COURSE OUTCOMES

UNIT – I : Static Electric field

PART A - C212.1

1. Define scalar and vector quantities.

Scalar quantity: A scalar is a quantity which is completely characterized by its magnitude. Examples: mass, density, pressure, volume etc.

Vector quantity: A vector is a quantity which is characterized by both its magnitude and direction. Examples: Force, velocity, acceleration etc.

2. Write the expression for divergence in all the three coordinate systems.

Co-ordinate System	Divergence
Cartesian	$\nabla.\vec{A} = \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z}$
Cylindrical	$\nabla.\vec{A} = \frac{1}{\rho}\left[\frac{\partial}{\partial \rho}(\rho A_\rho) + \frac{\partial}{\partial \phi}(A_\phi) + \frac{\partial}{\partial z}(\rho A_z)\right]$
Spherical	$\nabla.\vec{A} = \frac{1}{r^2 \sin\theta}\left[\frac{\partial}{\partial r}(r^2 \sin\theta A_r) + \frac{\partial}{\partial \theta}(r\sin\theta A_\theta) + \frac{\partial}{\partial \phi}(rA_\phi)\right]$

3. State the relation between Cartesian and cylindrical co-ordinate system.

From Cartesian to cylindrical :(i) $\rho = \sqrt{x^2 + y^2}$ (ii) $\phi = \tan^{-1}\left(\frac{y}{x}\right)$ and (iii) z = z

From cylindrical to Cartesian: (i) x = ρ cos ϕ (ii) y = ρ sin ϕ and (iii) z = z

4. Convert the point P (4, 25°, 120°) from spherical to Cartesian coordinates and the point P (3,4,5) from Cartesian to spherical co-ordinates.

Given, r = 4; θ = 25^0; $\phi = 120^0$

x = r sinθ cosϕ=-0.845 ; y = r sinθ sinϕ=1.463 and z = r cosθ=3.62.

Given, x = 3; y = 4; z = 5

$r = \sqrt{x^2 + y^2 + z^2}$ =0.707; $\theta = \cos^{-1}\left(\frac{z}{r}\right) = 45°$ and $\phi = \tan^{-1}\left(\frac{y}{x}\right) = 53°$

5. State Coulomb's law. (Dec 2016)

Coulomb's law states that the force between two point charges is proportional to the product of charges and is inversely proportional to the square of the distance between them. Mathematically we can write, $F = K\frac{Q_1 Q_2}{R^2}$, where F = force in Newton , Q_1 and Q_2 = point charges in coulombs, K = 1/(4πε) and R = distance between Q_1 and Q_2 in meters.

6. State the principle of superposition of fields.

The principle of superposition of fields states that the resultant force on any one charge is a vector sum of individual forces due to respective charges. So, if there are 'n' charges then the resultant force on charge 1 due to all charges is, $F_{total} = F_{21} + F_{31} + F_{41} + \ldots + F_{n1}$

7. Define line charge, surface charge and volume charge density. (June 2015)

Line charge density is defined as the total charge per unit length i.e., ρ_l = dQ/dl , C/m

Surface charge density is defined as the total charge per unit area. i.e., ρ_s = dQ/dS , C/m^2

Volume charge density is defined as the total charge per unit volume. i.e., ρ_v = dQ/dV , C/m^3

8. State Stoke's theorem.

Stoke's theorem states that the integration of any vector around a closed path is always equal to the integration of curl of that vector throughout the surface enclosed by that path.

$$\oint_L \vec{A}\cdot d\vec{l} = \int_S \left(\nabla \times \vec{A}\right)\cdot d\vec{S}$$

9. Write the expression for curl in all the three coordinate systems.

Co-ordinate System	Curl
Cartesian	$\nabla X\vec{A} = \begin{vmatrix} \vec{a}_x \vec{a}_y \vec{a}_z \\ \frac{\partial}{\partial x} \frac{\partial}{\partial y} \frac{\partial}{\partial z} \\ A_x A_y A_z \end{vmatrix}$
Cylindrical	$\nabla X\vec{A} = \frac{1}{\rho}\begin{vmatrix} \vec{a}_\rho \rho\vec{a}_\phi \vec{a}_z \\ \frac{\partial}{\partial \rho} \frac{\partial}{\partial \phi} \frac{\partial}{\partial z} \\ A_\rho \rho A_\phi A_z \end{vmatrix}$
Spherical	$\nabla X\vec{A} = \frac{1}{r^2 \sin\theta}\begin{vmatrix} \vec{a}_r r\vec{a}_\theta r\sin\theta\vec{a}_\phi \\ \frac{\partial}{\partial r} \frac{\partial}{\partial \theta} \frac{\partial}{\partial \phi} \\ A_r rA_\theta r\sin\theta A_\phi \end{vmatrix}$

10. Define gradient and write the expression for gradient in all the three coordinate systems. (Nov/Dec 2013, May/June 2014, May 2017)

The gradient of a scalar field V is a vector that represents both the magnitude and direction of the maximum space rate of increase of V

Co-ordinate System	Gradient
Cartesian	$\nabla V = \left(\frac{\partial}{\partial x}\vec{a}_x + \frac{\partial}{\partial y}\vec{a}_y + \frac{\partial}{\partial z}\vec{a}_z\right)V$
Cylindrical	$\nabla V = \left(\frac{\partial}{\partial \rho}\vec{a}_\rho + \frac{1}{\rho}\frac{\partial}{\partial \phi}\vec{a}_\phi + \frac{\partial}{\partial z}\vec{a}_z\right)V$
Spherical	$\nabla V = \left(\frac{\partial}{\partial r}\vec{a}_r + \frac{1}{r}\frac{\partial}{\partial \theta}\vec{a}_\theta + \frac{1}{r\sin\theta}\frac{\partial}{\partial \phi}\vec{a}_\phi\right)V$

11. State divergence theorem. (June 2016, May 2017)

Divergence theorem states that the integral of the normal component of any vector field over a closed surface is equal to the integral of divergence of this vector field throughout the volume enclosed by the closed surface.

$$\oint_S \vec{A}\cdot d\vec{S} = \int_v \left(\nabla\cdot\vec{A}\right)dv$$

12. What is solenoidal and irrotational field?

A vector field having zero divergence is called a solenoidal field and a vector field having zero curl is called an irrotational field.

13. Give the relation between electric field E and potential V.

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

14. What are the differential elements in Cartesian, cylindrical and spherical co-ordinate systems?

S.No.	Co-ordinate System	Differential elements		
		Differential length	Differential surface area	Differential volume
1.	Cartesian	*dx*, *dy* and *dz*	$dS_x = dydz$ $dS_y = dxdz$	$dv = dx\,dy\,dz$

			$dS_z = dxdy$	
2.	Cylindrical	$d\rho$, $\rho d\phi$ and dz	$dS_\rho = \rho d\phi\ dz$ $dS_\phi = \rho d\phi\ dz$ $dS_z = d\rho\ \rho d\phi$	$dv = d\rho\ \rho d\phi\ dz$
3.	Spherical	dr, $rd\theta$ and $r\sin\theta d\phi$	$dS_r = rd\theta\ r\sin\theta d\phi$ $dS_\theta = dr\ r\sin\theta d\phi$ $dS_\phi = dr\ rd\theta$	$dv = dr\ rd\theta\ r\sin\theta d\phi$

15. Write and explain coulomb's law in vector form (Nov 2016).

$$Q_1 \xrightarrow[\vec{R}_{12}]{} Q_2$$

Coulomb's law states that the force between two point charges is directly proportional to the product of the charges and is inversely proportional to the square of the distance between them. So, in general the vector form of Coulomb's law can be expressed as,

$$\vec{F}_{12} = k\frac{Q_1 Q_2}{R_{12}^{\ 2}}\hat{a}_{R_{12}} \quad ; \mathrm{k} = \frac{1}{4\pi\varepsilon}$$

where Q_1 and Q_2 = point charges in coulombs, $\vec{F}_{12}$ = force exerted between Q_1 and Q_2 in Newton , and $\vec{R}_{12}$ = distance vector between Q_1 and Q_2.

16. State the conservative property of an electric field.

If we want to move a point charge from one point say 'A' to another point 'B' then some force is required to act on a point charge. Same principle is applicable if we want to move a body from one position to another. In this case a force is required to move a body. We know that the 'work done' is the product of force and displacement. Thus, work will be done or by the body. Some energy is represented by this work. If there is no mechanism by which an energy represented by this work can be dissipated then the field is called as conservative field.

17. What is an electric potential? Write expression for potential due to an electric dipole. (Dec '16)

Electric 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. Potential, $\mathrm{V} = \frac{\mathrm{q}}{4\pi\varepsilon \mathrm{r}}$. Potential due to an electric dipole is given by

$\mathrm{V} = \frac{\mathrm{q}}{4\pi\varepsilon_0}\left(\frac{\mathrm{d}\cos\theta}{\mathrm{r}^2}\right)$, where d is the distance between two point charges of equal magnitude and opposite sign and r is the distance of point interest P from origin.

18. Define electric dipole. (June 2016)

An electrical dipole or simply a dipole is the name given to two point charges of equal magnitude and opposite sign, separated by a distance which is small compared to the distance to the point P at which we want to know the electric and potential fields.

19. What is an electric flux and electric flux density?

If the charge +Q present on inner sphere is increased then the charge –Q, developed on outer sphere also increases. That means electric displacement is proportional to the magnitude of charge Q. This displacement is not dependent on the medium between two spheres. This electric displacement is also called as the displacement flux or electric flux. The net flux passing normal through the unit surface area is called the electric flux density.

20. State Gauss's law in electrostatics and its expression. (June 2015, Dec 2015)

Gauss's law states that the electric flux passing through any closed surface is equal to the total charge enclosed by that surface. $\psi = \oint_S \vec{D}.d\vec{s} =$ Charge enclosed $= Q$

21. List the applications of Gauss's law. (Dec 2015)

- The Gauss's law is used to find E or D for symmetrical charge distributions, such as point charge, an infinite line charge, an infinite sheet of charge and a spherical distribution of charge.

- The Gauss's law is also used to find the charge enclosed or the flux passing through the closed surface.

22. Define electric field. **(June 2013)**

Electric field intensity is the vector force on a unit positive test charge. It is given by $E = \frac{Q}{4\pi\epsilon_0 R^2} a_R$.

Where R = Magnitude of the vector $\vec{R}$, the directed line segment from the point at which the point charge Q is located to the point at which E is desired and a_R is a unit vector in the R direction.

23. Find Electric field at (1,1,1) if the potential is V = $xyz^2+x^2yz+xy^2z$ (V) (Dec 2015)

Solution: Electric field, $E = -\nabla V$

In Cartesian co-ordinate system, $\nabla V = \left(\frac{\partial}{\partial x}\vec{a}_x + \frac{\partial}{\partial y}\vec{a}_y + \frac{\partial}{\partial z}\vec{a}_z\right)V$

$\nabla V = \left(\frac{\partial V}{\partial x}\vec{a}_x + \frac{\partial V}{\partial y}\vec{a}_y + \frac{\partial V}{\partial z}\vec{a}_z\right)$, Here, potential V = $xyz^2+x^2yz+xy^2z$

$= (yz^2 + 2xyz + y^2z)\vec{a}_x + (xz^2 + x^2z + 2xyz)\vec{a}_y + (2xyz + x^2y + xy^2)\vec{a}_z$

Therefore, E = -{ $(yz^2 + 2xyz + y^2z)\vec{a}_x + (xz^2 + x^2z + 2xyz)\vec{a}_y + (2xyz + x^2y + xy^2)\vec{a}_z$ }

Electric field E at (1,1,1) , E = -{ $(1+2+1)\vec{a}_x + (1+1+2)\vec{a}_y + (2+1+1)\vec{a}_z$ }

= -{ $4\vec{a}_x + 4\vec{a}_y + 4\vec{a}_z$ }, volt/m

PART B - C212.1

1. (i)A circular disc of radius 'a' is uniformly charged with ρ_S C/m^2. If the disc lies on the $z = 0$ plane with its axis along z-axis, find the expression for electric field intensity $\vec{E}$ at any point on the z-axis. Using this result, obtain the expression for $\vec{E}$ field due to an infinite sheet of charge in the $z = 0$ plane**.**
   (ii) Explain the concept of superposition principle of electric field intensity **(Dec2016)**
2. (i) If $V = 2x^2y + 20z - \frac{4}{x^2 + y^2}$ V, find electric field & flux density at P(6,–2,3)
   (ii) Given field intensity $E = 40xy\hat{a}_x + 20x^2\hat{a}_y + 2\hat{a}_z$ V/m, calculate the potential difference between two points P(1,-1,0) and Q(2,1,3).
3. Given an electric field $E = -\frac{6y}{x^2}\hat{a}_x + \frac{6}{x}\hat{a}_y + 5\hat{a}_z$ V/m, find the potential difference V_{AB} between A (-7,2,1) and B (4,1,2).
4. (i) State and prove Gauss law and explain any one applications of Gauss law.
   (ii) Given two vectors $\vec{A} = 3\vec{a}_x + 4\vec{a}_y - 5\vec{a}_z$ and $\vec{B} = -6\vec{a}_x + 2\vec{a}_y + 45\vec{a}_z$, determine the unit vector normal to the plane containing the vectors $\vec{A}$ and $\vec{B}$. **(May 2016)**
5. (i)Derive the expression for energy and energy density in static electric fields. **(Dec 2016)**
   (ii)The two point charges 10 μC & 2 μC are located at (1,0,5) &(1,1,0) respectively. Find the potential at (1, 0,1), assuming zero potential at infinity. **(Dec 2015)**
6. (i) State and prove Stoke's theorem and Divergence's Theorem. **(Dec 2013, 2015, 2016)**
   (ii) Determine the electric flux density at (1,0,2) if there is a point charge 10mC at (1,0,0) and a line charge of 50mC/m along y axis. **(Dec 2015)**
7. 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. **(May 2016)**

8. (i) Transform $\vec{A} = y\vec{a}_x + x\vec{a}_y + \frac{x^2}{\sqrt{(x^2+y^2)}}\vec{a}_z$ from Cartesian to cylindrical coordinates.

   (ii) A charge +Q is located at A(-a,0,0) & another charge -2Q is located at B(a,0,0). Show that the neutral point also lies on x-axis, where x= -5.83a. **(June 2015)**

9. (i) Given that the potential $V = \frac{10\sin\theta\cos\phi}{r^2}$ find flux density D at (2,π/2,0).

   (ii) Given $D = 2rz^2 a_r + r\cos^2\phi a_z$. Prove divergence theorem. **(May 2017)**

10. (i)Using Gauss law, find the electric field intensity for the uniformly charged sphere of radius 'a', find the $\vec{E}$ everywhere.

    (ii)Derive the equation for scalar electric potential. **(May 2017)**

UNIT - II Conductors and Dielectrics

PART A – C212.2

1. Write down Laplace equation in all three coordinate systems. (May 2016)

Co-ordinate System	**Curl**
Cartesian	$\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = 0$
Cylindrical	$\frac{1}{\rho}\frac{\partial}{\partial\rho}\left(\rho\frac{\partial V}{\partial\rho}\right) + \frac{1}{\rho^2}\frac{\partial^2 V}{\partial\phi^2} + \frac{\partial^2 V}{\partial z^2} = 0$
Spherical	$\frac{1}{r^2}\frac{\partial}{\partial r}\left(\rho^2\frac{\partial V}{\partial r}\right) + \frac{1}{r^2\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial V}{\partial\theta}\right) + \frac{1}{r^2\sin^2\theta}\frac{\partial^2 V}{\partial\phi^2} = 0$

2. What is dielectric polarization. (May 2016)

Whenever a centre of an electron cloud is separated from the nucleus, an electric dipole is formed. This dipole gets aligned with the applied electric field.This process is called polarization of dielectrics. Electric polarization P is defined as the total dipole moment per unit volume. It is measured in coulombs per square metre.

3. Define dielectric break down.

The ideal dielectric is non conducting but practically no dielectric can be ideal. As the electric field applied to dielectric increases sufficiently, due to the force exerted on the molecules, the electrons in the dielectric become free. Under such large dielectric field, the dielectric becomes conducting due to presence of large number of free electrons. This condition of dielectric is known as dielectric breakdown.

4. What is the major difference between a dielectric and conducting medium?

The major difference between a dielectric and conducting medium is that the dielectric does not contain free charges. In this case the charges are tightly bound together to form atoms and molecules.

5. List the properties of dielectric materials.

- When a dielectric material is placed in an external electric field, there are no induced free charges that move to the surface. So interior charge density and electric field do not vanish.
- Dielectrics contain bound charges, so there is no effect of external electric field.
- External E field causes polarization of dielectric material & electric dipoles are created.
- Induced electric dipoles modify the electric field both inside and outside the dielectric material. The molecules of some dielectrics possess permanent dipole moments, even in the absence of external electric field. Such materials are called as electrets.
- Polarized dielectric gives rise to an equivalent volume charge density.

6. Define capacitance and capacitors. (May 2017)

Consider two conducting materials M_1 and M_2 which are placed in a dielectric medium having permittivity ε. The material M_1 carries a positive charge Q while the material M_2 carries a negative charge, equal in magnitude as Q. there are no other charges present and total charge of the system is zero. In conductors, charge cannot reside within the conductor and it resides only on the surface. Thus for M_1 and M_2, charges +Q and –Q reside on the surfaces of M_1 and M_2 respectively. Such a system which has two conducting surfaces carrying equal and opposite charges, separated by a dielectric is called capacitive system giving rise to a capacitance.

A capacitor is a passive electronic component that stores energy in the form of an electrostatic field. In its simplest form, a capacitor consists of two conducting plates separated by an insulating material called the dielectric.

7. What is potential energy?

In order to bring a positive charge near another fixed charge requires work. This work is done by an external source. Now while moving this positive charge, the energy is expanded. This energy represents the potential energy.

8. Write and explain energy stored in terms of charge and capacitance.

Electrostatic energy $W = (1/2)\,CV^2 = (1/2)\,QV = Q^2/2C$

9. State the boundary conditions at the interface between two perfect dielectrics.

- The tangential components of electric field is continuous across the boundary that is $E_{t1} = E_{t2}$ and the tangential components of electric flux density are not continuous across the boundary
- The normal component of electric flux density is continuous across the boundary that is $D_{n1} = D_{n2}$ and the normal components of electric field intensity are inversely proportional to the relative permittivities of the two media.

10. State the boundary conditions at the interface between conductor & free space. (Dec 2015)

- The tangential component of electric field is zero at the boundary and the tangential component of electric flux density is also zero at the boundary.
- The normal component of electric flux density is equal to the surface charge density. i.e. $D_N = \rho_s$ and the normal component of electric field intensity is $E_N = \rho_s / \varepsilon$.

11. Determine the capacitance of the parallel plate capacitor composed of tin foil sheets, 25cm^2 for plates separated through a glass dielectric 0.5 cm thick with relative permittivity of 6. (June 2013)

Solution:

$C = \dfrac{\varepsilon_0 \varepsilon_r A}{d}$. Here $\varepsilon_r = 6$, $A = 25\times10^{-4}$ m^2 and $d = 0.5 \times 10^{-2}$ m. Substitute to get C = 26.55pF

12. Find the potential at r_A = 5m with respect to r_B = 15m due to a point charge of 500pC at the origin. Assume zero reference at infinity.

$$V = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{r_A} - \frac{1}{r_B}\right] = \frac{500\times10^{-12}}{4\pi\times8.85\times10^{-12}}\left[\frac{1}{5} - \frac{1}{15}\right] = 1.95V$$

13. Determine the capacitance of a conducting sphere of radius 5 cm deeply immersed in sea water (*ε_r* = 80).

Capacitance of isolated sphere, $C = 4\pi\varepsilon_0\varepsilon_r a = 4\pi \times 8.85 \times 10^{-12} \times 80 \times 5 \times 10^{-2} = 4.45 \times 10^{-10}$ F

14. A lead (σ = 5 x 10^6 S/m) bar of square cross section 3cm x 3 cm has a hole of radius 0.5 cm bored along its length of 4 m. Find the resistance between the square ends.

$R = \rho l/A$ Here l = 4 m, $\rho = 1/\sigma$, A = (3cm x 3cm) - (π x (0.5cm)^2) R = 974 μΩ

15. State the point form of Ohm's law. (June 2013)

Point form of ohm's law states that the field strength within a conductor is proportional to the current density. J α E (or) J= σE where σ is conductivity of the material.

16. State and explain the equation of continuity in point form. (Dec 2013)

$J = -\partial\rho_v / \partial t$. Since the charge is conserved, the outward flux of J must therefore be equal to the rate of loss of charge within the volume.

17. Write the boundary conditions for electric field. (June 2014)

- The tangential components of electric field is continuous across the boundary that is $E_{t1} = E_{t2}$ and the tangential components of electric flux density are not continuous across the boundary

➢ The normal component of electric flux density is continuous across the boundary that is $D_{n1} = D_{n2}$ and the normal components of electric field intensity are inversely proportional to the relative permittivities of the two media.

18.Define dielectric strength. (May 2017)

The minimum value of the applied electric field at which the dielectric breaks down is called dielectric strength of that dielectric.

19. 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. (Dec 2015)

Solution: Energy stored in the capacitor, W =(1/2) CV^2

E = V/d => V = Ed = 1000 X 0.02=20 volts

Therefore, W = 0.5 X 20 X 10^{-12} X 20^2 = 4 X10^{-9} Joules

20. Write the equation for energy stored in electrostatic field in terms of field quantities?(May '17)

The electrostatic energy in terms of $\vec{E}$ and $\vec{D}$ is given by, $W_E = \frac{1}{2}\int_V \left(\vec{D}.\vec{E}\right) dv$, Joules

21. Define resistance of a conductor. (Dec 2016)

According to the point form of Ohms law (fields are uniform) the resistance of the conductor is given by $R = \frac{L}{\sigma s}\ \Omega$ .When the fields are non uniform, the expression for resistance of conductor becomes

$$R = \frac{V_{ab}}{I} = \frac{-\int_b^a \vec{E}.d\vec{l}}{\int_s \sigma \vec{E}.d\vec{s}} \quad \Omega$$

22. Give Laplace's and Poisson's equations? (Dec 2016)

Laplace's equation, $\nabla^2 V = 0$

Poisson's equations, $\nabla^2 V = \frac{-\rho_v}{\varepsilon}$

23. What is the practical application of method of images? (May 2017)

The method of image charges is used in electrostatics to simply calculate or visualize the distribution of the electric field of a charge in the vicinity of a conducting surface. It is based on the fact that the tangential component of the electrical field on the surface of a conductor is zero, and that an electric field E in some region is uniquely defined by its normal component over the surface that confines this region.

24 Define current density. (June 2015)

Current density is defined as current per unit area. It is denoted by J=I/A Amp/m^2

PART B – C212.2

1. Derive the boundary conditions of the normal and tangential components of electric field at the interface of two media with different dielectrics**. (June 2013, Dec 2013, June 2016, Dec 2016)**
2. (i) Derive the relationship between polarization and electric field intensity. **(June 2016)**
   (ii) 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 gap of 1 mm on both sides, determine the capacitance. **(June 2016)**
3. A spherical capacitor consists of an inner conducting sphere of radius 'a' & an outer conductor with spherical inner wall of radius 'b'. The space between the conductors is filled with a dielectric of permittivity 'ε'. Determine the capacitance. **(Dec 2015, June 2016)**
4. Determine whether or not the following potential fields satisfy the Laplace's equation.
   (i) V =$x^2 - y^2 + z^2$ (ii) V = r cosϕ + z (iii) V = r cosθ +ϕ.
5. If Given $\vec{J} = \frac{1}{r^3}\left(2\cos\theta \vec{a}_r + \sin\theta \vec{a}_\theta\right)$ A/m^2 in spherical coordinates, find the current through

(i) A hemispherical shell of radius 20cm.

(ii) A spherical shell of radius 10 cm. **(June 2015)**

6. (i) Derive the expression for relaxation time by solving the continuity equation. **(Dec 2015)**
   (ii) Calculate the relaxation time of mica ($\sigma = 10^{-15}$ S/m, $\varepsilon_r = 6$) and paper ($\sigma = 10^{-11}$ S/m, $\varepsilon_r = 7$)
7. Derive an expression for capacitance of a coaxial cable**.** **(Dec2016, May 2017)**
8. (i)Derive an expression for polarization 'P'. **(Dec 2016)**
   (ii)Write the Poisson's and Laplace's equations **(June 2014, Dec 2015)**
9. Derive the boundary condition for the E-field and H-field in the interference between dielectric and free space. **(May 2017)**
10. Derive the boundary conditions for conductor to free space interface.

UNIT - III : Static Magnetic Fields

PART A – C212.3

1. State and explain Biot-Savart's law. (June 2013,2014, Dec 2015)

The magnetic flux density at any point due to current element is proportional to the current element and sine of the angle between the elemental length & line joining and inversely proportional to the square of the distance between them. i.e **dH = I dl sin θ/4πr²** A/m.

2. State Ampere circuital law. (Dec 2015, Dec2016)

Ampere's circuital law states that the line integral of magnetic field intensity around a closed path is equal to the direct current enclosed by that path. $\oint_l H.dl = I$

3. Derive point form of Ampere's circuital law. (Dec 2015)

Integral form of Ampere's circuital law is $\oint_l H.dl = I$

Using Stoke's theorem**,** $\oint_L \vec{H}\cdot d\vec{l} = \int_S \left(\nabla\times\vec{H}\right)\cdot d\vec{S} = \int_S \vec{J}.d\vec{S}$ If integration is carried over identical surfaces, then, $\nabla X\vec{H} = \vec{J}$ that is the point form of ampere's circuital law.

4. Define Stoke's theorem.

It states that integration of any vector around a closed path is always equal to the integration of curl of that vector throughout the surface enclosed by that path.

5. Define Gauss's law for the magnetic field.

The total magnetic flux passing through the surface is zero. ie. The number of lines entering into the surface is equal to number of lines leaving the surface. In integral form, $\int_S B.ds = 0$. In point form or differential form, $\nabla.B = 0$.

6. List the applications of Ampere's circuital law.

The applications of Ampere's circuital law are to determine magnetic field intensity for an infinitely long straight conductor, a co-axial cable, an infinite sheet of current when the current distribution is symmetrical.

7. Define magnetic flux and magnetic flux density (or) give the relation between magnetic flux and magnetic flux density. (June 2015)

The imaginary lines of magnetic force existing in the magnetic field are called the magnetic flux. The magnetic flux density is defined as the flux passing per unit area through a plane at right angles to the flux. The unit is weber per square metre. Magnetic flux density = ϕ / A , wb/m^2 or Tesla.

8. Define scalar magnetic potential. (June 2015, June 2016)

Magnetic scalar potential is defines as dead quantity whose negative gradient gives the magnetic intensity if there is no current source present. H = $-\nabla V_m$ where V_m is the magnetic scalar potential

$V_m = -\int H.dl$

9. Define vector magnetic potential. (June 2013, June 2016, Dec 2016)

The vector potential in a magnetic field whose curl gives the magnetic flux density is called vector magnetic potential of that field. It is denoted as A and measured in wb/m.

10. Write the relation between magnetic vector potential and magnetic flux density.

Magnetic flux density B**=∇xA ,** where A is the magnetic vector potential.

11. Define magnetic dipole.

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

12. What is the relation between B and H?

The magnetic flux density B is related to the magnetic field intensity H as B =μH, $\mu = \mu_0 \mu_r$

13. Define magnetic dipole moment. **(Dec 2013)**

The magnetic dipole moment of a current loop is defined as the product of current through the loop and the area of the loop, directed normal to the current loop.

14. Define magnetic susceptibility.

Magnetic susceptibility is defined as the ratio of magnetization to the magnetic field intensity. It is dimensionless quantity.

15. Define hysteresis.

The phenomenon which causes magnetic flux density to lag behind magnetic field intensity so that the magnetization curve for increasing and decreasing applied fields is not the same, is called the hysteresis.

16. A region contains a magnetic vector potential of $\vec{A} = x^2 yz\hat{a}_x + xz\hat{a}_z$. Find magnetic flux density in the region.

Solution: Magnetic flux density, $\vec{B} = \nabla \times \vec{A} = (x^2 y - z)\hat{a}_y - x^2 z\hat{a}_z$

17. The plane y = 1 carries a current $\vec{K} = 50\hat{a}_z$ mA/m. Find the magnetic field intensity at origin.

H = $\frac{1}{2}\vec{K} \times \hat{a}_n = \left(\frac{1}{2}\right)50\hat{a}_z \times -\hat{a}_y = 25\hat{a}_x$ mA/m

18. An infinitely long conductor carries a current of 10 A. At what distance from the conductor would be magnetic field intensity be 0.795 A/m?

H = I/(2πρ). Given H = 0.795 A/m and I =10A. Substituting the given values in H, we get ρ = 2 m.

19. Is the magnetostatic field conservative in nature?

No. It is non-conservative because ∇ x H ≠ 0

20. In case of magnetic field intensity due to finite length current, how will you decide the signs of α_1 and α_2 ?

If point P is between two ends then α_1 is negative and α_2 is positive.

If point P is above the upper end then α_1 and α_2, both are having negative sign.

If point P is below the lower end then α_1 and α_2, both are having positive sign.

21. A current of 3 A flowing through an inductor of 100 mH. What is the energy stored in inductor? (June 2016)

Solution: Energy stored in an inductor **=** $\frac{1}{2}(LI^2) = \frac{1}{2}(100X10^{-3}X3^2) = 0.18$ Joules

22. Differentiate between a magnetic charge and an electric charge.

It is possible to isolate an electric charge but magnetic charges always exist as pairs.

23. If the Magnetic field $\vec{B} = 25x\hat{a}_x + 12y\hat{a}_y + \alpha z\hat{a}_z$, find α. **(June 2014)**

Use ∇.B = 0 ⇒ 25 +12+α=0 ⇒ α = -37

<u>PART B - C212.3</u>

1. Derive an expression for magnetic field intensity due to an infinitely long co-axial cable. **(June 2016)**
2. (i)Obtain the expression for $\vec{H}$ at the centre of a circular wire. **(June 2014)**

   (ii)At a point P(x,y,z) the components of vector magnetic potential A are given as $A_x = (4x + 3y + 2z)$; $A_y = (5x + 6y + 3z)$ and $A_z = (2x + 3y + 5z)$. Determine magnetic flux density B at any point P.

3. State Biot-Savart's law. Derive the expressions for magnetic field intensity and magnetic flux density at the centre of a square current loop of side l. Then determine the same for square loop of sides 5m carrying current of 10A. **(June 2016)**
4. (i) In cylindrical co-ordinates, $A = 50\rho^2 \hat{a}_z$ 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.
   (ii) For a current distribution in free space, $\vec{A} = (2x^2y + yz)\hat{a}_x + (xy^2 - xz^3)\hat{a}_y - (6xyz - 2x^2y^2)\hat{a}_z$ (Wb/m). Calculate magnetic flux density. **(Dec 2015)**
5. Derive vector magnetic potential from Biot Savart's law. **(May 2017)**

6. (i) Derive Ampere circuital Law.
   (ii)Derive the expressions which mutually relate current density J, Magnetic field B, and Magnetic vector potential A. **(June 2014, Dec 2015)**
7. (i) Magnetic Vector potential $\vec{A} = \frac{-\rho^2}{4}\vec{a}_z$ Wb/m, calculate the total magnetic flux crossing the surface $\phi = \frac{\pi}{2}, 1 < \rho \le 2m, 0 \le z \le 5m.$
   (ii) $\vec{H} = 3\cos x\vec{a}_x + z\cos x\vec{a}_y$ A/m for $z \ge 0$ and $\vec{H} = 0$ for z < 0. This $\vec{H}$ is applied to a perfectly conducting surface in xy plane. Find J on the conductor surface. **(June 2015)**
8. (i)Derive the equation for the magnetization for the materials and show that $J_b = \nabla \times m$ and $K_b = m \times \vec{a}$
   (ii)Find the magnetic flux density for the infinite current sheet in the xy plane with current density $K=K_y a_y$ A/m current. **(May 2017)**
9. From Biot-Savart's law obtain expression for magnetic field intensity and vector potential at a point P and distance R from infinitely long straight current carrying conductor. **(Dec 2016).**
10. (i)Consider two identical circular current loops of radius 3m and opposite current 20Amps are in parallel planes, separated on their common axis by 10m. Find the magnetic field intensity at a point midway between the two loops.
    (ii) State Biot-Savart's law. Find the magnetic field intensity at the origin due to current element $Id\vec{l} = 3\pi(\hat{a}_x + 2\hat{a}_y + 3\hat{a}_z)\mu$ A.m at (3,4,5) in free space. **(Dec 2016)**

UNIT – IV : Magnetic forces and Materials

PART A – C212.4

1.Define self inductance.
The self inductance is defined as the ratio of the total flux linkages to the current which they link. That is L = Nϕ / I where N is the number of turns of the coil, ϕ is the total flux in webers and I is the current passing through each turn. The unit of inductance is wb/amp or henry.

2.**Give the expression for Lorentz force equation**. **(Dec 2016)**
A charged particle in motion in a magnetic field of flux density B experiences force. The force is proportional to the product of the magnitude of the charge q, its velocity v and flux density B, and to the sine of the angle between v and B. The direction of the force is perpendicular to both v and B.

$F = qvB\sin\theta$ **or** $\vec{F} = q[\vec{E} + (\vec{v} \times \vec{B})]$

3.Define torque and write an expression for torque in vector form. (June 2015)
Torque: when a current carrying loop is placed in a magnetic field, there will be a force acting on this loop which causes the rotation of loop. The tangential force times the radial distance at which it acts is called as torque. **T = BIA sin** α
Torque = mB sin α, where magnetic moment m = Current X Area = I A. In vector form, **T = m x B**

4.Write down the equation for force on differential current element.

F =BIL sinθ, where B = magnetic flux density, I = Current flowing through the current element, L =length of the differential current element.

5.Write down the equation for force between parallel conductors.

$$F = \frac{\mu_0 I^2 L}{2\pi R} Newtons$$

6.Define mmf.

Magnetomotive force(mmf) is given by mmf = flux X reluctance, Amp turns

7.Define and explain mutual inductance.

The mutual inductance between two coils is defined as the ratio of induced magnetic flux linkage in one coil to the current flowing in other coil. That is $M = N_2 \Phi_{12} / i_1$, where N_2 is the number of turns in coil 2, Φ_{12} is magnetic flux links coil 2, i_1 is the current through coil 1.

8.Differentiate between dia, para & ferromagnetic materials. (June 2016)

Diamagnetic : In diamagnetic materials magnetization is opposed to the applied field. It has weak magnetic field. Examples: Hydrogen, helium, copper, gold, sulphur, graphite.

Paramagnetic : In paramagnetic materials magnetization is in the same direction as the field. It has weak magnetic field. Examples: oxygen, neodymium oxide, potassium, tungsten etc.

Ferromagnetic : In ferromagnetic materials magnetization is in the same direction as the field. It has strong magnetic field. Examples: Iron, cobalt, nickel.

9.Distinguish between solenoid and toroid.

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 in the form of a ring and thereby closed on itself, it becomes toroid.

10.Define reluctance.

Reluctance is the ratio of mmf of magnetic circuit to the flux through it. $R = \frac{mmf}{flux}$

11. D**efine magnetization.**

Magnetization is defined as the ratio of magnetic dipole moment to unit volume. M = Magnetic dipole / volume.

12. Define magnetic susceptibility.

Magnetic susceptibility is defined as the ratio of magnetization to the magnetic field intensity. It is dimensionless quantity. $\psi_m = M / H$

13. What is energy density in the magnetic field? (Dec 2015)

Energy density $w = ½ BH = ½ \mu H^2$

14. State and explain about the boundary conditions at the magnetic surfaces

- The normal components of magnetic field is continuous across the boundary that is $B_{n1} = B_{n2}$ and the normal components of magnetic field intensity are not continuous across the boundary.
- The tangential components of magnetic field is continuous across the boundary that is $H_{t1} = H_{t2}$ when linear current density k = 0 and the tangential components of magnetic flux density are not continuous across the boundary .

15. Find the permeability of the material whose magnetic susceptibility is 4.

Solution: $\mu = \mu_0 \mu_r = \mu_0 (1 + \chi_m) = 5\mu_0$

16. Write expressions for energy in magneto static fields. (June 2015)

Energy in magnetostatic field = (1/2) L I^2.

17. What is anti ferromagnetic material?

In these materials, atomic moments are anti parallel due to forces between adjacent atoms. These materials are slightly affected by an external magnetic field and have zero net magnetic moment. Anti ferromagnetic characteristics are present below room temperature.

18. What is ferromagnetic material?

These materials have large dipole moment caused by uncompensated electron spin moments. These moments are lined parallel with domain, (regions containing large number of atoms) due to inter atomic forces. Domains have various shapes and sizes ranging from micro meter to cm and strong moments varying in direction.

19. Compare self inductance and mutual inductance. (Dec 2013)

The self inductance of a coil is defined as the ratio of induced magnetic flux linkage to the current flowing in the same coil. i.e. $L = N_1\phi_1/I_1$.The mutual inductance between two coils is defined as the ratio of induced magnetic flux linkage in one coil to the current flowing in other coil. That is $M = N_2 \Phi_{12} / i_1$, where N_2 is the number of turns in coil 2, Φ_{12} is magnetic flux links coil 2, i_1 is the current through coil 1.

20. 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. (June 2014)

The magnetic field inside the solenoid $H = nI\, a_z$.

21. In a ferromagnetic material (μ=4.5μ_0), the magnetic flux density is $\vec{B} = 10y\vec{a}_x$ mWb/m^2. Calculate the magnetization vector. (Dec 2015)

Solution: Magnetization vector, $\vec{M} = \frac{\vec{B}}{\mu_0} - \vec{H} = \frac{\vec{B}}{\mu_0} - \frac{\vec{B}}{\mu_0\mu_r} = \frac{7.778\vec{a}_x}{\mu_0}$

22. Calculate the mutual inductance of two inductively tightly coupled coils with self-inductance of 25mH and 100mH. (Dec 2016)

Solution: Given, $L_1 = 25\text{mH}$, $L_2 = 100\,\text{mH}$

Mutual inductance, $M = \sqrt{L_1L_2} = \sqrt{25\text{mH} \times 100\,\text{mH}} = 50\,\text{mH}$

22. Mention the force between two current elements. (June 2016)

The force between two differential current elements,

$$d(d\vec{F}_2) = \mu_0 \frac{I_1I_2}{4\pi R_{12}^2} d\vec{L}_2 \times (dL_1 \times \vec{a}_{R_{12}})$$

23. Define skin depth? (May 2017)

In a medium which has conductivity, the wave is attenuated as it progress owing to the losses which occur. In a good conductor at radio frequencies the rate of attenuation is very great and the wave may penetrate only a short distance before being reduced to a negligibly small percentage of its original strength. Such circumstance is called depth of penetration or skin depth defined as δ, the depth the wave has been attenuated to 1/e or approximately 37% of its original value.

PART B – C212.4

1. Derive an expression for a torque on a closed rectangular loop carrying current. **(Dec 2013)**
2. Classify the materials based on magnetic properties. **(May 2017)**
3. An iron ring with a cross sectional area of 3 cm^2 and mean circumference of 15cm is wound with a 250 turns wire carrying a current of 0.3 A. The relative permittivity of the ring is 1500. Calculate the flux established in the ring.
4. Derive the equation to find the force between the two current elements. **(May 2017)**
5. 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 magnetic field within the conductors and the internal self inductance per unit length of the composite conductor. **(Dec 2013, June 2015)**
6. Derive an expression for the inductance of a co-axial cable. **(May 2017)**
7. Derive the expression for inductance and magnetic flux density inside the solenoid. Calculate the inductance of the solenoid and energy stored when a current of 8 A flowing through the solenoid of 2m long, 10 cm diameter and 4000 turns. **(Dec 2016)**
8. (i) Derive the expression for inductance of a solenoid. Calculate the inductance of solenoid, 8 cm in length, 2cm in radius, having μ_r=100 and 1000 turns. **(June 2016)**

(ii) Give the comparison between magnetic and electric circuits. **(June 2016)**

9. (i)Derive the expression for force on a moving charge in a magnetic field and Lorentz force equation.
(ii)Derive the inductance of a toroid**.** **(June 2016)**

10. (i)A charged particle with velocity $\vec{u}$ is moving in a medium containing uniform field $\vec{E} = E\vec{a}_x$ V/m and $\vec{B} = B\vec{a}_y$ Wb/m^2. What should $\vec{u}$ be so that the particle experiences no net force on it? **(Dec 2016)**
(ii)State and derive the magnetic boundary conditions between the two magnetic mediums. **(Dec 2013, 2015, 2016)**

UNIT - V : Time varying fields and Maxwell's Equations

PART A – C212.5

1. State Faraday's law of induction. **(June 2015, June 2016)**

Faraday's law states that electromagnetic force induced in a circuit is equal to the rate of change of magnetic flux linking the circuit. $\text{emf} = -\dfrac{d\phi}{dt}$, where ϕ is the flux through each turn. The negative sign shows that the induced voltage acts in such a way as to oppose the flux producing it.

2. State and explain Lenz's law.

According to Lenz's law, the induced emf behaves in such a way that it opposes the reason which produces it. Consider the coil having N turns, then according to Faraday's law, induced emf is given by, emf **=** - N dΦ/dt. Here negative sign indicates that the induced emf opposes the change in magnetic flux. But it is not opposing the flux itself. This is called as Lenz's law.

3. Explain the terms transformer emf.

The closed circuit in which emf induced is stationary and the magnetic flux is sinusoidally varying with time. This is similar to transformer action and emf is called transformer emf.

4. Explain the term motional emf.

Magnetic field is stationary, not varying with time while the closed circuit is revolved to get the relative motion between them. This action is similar to generator action and is called motional emf or generator emf.

5. What is the emf induced when a moving circuit is in a stationary field?

The emf induced due to the movement of conductor (in this case, moving circuit) in a stationary magnetic field is called motional emf or generator emf.

6. Distinguish between Conductor and Dielectric.

$\sigma/\omega\varepsilon = 1$, the ratio of conduction current density to displacement current density in the medium provides dividing line between conductors ad dielectrics.

If $\sigma/\omega\varepsilon >> 1$, then the medium is a very good conductor, If $\sigma/\omega\varepsilon << 1$, then the medium is a dielectric.

7. Define displacement current

A current through a capacitive element is called displacement current. Displacement current density is $J_D = \partial D / \partial t = \varepsilon\, \partial E / \partial t$. By Maxwell's equation for free space $\nabla \times H = J_D + \partial D / \partial t$

8. Define conduction current and displacement current densities and derive the relationship between them.

A current through a resistive element is called conduction current whereas current through a capacitive element is called displacement current. $\nabla \times H = J + \varepsilon\, \partial E / \partial t$.

9. Define Ampere's circuital law

Ampere's circuital law states that the line integral of magnetic field intensity H about any closed path is exactly equal to the direct current enclosed by that path. $\int H.dl = I$.

10. Give the differential form of Maxwell's equations.

$\nabla \times H = J_D + \partial D / \partial t = \sigma E + \varepsilon\, \partial E / \partial t$, $\nabla \times E = - \partial B / \partial t = - \mu\, \partial H / \partial t$, $\nabla . D = \rho$, $\nabla. B = 0$

11. Write down the Maxwell's equations in point phasor form

$\nabla \times H = J + j\omega D = (\sigma + j\omega\varepsilon)E$, $\nabla \times E = - j\omega B = -j\omega\mu H$, $\nabla . D = \rho$, $\nabla. B = 0$

12. Give the differential form of Maxwell's equations in free space. (Dec 2015)

$\nabla \times H = \partial D / \partial t = \varepsilon\, \partial E / \partial t$, $\nabla \times E = - \partial B / \partial t = - \mu\, \partial H / \partial t$, $\nabla . D = 0$, $\nabla. B = 0$

13. Explain when $\nabla \times E = 0$

In a region in which there is no time changing magnetic flux, the voltage around the loop would be zero. By Maxwell's equation $\nabla \times E = - \partial B / \partial t = 0$

14. Explain why $\nabla . D = 0$

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

15. Explain why ∇ . B = 0

∇ . B = 0 signifies that magnetic monopoles do not exist. The net magnetic flux emerging through any closed surface is zero.

16. What is Poynting Vector (or) Poynting theorm? (June 2015, June2016)

The Poynting Vector is defined as rate of flow of energy of a wave as it propagates. It is the vector product of electric field and magnetic field. P = E x H.

17. Define phase velocity. (Dec2016)

The phase velocity of a wave is the rate at which the phase of the wave propagates in space. This is the velocity at which the phase of any one frequency component of the wave travels.

18. What is a time varying field?

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

19. How can we achieve both conduction and displacement current in single element?

We can replace two separate elements, a resistor and a capacitor by a single element through which both the conduction current and the displacement current passes. This is achieved by using a capacitor filled with the conducting dielectric medium.

20. What is conduction current?

The current passing through resistor (R) of parallel RC combination because of the actual motion of charges is called as the conduction current.

21. Distinguish conduction current and Displacement current. (June 2013, May 2017)

- Conduction current is the actual current produced due to motion of electrons while displacement current is the apparent current produced by time varying electric field
- Conduction current density is given by $J_C = \sigma E$ while displacement current density is given by $J_D = \partial D / \partial t$
- Conduction current obeys Ohm's law but displacement current does not obey Ohm's law.

22.Find the displacement current density for field $\vec{E} = 300\sin 10^9 t$ V/m (Dec '16)

Solution: Displacement current density = $\vec{J}_D = \varepsilon \frac{\partial \vec{E}}{\partial t} = \varepsilon \frac{\partial}{\partial t}\left(300\sin 10^9 t\right) = \varepsilon\, 300 \times 10^9\, t \times \cos 10^9 t$

23.List any two properties of uniform plane waves. (May2017)

The properties of uniform plane wave are as follows:

- At every point in space, the electric field E and Magnetic field H are perpendicular to each other and to the direction of the travel.
- The fields vary harmonically with time and at the same frequency, everywhere in space.
- Each field has the same direction, magnitude and phase at every point in any plane perpendicular to the direction of wave travels.

PART B – C212.5

1. Derive Maxwell's equations from Ampere's circuital law, Faraday's law and Gauss law in integral form and point form. **(June 2013, 2014, 2016, Dec 2015)**
2. (i) If $D = 20x\vec{a}_x - 15y\vec{a}_y + kz\vec{a}_z$ μC/m², find the value of k to satisfy the Maxwell's equations for region σ = 0 and ρ_v = 0.
   (ii) If the magnetic field $H = \left(3x\cos\left(3 + 6y\sin\alpha\right)\right)\hat{a}_z$, find current density J if fields are invariant with time.
3. (i)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 $I_c = 3\sin wt$ mA. If $\omega = 10^8$ rad/s find the displacement current.
   (ii) An electric field in a medium which is source free is given by $E = 1.5\cos(10^8 t - \beta z)\widehat{a_x}$ V/m. Find the **B**, **H** and **D**. Assume $\varepsilon_r = 1, \mu_r = 1, \sigma = 0.$ **(June 2013)**
4. State and prove Poynting theorem and derive the expression for Poynting vector. **(Dec 2013, June2014, Dec 2015,2016)**

5 .Starting from Maxwell's equation, derive homogeneous vector Helmholtz's equation in phasor form. **(June 2016)**

6. Derive the wave equation starting from Maxwell's equation for free space. **(Dec 2016, May 2017)**

7.Determine the propagation constant and intrinsic impedance for a material having $\mu_r = 1, \varepsilon_r = 9$ and $\sigma = 0.25$pS/m, if the frequency is 2.0 MHz.

8. Derive the expression for total power flow in a coaxial cable. **(June 2015)**
9. From the basic laws derive the time varying Maxwell's equation and explain the significance of each equation in detail. **(Dec 2016,May 2017)**

10.Explain the transformer emf using Faraday's law. **(May 2017)**

11.With relevant examples explain in detail the practical application of electromagnetic fields. **(May'17)**

12.Propose the salient points to be noted when the boundary conditions are applied. **(May 2017)**