which is the Ampere's law in the point form.

14. What is magnetic dipole moment?[Understand] **(Nov2015,Nov 2013,May 2009,Nov 2007)**
The magnetic moment is the product of current and area. Magnetic moment is also defined as the maximum torque per magnetic induction of flux density.

m = IA

15. Define magnetic scalar potential. [Understand] **(May 15 N)**
It is defined as scalar quantity whose negative gradient gives the magnetic intensity if there is no current source present.
$\vec{H} = -\nabla V_m$
V_m = Magnetic scalar potential

16. What is meant by magnetic flux density? [Understand] **(May 15 N ,Nov 2012)**
Magnetic flux density (B) = $\frac{\text{Magnetic flux}}{\text{Area}}$
B = $\underline{\Phi}$ Webers/m^2 (Tesla)

17. What is meant by magnetic field intensity? [Understand] **(May 2012,Nov 2009)**
Magnetic flux density - (B)
Magnetic field intensity - (H)
$B = \mu H$ $\mu = \mu_0\mu_r$ $H = \frac{B}{\mu}$
μ_0 = Permeability of free space = $4\pi \times 10^{-7}$
μ_r = Relative permeability

18. Write down the expression for the torque experienced by a current carrying loop situated in a magnetic field. [Understand] **(May 2012)**
Torque,T=BIASin¯=mBSin¯=m x B
m=IA
m-magnetic moment
B-Magnetic flux density
I-Current in the loop
A-Area of the loop

19. State Coulomb's law of electrostatic charges. [Understand] **(Nov 2011)**

Coulomb's law states that force between two point charges is

(i)Directly proportional to product of two charges

(ii)Inversely proportional to square of the distance between them

$$F \propto \frac{Q_1 Q_2}{r^2} = \frac{Q_1\, Q_2}{4\pi\varepsilon r^2}$$

20. Mention the importance of Lorentz force equation. .[Remember] **(May 2007)**

Lorentz force equation is used to determine

- Electron orbits in the magnetron
- Proton path in cyclotron
- Plasma characteristics in magneto hydro dynamic generator (MHD).

21. A current of 2 A flowing is flowing in an inductor of inductance 100 mH.What is the energy stored in the inductor? .[Apply] **(Nov 2006)**

$W = ½\, LI^2 = ½ \text{ x}100\text{x}10^{-3}\text{x}2^2 = 0.2$ Joules

22. Write an expression for torque in vector form. .[Remember] **(Nov 2006)**

Torque is the vector product of magnetic moment and magnetic flux density.

$$\vec{T} = \vec{m} \times \vec{B}$$

23. State ampere's circuital law. Must the path of integration be circular? .[Remember]

The line integral of the tangential component of the magnetic field strength around a closed path is equal to the current enclosed by the path.

$$\int H.dl = I$$

The path of integration must be enclosed one. It must be any shape and it need not be circular alone.

19. State the expression of $\overline{H}$ due to infinite sheet of current. .[Remember]

In general, for an infinite sheet of current density $\overline{K}$ A/m we can write,

$$\boxed{\overline{H} = \frac{1}{2}\, \overline{K} \times \overline{a}_N}$$

Where $\overline{a}_N$ = Unit vector normal from the current sheet to the point at which $\overline{H}$ is to be obtained.

20. Define curl of $\overline{H}$..[Remember]

In general,

$$\frac{\int \overline{H} \bullet d\overline{L}}{\Delta S_N} = J_N$$

Where J_N = Current density normal to the surface ΔS.

The term on left hand side of the equation is called curl $\overline{H}$. The ΔS_N is area enclosed by the closed line integral.

21. Define magnetic flux and magnetic flux density. .[Remember]

The imaginary lines of magnetic force existing in the magnetic field is called the magnetic flux. The flux in webers passing through unit area in a plane at right angles to the direction of flux is called flux density. The flux is measured in webers while flux density is Wb/m^2.

22. State Gauss law for magnetic field. .[Remember]

The total magnetic flux passing through any closed surface is equal to zero.

$$\oint \vec{B}.\overrightarrow{ds} = 0 \quad or \quad \nabla.\vec{B} = 0$$

23. Give the force on a current element. .[Remember]

The force on a current element Idl is given by,

$$d\vec{F} = I\,\overrightarrow{dl} \times \vec{B}$$

24. Explain the conservative property of electric field. .[Remember]

The work done in moving a point charge around a closed path in an electric field is zero. Such a field is said to be conservative.

$$\int E.dl = 0$$

25. What are equipotential surfaces? .[Remember]

An equipotential surface is a surface in which the potential energy at every point is of the same value.

26. Give four similarities between electrostatic field and magnetic field. .[Understand]

ELECTROSTATIC FIELD	MAGNETIC FIELD
Electric flux density E volts/m	Magnetic flux density H A/m
Electric flux density D = εE c/m	Magnetic flux density B=μH web/m^2
Energy stored is ½ CV^2	Energy stored is ½ LI^2
Charges are at rest	Charges are in motion

27. Find the maximum torque on an 100 turn rectangular coil, 0.2m, carrying a current of 2a in the field of flux density 5web/m^2. .[Apply]

$N = 100$, $A = 0.2 \times 0.3 = 0.06\ m^2$, $I = 2A$, $B = 5Web/\ m^2$

$$T_{max} = NIAB$$
$$= 100 \times 2 \times 0.06 \times 5$$
$$= 60 \text{ Newton – metre.}$$

28. Define magnetic dipole. .[Remember]

A small bar magnet with pole strength Q_m and length l may be treated as magnetic dipole whose magnetic moment is $Q_m l$.

29. Write the Poisson's equation for magnetic field. .[Remember]

$$\nabla^2 \vec{A} = -\mu_0 \vec{J}$$

$\vec{A} = Magnetic\ vector\ potential$ $\quad$ $\vec{J} = Current\ density$

30. Write down the equation for general, integral and point form of ampere's law. .[Remember]

General Form : $\int H.dl = I$

Integral Form : $\int H.dl = \iint_S J.ds$

Point Form : $\nabla \times H = J$

31. List the applications of ampere's circuital law. .[Remember]

The applications of Ampere's circuital law are to find $\overline{H}$ for,

1) Infinitely long straight conductor
2) Co-axial cable
3) Infinite sheet of current

32. State the expression of $\overline{H}$ due to the infinitely long straight conductor along z axis carrying current I. .[Remember]

$$\overline{H} = \frac{I}{2\pi r}\ \overline{a}_\Phi \text{ A/m}$$

$$\overline{B} = \mu \overline{H} = \frac{\mu I}{2\pi r}\ \overline{a}_\Phi \text{ Wb/m}^2$$

33. State the expression of $\overline{H}$ due to straight conductor of finite length, carrying current I. [Remember]

$$\overline{H} = \frac{I}{4\pi r} [\sin \alpha_2 - \sin \alpha_1] \, \overline{a}_\Phi \text{ A/m}$$

$$\overline{B} = \mu \overline{H} = \frac{\mu I}{4\pi r} [\sin \alpha_2 - \sin \alpha_1] \, \overline{a}_\Phi \text{ Wb/m}^2$$

34. State the expression of $\overline{H}$ on the axis of a circular loop, at a distance Z. .[Remember]

$$\overline{H} = \frac{I r^2}{2(r^2 + z^2)^{3/2}} \, \overline{a}_z \text{ A/m}$$

35. Write the Laplace's equation for magnetic field? .[Remember]

$\nabla^2 V_m = 0$, V_m = Magnetic scalar potential

36. Calculate the mutual inductance of two inductively tightly coupled coils with self inductance of 25 mH and 100 mH. [Apply] (**Nov 2016N**)

$M = K\sqrt{L_1 L_2} = 1. \sqrt{25 \times 100} = 50$ mH.

37. Mention the force between too current elements. [Remember] (**May 2016N**)

$$F_1 = \frac{\mu_0 I_1 I_2}{4\pi} \oint_{L_1} \oint_{L_2} \frac{dl_1 \times (dl_2 \times a_{R_{21}})}{R_{21}^2}$$

38. Differentiate diamagnetic and ferromagnetic material. [Understand] (**May 2016N**)

Diamagnetic material	**Ferromagnetic material**
The magnetic moment, intensity of magnetisation and magnetic susceptibility are all negative while magnetic permeability has value less than1. Repelled by a strong magnet	The magnetic moment, intensity of magnetisation and magnetic susceptibility are all positive and quite large and magnetic permeability is of the order of hundreds and thousands.
The magnetic susceptibility is independent of temperature	The magnetic susceptibility decreases with rise of temperature

39. In a ferromagnetic material (μ=4.5μ0), the magnetic flux density is B=10ya_x mWb/m^2. Calculate the magnetization vector (μ_{-0} =4π x 10^{-7} H/m). [Understand] (**Nov 2015N**)

40. What is the energy stored in a magnetic field in terms of field quantities? [Remember] (**Nov 2015N**)

energy stored in the magnetic field (W_m).

$$\boxed{W_m = \frac{1}{2}LI^2}$$

inductance of the solenoid is, $L = \frac{\lambda}{I} = \frac{\mu A N^2}{l}$

magnetic energy stored in the solenoid is, $W_m = = \frac{1}{2}LI^2 = \frac{1}{2}\frac{\mu A N^2}{l}I^2$

41. An infinite solenoid (n turns per unit length, current I) is filled with a linear material of susceptibility χ_m. Find the magnetic field inside the solenoid. [Remember] (**Nov 2015**)

H= NI/L

42. Write the expression for energy stored in an inductor. [Remember] **(May15N,May 2012)**

W = ½ LI^2(Joules)

L-Inductance of inductor(Henry)

I-Current(Amperes)

44. Write an expression for torque in vector form. [Remember]**(May 15N)**

$$\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$$
$$\tau = \|\mathbf{r}\|\,\|\mathbf{F}\|\sin\theta$$

where

$\boldsymbol{\tau}$ is the torque vector and τ is the magnitude of the torque,

r is the displacement vector (a vector from the point from which torque is measured (typically the axis of rotation) to the point where force is applied),

F is the force vector,

× denotes the cross product,

θ is the angle between the force vector and the lever arm vector.

45. Define mutual inductance of a system. [Remember] **(May15,Nov 2009,May 2009)**

The mutual inductance between two coils is defined as the ratio of induced magnetic flux linkage in one coil to the current through in coil.

$$M = \frac{N_2\Phi_{12}}{I_1}$$

where, N_2 is no of turns in coil 2

Φ_{12} is magnetic flux links coil 2

I_1 is the current through coil 1.

46. An infinite solenoid (n turns per unit length , Current I) is filled with a linear material of susceptibility χ_m. Find the magnetic field inside the solenoid. [Understand]**(May2014)**

$$\oint \mathbf{H} \cdot d\mathbf{l} = \mathbf{I}_f \quad \text{(integral form)}$$

$$H\ell = n\ell I \quad \therefore \quad \mathbf{H} = nI\hat{\mathbf{z}}$$

$$\mathbf{B} = \mu_0(1+\chi_m)nI\hat{\mathbf{z}}$$

47. Compare self inductance and mutual inductance.[Remember] **(Nov 2013)**

The self inductance of a coil is defined as the *ratio* of total m flux linkage the circuit to the current through the coil. $L = \frac{N\varphi}{I}$ where, Φ is magnetic flux , N is number of turns of coil , I is the current.

The mutual inductance between two coils is defined as the ratio of induced magnetic flux linkage in one coil to the current through in coil.

$$M = \frac{N_2\Phi_{12}}{I_1}$$

where, N_2 is no of turns in coil 2 , Φ_{12} is magnetic flux links coil 2 ,I_1 is the current through coil 1.

48. Define the term relative permeability. [Remember] **(Nov 2012, May 2009)**

Magnetic flux density - (B)

Magnetic field intensity - (H)

$B = \mu H \qquad \mu = \mu_0\mu_r \qquad = B/H$

μ_0 = Permeability of free space = $4\pi \times 10^{-7}$

μ_r = Relative permeability

49. Define Magnetization[Remember] **(Nov 2011,May 2010,Nov 2006)**

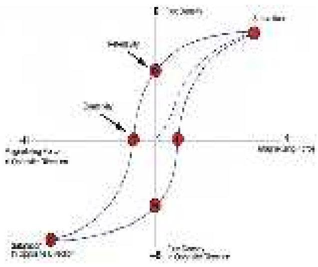
Magnetization is defined as the ratio of magnetic dipole moment per unit volume as volume shrinks to zero.

$$M = \frac{\text{Magnetic dipole}}{\text{Volume}}$$

$$\vec{M} = \frac{\vec{m}}{V}$$

50. Draw the B-H curve for classifying magnetic materials. [Remember] **(May 2011,Nov 2010)**

The phenomenon which causes 'B' to lag behind 'H' as that the magnetization curve for increasing and decreasing applied fields is not the same is called the hysteresis.



51. Classify the magnetic materials. [Remember] **(Nov 2008,May 2008)**

Magnetic materials are classified into three groups. They are:

(a) Diamagnetic

(b) Paramagnetic

(c) Ferromagnetic

52. What is magnetic boundary condition? [Remember] **(Nov 2005)**

i) The normal components of flux density B is continuous across the boundary.

ii) The tangential component of field intensity is continuous across the boundary.

53. Define self inductance. [Remember]

Self inductance is defined as the rate of total magnetic flux linkage to the current through the coil.

54. State Lenz law. [Remember]

Lenz's law states that the induced emf in a circuit produces a current which opposes the change in magnetic flux producing it.

$$emf = -\frac{d\varphi}{dt}$$

55. What is the effect of permittivity on the force between two charges? [Remember]

Increase in permittivity of the medium tends to decrease the force between two charges and decrease in permittivity of the medium tends to increase the force between two charges.

56. Distinguish between diamagnetic, paramagnetic and ferromagnetic materials. [Understand]

Diamagnetic: In this type, the magnetization is opposed to the applied field. It has Weak magnetic field.

Paramagnetic: The magnetization is same direction as the field. It has weak magnetic Field.

Ferromagnetic: The magnetization is in the same direction as the field. It has strong magnetic field.

57. Define inductance. [Remember]

The inductance of a conductor is defined as the ratio of the linking magnetic flux to the current producing the flux. $L = \frac{N\varphi}{I}$

58. What is main cause of eddy current? [Remember]

The main cause of eddy current is that it produces ohmic power loss and causes local heating.

59. Define self inductance. [Remember]

The self inductance of a coil is defined as the *ratio* of total m flux linkage the circuit to the current through the coil. $L = \frac{N\varphi}{I}$

where, Φ is magnetic flux
N is number of turns of coil , I is the current.

60. Define coupling coefficient. [Remember]

The fraction of the total flux produced by one coil linking the second coil is called the coefficient of coupling (K).

$$K = \frac{\varphi_{12}}{\varphi_1} = \frac{\varphi_{21}}{\varphi_2}$$

$K=M/\sqrt{L_1L_2}$

61. How mutual inductances between two coils are related to their self inductances? [Understand]

$$M=K\sqrt{L_1L_2}$$

Where,

K is coupling coefficient

L_1 is self inductance of coil 1

L_2 is self inductance of coil 2

M is mutual inductance.

62. What will be effective inductance, if two inductors are connected in (a) and (b) parallel? [Understand]

a)For Series $L= L_1 + L_2 \pm 2M$ + *sign for aiding*

b) For Parallel $L = \frac{L1L2—M^2}{L_1+L_2\pm2M}$ - *sign* for *opposition*

63. Two coils, having self inductance of l mH and 2mH and mutual of 3mH are connected in series. Find the effective inductance [Understand]

of the series combination.

L1 = l mH

L2=2mH

M=0.5mH

i) L=L1 +L2-2M (opposition)

=1+2-1

=2mH

ii)L =L1 +L2+2M (aiding)

= 1+2+1

= 4mH

64. Define mmf. [Remember]

magnetic motvie force (mmf) is given by

mmf= flux x reluctance

mmf =Φ.R Amp.turns.

65. Define reluctance. [Remember]

Reluctance is the ratio of mmf of magnetic circuit to the flux through I.

$$R= \frac{m\ rn\ f}{flux\ \Phi}$$

66. In a solenoid with an inductance of 5mH current is increasing at the rate of 100A/sec. What is the value of induced emf? [Understand]

$$emf = L\frac{di}{dt} = 5x10^{-3}xl00 = 0.5\ V$$

What is energy density in the magnetic field? [Understand]

Energy density $W=1/2\ BH = 1/2\mu H^2$

67. Define permeance. [Remember]

Permeance is the reciprocal of reluctance.

68. Distinguish between solenoid and toroid. [Understand]

Solenoid is a cylindrically shaped coil consisting of a large number of closely spaced turns of insulated wire wound usually on a non-magnetic frame. If a long, slender solenoid is bent into the form of a ring and thereby closed on itself, it becomes toroid.

PART B

1. Consider an infinitely long coaxial transmission line and obtain the expressions for magnetic field intensity (H) everywhere using Ampere's circuit law. **(May 21)** [Understand]
2. Determine the necessary boundary conditions between two different magnetic media μ1 and μ2. **(May 21)** [Understand]
3. Determine the expression of self inductance for a solenoid having inner radius 'a' and outer radius 'b'. (7) **(May 21)** [Apply]
4. Calculate the self inductance of a solenoid having 500 turns about a cylindrical core of 2 cm radius in which μr = 50 for 0 < ρ < 0.5 cm. (8) **(May 21)** [Apply]
5. Find the magnetic field at the centre of a square loop, which carries a steady current I, Let R be the distance from centre to side. Find the field at the centre of a n-sided polygon, carrying a steady current I. Again, let R be the distance from the centre to any side. Find the formula in the limit n (number of sides) tends to infinity. [Understand] **13(May 19, 17R) (8)(May 2016**)
6. Define (i) the mutual inductance between two circuits and ,(ii) self inductance of a single coil. Also explain how the self inductance of a wire wound inductor depends on its number of turns. [Understand] **13(May 19, 17R)**
7. From the biot savarts law obtain the expression for magnetic field intensity and vector potential at a point P and distance R from infinitely long straight current carrying conductor. **(Apr 18N,Nov 16N)** [Understand]
8. Find the magnetic field a distance h above the center of a circular loop of radius R, which carries a steady current I. **)** [Understand] **(May 18N,May 2016**)
9. Derive the vector magnetic potential from biotsavart law. **(8) (May 17N)** [Understand]
10. Find the magnetic flux density for the infinite current sheet in the xy plane with current density $K=Kya_y$ A/m current. **(7) (May 17N)** [Understand]
11. Derive the equation for the magenetization for the materials and show that J_b = xm and K_b =mxa_n **(6) (May 17N)** [Understand]
12. Consider two identical circular current loops of radius 3m and opposite current 20 Amps are in parallel planes seperated on their common axis by 10m. Find the magnetic field intensity at a point midway between the two loops. **(8)(Nov 16N)** [Apply]
13. State biorts savarts law. Find the magnetic field intensity at the origin due to the current element Idl = 3π (a_x +2 a_y + 3 a_z) Am at (3,4,5) in free space. **(8)(Nov 16N)** [Apply]
14. State Biot-Savart's law. Derive the expressions for magnetic field intensity and magnetic flux density at the centre of the square current loop of side l. Then determine the same for square loop of sides 5m carrying current of 10 A. [Understand] **16)** (**May 2016N**)

15. Derive an expression for magnetic field due to an infinitely long coaxial cable. **(16)** (**May 2016N**) .[Remember]
16. Derive the expressions which mutually relate current density J, Magnetic field B and Magnetic vector potential A. [Understand]
    (8) (**May 2016**)
17. An infinitely long, straight conductor with a circular cross section of radius 'b' carries a steady current 'I'. Determine magnetic flux density both inside and outside the conductor. [Understand] **(16)** (**Nov 2015N**)
18. Derive the expression for vector magnetic potential in terms of current density. **)** [Understand]
    (10) (**Nov 2015N**)
19. For a current distribution in free space, $A= (2x^2y + yz)\, a_x + (xy^2 - xz^3)\, a_y - (6xyz - 2x^2y^2)\, a_z$ (Wb/m). Calculate magnetic flux density. [Understand] **(6)** (**Nov 2015N**)
20. An iron ring with a cross sectional area of 3 cm square and mean circumference of 15 cm is wound with 250 turns wire carrying a current of 0.3 A. The relative permeability of ring is 1500. Calculate the flux established in the ring. [Apply] **(8)** (**Nov 2015**)
21. Derive the expressions for magnetic field intensity and magnetic flux density due to finite and infinite line carrying a current 1. [Understand] **(16)** (**Nov 2015**)
17. Magnetic vector potential $A=-\rho^2/4\ a_z$ Wb/m, calculate the total magnetic flux crossing the surface $\phi=\pi/2$, $1\leq\rho\leq 2$m, $0\leq z\leq 5$m. [Apply] **(8) (May 15N)**
18. H= 3 cos xax + z cos x ay, A/m for z>=0 and H=0 for z<0. This magnetic field is applied to a perfectly conducting surface in xy plane. Find current density on conductor surface. [Apply] **(8) (May 15N)**
19. Obtain the expression for magnetic field intensity at the centre of a circular wire**.** [Understand] **(8) (May 15N)**
20. At a point P(x,y,z) the components of vector magnetic potential A are given as Ax=4x+3y+2z; Ay=5x+6y+3z; Az=2x+3y+5z. Find B at point P.
    (4) (May 15N)
21. Explain the magnetic field intensity due to a straight wire. [Understand] **(4) (May 15N)**
22. Define magnetic flux density and magnetic moment**.** [Understand] **(4) (May 15)**
23. Find H in rectangular co-ordinates at P (2,3,4) if ther is a current filament on the z axis carrying 8mA in az direction**.** [Apply] **(4) (May 15)**
24. Express Biot savart law in vector form and describe it. [Understand] **(4) (May 15)**
25. State Ampere's circuital law and discuss about any two simple applications of it**.** [Understand] **(8) (May 15)**
26. Find H in rectangular components at P(2,3,4) if there is a current filament on the z axis carrying 8mA in the α2 direction. Repeat if the filament is located at x=-1 and y=2. Find H if both filaments are present. [Apply] **(6) (Nov 14)**

27. State Ampere's force equation for a moving charge and explain its applications. [Understand] **(6) (Nov 14)**
28. Derive the expression for Torque on a loop carrying a current I. [Understand] **(10) (Nov 14)**
29. State and prove the boundary conditions for static magnetic field and static electric field. [Understand] **(10) (Nov 14)**
30. Find the magnetic field at the center of a square loop which carries a steady current I , let R be the distance from center to side. Find the field at the center of n sided polygon carrying a steady current I. Again let R be the distance from the center to any side. Find formula in the limit n(number of sides) tends to infinity. [Understand] **(8)(May 2014)**
31. Derive an Expression for magnetic field intensity on the axis of a circular loop of radius R a carrying current I. [Understand] **(8)(May 2014,Nov2012)**
32. Derive Ampere's Law. [Understand] **(8)(May 2014)**
33. Derive the expression which mutually relate current density J,magnetic field B and Magnetic vector Potential A[Understand].**(8)(May 2014)**
34. Derive an expression for Biot-Savart's law. Derive the equation for Torque on current carrying loop. [Understand] **(Nov 2013)**
35. Find H Field on the axis of a ring carrying a constant current.Highlight the similarities between Biort-Savart Law and coulomb's Law. [Understand] **(Nov 2013)**
36. Derive the expression for Magnetic field intensity and magnetic flux density due to finite and infinite line carrying a current L. [Understand] **(May 2013)**
37. Derive an expression for force between two current carrying conductors.[Understand] **(8) (May 2013)**
38. An iron ring with the cross sectional area of 3 cm square and mean circumference of 15cm is wound with 250turns wire carrying a current 0.3 A. The relative permeability of ring is 1500. Calculate the flux established in the ring. [Apply] **(8) (May 2013)**
39. Derive an expression for magnetic field intensity due to a linear conductor of infinite length carrying a current I at a distant point P.Assume R to be the distance between conductor and point P.Use Biot Savart's law. **(8)(Nov2012,Nov 2010)**
40. Obtain the expression for Scalar and Vector Magnetic Potential. .[Understand] **(8)(Nov2012)**
41. At a point P(x,y,z) the components of vector magnetic potential $\vec{A}$ are given as $A_x=4x+3y+2z$, $A_y=5x+6y+3z$ and $A_z=2x+3y+5z$. Determine the magnetic flux density B at the point P. [Apply]**(4)(Nov2012)**
42. Given the magnetic flux density $B = 2.5 (\sin \pi x/2)e^{-2y}\, a_z\ Wb/m^2$, find the total magnetic flux crossing the strip defined by $z=0, y\geq 0, 0 \leq x \leq 2m$. [Apply] **(4)(Nov2012)**
43. Find the magnetic field intensity due to a finite wire carrying a current I and hence deduce an expression for magnetic field intensity at the centre of a square loop.[Understand]**(8)(May 2012)**
44. Derive the magnetic field intensity in the different regions of co-axial cable by applying Ampere's circuital law.[Understand] **(8)(May 2012)**
45. Obtain the expressions for scalar and vector magnetic potential. [Understand] **(8)(May 2012)**

46. The vector magnetic potential $\vec{A} = (3y-3)\vec{a}_x + 2xy\vec{a}_y$ Wb/m in a certain region of free space.(1)Show that $\nabla.\vec{A} = 0$.(2)Find the magnetic flux density B and the magnetic field intensity $\vec{H}$ at P(2,-1,3). [Apply] **(8)(May 2012,2010)**
47. Find the magnetic field intensity due to a finite wire carrying a current I and hence deduce an expression for magnetic field intensity at the centre of a square loop**.**[Understand] **(8)(Nov 2011)**
48. A circular loop located on $x^2+y^2=4, z=0$ carries a direct current of 7 A along a_Φ.Find the magnetic field intensity at (0,0,-5).[Apply] **(4)(Nov 2011)**
49. Using ampere's circuital law determine the magnetic field intensity due to a infinite long wire carrying a current I. [Understand] **(4)(Nov 2011)**
50. A differential current element I dz a_z is located at the origin in free space. Obtain the expression for vector magnetic potential due to the current element and hence find the magnetic field intensity at the point (ρ, Φ,z).[Understand] **(8)(Nov 2011)**
51. Using Biot-Savart's law,derive the magnetic field intensity on the axis of a circular loop carrying a steady current I.[Understand] **(8)(May 2011,Nov 2010)**
52. Using Ampere's circuital law, derive the magnetic field intensity due to a co-axial cable carrying a steady current I.[Understand] **(8)(May 2011)**
53. Derive an expression for torque on a closed rectangular loop carrying a current I. [Understand] **(8)(May 2011,May 2009)**
54. In cylindrical co-ordinates, $\vec{A} = 50 \circ {}^{2}\vec{a}_z$ Wb/m is a vector magnetic potential in a certain region of free space.Find the magnetic field intensity(H),magnetic flux density(B) and current density(J). [Apply] **(8)(May 2011)**
55. Derive an expression for magnetic field intensity due to a linear conductor of infinite length carrying a current I at a distant point P.Assume R to be the distance between conductor and point P.Use Biot Savart's law.[Understand] **(8)(Nov 2010)**
56. Obtain the expressions for scalar and vector magnetic potential.[Understand] **(8)(Nov 2010)**
57. State and explain Ampere's circuital law. **(8)(May 2010,May 2009,Nov 2006)**
58. Find an expression for H at any point due to a long, straight conductor carrying I amperes.**(8)(May 2010,May 2008)**
59. Find the maximum torque on an 85 turns rectangular coil with dimension(0.2X0.3)m, carrying a current of 5 Amps in a field B=6.5 T. [Apply] **(8)(May 2010)**
60. Derive an expression for magnetic vector potential.[Understand]. **(8)(May 2010)**
61. Derive an expression for force between two parallel wires carrying currents in the same direction. **(6)(Nov 2009,May 2008,Nov 2007)**
62. Two wires carrying currents in the same direction of 5000 A and 10000 A are placed with their axes 5 cm apart.Calculate the force between them in 'N' per meter length. [Apply] **(10)(Nov 2009)**
63. Explain Biot Savart's law.[Understand].**(8)(Nov 2009,May 2009)**
64. Explain Magnetic moment. .[Understand] **(8)(Nov 2009,May 2009)**

65. Find an expression for H at any point due to an infinitely long,current carrying conductor. **(10)(May 2009)**
66. A circular loop located on $x^2+y^2=9, z=0$ carries a direct current of 10 A along a_Φ.Find the magnetic field intensity at (0,0,4) and (0,0,-4). [Apply] **(16)(Nov 2009)**
67. Find the magnetic flux density at a point on the axis of a circular loop of a radius b that carries current I. .[Understand] **(16)(Nov 2009)**
68. Find the magnetic field intensity at the centre '0' of a square of sides equal to 5 m and carrying 10 amperes of current. [Understand]**(8)(May 2009)**
69. Explain the concepts of (i)scalar magnetic potential (ii)vector magnetic potential. .[Understand] **(16)(Nov 2008,Nov 2006)**
70. Determine the force per metre length between two long parallel wires A and B separated by 5 cm in air and carrying currents of 40 Amps in the same direction. .[Understand] **(8)(May 2007)**
71. Obtain the expression for for magnetic field intensity at the centre of a circular wire.[Understand]. **(8)(May 2007)**
72. Obtain the expression for magnetic field intensity at the centre of square loop.**(8)(May 2007)**
73. If the vector magnetic potential is given by $A = \frac{10}{x^2+y^2+z^2} u_x$ obtain the magnetic flux density in vector form. [Apply] **(8)(May 2007)**
74. Find an expression for force acting on a square loop carrying a current I.[Understand] **(8)(Nov 2006)**
75. Two small identical conducting sphere have charges of 2nc and-1nc respectively. When they are separated by 4cm apart, find the Magnitude of the force between them. If they are brought into Contacts and then again separated by 4cm.find the force between them..[Analyse] **(8)(Nov 2006)**
76. Obtain the expressions for D and E using Gauss's law. [Understand] **(8)(May 2007)**
77. A uniform line charge ρ_L = 25 nc/m lies on the line, x = -3m and y = 4m, in free space, find the electric field intensity at a point (2, 3, 15) m. [Apply] **(8)(May 2007)**
78. A circular disc of 10cm radius is charged uniformly with a total charge of 10^{-6}c.find the electric intensity at a point 30cm away from the disc along the axis. [Apply]
79. When a current carrying wire is placed in an uniform magnetic field, show that torque acting on it is T= $\overline{m}$ X $\overline{B}$. [Analyse]
80. Derive the boundary condition for the E Field and H Field in the interference between dielectric and free space. **(13) (May 17N)** [Analyze]
81. Propose the salient points to be noted when the boundary conditions are applied. **(8) (May 17N)** [Understand]
82. Derive an expression for force between two current carrying conductors. [Understand] **(6) May 17N (8) (Nov 2015)**
83. Classify the materials based on magnetic properties. **(5) (May 17N)** [Understand]
84. Find the expression of inductance for the co-axial.**(8) (May 17N)**[Remember]

85. A charged particle with velocity u is moving in a medium containing uniform field E= Ea_x V/m and B = B a_y Wb/m2. What should u be so that the particle experiences no net force on it?(8) **(Nov 16N)** [Analyze]
86. State and derive the magnetic boundary conditions between the two magnetic mediums.(8) **(Nov 16N)** [Understand]
87. Derive the expression for inductance and magnetic flux density inside the solenoid. Calculate the inductance of the solenoid and energy stored when a current 8A flowing through the solenoid of 2m long, 10cm diameter and 4000 turns.(16) **(Nov 16N)** [Analyze]
88. Derive the expression for force on a moving charge in a magnetic field and Lorentz force equation. [Understand] **(8)** (**May 2016N**)
89. Derive the inductance of a toroid. [Understand] **(8)** (**May 2016N**)
90. Derive an expression for inductance of a solenoid. Calculate the inductance of solenoid, 8 cm in length, 2 cm in radius, having μ_r= 100 and 1000 turns. [Apply] **(8)** (**May 2016N**)
91. Give the comparison between magnetic and electric circuits. [Understand] **(8)** (**May 2016N**)
92. Derive the boundary relations for [Understand] **(16)(May 2016)**
    (i) E- field
    (ii) H- field
93. A composite conductor of cylindrical cross section used in overhead line is made of a steel inner wire of radius "a" and an annular outer conductor of radius "b", the two having electrical contact. Evaluate the H-field within the conductors and the internal self-inductance per unit length of the composite conductor. [Understand] **(16)(May 2016)**
94. Explain about magnetization vector and derive the expression for relative permeability. [Understand]
95. State and explain Ampere's force law. [Understand] (**10**) (**Nov 2015N**)
96. Derive the boundary conditions of static magnetic field at the interface of two different magnetic medium. [Understand] (**6**) (**Nov 2015N**)
97. Derive an expression for force between two current carrying conductors. [Understand] **(8)** (**Nov 2015**)
98. Derive the expressions for inductance of a toroidal coil carrying current[Understand].**(8)(Nov 2015)**
99. A solenoid is 50 cm long, 2 cm in diameter and contains 1500 turs. The cylindrical core has a diameter of 2 cm and a relative permeability of 75. This coil is co-axial with a second solenoid, also 50 cm long, but 3 cm diameter and 1200 turns. Calculate L for the inner solenoid and L for the outer solenoid. [Apply] **(8)(Nov 2015)**
100. A strategy current with normal component Jn is flowing across the interface between the two conducting media of conductivities σ1 and σ2 and permittivities ε1 and ε2 respectively. Show that there must be a surface charge density on the interface. Find its magnitude. **(6)(May 15N)**

101. Find the magnetic field of current in a straight circular cylindrical conductor of radius “a”, and express the magnetic field as a vector in terms of current density, J. [Understand] **(10) (May 15N)**

102. A composite conductor of cylindrical cross section used in overhead lines is made of a steel inner wire of radius Ri and an annular outer conductor of radius R0, the two having electrical contact. Find the magnetic field within the conductors and the internal self inductance per unit length of the composite conductor. [Understand] **(16) (May 15N)**

103. Derive an expression for torque on a loop carrying a c current I**.** [Understand] **(12) (May 15)**

104. Discuss in detail the nature of magnetic materials**.** [Understand] **(6) (May 15)**

105. A solenoid is 50 cm long , 2 cm in dia and contains 1500 turns. The cylindrical core has a diameter of 2 cm and relative permeability of 75.the coil is coaxial with a second solenoid 50 cm long,3cm in dia and having 1200 turns.calculate the inductance for the inner solenoid . find inductance of the outer solenoid , determine mutual inductance between the two solenoids. [Apply] **(6) (May 15)**

106. Calculate the self-inductances of and the mutual inductances between two coaxial solenoids R1, and R2, R2>R1, carrying currents I1 and I2 with n1 and n2 turns/m respectively. **(6) (Nov 14)** [Apply]

107. Derive the expression for energy density in magnetic fields. [Understand] **(6) (Nov 14)**

108. A small loop of wire (radius a)lies a distance z above the center of a large loop (radius b). The planes of the two loops are parallel and perpendicular to the common axis . Suppose current I flows in the big loop. Find the flux through the little loop. Find the mutual inductance.[Apply] **(May2014)**

109. Discuss the magnetic boundary conditions.[Understand] **(6)(May2014)**

110. Solve the Laplace’s equation for the potential field in the homogeneous region between two concentric conducting spheres with radius ‘a’ and ‘b’ where b>a,V=0 at r=b and $V=V_0$ at r=a.Find the capacitance between the two concentric spheres. [Apply] **(8)(Nov 2012,May 2011)**

111. Derive the expression for inductance of a toroidal coil carrying current. [Understand] **8)(Nov 2012,May 2012)**

112. Considering a toroidal coil, derive an expression for energy density. [Understand] **(8)(Nov 2013)**

113. Derive the expression for inductance of a toroidal coil carrying current. [Understand] **(8)(May 2012)**

114. A solenoid is 50 cm long,2 cm in diameter and contains 1500 turns. The cylindrical core has a diameter of 2 cm and a relative permittivity of 75.This coil is co-axial with a second solenoid also 50 cm long but 3 cm diameter and 1200 turns. Calculate L for the inner solenoid and L for the outer solenoid. [Apply] **(8)(May 2012)**

115. Derive an expression for inductance of a solenoid with N turns and l metre length carrying a current of I amperes. **(6)(Nov 2011,May 2010,Nov 2007)**

116. An iron ring of relative permeability 100 is wound uniformly with two coils of 100 and 400 turns of wire.The cross section of the ring is 4 cm^2.The mean circumference is 50 cm.Calculate

(i)the self inductance of each of the two coils[Apply] **(10)**(**Nov 2011)**

(ii)the mutual inductance

(iii)Total inductance when the coils are connected in series with flux in the same sense

(iv)Total inductance when the coils are connected in series with flux in the opposite sense.

117. Find the permeability of the material whose magnetic susceptibility is 49. [Apply] **(4)(May 2011)**

118. The inner and outer conductors of a coaxial cable are having radii ‘a’ and ‘b’ respectively.If the inner conductor is carrying current I and the outer conductor is carrying current I in the opposite direction,derive the expressions for(i)the internal inductance and (ii)the external inductance [Apply] **(12)**(**May 2011)**

119. Derive the expression for inductance of a toroidal coil carrying current. [Understand] **(8)(Nov 2010)**

120. A solenoid is 50 cm long ,2 cm in diameter and contains 1500 turns.The cylindrical core has a diameter of 2 cm and a relative permeability of 75.The coil is coaxial with a second solenoid,also 50 cm long but 3 cm diameter and 1200 turns.Calculate L for the inner solenoid and L for the outer solenoid.[Apply] **(8)(Nov 2010)**

121. Derive the boundary conditions at an interface between two magnetic medias. [Understand] **(8)(May 2010,May 2009,May 2008,May 2007,Nov 2006)**

122. Obtain an expression for energy stored in inductor. [Understand] **(8)(May 2009)**

123. What is magnetization?Explain it.[Understand] **(8)(May 2009)**

124. A solenoid has an inductance of 2 mH.If the length of the solenoid is increased by two times and radius is decreased to half of its original value,find the new inductance. [Apply] **(8)(May 2009)**

125. Show that the inductance of the cable $L = \frac{\mu I}{2\pi}\ln(b/a)$ H.[Understand] **(8)(May 2008)**

126. Calculate the inductance of solenoid of 200 turns wound tightly on a cylindrical tube of 6 cm diameter.The length of the tube is 60 cm and the solenoid is in air. [Apply] **(8)(Nov 2007)**

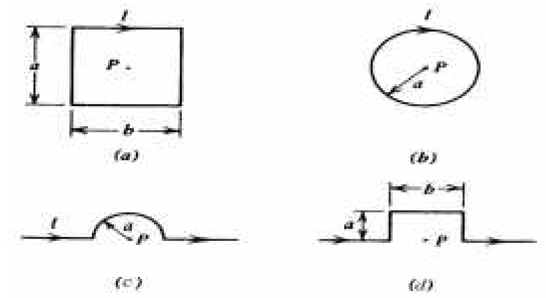
127. Obtain the expression for the inductance of toroid. [Understand] **(8)(May 2007)**

128. Derive the expression for co-efficient of coupling in terms of mutual and self inductances. [Understand]

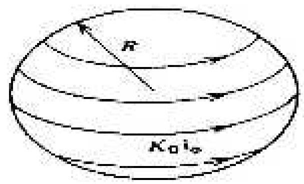
129. An iron ring with a cross sectioned area of 3cm^2 and a mean Circumference of 15cm is wound with 250 turns wire carrying a current of 0.3A. The relative permeability of the ring is 1500.calculate the flux established in the ring. [Apply]

ASSIGNMENT

1. Find the magnetic field intensity at the point P shown due to the following line currents: [Analyze]



2. A constant current $K_o \bar{i}$ flows on the surface of a sphere of radius R. [Analyze]

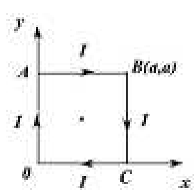


(a) What is the magnetic field intensity at the center of the sphere?
(Hint: $\bar{i}\ \bar{i}_r \cos \cos \bar{i}_x \cos \sin \bar{i}_y \sin \bar{i}_z$)

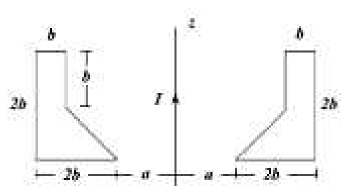
(b) Use the results of (a) to find the magnetic field intensity at the center of a spherical shell of inner radius R_1 and outer radius R_2 carrying a uniformly distributed volume current

$J \quad J_o$

3. A square loop of radius 'a' lies in the z=0 plane and carries current of I as shown in Figure Determine the magnetic field at the centre of the loop. [Analyze]



4. A very long straight wire is encircled by a ring having a cross section as shown in the Figure Calculate the magnetic flux through the ring. Assume ($\mu = \mu_0$)[Analyze]

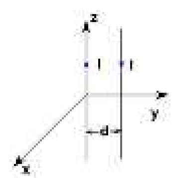


5. A circular loop of radius 'a' lies in the x y plane and carries current of I amps. Obtain the magnetic flux density at the centre of the loop. What is the flux density (approx) at a point on the axis far away from the loop [Understand]

6. A filamentary current carrying conductor that carries a current I is bent into a regular polygon of N sides. Determine the magnetic flux intensity at the centre of the polygon. What happens when N becomes very large? [Understand]

7. The magnetic vector potential is $\vec{A} = \frac{-\rho^2}{2}\hat{a}_z$ Wb/m .Calculate the total magnetic flux crossing the surface $\phi = 0, 0 \leq \rho \leq 1\,\text{m} \quad 0 \leq z \leq 1\,\text{m}$.[Apply]

8. Determine the force per unit length between two infinitely long parallel conductors carrying current *I* in the opposite direction, this conductors being separated by a distance ‘ *d* ' as shown in the figure [Analyze]



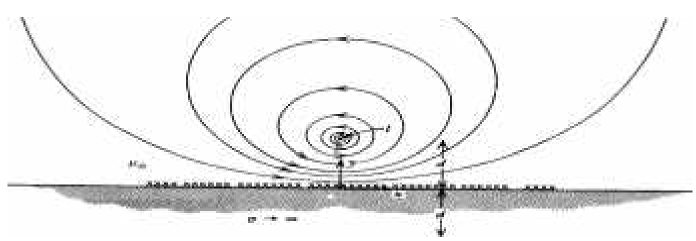
9. What is magnetic dipole moment? [Remember]
10. Write Lorent’z force equation for a moving charge. [Remember]
11. At a point P(x,y,z) the components of vector magnetic potential A are given as Ax=4x+3y+2z; Ay=5x+6y+3z; Az=2x+3y+5z. Find B at point P.
12. Find H in rectangular co-ordinates at P (2,3,4) if ther is a current filament on the z axis carrying 8mA in az direction**.**
13. Find H in rectangular components at P(2,3,4) if there is a current filament on the z axis carrying 8mA in the α2 direction. Repeat if the filament is located at x=-1 and y=2. Find H if both filaments are present.
14. Define magnetic vector potential. [Remember]
15. What is meant by magnetic flux density? [Remember]
16. Write down the expression for the torque experienced by a current carrying loop situated in a magnetic field. [Remember]
17. An iron ring with the cross sectional area of 3 cm square and mean circumference of 15cm is wound with 250turns wire carrying a current 0.3 A. The relative permeability of ring is 1500. Calculate the flux established in the ring. [Apply]
18. State Ampere’s circuital law. [Remember]

19. A circular loop located on $x^2+y^2=4, z=0$ carries a direct current of 7 A along a_Φ.Find the magnetic field intensity at (0,0,-5). [Apply]
20. In cylindrical co-ordinates, $\vec{A} = 50\rho^2\vec{a}_z$ Wb/m is a vector magnetic potential in a certain region of free space.Find the magnetic field intensity(H),magnetic flux density(B) and current density(J). [Apply]
21. Find the maximum torque on an 85 turns rectangular coil with dimension (0.2X0.3)m,carrying a current of 5 Amps in a field B=6.5 T. [Apply]
22. State ampere's circuital law. Must the path of integration be circular? [Remember]
23. Write an expression for torque in vector form. [Remember]
24. Write down the equation for general, integral and point form of ampere's law. [Remember]
25. A circular loop located on $x^2+y^2=9, z=0$ carries a direct current of 10 A along a_Φ. Find the magnetic field intensity at (0,0,4) and (0,0,-4). [Apply]
26. A uniform line charge ρ_L = 25 nc/m lies on the line, x = -3m and y = 4m, in free space, find the electric field intensity at a point (2, 3, 15) m. [Apply]
27. A circular disc of 10cm radius is charged uniformly with a total charge of 10^{-6}c.find the electric intensity at a point 30cm away from the disc along the axis. [Apply]
28. Two wires carrying currents in the same direction of 5000 A and 10000 A are placed with their axes 5 cm apart. Calculate the force between them in 'N' per meter length. [Apply]
29. The vector magnetic potential $\vec{A} = (3y-3)\vec{a}_x + 2xy\vec{a}_y$ Wb/m in a certain region of free space. [Apply]

    (1)Show that $\nabla.\vec{A}=0$.

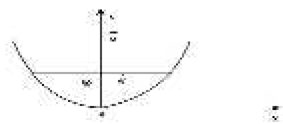
    (2)Find the magnetic flux density B and the magnetic field intensity $\vec{H}$ at P(2,-1,3).

30. A line current *I* of infinite extent in the z-direction is at a distance d above a perfectly conducting plane. [Analyze]

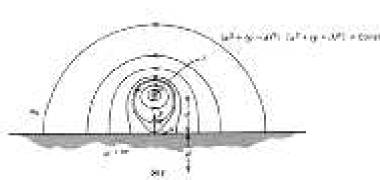


(a) Use the method of images to satisfy boundary conditions and find the magnetic vector potential for $y>0$.
(b) What is the magnetic field for $y>0$?
(c) What is the surface current distribution that flows on the $y=0$ surface?
(d) What is the force per unit length on the line current at $y=d$?

31. A wire in the shape of a parabola $y = kx^2$ is in a uniform magnetic field $\vec{B}$ perpendicular to the plane XY. A jumper translates without initial velocity and at a constant acceleration *a* from the apex of the parabola as shown in figure 5.1. Find e.m.f induced in the formed contour as a function of the co ordinate y. [Analyze]



32. Consider an infinitely long filamentary conductor carrying a current I lies along the Z-axis. A square loop of side a moves away from the conductor with a uniform velocity v_0 along the x -axis and the plane of the loop is normal to y -axis. Determine the induced emf on the loop. [Analyze]



33. A line current *I* of infinite extent in the *z* direction is at a distance *d* above an infinitely permeable material as shown. [Analyze]

a) What is the boundary condition on the magnetic field at $y=0$?
b) Use the method of images to satisfy the boundary condition of (a) and find the magnetic vector potential for $y>0$.
c) What is the magnetic field for $y>0$?
d) Derive the equation of the magnetic field lines for $y>0$.
e) What is the force per unit length on the line current at $y=d$?

34. An infinite solenoid (n turns per unit length, Current I) is filled with a linear material of susceptibility χ_m. Find the magnetic field inside the solenoid. [Apply]

35. Define the term relative permeability.

36. Draw the B-H curve for classifying magnetic materials.

37. A solenoid is 50 cm long, 2 cm in dia and contains 1500 turns. The cylindrical core has a diameter of 2 cm and relative permeability of 75.the coil is coaxial with a second solenoid 50 cm long, 3cm in dia and having 1200 turns. Calculate the inductance for the inner solenoid. Find inductance of the outer solenoid, determine mutual inductance between the two solenoids. [Apply]
38. An iron ring of relative permeability 100 is wound uniformly with two coils of 100 and 400 turns of wire. The cross section of the ring is 4 cm^2.The mean circumference is 50 cm. Calculate[Apply]

    (i)the self inductance of each of the two coils

    (ii)the mutual inductance

    (iii)Total inductance when the coils are connected in series with flux in the same sense

    (iv)Total inductance when the coils are connected in series with flux in the opposite sense.
39. Calculate the self-inductances of and the mutual inductances between two coaxial solenoids R1, and R2, R2>R1, carrying currents I1 and I2 with n1 and n2 turns/m respectively. [Apply]
40. Define mutual inductance of a system. [Remember]
41. Classify the magnetic materials. [Remember]
42. What is magnetic boundary condition? [Remember]
43. Calculate the self-inductances of and the mutual inductances between two coaxial solenoids R1, and R2, R2>R1, carrying currents I1 and I2 with n1 and n2 turns/m respectively. [Understand]
44. An iron ring with a cross sectioned area of 3cm^2 and a mean Circumference of 15cm is wound with 250 turns wire carrying a current of 0.3A. The relative permeability of the ring is 1500.calculate the flux established in the ring. [Apply]
45. Find the magnetic field of current in a straight circular cylindrical conductor of radius “a”, and express the magnetic field as a vector in terms of current density, J. [Understand]
46. State Faraday’s law of electromagnetic induction. [Remember]
47. What will be effective inductance, if two inductors are connected in (a) and (b) parallel?
48. Two coils, having self-inductance of l mH and 2mH and mutual of 3mH are connected in series. Find the effective inductance of the series combination. [Understand]

49. Calculate the inductance of solenoid of 200 turns wound tightly on a cylindrical tube of 6 cm diameter.The length of the tube is 60 cm and the solenoid is in air. [Apply]
50. A solenoid with a radius of 2 cm is wound with 20 turns per cm length and carries 10mA. Find h at the centre if the total length is 10cm. [Apply]
51. Find the permeability of the material whose magnetic susceptibility is 49.
52. A solenoid is 50 cm long , 2 cm in dia and contains 1500 turns. The cylindrical core has a diameter of 2 cm and relative permeability of 75.the coil is coaxial with a second solenoid 50 cm long,3cm in dia and having 1200 turns.calculate the inductance for the inner solenoid . find inductance of the outer solenoid , determine mutual inductance between the two solenoids. [Apply]
53. A solenoid has an inductance of 2 mH.If the length of the solenoid is increased by two times and radius is decreased to half of its original value, find the new inductance. [Apply]
54. Calculate the inductance of solenoid of 200 turns wound tightly on a cylindrical tube of 6 cm diameter.The length of the tube is 60 cm and the solenoid is in air. [Apply]
55. In a solenoid with an inductance of 5mH current is increasing at the rate of 100A/sec. What is the value of induced emf? [Apply]
56. A solenoid has an inductance of 2 mH.If the length of the solenoid is increased by two times and radius is decreased to half of its original value, find the new inductance. [Apply]

UNIT IV

TIME-VARYING FIELDS AND MAXWELL's EQUATIONS

Faraday's law, Displacement current and Maxwell-Ampere law, Maxwell's equations, Potential functions, Electromagnetic boundary conditions, Wave equations and solutions, Time-harmonic fields

Part-A

1. What is meant by displacement current? [Remember] **(May 21) (May 19, R17)**

   Displacement current is given by

   $$J_d = \epsilon_0 \frac{\partial E}{\partial t}$$

2. State Faraday's law. **(May 21, Nov17N, May 2016N, May 2016May 15N, Nov 2013, May 2012, Nov 2012, May 2012,Nov 2009,May 2009)** [Remember]

   Faraday's law states that Electromagnetic force induced in a circuit is equal to the rate of change of magnetic flux linking in the circuit.

   Emf = - N dΦ/dt

3. Write electromagnetic boundary conditions. [Remember] **(May 19, R17)**

   $$\epsilon_1 E_1^{\perp} = \epsilon_2 E_2^{\perp}$$

   $$E_1^{\parallel} = E_2^{\parallel}$$

   $$B_1^{\perp} = B_2^{\perp}$$

   $$\frac{1}{\mu_1} B_1^{\parallel} = \frac{1}{\mu_2} B_2^{\parallel}$$

4. Define Skin Depth. [Remember] **(Nov17N, May 17N, Nov 2011,May 2011,May 2010,May 2009,May 2008,Nov 2007,May 2007)**

   The phenomenon whereby field intensity in a conductor rapidly decreases is known as skin effect.

   Skin depth is defined as that depth in which the wave has been attenuated to 1/e or approximately 37% of its original value.

$$\delta = \frac{1}{\alpha}$$

5. Define Dielectric Strength. [Remember] **(May 17N)**

   The maximum voltage that can be applied to a given material without causing it to break down, usually expressed in volts or kilovolts per unit of thickness.

6. List any two properties of Uniform plane wave. [Remember] **(May 17N)**

   The uniform plane wave has following properties ,

   E and Hand direction of the wave are perpendicular to each other. Infact they form right handed orthogonal coordinate system when taken in that sequence. This wave, is therefore a 'Transvers Electromagnetic Wave' (TEM) Wave.

   The ratio E/H for the wave is equal to the intrinsic impedance of the medium, η .

7. Distinguish between conduction current and displacement current. [Understand] **(May 17N, May 2013)**

   Conduction current:It is the current flowing through a conductor of resistance R.

   $$I_C = \frac{V}{R}$$

   Displacement current:It is the current through a capacitor.

   $$I_D = \frac{dQ}{dt}$$

8. Find the displacement current density for the field E= 300 Sin 10^8t V/m.[Apply]**(Nov 16N)**

   $$I_D = \frac{dQ}{dt}$$

9. Define Phase velocity. [Remember] **(Nov 16N)**

   The speed of propagation of a sine wave or a sinusoidal component of a complex wave, equal to the product of its wavelength and frequency.

10. What are uniform plane waves? [Remember] **(May 2016,Nov 14,Nov 2009)**

    For the plane wave, if the amplitude is constant over the plane surface then it is called as “uniform plane wave”. Electromagnetic waves which consist of electric and magnetic fields that is perpendicular to each other and to the direction of propagation and are uniform in plane perpendicular to the direction of propagation are known as uniform plane waves.

11. What are the Maxwell’s equations for free space medium? [Remember] (**Nov 2015N**)

    $$\int H.dl = \iint (\partial D/\partial t)\, ds$$

$\int E.dl = -\iint \partial B/\partial t.ds$

$\iint D.ds = 0$ $\iint B.ds = 0$

12. In a medium, the electric field intensity is $E=10 \sin(1000t - 10x)\, a_y$ V/m. Calculate the displacement current density ($\varepsilon_r = 80$, $\varepsilon_0 = 8.854 \times 10^{-12}$ F/m). [Apply] (**Nov 2015N**)

Displacement current density $J_D = I_D/A = \partial D / \partial t = \varepsilon \partial E / \partial t$

13. Maxwell's second equation is based on a famous law. What is it? Justify your answer. [Remember](**Nov 2015**)

Faradays law $\int E.dl = -\iint \partial B/\partial t.ds$

14. An EM wave has E_x and H_y components of electric and magnetic fields respectively. Find the direction of power flow. [Remember] **(Nov 2012)**

P=E X H Power flows in the z direction.

15. Write down any two of the Maxwell's equations for free space in integral form.[Remember] **(Nov 2011,May 2007)**

$\int H.dl = \iint (\partial D/\partial t)\, ds$ $\int E.dl = -\iint \partial B/\partial t.ds$

$\iint D.ds = 0$ $\iint B.ds = 0$

16. Write down the Maxwell's equation derived from Faraday's law[Remember] **(Nov 2010,Nov 2007)**

Maxwells Equation II:

Integral form: $\mathbf{\int E.dl = -\iint \partial B/\partial t.ds}$

Point form: $\mathbf{\nabla \times E = -\partial B/\partial t}$

17. What is displacement current density[Remember] **(May 2010,Nov 2009)**

Displacement current density $J_D = I_D/A = \partial D / \partial t = \varepsilon \partial E / \partial t$

18. What is the significance in modified form of Ampere's law [Remember] **(May 2009)**

It is used to derive Maxwell's equation III.

Integral form: $\mathbf{\iint D.ds = \iiint \rho dv}$

Point form: $\mathbf{\nabla . D = \rho}$

19. Write down the Maxwell's equations for free space in point form. [Remember] **(Nov 2009,Nov 2008)**

$$\nabla \times \mathbf{H} = \partial \mathbf{D}/\partial t \qquad \nabla \times \mathbf{E} = -\partial \mathbf{B}/\partial t$$

$$\nabla \cdot \mathbf{D} = 0 \qquad \nabla \cdot \mathbf{B} = 0$$

20. Write down Maxwell's equations derived from faraday's law. [Remember] **(Nov 2007,Nov 2006)**

Maxwell's Equation I:

Integral form: $\oint \mathbf{H} \cdot d\mathbf{l} = \iint (\partial \mathbf{D}/\partial t + \sigma \mathbf{E})\, ds$

Point form: $\nabla \times \mathbf{H} = \sigma \mathbf{E} + \partial \mathbf{D}/\partial t$

21. What is a time varying field? [Remember]

A time varying field is a dynamic electromagnetic field in which a changing material field gives rise to all electric field and vice – versa. Thus in this case there is mutual dependence between electric and magnetic fields.

22. What is the significance of displacement current? [Remember]

The concept of displacement current was introduced to justify the production of magnetic field in empty space. It signifies that a changing electric field induces a magnetic field .In empty space the conduction current is zero and the magnetic fields are entirely due to displacement current.

23. Distinguish between conduction and displacement currents. [Remember]

The current through a resistive element is termed as conduction current whereas the current through a capacitive element is termed as displacement current.

24. Explain the difference among conduction, displacement and eddy currents. [Remember]

Conduction current $Jc = dQ / dt = \sigma E$

Displacement current $J_D = \partial D / \partial t = \varepsilon \partial E / \partial t$

Eddy current is a circulating current in the material. A uniform time varying magnetic flux in a high magnetic having non zero conductivity induces conduction current that circulates around the axis of the core.

25. What is the difference between Faraday's theory of magnetic field and Ampere's theory of magnetic field? [Remember]

Faraday's law says that the time varying magnetic field causes the electric field and Ampere's law says that, time varying electric field causes magnetic field.

26. Write the Maxwell's equation from Ampere's law both in integral and point forms. [Remember]

$\oint H.dl = \int\int_s (J + \frac{\partial D}{\partial t}) ds$ (Integral form)

$\nabla * H = J + \frac{\partial D}{\partial t}$ (point form)

27. Give the differential relation between H and J. [Remember]

∇ X H = J, which is the point form of Ampere's Law.

28. Write down the Maxwell's equation from Gauss law in point form. [Remember]

$\nabla.D = \rho$ (Electric field)

$\nabla.B = 0$ (magnetic field)

29. Explain why $\nabla.D$ =0? [Remember]

In a free space there is no change enclosed by the medium. The volume charge density is zero.

By Maxwell's equation $\nabla.D = \rho = 0$.

30. Explain the significance of displacement current. Write the Maxwell's equation in which it is used. [Remember]

$i_D = \int J_D.ds = \int \partial D / \partial t.ds$

$i_D = \varepsilon \partial E / \partial t.ds$. This is a current which directly passes through the capacitor,

Maxwell's equation ∇ x H = $J_c + J_D$

$= \sigma E + \varepsilon \partial E / \partial t$ (Differential form)

Or $\oint H.dl = \int_s (J + \partial D / \partial t) ds$ (Integral form)

$= \int_s (\sigma + j\omega\varepsilon)Eds$

Part-B

1. Illustrate the inconsistency of Ampere's circuital law for time varying fields, and what is the remedial solution proposed by Maxwell ? Also give the differential form representation of all the four Maxwell's equations. [Understand] **May 21**
2. Derive wave equation from Maxwell's equation. (6) [Understand] **May 21**
3. Write Faraday's law in differential and integral forms and explain faraday's experiments. [Understand] **May 21**
4. Write Maxwell's equation in differential and integral forms. Examine them and give its physical interpretation. [Understand]**13 (May 19, 17R)**
5. Derive wave equations for electric and magnetic fields. [Understand]**13 (May 19, 17R)**
6. Derive the Maxwell's equation in differential and integral forms. [Understand] **(13)Apr 18N, Nov 17N (16)**(**May 2016N**)
7. With relevant practical applications explain in detail the particle applications of electromagnetic fields. [Understand] **(15) (May 17N)**
8. From the basic laws derive the time varying Maxwell's equation and explain the significance of each equation in detail**.** [Understand] **(13) (May 17N, Nov 16N)**
9. Explain the transformer emf using Faradays law. [Understand] **(5) (May 17N)**
10. Starting from Maxwells equation derive the equation for E field in the form of wave in free space. [Understand] **(13) (May 17N)**
11. Explain the condition and propogation of uniform plane wave in good conductor and derive tne wave constants. [Understand] **(13) (May 17N)**
12. Derive the wave equations for electric and magnetic fields.[Understand] **(16)** (**Nov 16N**) **(8)** (**Nov15**)
13. Starting from Maxwell's equation, derive homogeneous vector Helmholtz's equation in phasorform. [Understand] **(16)** (**May 2016N**)
14. Derive the Ampere's law. [Understand] **(8)**(**May 2016**)
15. With necessary explanation, derive the Maxwell's equation in differential and integral forms. [Understand] **(16)** (**May 2016**)
16. The conduction current flowing through a wire with conductivity $\sigma = 3 \times 10^7$ s/m and the relative permeability $\varepsilon_r = 1$ is given by $I_c = 3 \sin \omega t$ (mA). $\omega = 10^8$ rad/sec, find the displacement current. [Apply] **(8)**(**May 2016**)
17. An electric field in a medium which is source free is given by $E = 1.5 \cos (10^8 t - \beta z)\, \bar{a}_x$ V/m. Find B, H and D. Assume $\varepsilon_r = 1$, $\mu_r = 1$, $\sigma = 0$. [Apply] **(8)** (**May 2016**)
18. Derive Wave Equation from Maxwell's equations. [Understand] **(8)**(**May 2016**)
19. Derive the Maxwell's equation both in integral form and differential form Ampere's law and Gauss's law. [Understand] **(16)** (**Nov 2015N**)
20. State and explain the pointing theorem and derive the expression for pointing vector. [Understand] **(16)** (**Nov 2015N**)

21. Write the inconsistency of Ampere's law. Is it possible to construct generator of EMF which is constant and does not vary with time by using EM induction principle? Explain. [Understand] **(16)** (**Nov 2015**)
22. The electric field intensity of a linearly polarized uniform plane wave propagating in the +z direction in seawater is E= 100 cos (10^7 πt)i V/m at z=0. The constitutive parameters of seawater are εr = 72, μr = 1, and conductivity σ = 4 S/m. Determine the attenuation constant, phase constant, intrinsic impedance, phase velocity, wavelength and skin depth. Also find the distance at which the amplitude of E is 1% of its value at z=0. [Apply] **(8)** (**Nov 2015**)
14. Is it possible to construct a generator of emf which is constant and does not vary with time by using the principle of EM inductor? Explain. [Analyse] **(6) (May 15N)**
15. In a parallel plate capacitor, a time-varying current i(t)=Im cos wt flows through its leads. The places have the surface area S and the distance between them is d. Show that the displacemtne current through the capacitor is exactly Im cos wt. Ignore the fringing effects. [Understand] **(10) (May 15N)**
16. If D=20 x a_x – 15y a_y + kz a_z μC/m2, find the value of K to satisfy Maxwell's equations for region σ=0 and ρ_v=0. [Apply] **(4) (May 15N)**
17. If H= (3x cos(3+6y sinα))αz, find J if field are invariant with time. [Apply] **(4)(May 15N)**
18. Derive the expression for total power flow in a coaxial cable. [Understand] **(8) (May 15N)**
19. From basic principles , derive maxwells four equation in integral form and differential form. [Understand] **(12) (May 15)**
20. State the modified form of amperes circuital law. Why was it modified? Justify. [Understand] **(4) (May 15)**
21. Derive expression for Instantaneous, average and complex pointing vector.[Understand] **(12) (May 15)**
22. Interpret E x H. [Understand] **(4) (May 15)**
23. Derive Maxwell's equations from basic principles[Understand]. **(10) (Nov 14)**
24. Derive the expression for power flow in a co-axial cable. [Understand] **(6) (Nov 14)**
25. Derive the expression for pointing vector. [Understand] **(10) (Nov 14)**
26. Why is Ampere's circuital law modified? How is it modified? Substantiate. [Understand] **(6) (Nov 14)**
27. Derive wave Equation from Maxwell's Equations. [Understand] **(8) (Nov 14)**
28. Explain ampere's circuit law. [Understand] **(8)(May 2014)**
29. State and prove pointing theorem. [Understand] **(8)(May 14,Nov 2012), (10)(Nov 2011, May 2011,Nov 2009)**
30. Derive Maxwell's four equations in integral differential form with their physical interpretation. [Understand] **(8) (May2014) (16)(Nov 2009,May 2009,Nov 2008,May 2008,May 2007,Nov 2006)**
31. State and prove pointing theorem. Write the expression for instantaneous, average, complex pointing vector. [Understand] **(Nov 2013)**

32. Write the inconsistency of Ampere's law. Is it possible to construct a generator of EMF which is constant and does not vary with time by using EM induction principle? Explain. [Analyse] **(Nov 2013)**
33. Derive the expression for total power flow in co-axial cable. [Understand]**(8)(Nov 2012,May 2011)**
34. Electric flux density in a charge free region is given by $\vec{D}=10x\vec{a}_x+5y\vec{a}_y+kz^2$ μC/m², find the constant k.[Apply] **(6)(Nov 2012,May 2011)**
35. If electric field intensity in free space is given by $\vec{E}=\frac{50}{\circ}Cos(10^8t-10z)\vec{a}_\circ$ V/m, find the magnetic field intensity H. [Apply] **(10)(Nov 2012,May 2011)**
36. Derive the Maxwell's second equation from Faraday's law. [Apply] **(8)(May 2012)**
37. In a material for which $\sigma = 5.0\ S/m$ and $\varepsilon_r = 1$ the electric field intensity is E=250 sin 10^{10}t V/m.Find the conduction and displacement current densities and the frequency at which both have equal magnitudes. [Apply] **(8)(May 2012)**
38. Explain the following: Poynting vector, average power and instantaneous power. [Understand] **(8)(May 2012)**
39. In free space H=0.2 cos(ωt-βx) a_z A/m.Find the total power passing through a circular disc of radius5 m. [Apply] **(8)(May 2012)**
40. Derive an expression for displacement current density J_d. [Understand] **(6)(Nov 2011)**
41. A rectangular loop of length a=1 m and width b=80 cm is placed in an uniform magnetic field.Calculate the maximum value of induced emf if the magnetic flux density B=0.1 Wb/m² is constant and the loop rotates with a frequency of 50 Hz. [Apply] **(6)(Nov 2011)**
42. Give the physical interpretation of Maxwell's first and second equation[Understand] **(4)(Nov 2011)**
43. State and prove pointing theorem. [Understand] **(10)(Nov 2011, May 2011,Nov 2009)**
44. In free space, $\vec{E}=50COS(\mu t- \ z)\vec{a}_x$ V/m.Find the average power crossing a circular area of radius 2.5 m in the plane z=0 .Assume $E_m=H_m\eta_0$ and $\eta_0=120\pi\ \Omega$. [Apply] **(6)(Nov 2011)**
45. Derive the expression for total power flow in co-axial cable.[Understand] **(8)(May 2011)**
46. Electric flux density in a charge free region is given by $\vec{D}=10x\vec{a}_x+5y\vec{a}_y+kz^2$ μC/m²,find the constant k. [Apply] **(6)(May 2011)**
47. If electric field intensity in free space is given by $\vec{E}=\frac{50}{\circ}Cos(10^8t-10z)\vec{a}_\circ$ V/m,find the magnetic field intensity H. [Apply] **(10)(May 2011)**
48. Generalise Ampere's law for time varying fields. [Understand] **(8)(Nov 2010)**
49. List the Maxwell's equations in integral and point form for free space conditions. **(8)(Nov 2010)**

50. Explain the following:Poynting vector,average power and instantaneous power. [Understand] **(8)(Nov 2010)**
51. In free space H= 0.2 cos(ωt-βz) a_z A/m.Find the total power passing through a circular disc of radius 5 cm. [Apply] **(8)(Nov 2010,May 2010)**
52. Derive modified form of Ampere's circuital law in integral and differential forms.**(8)(May 2010,Nov 2007)**
53. Find the amplitude of displacement current density inside a capacitor where ϵ_r =600 and $\vec{D} = 3\times10^{-6}\sin(6\times10^{6}t - 0.3464x)\vec{a}_z$ C/m^2.[Apply] **(8)(May 2010)**
54. Derive Maxwell's four equations in integral differential form with their physical interpretation.[Understand] **(16)(Nov 2009,May 2009,Nov 2008,May 2008,May 2007,Nov 2006)**
55. Explain the following (i)Conduction Current (ii)Displacement Current(iii)Equation of Continuity [Understand] **(16)(May 2009)**
56. Explain the instantaneous,average and complex pointing vector. [Understand]**(16)(May 2009,May 2007)**
57. Discuss pointing vector and pointing theorem. [Understand] **(16)(Nov 2008,May 2007,Nov 2006)**
58. Explain briefly about the motional emf and derive an expression for it. [Understand] **(8)(Nov 2007)**
59. Given the conduction current density in a lossy dielectric as $J_C = (0.02\,Sin\,10^9 t)\,A/m^2$.Find the displacement current density if $\sigma = 10^3\,mho/m, \epsilon_r = 6.5$.[Apply] **(8)(Nov 2007)**
60. Do the fields $\vec{E} = E_m \sin x \sin t\,\vec{a}_y, \vec{H} = \frac{E_m}{\mu_0}\cos x \cos t\,\vec{a}_z$ satisfy Maxwell's equations? [Analyse] **(8) (Nov 2007)**
61. Briefly explain about power flow in co-axial cable. [Understand] **(8)(May 2007,Nov 2006)**
62. Explain about displacement current and displacement current density. Also find its displacement current density for the field E= 300 sin 10^{9} t V/m.[Apply] **(8)(Nov 2006)**
63. A conductor 1cm in length is parallel to z-axis and rotates at radius of 25 cm at 1200pm. Find induced voltage, if the radial field is given by B = 0.5 a_r T.[Apply] **(8)(May 2007)**
64. Show that the ratio of the amplitude of the conduction current density and displacement current density is σ/ωε, for the applied field amplitude ratio if the applied field is E =E_m $e^{-t/\lambda}$. Where λ is real? .[Apply] **(8)(May 2007)**
65. What do you by displacement current? Write down the expression for the total current density.[Understand] **(8)(Nov 2005)**
66. A conducting cylinder of radius 5cms, height 20cm, rotates at 600rps in a radial field B = 0.5 Tesla. The sliding contacts at the top and bottom are connected to a voltmeter what is the reading of Voltmeter? [Understand] **(8)(May 2006)**

67. Differentiate conduction and displacement current and derive the same .Explain the need of displacement current in Maxwell's equations. [Understand] **(8)(Nov 2006)**
68. A magnetic field, H =3cosxa_x+zcosxa_y, A/m, for z > 0, =0 for z < 0 is applied to a perfectly conducting surface in xy plane. Find current density on the conductor surface. .[Apply] **(8)(May 2007)**
69. What is a ferromagnetic material? Name at least five ferromagnetic materials. Draw the hysteresis loop of a ferromagnetic material. [Understand]
70. Compare the magnitude of conduction current density and displacement current density in a good conductor in which σ = 10^7 S/m, Єr = 1 when E = 1sin 120πt. Comment on the result. .[Apply]
71. Explain (a) Motional emf. (b) Transformer emf. [Understand]
72. Explain the different methods of emf induction with necessary governing equations and with suitable examples. [Understand]
73. Write short notes on Faradays laws of electromagnetic induction. [Understand]
74. Derive wave equation from maxwells equation. [Understand] **(6) (May 15)**

ASSIGNMENT

1. Considering a losses having $\mu = 2\mu_0$ and $\epsilon = 5\epsilon_0$. If $\vec{H} = \cos(wt - 5y)\hat{a}_x\ A/m$, determine the frequency *f* & the electric field $\vec{E}$. [Apply]
2. In a charge free non magnetic dielectric region, the magnetic field is given by

$$\vec{H} = 5\cos(10^9 t - 4y)\hat{a}_3\ A/m$$ [Apply]

3. Explain why ▼.B= 0 . [Understand]
4. Write down the the expressions for average power flow in electromagnetic field and average poynting vector. [Remember]
5. If D=20 x a_x – 15y a_y + kza_zμC/m2, find the value of K to satisfy Maxwell's equations for region σ=0 and ρ_v=0. [Understand]
6. If H= (3x cos(3+6y sinα))αz, find J if field are invariant with time. Interpret E x H.
7. Distinguish between conduction current and displacement current. [Remember]
8. An EM wave has E_x and H_y components of electric and magnetic fields respectively. Find the direction of power flow. [Understand]
9. Electric flux density in a charge free region is given by $\vec{D} = 10x\vec{a}_x + 5y\vec{a}_y + kz^2$ μC/m^2, find the constant k. [Understand]

10. If electric field intensity in free space is given by $\vec{E}=\frac{50}{\circ}Cos(10^8 t-10z)\vec{a}_{\circ}$ V/m, find the magnetic field intensity H. [Understand]
11. What is the significance in modified form of Ampere's law? [Remember]
12. Write down the Maxwell's equations for free space in point form. [Remember]
13. Explain the significance of displacement current. Write the Maxwell's equation in which it is used. [Understand]
14. If electric field intensity in free space is given by $\vec{E}=\frac{50}{\circ}Cos(10^8 t-10z)\vec{a}_{\circ}$ V/m,find the magnetic field intensity H. [Understand]
15. Find the amplitude of displacement current density inside a capacitor where ϵ_r =600 and $\vec{D}=3\times10^{-6}\sin(6\times10^6 t-0.3464x)\vec{a}_z$ C/m^2. [Understand]
16. A conductor 1cm in length is parallel to z-axis and rotates at radius of 25 cm at 1200pm. Find induced voltage, if the radial field is given by B = 0.5 a_rT. [Apply]
17. What is displacement current density? [Remember]
18. In a material for which $\sigma = 5.0\ S/m$ and $\varepsilon_r = 1$ the electric field intensity is E=250 sin 10^{10}t V/m.Find the conduction and displacement current densities and the frequency at which both have equal magnitudes. [Understand]
19. Electric flux density in a charge free region is given by $\vec{D}=10x\vec{a}_x+5y\vec{a}_y+kz^2$ μC/m^2,find the constant k. [Apply]

UNIT V

PLANE ELECTROMAGNETIC WAVES

Plane waves in lossless media, Plane waves in lossy media (low-loss dielectrics and good conductors), Group velocity, Electromagnetic power flow and Poynting vector, Normal incidence at a plane conducting boundary, Normal incidence at a plane dielectric boundary

1. Define poynting vector. **((May 21, May 18N, May 2016N,May 15N,May 15,Nov15,May 2010,May 2009,May 2008,Nov 2007)** [Remember]

   The vector product of electric field intensity and magnetic field intensity at a point is a measure of the rate of energy flow per unit area at that point.

   The pointing vector is defined as rate of flow of energy of a wave as it propagates.

   $$P = \vec{E} \times \vec{H}$$

2. A sinusoidal electrical intensity of amplitude 250 V/m and frequency 1 GHz exists in a lossy dielectric medium that has a relative permittivity of 2.5 and loss tangent of 0.001. Find the effective conductivity of the lossy medium. [Understand] **(May 21)**

3. What is Brewster angle? [Remember] **(May19 17R)** (**May 15,Nov14,Nov 2013,May 2013,May 2012, May 2010,Nov 2009,Nov 2008,May 2008,Nov 2006**)

   The incident angle at which there is no reflection is called the Brewster angle θ_B. The Brewster angle is also known as the polarizing angle because an arbitrarily polarized incident wave will be reflected with only the component of **E** perpendicular to the plane of incidence. Brewster angle is an angle at which there is no reflected wave for parallely polarized wave.

   $\theta = \tan^{-1}\sqrt{\varepsilon_2/\varepsilon_1}$

   where ,

   ε_1 is the dielectric constant of medium 1

   ε_2 is the dielectric constant of medium 2

4. Define phase velocity and group velocity. **(May19 17R)**

   Phase velocity and group velocity is given by

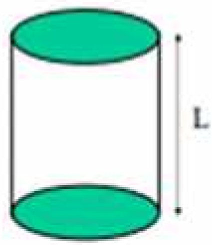
$$v_p = \frac{\omega}{\beta} \quad , \quad v_g = \frac{d\omega}{d\beta}.$$

5. Find the poynting vector on the surface of a long straight conducting wire (of radius b and conductivity σ) that carries a direct current I.[Understand] (**May 2014**)

Since we have a d-c situation, the current in the wire is uniformly distributed over its cross-sectional area.

$$\mathbf{J} = \hat{z}\frac{I}{\pi b^2}$$

$$\mathbf{E} = \frac{\mathbf{J}}{\sigma} = \hat{z}\frac{I}{\sigma \pi b^2}$$



6. Write down instantaneous, average and complex pointing vectors. [Remember] **(May 2013, May 2012,Nov 2010)**

   Instantaneous poynting vector is

   The complex poynting vector is P=1/2 E×H* where H* complex conjugate of H.

   Average pointing vector P_{ave}=1/2 Re[E×H*]

7. What is the electric field and the power flow in the co-axial cable? [Remember] **(Nov 2011)**

   Electric field $E = \dfrac{V}{r \ln(\frac{b}{a})}$

   Power flow in a coaxial cable,W=VI Watts.

8. Define complex poynting vector. [Remember] **(May 2011,May 2007)**

   The complex poynting vector is P=1/2 E×H* where H* complex conjugate of H.

9. State poynting theorem.[Remember] **(May 2009,Nov 2008)**

   The net power flowing out of a given volume is equal to the time rate of decrease of the energy stored .

10. What is meant by skin effect? Mention its significance. [Understand] **(May 15,May 2014,Nov 2011,May 2011,May 2010,May 2009,May 2008,Nov 2007,May 2007)**

    The phenomenon whereby field intensity in a conductor rapidly decreases is known as skin effect.Skin depth is defined as that depth in which the wave has been attenuated to 1/e or approximately 37% of its original value.

$$\delta = \frac{1}{\alpha}$$

11. Write the constructive relations concerning the characteristics of the medium in which the fields exist.[Remember] **(Nov 2013)**

$$\nabla^2 E - \text{«±} \frac{\partial E}{\partial t} - \text{«£} \frac{\partial^2 E}{\partial t^2} = 0$$

$$\nabla^2 H - \text{«±} \frac{\partial H}{\partial t} - \text{«£} \frac{\partial^2 H}{\partial t^2} = 0$$

12. Find the skin depth at a frequency of 3 MHz is aluminium where Given [Understand] **(May 2013)**

$$\text{¢} = \sqrt{\frac{2}{\text{µ«±}}} = \frac{1}{\sqrt{\text{®}f\text{«±}}} = 1.49 \times 10^{-3}\, m$$

13. Define a wave.[Remember] (**Nov 2012,May 2009,Nov 2007**)

    If a physical phenomenon that occurs at one place at a given time is reproduced at other places at later times, the time delay being proportional to the space separation from the first location then the group of phenomena constitutes a wave.

14. Determine the skin depth of copper at 60 Hz with S/m.Given [Understand] (**May 2012**)

$$\text{¢} = \sqrt{\frac{2}{\text{µ«±}}} = \frac{1}{\sqrt{\text{®}f\text{«±}}} = 8.53\, m$$

15. What is meant by polarization of a uniform plane wave? [Remember] (**May 2011,Nov 2010,Nov 2006**)

Polarization is defined as the time varying nature of the electric field vector at some fixed point in space.

16. Define reflection coefficient. [Remember] (**May 2009**)

Reflection coefficient is defined as the ratio of the magnitude of the reflected field to that of the incident field.

17. What are the types of polarization? [Remember] **(Nov 2009)**

- Linear Polarization
- Circular Polarization
- Elliptical Polarization

18. State one dimensional wave equation.[Remember] (**Nov 2008**)

$$\nabla^2 E - \text{«±} \frac{\partial E}{\partial t} - \text{«£} \frac{\partial^2 E}{\partial t^2} = 0$$

$$\nabla^2 H - \text{«±} \frac{\partial H}{\partial t} - \text{«£} \frac{\partial^2 H}{\partial t^2} = 0$$

19. What is meant by circular polarization? [Remember] (**May 2007**)

If x and y component of electric field $\vec{E}_x$ and $\vec{E}_y$ have equal amplitude and 90° phase difference, the locus of the resultant electric field $\vec{E}$ is a circle and the wave is said to be circularly polarized.

20. What is meant by linear polarization? [Remember] (**May 2007**)

If x and y component of electric field $\vec{E}_x$ and $\vec{E}_y$ are present and are in phase, the resultant electric field has a direction at an angle of tan inverse of(E_y/E_x) and if this angle is constant with time, the wave is said to be linearly polarized.

$$\text{Tan } \theta = E_y/E_x$$

21. Define intrinsic impedance or characteristic impedance. [Remember] (**May 2007,Nov 2005**)

It is the ratio of electric field to magnetic field. It is also the ratio of square root of permeability to permittivity of medium.

$\eta = E/H = \sqrt{\mu/\epsilon}$ ohms

22. Define plane wave. [Remember]

For the wave, if the phase of all points on a plane surface is same then wave is called as uniform plane wave.

23. In a time varying situation how do you define a good conductor? Define loss tangent of a medium. [Understand]

    For a good conductor, $\sigma/\omega\varepsilon >> 1$ Loss tangent = $\tan\delta = \sigma/\omega\varepsilon$

22.Mention the properties of uniform plane wave. [Remember]

i) At every point in space, the electric field E and magnetic field H are perpendicular to each other.

ii) The fields vary harmonically with time and at the same frequency everywhere in space.

PART B

1. What is uniform plane wave ? Derive the relationship between E and H in a uniform plane wave. [Understand] **(May 21)**
2. Derive expressions for instantaneous, average and complex pointing vectors. [Understand] **(May 21)**
3. Analyze the wave behavior at boundaries under oblique incidence and derive the Brewster's angle. [Understand] **(May 21)**
4. A 1.8 Khz wave propagates in a medium characterized by $\mu_r = 1.6$, $\varepsilon_r = 25$ and conductivity $\sigma = 2.5$ S/m.The electric field intensity in the region is given by $E = 0.1e^{-az} \cos(2\pi ft - \beta_z)$ i (V/m). Détermine the atténuation constant, propagation constant, internsic impedence, phase velocity, skin depth and wavelength of the wave. (Apply) **15 (May19 17R)**
5. Derive Poyntingtheorem. [Understand]**13 (May19 17R)**
6. Analyze the wave reflection and transmission at normal incidence at the boundary between two linear media. [Understand]**13 (May19 17R)**

7. Deduce the Poynting's theorem from Maxwell's equation and find the total time average power, crossing a given surface S. [Understand] **(May 18N,Nov 2017N)**
8. In a medium characterized by $\sigma = 0$, $\mu = \mu_0$, $\varepsilon = 4\varepsilon_0$, $E = 20 \sin(10^8 t - \beta z)\, a_y$ V/m. Calculate B and H. **(Nov 2017N)**
9. State and prove pointing theorem. Write the expression for instantaneous, average and complex polynting vector. [Understand]**(8) (May 17N, Nov 16N) (16)**(**Nov 2015**)
10. What is a uniform plane wave? Derive the relation between Eand H in a uniform plane wave. [Understand] **(10)(May 15)**
11. Describe the concept of Plane Wave propagation in good conductors. [Understand] **(8) (Nov 14)**
12. Explain with relevant expressions, the concept of reflection of plane waves by a perfect dielectric at both normal and oblique incidence. [Understand] **(16) (Nov 14)**
13. Analyze the wave behavior at boundaries under oblique incidence and derive the brewester angle. [Analyse] **(12)(May 2014)**
14. Prove that a linearly polarized wave can be resolved into right hand circularly polarized wave and a left hand circularly polarized wave of equal amplitude. [Understand] **(4)(May 2014)**
15. Derive the wave equation for Electric and Magnetic fields. [Understand] (**8)(May 2014)**
16. Derive the wave equation from Maxwell's equations. Give the illustration for plane waves in Good conductors. [Understand] **(Nov 2013)**
17. Explain the parallel polarization with respect to oblique incidence. Discuss the types of polarization. [Understand] **(Nov 2013)**
18. Explain in detail on what happens when the wave is incident[Understand] **(May 2013)**
    i) Normally on perfect conductor **(8)**
    ii) Obliquely to the surface of perfect dielectrics. **(8)**
19. A plane sinusoidal electromagnetic wave traveling in space has E_{max}=150μ V/m.
    i) Find the accompanying H_{max}
    ii) Propogation is in X direction and in H is oriented in Y direction. What is the direction of E?
    iii) Compute the average power transmitted. .[Apply] **(May 2013)**

20. From Maxwell's equation, derive the electromagnetic wave equation in conducting medium for E and H fields. [Understand] **(10)(Nov 2012,Nov 2011,May 2011,Nov 2010)**
21. Calculate the attenuation constant and phase constant for a uniform plane with frequency 100 GHz in a conducting medium for which $\mu_r = 1$ and $\sigma = 58X\ 10^6$ S/m. [Apply] **(6)(Nov 2012,May 2011)**
22. With reference electromagnetic waves , explain the following Linear , Circular & Elliptical Polarization [Understand] (**3,3,2)(Nov 2012)**
23. A plane wave is incident, normally on a perfect conductor. Derive the expression for standing wave. Find the location of nodes and antinodes in E & H fields. Sketch the standing wave pattern. [Understand] (**8)(Nov 2012)**
24. A uniform plane wave in a medium having $\sigma = 10^{-3}$ S/m, $\varepsilon = 80\varepsilon_0$ and $\mu = \mu_o$ is having a frequency of 10 KHz. **(May 2012)** .[Apply]

    (i)Verify whether the medium is good conductor. **(3)**

    (ii)Calculate the following:

(1)Attenuation constant **(2)**	(4)Intrinsic impedance **(2)**
(2)Phase constant **(2)**	(5)Wavelength **(2)**
(3)Propagation Constant **(2)**	(6)Velocity of propagation **(3)**

25. A uniform plane wave in free space is normally incident on a dielectric having relative permittivity 4 and relative permeability 1.The electric field of incident wave is given by $E = E_0 e^{-jz} a_x$ to z<0,where E_O is a real constant. Calculate [Apply] **(May 2012)**

    (i)Frequency and wavelength of incident and transmitted waves. **(4)**

    (ii)Magnetic field of incident waves. **(3)**

    (iii)Transmission coefficient and the expression for the electric field of the transmitted waves. **(6)**

    (iv)Expression for the magnetic field of the transmitted wave. .[Apply]
26. From Maxwell's equation, derive the electromagnetic wave equation in conducting medium for E and H fields. **(10)(Nov 2011,May 2011,Nov 2010)**
27. The electric fields associated with a plane wave traveling in a perfect dielectric medium is given by $E_x(z,t) = 10\cos[2\Pi \times 10^7 t - 0.1\Pi x] V/m$.Find the velocity of propagation and intrinsic impedance. Assume $\mu = \mu_0$.[Apply] **(6)(Nov 2011,Nov 2010)**

28. A uniform plane wave in free space is normally incident on a dielectric having relative permittivity 4 and relative permeability 1.The electric field of incident wave is given by $\vec{E} = E_0 e^{-jz}\vec{a}_x, z = 0,$ where E_O is a real constant. Calculate.[Apply] **(16)(Nov 2011)**
    - Frequency and wavelength of incident and transmitted waves.
    - Magnetic field of incident wave
    - Transmission coefficient and the expression for the electric field of the transmitted wave
    - Expression for the magnetic field of the transmitted wave.
29. Calculate the attenuation constant and phase constant for a uniform plane with frequency 100 GHz in a conducting medium for which μ_r =1 and σ = 58X 10^6 S/m. [Apply] **(6)(May 2011)**
30. Explain different types of polarizations of uniform plane waves. **(8)(May 2011,Nov 2010,Nov 2009,May 2009, May 2007)**
31. E and H waves travelling in free space are normally incident on the interface with perfect dielectric with ε_r = 3.Compute the magnitudes of incident,reflected and transmitted E and H waves at the surface. .[Apply] **(8)(May 2011)**
32. Derive the general wave equation. [Understand] **(8)(May 2010,May 2008,Nov 2006)**
33. Discuss the wave motion in good conductors. [Understand] **(8)(May 2010)**
34. Explain the reflection of plane waves by a perfect dielectric.[Understand] **(16)(May 2010)**
35. Derive the wave equation for free space from Maxwell equations. [Understand] **(8)(Nov 2009,May 2009)**
36. Derive the wave equation for a conducting medium. [Understand] **(8)(Nov 2009,May 2009)**
37. Derive the reflection coefficient of a plane wave when it hits the conductor obliquely. [Understand] **(10)(Nov 2009)**
38. Derive the reflection coefficient and transmission coefficient of plane waves when it has normal incidence on a perfect dielectric material. [Understand] **(16)(May 2009)**
39. Obtain the expression for reflection coefficient by a perfect dielectric normal incidence. [Understand] **(16)(Nov 2009)**
40. Calculate intrinsic impedance η,propagation constant and wave velocity for a conducting medium in which σ = 58 MS/m μ_r =1, ε_r = 1 at a frequency of 100 MHz[Apply]. **(8)(May 2009)**

41. Explain reflection of uniform plane waves with normal incidence at a plane dielectric boundary. [Understand] **(8)(May 2009)**
42. A uniform plane wave in a medium with σ = 10^{-3} S/m, ε = 80 ε_0 and μ = μ_0 has a frequency of 10 KHz.Calculate the different parameters of the wave.[Apply] **(16)(Nov 2008)**
43. A normally incident electric field has amplitude E =1 V/m in free space just outside the sea water in which ε_r = 80 , μ_r=1 , σ = 2.5 S/m.For a frequency of 30 MHz at what depth the amplitude of E will be 1 mV/m. .[Apply] **(16)(Nov 2008)**
44. Derive the equation of plane waves in
    - Free space
    - Homageneous material
    - Conducting medium **(8)(May 2008)**
45. Briefly explain about the wave incident[Understand]
    - Normally on a perfect dielectric
    - Obliquely to the surface of a perfect insulator **(16)(May 2008)**
46. Derive the wave equations in phasor form and also derive ~, ,¥,¦ . [Understand] **(16)(Nov 2007)**
47. Explain about propagation of EM wave in a good conductor.[Understand] **(8)(Nov 2007)**
48. A uniform plane wave is travelling with a velocity of 2.5×10^5 m/s having wavelength λ =0.25 mm in a good conductor.Calculate the frequency of wave and the conductivity of a medium. [Apply] **(8)(Nov 2007)**
49. Explain about the propagation of plane waves in lossy dielectrics. **(8)(May 2007,Nov 2006)**
50. Describe abut reflection of plane waves by perfect dielectric.[Understand] **(8)(May 2007)**
51. Discuss the parameters : ¥ ,~ , ,¦ , ª , µ , V_{phase} and V_{group}. **(8)(Nov 2005)**
52. Define Brewster angle and discuss the Brewster angle and degree of polarization. **(8)(Nov 2005)**
53. Explain the propagation of EM waves inside the conductor. **(8)(Nov 2005)**
54. Calculate the attenuation constant and phase constant for a uniform plane with frequency 10GHz in a medium for which μ = μ_0, ε_r = 2.3 and σ = $2.56 * 10^{-4}$ S/m[Apply] **(8)(May 2007)**
55. Derive the expressions for the attenuation constant, phase constant and intrinsic impedance for a uniform plane wave in a good conductor. [Understand] **(8)(May 2007)**

56. Assume that E and H waves, traveling in free space, are normally Incident on the interface with a perfect dielectric with ε_r =3. Calculate the magnitudes of incident, reflected and transmitted E and H waves at the interface[Apply] **(8)(May 2007)**
57. A uniform plane wave of 200MHz, traveling in a free Space impinges normally on a large block of material having ε_r = 4,μ_r= 9, σ =0. Calculate transmission and reflection co-efficient of interface.[Apply] **(8)(May 2007)**
58. Determine the amplitude of the reflected ad transmitted E and H at the interface of two media with the following properties. Medium 1: μ_r=1, ε_r=8.5,σ = 1.Medium 2: free space. Assume normal incidence and the amplitude of E in the medium 1 at the interface is 1.5 mV/m. Derive all the formulae used. .[Apply]
59. A plane wave propagating through a medium with μ_r=2, ε_r=8 has E = 0.5 sin (10^8 t-β_z)a_z (V/m). Determine (i) β (ii) The loss tangent(iii) wave impedance (iv) wave velocity (v) H field. [Apply]
60. A plane traveling wave has a peak electric field intensity E as 6 kV/m. If the medium is lossless with μ_r=1, ε_r=3, find the velocity of the EM wave , peak poynting vector, impedance of the medium and the peak value of the magnetic field H. Derive all the formulae used. [Apply]

ASSIGNMENT

1. Express the following phasors in their instantaneous from[Apply]

   (i) $\vec{B} = \frac{10}{\rho} e^{-j3z} \hat{a}_\rho$

   (ii) $\vec{A} = \left(1 - j\sqrt{3}\right) e^{-j\beta x} \hat{a}_z$

2. Find the poynting vector on the surface of a long straight conducting wire (of radius b and conductivity σ) that carries a direct current I. [Remember]
3. Derive the expression for power flow in a co-axial cable. [Remember]
4. In free space H=0.2 cos(ωt-βx) a_z A/m.Find the total power passing through a circular disc of radius 5 m. [Understand]
5. In free space H= 0.2 cos(ωt-βz) a_z A/m.Find the total power passing through a circular disc of radius 5 cm. [Understand]

6. What is the electric field and the power flow in the co-axial cable? [Remember]
7. Define poynting vector. [Remember]
8. In free space, $\vec{E} = 50COS(\mu t - z)\vec{a}_x$ V/m.Find the average power crossing a circular area of radius 2.5 m in the plane z=0 .Assume $E_m=H_m\eta_0$and $\eta_0=120\,\pi\,\Omega$. [Apply]