

Electro Magnetic Theory

1.State stokes theorem.

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

$$\oint \mathbf{H} \cdot d\mathbf{l} = \int (\nabla \times \mathbf{H}) \cdot d\mathbf{s}$$

2.State coulombs law.

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.

$$F = \frac{Q_1 Q_2}{4\pi \epsilon_0 r^2} \hat{r}$$

3.State Gauss law for electric fields

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

4.Define electric flux.

The lines of electric force is electric flux.

5.Define electric flux density.

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

6.Define electric field intensity.

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

$$\begin{aligned} E &= F/Q \\ &= \frac{Q}{4\pi \epsilon_0 r^2} \text{ V/m} \end{aligned}$$

7.Name few applications of Gauss law in electrostatics.

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

8.What is a point charge?

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

9.Define linear charge density.

It is the charge per unit length.

10.Write poisson's and laplace 's equations.

Poisson 's eqn:

$$\nabla^2 V = -\rho / \epsilon_0$$

Laplace' s eqn:

$$\nabla^2 V = 0$$

11.State the condition for the vector F to be solenoidal.

$$\nabla \cdot F = 0$$

12. .State the condition for the vector F to be irrotational.

$$\nabla \times F = 0$$

13.Define potential difference.

Potential difference is defined as the work done in moving a unit positive charge from one point to another point in an electric field.

14. Define potential.

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.

$$V = Q / 4 \pi \epsilon_0 r$$

15. Give the relation between electric field intensity and electric flux density.

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

16. Give the relationship between potential gradient and electric field.

$$E = - \nabla V$$

17. What is the physical significance of div D ?

$$\nabla \cdot D = \rho_v$$

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.

18. Define current density.

Current density is defined as the current per unit area.

$$J = I/A \text{ Amp/m}^2$$

19. Write the point form of continuity equation and explain its significance.

$$\nabla \cdot J = - \frac{\partial \rho_v}{\partial t}$$

20. Write the expression for energy density in electrostatic field.

$$W = 1/2 \epsilon E^2$$

21. Write the boundary conditions at the interface between two perfect dielectrics.

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) $D_{n1} = D_{n2}$

22. Write down the expression for capacitance between two parallel plates.

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

23. What is meant by displacement current?

Displacement current is nothing but the current flowing through capacitor.

$$J = \frac{D}{t}$$

24. State point form of ohms law.

Point form of ohms law states that the field strength within a conductor is proportional to the current density.

$$J = \sigma E$$

25. Define surface charge density.

It is the charge per surface area.

26. State amperes circuital law.

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

$$\oint H \cdot dl = I$$

27. State Biot-Savarts law.

It states that 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 and is inversely proportional to the square of the distance between them

$$dB = \frac{\mu_0 I dl \sin \theta}{4\pi r^2}$$

28. Define magnetic vector potential.

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

$$B = \nabla \times A$$

$$A = \frac{\mu_0}{4\pi} \int \frac{J}{r} dv \text{ web/m}^2$$

29. Write down the expression for magnetic field at the centre of the circular coil.

$$H = I/2a.$$

30. Give the relation between magnetic flux density and magnetic field intensity.

$$B = \mu H$$

31. Write down the magnetic boundary conditions.

- 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.

32. Give the force on a current element.

$$dF = BId\sin$$

33. Define magnetic moment.

Magnetic moment is defined as the maximum torque per magnetic induction of flux density.

$$m = IA$$

34. State Gauss law for magnetic field.

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

$$\oint B \cdot ds = 0$$

35. Define a wave.

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.

36. Mention the properties of uniform plane wave.

- 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.

37. Write down the wave equation for E and H in free space.

$$\nabla^2 H - \mu_0 \epsilon_0 \frac{\partial^2 H}{\partial t^2} = 0.$$

38. Define intrinsic impedance or characteristic impedance.

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

39. Give the characteristic impedance of free space.

377 ohms

40. Define propagation constant.

Propagation constant is a complex number

$$\gamma = \alpha + j\beta$$

where α is attenuation constant

β is phase constant

$$\gamma = j\omega\sqrt{\mu(\epsilon + j\sigma)}$$

41. Define skin depth

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

$$\delta = 1/\alpha = 2/\gamma$$

42. Define Poynting vector.

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

$$P = E \times H$$

43. State Poynting's Theorem.

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

44. Give significant physical difference between Poisson's and Laplace's equations.

When the region contains charges Poisson's equation is used and when there are no charges Laplace's equation is applied.

45. Give the difficulties in FDM.

FDM is difficult to apply for problems involving irregular boundaries and non-homogeneous material properties.

46. Explain the steps in finite element method.

- i) Discretisation of the solution region into elements.
- ii) Generation of equations for fields at each element.
- iii) Assembly of all elements
- iv) Solution of the resulting system

47. State Maxwell's fourth equation.

The net magnetic flux emerging through any closed surface is zero.

48. State Maxwell's Third equation

The total electric displacement through the surface enclosing a volume is equal to the total charge within the volume.

49. State the principle of superposition of fields.

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

50. Define Ohm's law at a point

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

51. Define self inductance.

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

52. Define pointing vector.

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.

53. Give the formula to find potential at a point which is surrounded by four orthogonal points in FDM.

$$V_0 = \frac{1}{4}(V_1 + V_2 + V_3 + V_4)$$

54. Give the formula to find potential at a point which is surrounded by six orthogonal points in FDM.

$$V_0 = \frac{1}{6}(V_1 + V_2 + V_3 + V_4 + V_5 + V_6)$$

55. State Lenz law.

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

56. What is the effect of permittivity on the force between two charges?

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.

57. State electric displacement.

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

58. What is displacement flux density?

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

59. What is the significance of displacement current?

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.

60. Distinguish between conduction and displacement currents.

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

61. Define magnetic field strength.

The magnetic field strength (H) is a vector having the same direction as magnetic flux density.

$$H = B/\mu$$

62. Give the formula to find the force between two parallel current carrying conductors.

$$F = \mu I_1 I_2 / 2 R$$

63. Give the expression for torque experienced by a current carrying loop situated in a magnetic field.

$$T = IAB \sin$$

64. What is torque on a solenoid?

$$T = NIAB \sin$$

65. Explain the conservative property of electric field.

The work done in moving a point charge around a closed path in a electric field is zero.

Such a field is said to be conservative.

$$\oint E \cdot dl = 0$$

66. Write the expression for field intensity due to a toroid carrying a filamentary current I

$$H = NI / 2 R$$

67. What are equipotential surfaces?

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

68. Define loss tangent.

Loss tangent is the ratio of the magnitude of conduction current density to displacement current density of the medium.

$$\tan \delta = \sigma / \omega \epsilon$$

69. Define reflection and transmission coefficients.

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

70. Define transmission coefficients.

Transmission coefficient is defined as the ratio of the magnitude of the transmitted field to that of incident field.

71. What will happen when the wave is incident obliquely over dielectric –dielectric boundary?

When a plane wave is incident obliquely on the surface of a perfect dielectric part of the energy is transmitted and part of it is reflected. But in this case the transmitted wave will be refracted, that is the direction of propagation is altered.

72. What is the expression for energy stored in a magnetic field?

$$W = \frac{1}{2} LI^2$$

73. What is energy density in magnetic field?

$$W = \frac{1}{2} \mu H^2$$

74. 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 into the form of a ring and there by closed on itself it becomes a toroid.

75. Describe what are the sources of electric field and magnetic field?

Stationary charges produce electric field that are constant in time, hence the term electrostatics. Moving charges produce magnetic fields hence the term magnetostatics.

76. What are the significant physical differences between Poisson 's and laplace 's equations.

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 poissons equation can be used to find the potential.

When the region is free from charge laplace equation is used to find the potential.

77. State Divergence Theorem.

The integral of the divergence of a vector over a volume v is equal to the surface integral of the normal component of the vector over the surface bounded by the volume.

78. Give the expression for electric field intensity due to a single shell of charge

$$E = Q / 4 \pi r^2$$

79. Give the expression for potential between two spherical shells

$$V = 1/4 \pi \epsilon_0 (Q1/a - Q2/b)$$

80. Define electric dipole.

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

81. What is electrostatic force?

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

82. Define divergence.

The divergence of a vector F at any point is defined as the limit of its surface integral per unit volume as the volume enclosed by the surface around the point shrinks to zero.

83. How is electric energy stored in a capacitor?

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

84. What are dielectrics?

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.

85. What is a capacitor?

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.

86. Define dielectric strength.

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.

87. What meaning would you give to the capacitance of a single conductor?

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

88. Why water has much greater dielectric constant than mica?

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

89. What is Lorentz force?

Lorentz force is the force experienced by the test charge. It is maximum if the direction of movement of charge is perpendicular to the orientation of field lines.

90. Define magnetic moment.

Magnetic moment is defined as the maximum torque on the loop per unit magnetic induction.

91. Define inductance.

The inductance of a conductor is defined as the ratio of the linking magnetic flux to the current producing the flux.

$$L = \frac{N \cdot \Phi}{I}$$

92. What's the main cause of eddy current?

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

93. How can the eddy current losses be eliminated?

The eddy current losses can be eliminated by providing laminations. It can be proved that the total eddy current power loss decreases as the number of laminations increases.

94. What is the fundamental difference between static electric and magnetic field lines?

There is a fundamental difference between static electric and magnetic field lines. The tubes of electric flux originate and terminate on charges, whereas magnetic flux tubes are continuous.

95. What are uniform plane waves?

Electromagnetic waves which consist of electric and magnetic fields that are 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.

96. Write short notes on imperfect dielectrics.

A material is classified as an imperfect dielectric for $\sigma \ll \omega \epsilon$, that is conduction current density is small in magnitude compared to the displacement current density.

97. What is the significant feature of wave propagation in an imperfect dielectric?

The only significant feature of wave propagation in an imperfect dielectric compared to that in a perfect dielectric is the attenuation undergone by the wave.

98. What is the major drawback of finite difference method?

The major drawback of finite difference method is its inability to handle curved boundaries accurately.

99. What is the method of images?

The replacement of the actual problem with boundaries by an enlarged region or with image charges but no boundaries is called the method of images.

100. When is method of images used?

Method of images is used in solving problems of one or more point charges in the presence of boundary surfaces.

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Part-B

1. Find the electric field intensity of a straight uniformly charged wire of length 'L' m and having a linear charge density of + C/m at any point at a distance of 'h' m. Hence deduce the expression for infinitely long conductor.

Hints: Field due to charge element is given by:

$$dE = \frac{dq}{4\pi\epsilon_0 r^2}$$

$$E_x = \frac{\lambda}{4\pi\epsilon_0 h} [\cos \theta_1 + \cos \theta_2]$$

$$E_y = \frac{\lambda}{4\pi\epsilon_0 h} [\sin \theta_1 - \sin \theta_2]$$

For infinitely long conductor

$$E = \frac{\lambda}{2\pi\epsilon_0 h}$$

2. Derive the boundary relations for electric fields.

Hints:

- i) The tangential component of the electric field is continuous at the surface

$$E_{t1} = E_{t2}$$

- ii) The normal component of the electric flux density is continuous if there is no surface charge density.

$$D_{n1} = D_{n2}$$

3. Find the electric field intensity produced by a point charge distribution at

P(1,1,0) caused by four identical 3nC point charges located at P1(1,1,0)

P2(-1,1,0) P3(-1,-1,0) and P4(1,-1,0).

Hints:

Find the field intensity at P by using the formula

$$E_p = \frac{1}{4\pi\epsilon_0} [(Q_1/r_{1p}^2) u_{1p} + (Q_2/r_{2p}^2) u_{2p} + (Q_3/r_{3p}^2) u_{3p} + (Q_4/r_{4p}^2) u_{4p}]$$

4. A circular disc of radius 'a' m is charged with a charge density of σ C/m². Find the electric field intensity at a point 'h' m from the disc along its axis.

Hints:

Find the field due to the tangential and normal components

Total field is given by

$$E = \frac{\sigma}{2} [1 - \cos \theta]$$

5. Four positive charges of 10^{-9} C each are situated in the XY plane at points (0,0) (0,1) (1,0) and (1,1). Find the electric field intensity and potential at (1/2, 1/2).

Hints:

Find the field intensity at point using the formula

$$E = \frac{Q}{4\pi\epsilon_0 r^2} \mathbf{ur}$$

Find the potential at point using the formula

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

Find the field intensity at the point due to all four charges by using the superposition principle.

6. Given an electric field $E = (-6y/x^2) \mathbf{x} + 6/x \mathbf{y} + 5 \mathbf{z}$. Find the potential difference V_{AB} given A(-7, 2, 1) and B(4, 1, 2)

Hints:

Find the potential using the formula $v = -\int E \cdot dl$ and substitute the points

7. Derive an expression for potential difference between two points in an electric field.

Hint:

The potential difference between two points r_1 and r_2 is

$$V = V_1 - V_2$$

$$V = \frac{Q}{4\pi\epsilon_0 r_1} - \frac{Q}{4\pi\epsilon_0 r_2}$$

8. Find the magnetic flux density at a point Z on the axis of a circular loop of radius 'a' that carries a direct current I.

Hints:

The magnetic flux density at a point due to the current element is given by

$$dB = \frac{\mu_0 I dl \sin\theta}{4\pi r^2}$$

$$B = \frac{\mu_0 I a^2}{2(a^2 + z^2)^{3/2}}$$

9. Determine the force per meter length between two long parallel wires A and B separated by 5cm in air and carrying currents of 40A in the same direction.

Hints:

Calculate the force per metre length using the formula

$$F/l = \frac{\mu_0 I_1 I_2}{2\pi d}$$

In the same direction force is attractive.

10. Derive an expression for magnetic vector potential.

Hint:

magnetic vector potential is

$$A = \frac{\mu}{4\pi} \int \frac{J}{r} dv$$

11. Derive the magnetic boundary relations.

i) The tangential component of the magnetic field is continuous across the boundary.
 $H_{t1} = H_{t2}$

ii) The normal component of the magnetic flux density is continuous across the boundary

$$D_{n1} = D_{n2}$$

12. Find the magnetic field intensity at a distance 'h' above an infinite straight wire carrying a steady current I.

Hints:

The magnetic flux density is calculated starting from Biot Savart's law.

The magnetic flux density at any point due to an infinite long conductor is given by

$$B = \frac{\mu I}{2d}$$

13. Two conducting concentric spherical shells with radii a and b are at potentials V_0 and 0 respectively. Determine the capacitance of the capacitor.

Hints:

Derive the capacitance between concentric spheres using the formula

$$C = Q/V$$

$$= 4\pi \epsilon_0 \left[\frac{ab}{b-a} \right]$$

14 State and derive an expression for Poynting's theorem.

Hints:

The net power flowing out of a given volume v is equal to the time rate of decrease of the energy stored within the volume minus the conduction losses.

15. Find the force/length between two long straight parallel conductors carrying a current of 10A in the same direction. A distance of 0.2m separates the conductors. Also find the force/length when the conductors carry currents in opposite directions.

Hints:

Calculate the force per metre length using the formula

$$F/L = \mu I_1 I_2 / 2d$$

In opposite direction force is repulsive

16 Derive an expression for torque acting on a loop.

Hints

:When a current loop is placed parallel to a magnetic field forces act on the loop that tends to rotate the tangential force times the radial distance at which it acts is called torque or mechanical moment of the loop.

$$T = m \times B$$

17. Derive an expression for energy and energy density in a electric field.

$$\text{Energy} = CV^2/2$$

$$\text{Energy density} = E^2/2$$

18. Derive an expression for energy and energy density in a magnetic field.

$$\text{Energy} = LI^2/2$$

$$\text{Energy density} = \mu H^2/2$$

19. Derive all the Maxwell's equations.

Hints:

- i) Maxwell's equation from electric Gauss law.
- ii) Maxwell's equation from magnetic Gauss law.
- iii) Maxwell's equation from Ampere's law.
- iv) Maxwell's equation from Faraday's law.

20. Derive an expression for displacement, conduction current densities. Also obtain an expression for continuity current relations

Hints:

$$\text{Displacement current density } J_d = \epsilon \frac{\partial E}{\partial t}$$

$$\text{Conduction current density } J_{\text{cond}} = \sigma E$$

21. Derive the general electromagnetic wave equation.

Hint:

Starting from the Maxwell's equation from Faraday's law and Ampere's law derive the Equation

$$\nabla^2 E - \mu \epsilon \frac{\partial^2 E}{\partial t^2} = -\mu \left(\frac{\partial J}{\partial t} + \nabla \rho \right)$$

22. Briefly explain reflection by a perfect dielectric when a wave is incident normally on a perfect dielectric and derive expression for reflection coefficient.

Hints:

When a plane electromagnetic wave is incident on the surface of a perfect dielectric part of the energy is transmitted and part of it is reflected.

$$E_r / E_i = (2 - 1) / (2 + 1)$$

23. Briefly explain reflection by a perfect dielectric when a wave is incident normally on a perfect conductor.

Hints

:When the plane wave is incident normally upon the surface of a perfect conductor, the wave is entirely reflected. Since there can be no loss within a perfect conductor, none of the energy is absorbed.

$$E(x,t) = 2E_i \sin x \sin t$$

24. Derive the relation between field theory and circuit theory for an RLC series circuit.

Hints :

Starting from field theory equation for a series RLC circuit derive the circuit equation

$$V = IR + L \frac{dI}{dt} + \frac{1}{C} \int I dt$$

25. State and explain Faraday's and Lenz's law of induction and derive Maxwell's equation.

Hints:

The total emf induced in a circuit is equal to the time rate of decrease of the total magnetic flux linking the circuit.

$$\oint \vec{X} \cdot \vec{F} = - \frac{d\Phi}{dt}$$

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