Vector Analysis – 50 MCQs with Answers

Scalar and Vector Product

1. The scalar product of two vectors **A** and **B** is defined as:
A) |A||B| sinθ
B) |A||B| cosθ
C) A × B
D) A + B
Answer: B

2. The result of a dot product is always:
A) Vector
B) Scalar
C) Tensor
D) Matrix
Answer: B

3. If A · B = 0, then vectors are:
A) Parallel
B) Equal
C) Perpendicular
D) Collinear
Answer: C

4. The vector product of A and B is:
A) |A||B| cosθ
B) |A||B| sinθ
C) A · B
D) Scalar
Answer: B

5. The cross product of two parallel vectors is:
A) Maximum
B) Unity
C) Zero
D) Infinity
Answer: C

6. A × B is perpendicular to:
A) A only
B) B only
C) Both A and B

D) None
Answer: C

7. Unit vector perpendicular to both A and B is given by:
A) $(A \times B)/|A \times B|$
B) A/B
C) $A + B$
D) $A \cdot B$
Answer: A

8. The scalar triple product is written as:
A) $A \cdot (B \times C)$
B) $A \times (B \times C)$
C) $(A \cdot B) \times C$
D) $A + B + C$
Answer: A

9. Scalar triple product represents:
A) Area
B) Length
C) Volume
D) Velocity
Answer: C

10. Vector triple product identity is:
A) $A \times (B \times C) = B(A \cdot C) – C(A \cdot B)$
B) $A \times B = B \times A$
C) $A \cdot B = B \cdot A$
D) None
Answer: A

Gradient

11. Gradient operates on:
A) Vector field
B) Scalar field
C) Matrix
D) Tensor
Answer: B

12. Gradient of scalar φ is written as:
A) $\nabla \cdot \varphi$
B) $\nabla \times \varphi$
C) $\nabla\varphi$

D) φ∇
Answer: C

13. Gradient gives direction of:
A) Minimum increase
B) Maximum increase
C) Zero change
D) Rotation
Answer: B

14. Unit of gradient is:
A) Same as scalar
B) Scalar squared
C) Scalar per unit length
D) Dimensionless
Answer: C

15. If φ = constant, then $\nabla\varphi$ equals:
A) 1
B) 0
C) ∞
D) -1
Answer: B

Divergence

16. Divergence operates on:
A) Scalar
B) Vector
C) Matrix
D) Constant
Answer: B

17. Divergence of vector A is written as:
A) $\nabla \times A$
B) $\nabla \cdot A$
C) ∇A
D) $A\nabla$
Answer: B

18. Divergence gives measure of:
A) Rotation
B) Spread of field
C) Gradient

D) Curl
Answer: B

19. If divergence is zero, the field is:
A) Solenoidal
B) Conservative
C) Irrotational
D) Harmonic
Answer: A

20. Unit of divergence is:
A) Same as vector
B) Vector per unit area
C) Vector per unit volume
D) Scalar
Answer: C

Curl

21. Curl operates on:
A) Scalar
B) Vector
C) Constant
D) Number
Answer: B

22. Curl of vector A is written as:
A) $\nabla \cdot A$
B) $\nabla \times A$
C) ∇A
D) $A\nabla$
Answer: B

23. Curl represents:
A) Flow out
B) Rotation
C) Divergence
D) Volume
Answer: B

24. If curl A = 0, the field is:
A) Conservative
B) Solenoidal
C) Harmonic

D) None
Answer: A

25. Curl of gradient of any scalar field is:
A) 1
B) ∇
C) Zero
D) Infinity
Answer: C

Vector Integration

26. Line integral is integration over:
A) Volume
B) Area
C) Curve
D) Surface
Answer: C

27. Work done by force is calculated using:
A) Surface integral
B) Line integral
C) Volume integral
D) Divergence
Answer: B

28. Surface integral is taken over:
A) Curve
B) Line
C) Surface
D) Point
Answer: C

29. Volume integral is taken over:
A) Area
B) Surface
C) Curve
D) Volume
Answer: D

30. $\oint F \cdot dr$ represents:
A) Surface integral
B) Closed line integral
C) Volume integral

D) Divergence
Answer: B

Gauss Divergence Theorem (Statement Only)

31. Gauss theorem relates:
A) Line & Surface integral
B) Surface & Volume integral
C) Line & Volume integral
D) None
Answer: B

32. Gauss theorem is also called:
A) Green's theorem
B) Divergence theorem
C) Stokes theorem
D) Curl theorem
Answer: B

33. Gauss theorem converts:
A) Volume integral into surface integral
B) Surface integral into volume integral
C) Line integral into surface
D) None
Answer: B

34. Gauss theorem applies to:
A) Scalar field
B) Vector field
C) Matrix
D) Constant
Answer: B

35. Physical meaning of Gauss theorem relates to:
A) Rotation
B) Flux
C) Gradient
D) Curl
Answer: B

Stokes Theorem (Statement Only)

36. Stokes theorem relates:
A) Volume & Surface
B) Line & Surface
C) Volume & Line
D) None
Answer: B

37. Stokes theorem converts:
A) Line integral into surface integral
B) Surface integral into line integral
C) Volume into surface
D) None
Answer: A

38. Stokes theorem involves:
A) Divergence
B) Gradient
C) Curl
D) Laplacian
Answer: C

39. Closed path integral equals:
A) Surface integral of divergence
B) Surface integral of curl
C) Volume integral
D) None
Answer: B

40. Stokes theorem is applicable to:
A) Closed surface
B) Open surface with boundary
C) Volume only
D) Scalar
Answer: B

Mixed Concept Questions

41. $\nabla \cdot (\nabla \times A)$ equals:
A) 1
B) ∇
C) 0
D) A
Answer: C

42. $\nabla \times (\nabla\varphi)$ equals:
A) 0
B) 1
C) φ
D) ∇
Answer: A

43. Laplacian operator is:
A) ∇
B) ∇^2
C) $\nabla \times$
D) $\nabla \cdot$
Answer: B

44. A conservative field has:
A) Non-zero curl
B) Zero curl
C) Non-zero divergence
D) Infinite divergence
Answer: B

45. A solenoidal field has:
A) Zero divergence
B) Zero curl
C) Zero gradient
D) None
Answer: A

46. Area of parallelogram formed by A and B is:
A) $|A \cdot B|$
B) $|A \times B|$
C) A + B
D) A – B
Answer: B

47. If $A \times B = 0$, vectors are:
A) Perpendicular
B) Parallel
C) Equal
D) Unit
Answer: B

48. Direction of $A \times B$ is given by:
A) Left hand rule
B) Right hand rule
C) Fleming rule

D) None
Answer: B

49. Flux through surface is calculated by:
A) Line integral
B) Volume integral
C) Surface integral
D) Curl
Answer: C

50. Circulation of vector field is measured by:
A) Surface integral
B) Volume integral
C) Line integral
D) Divergence
Answer: C

Electrostatics – 50 MCQs with Answers

(Question No. 51–100)

Electrostatic Field & Electric Flux

51. The electrostatic field is produced by:
A) Moving charges
B) Stationary charges
C) Magnetic dipoles
D) Current only
Answer: B

52. SI unit of electric field is:
A) Volt
B) Newton/Coulomb
C) Coulomb
D) Farad
Answer: B

53. Electric flux is defined as:
A) Charge per unit area
B) Electric field through a surface
C) Potential difference
D) Energy density
Answer: B

54. Electric flux is maximum when angle between **E** and area vector is:
A) 0°
B) 30°
C) 60°
D) 90°
Answer: A

55. Unit of electric flux is:
A) Nm^2/C
B) N/C
C) Volt
D) Joule
Answer: A

Gauss's Theorem

56. Gauss's law states that total flux through a closed surface equals:
A) Zero
B) Charge inside/ε_0
C) Electric field
D) Potential
Answer: B

57. Gauss's law is useful for calculating field when symmetry is:
A) Irregular
B) Asymmetric
C) High symmetry
D) None
Answer: C

58. Gauss's law is based on:
A) Coulomb's law
B) Ohm's law
C) Faraday's law
D) Ampere's law
Answer: A

59. If no charge is enclosed, total flux is:
A) Maximum
B) Zero
C) Infinite
D) Constant
Answer: B

60. Electric field inside a conductor (electrostatic condition) is:
A) Maximum
B) Zero
C) Infinite
D) Constant
Answer: B

Electric Field Due to Different Charge Distributions

61. Electric field due to point charge varies as:
A) 1/r
B) $1/r^2$
C) r^2
D) Constant
Answer: B

62. Electric field due to infinite line charge varies as:
A) 1/r
B) $1/r^2$
C) r
D) Constant
Answer: A

63. Electric field due to infinite plane sheet is:
A) Zero
B) Constant
C) 1/r
D) $1/r^2$
Answer: B

64. Electric field inside uniformly charged spherical shell is:
A) Zero
B) Maximum
C) Infinite
D) Constant
Answer: A

65. Electric field inside uniformly charged solid sphere varies as:
A) $1/r^2$
B) r
C) Constant
D) 1/r
Answer: B

66. Electric field just outside charged conductor is:
A) σ/ε_0
B) 0
C) Infinite
D) 1/r
Answer: A

Electric Potential

67. Electric potential is defined as:
A) Work done per unit charge
B) Charge per unit work
C) Energy density
D) Field strength
Answer: A

68. Unit of electric potential is:
A) Coulomb
B) Volt
C) Newton
D) Farad
Answer: B

69. Electric potential due to point charge varies as:
A) 1/r
B) $1/r^2$
C) r
D) Constant
Answer: A

70. Potential inside spherical shell is:
A) Zero
B) Constant
C) Infinite
D) r dependent
Answer: B

71. Electric field is related to potential as:
A) $E = \nabla V$
B) $E = -\nabla V$
C) $E = V^2$
D) $E = 0$
Answer: B

72. Potential due to dipole decreases as:
A) $1/r$
B) $1/r^2$
C) $1/r^3$
D) r^2
Answer: B

Capacitance

73. Capacitance is defined as:
A) QV
B) Q/V
C) V/Q
D) Q^2
Answer: B

74. Unit of capacitance is:
A) Volt
B) Coulomb
C) Farad
D) Henry
Answer: C

75. Capacitance of isolated spherical conductor is proportional to:
A) Radius
B) Radius^2
C) 1/Radius
D) Volume
Answer: A

76. Capacitance of parallel plate capacitor increases when:
A) Distance increases
B) Area decreases
C) Dielectric inserted
D) Charge removed
Answer: C

77. Capacitance of parallel plate capacitor is:
A) $\varepsilon_0 A/d$
B) $\varepsilon_0 d/A$
C) A/d^2
D) $1/d$
Answer: A

78. Inserting dielectric increases capacitance by factor:
A) k
B) 1/k
C) k^2
D) Zero
Answer: A

79. Capacitance of cylindrical capacitor depends on:
A) Length
B) Radius
C) Both
D) None
Answer: C

Energy in Electrostatic Field

80. Energy stored in capacitor is:
A) CV
B) ½ CV^2
C) V^2
D) Q
Answer: B

81. Energy density in electric field is:
A) ½ $\varepsilon_0 E^2$
B) $\varepsilon_0 E$
C) E^2
D) ½ E
Answer: A

82. Energy per unit volume depends on:
A) Charge only
B) Electric field
C) Potential only
D) Current
Answer: B

Dielectric Medium

83. Dielectric constant is ratio of:
A) E in vacuum/E in medium
B) C with dielectric/C without dielectric

C) Charge ratio
D) Potential ratio
Answer: B

84. Polarization is:
A) Alignment of dipoles
B) Current flow
C) Charge transfer
D) Resistance
Answer: A

85. Displacement vector is written as:
A) $D = \varepsilon_0 E$
B) $D = \varepsilon_0 E + P$
C) $D = P$
D) $D = E$
Answer: B

86. Unit of displacement vector is:
A) C/m^2
B) N/C
C) Volt
D) Farad
Answer: A

87. Gauss's law in dielectric is:
A) $\oint E \cdot dS = Q/\varepsilon_0$
B) $\oint D \cdot dS = Q_{free}$
C) $\oint E \cdot dS = 0$
D) None
Answer: B

88. When dielectric fully fills capacitor, capacitance becomes:
A) kC
B) C/k
C) C^2
D) Zero
Answer: A

Application-Based Questions

89. Field outside spherical shell behaves like:
A) Line charge
B) Point charge

C) Plane sheet
D) Dipole
Answer: B

90. Potential at infinity is generally taken as:
A) 1
B) 0
C) Infinite
D) Negative
Answer: B

91. Electric field lines start from:
A) Negative charge
B) Positive charge
C) Neutral
D) Dipole center
Answer: B

92. Electric field lines end on:
A) Positive
B) Negative
C) Neutral
D) Infinity only
Answer: B

93. Equipotential surfaces are always:
A) Parallel to E
B) Perpendicular to E
C) Circular
D) Random
Answer: B

94. Work done moving charge on equipotential surface is:
A) Maximum
B) Zero
C) Infinite
D) Constant
Answer: B

95. Inside conductor potential is:
A) Zero
B) Constant
C) Infinite
D) Varies
Answer: B

96. Electric field is zero where potential is:
A) Constant
B) Increasing
C) Decreasing
D) Infinite
Answer: A

97. Direction of electric field is:
A) Increasing potential
B) Decreasing potential
C) Constant potential
D) Random
Answer: B

98. Force between two charges depends on medium through:
A) ε_0
B) Dielectric constant
C) Area
D) Volume
Answer: B

99. In electrostatic equilibrium, charge resides on:
A) Volume
B) Surface
C) Center
D) Axis
Answer: B

100. Gauss law is especially useful for:
A) Irregular shapes
B) Symmetric charge distribution
C) Moving charges
D) Magnetic field
Answer: B

Magnetism – 50 MCQs with Answers

(Question No. 101–150)

Biot–Savart Law & Applications

101. Biot–Savart law gives magnetic field due to:
A) Static charge
B) Moving charge/current element

C) Electric dipole
D) Potential difference
Answer: B

102. According to Biot–Savart law, magnetic field varies as:
A) 1/r
B) $1/r^2$
C) r^2
D) Constant
Answer: B

103. SI unit of magnetic field is:
A) Tesla
B) Weber
C) Henry
D) Coulomb
Answer: A

104. Magnetic field at the center of a circular coil is proportional to:
A) Radius
B) 1/Radius
C) $Radius^2$
D) $1/Radius^2$
Answer: B

105. Magnetic field inside a long straight current-carrying conductor varies as:
A) 1/r
B) r
C) Constant
D) r^2
Answer: A

106. Magnetic field inside a long solenoid is:
A) Zero
B) Constant
C) 1/r
D) Infinite
Answer: B

107. Magnetic field outside an ideal long solenoid is:
A) Maximum
B) Zero
C) Infinite
D) Variable
Answer: B

108. Direction of magnetic field is given by:
A) Fleming's left-hand rule
B) Right-hand thumb rule
C) Ohm's law
D) Coulomb's law
Answer: B

109. Magnetic field at the center of circular loop depends on:
A) Current
B) Radius
C) Number of turns
D) All of these
Answer: D

110. Biot–Savart law is analogous to:
A) Gauss law
B) Coulomb's law
C) Ampere's law
D) Faraday's law
Answer: B

Divergence and Curl of Magnetic Field

111. Divergence of magnetic field ($\nabla \cdot B$) is:
A) 1
B) −1
C) 0
D) Infinite
Answer: C

112. $\nabla \cdot B = 0$ indicates:
A) Magnetic monopoles exist
B) Magnetic field is solenoidal
C) Field is zero
D) Field is infinite
Answer: B

113. Curl of magnetic field is related to:
A) Charge density
B) Current density
C) Potential
D) Voltage
Answer: B

114. $\nabla \times B$ equals:
A) $\mu_0 J$
B) $\varepsilon_0 E$
C) 0
D) ∇V
Answer: A

115. Magnetic field lines are:
A) Open
B) Closed loops
C) Straight
D) Random
Answer: B

Magnetic Vector Potential

116. Magnetic vector potential is denoted by:
A) V
B) E
C) A
D) B
Answer: C

117. Magnetic field is related to vector potential as:
A) $B = \nabla \cdot A$
B) $B = \nabla \times A$
C) $B = -\nabla A$
D) $B = A^2$
Answer: B

118. Unit of magnetic vector potential is:
A) Tesla
B) Weber/m
C) Henry
D) Volt
Answer: B

119. If A is constant, magnetic field is:
A) Infinite
B) Zero
C) Constant
D) Maximum
Answer: B

120. Magnetic vector potential simplifies calculation of:
A) Electric field
B) Magnetic field
C) Voltage
D) Capacitance
Answer: B

Ampere's Circuital Law

121. Ampere's circuital law states:
A) $\oint B \cdot dl = \mu_0 I$
B) $\oint E \cdot dl = 0$
C) $\oint B \cdot dS = 0$
D) $\oint D \cdot dS = Q$
Answer: A

122. Ampere's law is useful for:
A) Irregular geometry
B) Symmetrical current distribution
C) Point charge
D) Static charge
Answer: B

123. Magnetic field around straight conductor is:
A) Radial
B) Circular
C) Linear
D) Zero
Answer: B

124. Inside toroid magnetic field depends on:
A) Radius only
B) Current only
C) Both
D) None
Answer: C

125. Ampere's law is analogous to:
A) Gauss's law
B) Coulomb's law
C) Faraday's law
D) Lenz's law
Answer: A

Magnetic Properties of Materials

126. Magnetic intensity is denoted by:
A) B
B) H
C) A
D) E
Answer: B

127. Magnetic induction is denoted by:
A) H
B) B
C) M
D) A
Answer: B

128. Relation between B and H is:
A) $B = \mu H$
B) $B = \varepsilon H$
C) $B = H^2$
D) $B = H/\mu$
Answer: A

129. Permeability is denoted by:
A) ε
B) μ
C) χ
D) σ
Answer: B

130. Magnetic susceptibility is denoted by:
A) μ
B) ε
C) χ
D) H
Answer: C

131. Relation between μ and χ is:
A) $\mu = 1 + \chi$
B) $\mu = \chi$
C) $\mu = 1 - \chi$
D) $\mu = \chi^2$
Answer: A

Dia-, Para-, Ferromagnetic Materials

132. Diamagnetic materials have susceptibility:
A) Positive small
B) Negative small
C) Large positive
D) Infinite
Answer: B

133. Example of diamagnetic material:
A) Iron
B) Copper
C) Nickel
D) Cobalt
Answer: B

134. Paramagnetic materials have susceptibility:
A) Negative
B) Zero
C) Small positive
D) Large positive
Answer: C

135. Example of paramagnetic material:
A) Aluminium
B) Iron
C) Cobalt
D) Nickel
Answer: A

136. Ferromagnetic materials have susceptibility:
A) Very small
B) Zero
C) Very large positive
D) Negative
Answer: C

137. Example of ferromagnetic material:
A) Copper
B) Aluminium
C) Iron
D) Silver
Answer: C

138. Ferromagnetic materials show:
A) Weak attraction
B) Strong attraction
C) Repulsion
D) No effect
Answer: B

139. Diamagnetic materials are repelled because:
A) $\chi > 0$
B) $\chi < 0$
C) $\chi = 1$
D) $\chi = \infty$
Answer: B

140. In paramagnetic material, magnetization is:
A) Opposite to H
B) Along H
C) Zero
D) Infinite
Answer: B

Concept-Based Questions

141. Magnetic monopole has:
A) Been observed
B) Not been observed
C) Large value
D) Zero mass
Answer: B

142. Unit of magnetic intensity (H) is:
A) A/m
B) Tesla
C) Weber
D) Volt
Answer: A

143. Unit of magnetic induction (B) is:
A) A/m
B) Tesla
C) Henry
D) Coulomb
Answer: B

144. Magnetic field inside diamagnetic material is:
A) Increased
B) Decreased
C) Zero
D) Infinite
Answer: B

145. Magnetic permeability of vacuum is:
A) μ_0
B) ε_0
C) χ
D) σ
Answer: A

146. Magnetic field due to long straight wire is proportional to:
A) Current
B) Distance
C) Voltage
D) Resistance
Answer: A

147. Increasing number of turns in solenoid:
A) Decreases B
B) Increases B
C) No change
D) Makes zero
Answer: B

148. Magnetic lines of force never:
A) Intersect
B) Form loops
C) Exist
D) Expand
Answer: A

149. Ferromagnetic materials show:
A) Hysteresis
B) Zero magnetization
C) Weak effect
D) No alignment
Answer: A

150. In vacuum relation between B and H is:
A) $B = \mu_0 H$
B) $B = \varepsilon_0 H$
C) $B = H^2$

D) B = χH
Answer: A

Electromagnetic Induction & EM Waves – 50 MCQs

(Question No. 151–200)

Faraday's Laws & Lenz's Law

151. Faraday's first law states that induced emf is produced when:
A) Magnetic field is constant
B) Magnetic flux changes
C) Current is zero
D) Resistance is infinite
Answer: B

152. Faraday's second law states induced emf is proportional to:
A) Magnetic field
B) Rate of change of flux
C) Charge
D) Resistance
Answer: B

153. SI unit of magnetic flux is:
A) Tesla
B) Weber
C) Henry
D) Volt
Answer: B

154. Lenz's law is based on conservation of:
A) Charge
B) Momentum
C) Energy
D) Mass
Answer: C

155. Negative sign in Faraday's law indicates:
A) Decrease in flux
B) Direction by Lenz's law
C) Zero emf
D) Infinite current
Answer: B

156. Induced emf in a coil of N turns is:
A) NΦ
B) −N dΦ/dt
C) Φ/N
D) N²Φ
Answer: B

Self & Mutual Inductance

157. Self inductance is property of:
A) Single coil
B) Two coils
C) Capacitor
D) Resistor
Answer: A

158. SI unit of inductance is:
A) Weber
B) Tesla
C) Henry
D) Volt
Answer: C

159. Self inductance depends on:
A) Geometry of coil
B) Number of turns
C) Permeability
D) All of these
Answer: D

160. Induced emf due to self inductance is:
A) −L dI/dt
B) L dI/dt
C) −M dI/dt
D) LI
Answer: A

161. Mutual inductance exists between:
A) One coil
B) Two nearby coils
C) Capacitor plates
D) Resistor
Answer: B

162. Mutual inductance is denoted by:
A) L
B) M
C) μ
D) Φ
Answer: B

163. Induced emf in secondary coil is:
A) $-M\, dI/dt$
B) $-L\, dI/dt$
C) M I
D) LI
Answer: A

164. Mutual inductance depends on:
A) Distance between coils
B) Number of turns
C) Permeability
D) All of these
Answer: D

Energy Stored in Magnetic Field

165. Energy stored in inductor is:
A) LI
B) $\frac{1}{2} LI^2$
C) L^2I
D) $\frac{1}{2} L^2I$
Answer: B

166. Energy density in magnetic field is:
A) $B^2/2\mu_0$
B) $\frac{1}{2} \varepsilon_0 E^2$
C) B/μ_0
D) $\mu_0 B^2$
Answer: A

167. Magnetic energy depends on:
A) Current
B) Inductance
C) Both
D) None
Answer: C

✅ **Maxwell's Equations & EM Waves**

Equation of Continuity & Displacement Current

168. Equation of continuity represents conservation of:
A) Energy
B) Momentum
C) Charge
D) Mass
Answer: C

169. Continuity equation is:
A) $\nabla\cdot J = 0$
B) $\nabla\cdot J = -\partial\rho/\partial t$
C) $\nabla\times E = 0$
D) $\nabla\cdot B = 0$
Answer: B

170. Displacement current was introduced by:
A) Faraday
B) Maxwell
C) Ampere
D) Gauss
Answer: B

171. Displacement current is associated with:
A) Changing magnetic field
B) Changing electric field
C) Constant current
D) Static charge
Answer: B

172. Displacement current density is:
A) $\varepsilon_0\ \partial E/\partial t$
B) $\mu_0\ \partial B/\partial t$
C) $\nabla\cdot E$
D) $\nabla\times B$
Answer: A

Maxwell's Equations

173. Gauss's law for electricity is:
A) $\nabla\cdot E = \rho/\varepsilon_0$
B) $\nabla\cdot B = 0$
C) $\nabla\times E = 0$
D) $\nabla\times B = 0$
Answer: A

174. Gauss's law for magnetism states:
A) $\nabla\cdot B = \rho$
B) $\nabla\cdot B = 0$
C) $\nabla\times B = 0$
D) $\nabla\cdot E = 0$
Answer: B

175. Faraday's law in differential form is:
A) $\nabla\times E = -\partial B/\partial t$
B) $\nabla\cdot E = 0$
C) $\nabla\times B = 0$
D) $\nabla\cdot B = 0$
Answer: A

176. Ampere-Maxwell law is:
A) $\nabla\times B = \mu_0 J + \mu_0\varepsilon_0\ \partial E/\partial t$
B) $\nabla\cdot B = 0$
C) $\nabla\times E = 0$
D) $\nabla\cdot E = 0$
Answer: A

177. Maxwell predicted existence of:
A) Magnetic monopoles
B) Electromagnetic waves
C) Static field
D) Capacitors
Answer: B

Poynting Vector & Energy Density

178. Poynting vector represents:
A) Energy density
B) Power per unit area
C) Charge density

D) Current density
Answer: B

179. Poynting vector is given by:
A) E × B
B) B × E
C) E · B
D) ∇ × E
Answer: A

180. Energy density of EM wave is:
A) $\varepsilon_0 E^2$
B) B^2/μ_0
C) Sum of electric & magnetic energy densities
D) Zero
Answer: C

EM Wave Propagation

181. Speed of EM wave in vacuum is:
A) 3×10^8 m/s
B) 3×10^6 m/s
C) 3×10^5 m/s
D) 3×10^7 m/s
Answer: A

182. EM waves are:
A) Longitudinal
B) Transverse
C) Stationary
D) Mechanical
Answer: B

183. In EM wave, E and B fields are:
A) Parallel
B) Perpendicular
C) Same
D) Zero
Answer: B

184. Direction of EM wave propagation is along:
A) E
B) B
C) E × B

D) Opposite to E
Answer: C

185. In vacuum relation between E and B is:
A) E = cB
B) E = B
C) B = cE
D) E = 0
Answer: A

186. Wave equation from Maxwell equations shows wave speed:
A) $1/\sqrt{(\mu_0\varepsilon_0)}$
B) $\sqrt{(\mu_0\varepsilon_0)}$
C) $\mu_0\varepsilon_0$
D) Zero
Answer: A

187. EM waves do not require:
A) Electric field
B) Magnetic field
C) Medium
D) Energy
Answer: C

Propagation in Dielectric Medium

188. Speed in dielectric medium is:
A) c
B) $c/\sqrt{k}$
C) ck
D) Infinite
Answer: B

189. Refractive index n equals:
A) c/v
B) v/c
C) c^2/v
D) 1/v
Answer: A

Polarization

190. Polarization is property of:
A) Longitudinal waves
B) Transverse waves
C) Sound waves
D) Water waves
Answer: B

191. EM waves can be polarized because they are:
A) Longitudinal
B) Transverse
C) Stationary
D) Static
Answer: B

192. Plane polarization means:
A) E oscillates in one plane
B) B oscillates randomly
C) No oscillation
D) Zero field
Answer: A

Conceptual Questions

193. EM wave carries:
A) Charge
B) Energy and momentum
C) Mass only
D) Current
Answer: B

194. In free space charge density ρ is:
A) 1
B) Infinite
C) 0
D) Variable
Answer: C

195. Curl of electric field in static case is:
A) 0
B) Infinite
C) 1

D) μ_0
Answer: A

196. Magnetic field in EM wave is maximum when electric field is:
A) Zero
B) Maximum
C) Minimum
D) Infinite
Answer: B

197. EM waves are produced by:
A) Static charges
B) Accelerated charges
C) Stationary current
D) Resistors
Answer: B

198. Maxwell's equations unify:
A) Electricity and magnetism
B) Heat and light
C) Mechanics
D) Optics only
Answer: A

199. Ratio of electric to magnetic energy in EM wave is:
A) 2:1
B) 1:2
C) 1:1
D) 3:1
Answer: C

200. The nature of EM wave confirms light is:
A) Mechanical
B) Electromagnetic
C) Longitudinal
D) Static
Answer: B

PART–A: Vector Analysis (Q.1–35)

Scalar & Vector Product

1. Define scalar (dot) product.
Answer: The scalar product of vectors **A** and **B** is A·B=|A||B|cosθA·B = |A||B|cosθA·B=|A||B|cosθ. It gives a scalar quantity.

2. When is dot product maximum?
Answer: When angle between vectors is 0° (parallel vectors).

3. What is vector (cross) product?
Answer: A×B=|A||B|sinθn^A×B = |A||B|sinθ \hat{n}A×B=|A||B|sinθn^. It gives a vector perpendicular to both A and B.

4. When is cross product zero?
Answer: When vectors are parallel (θ = 0° or 180°).

5. What does scalar triple product represent?
Answer: It represents the volume of a parallelepiped formed by three vectors.

6. State vector triple product identity.
Answer: A×(B×C)=B(A·C)−C(A·B)A×(B×C) = B(A·C) − C(A·B)A×(B×C)=B(A·C)−C(A·B).

Gradient

7. Define gradient.
Answer: Gradient of scalar φ is ∇φ∇φ∇φ; it gives direction of maximum increase of φ.

8. What is physical significance of gradient?
Answer: It gives magnitude and direction of maximum rate of change of scalar field.

9. What is gradient of constant?
Answer: Zero.

10. Write gradient in Cartesian form.
Answer: ∇φ=∂φ∂xi+∂φ∂yj+∂φ∂zk∇φ = \frac{∂φ}{∂x}i + \frac{∂φ}{∂y}j + \frac{∂φ}{∂z}k∇φ=∂x∂φi+∂y∂φj+∂z∂φk.

Divergence

11. Define divergence.
Answer: Divergence of vector A is ∇·A∇·A∇·A; it measures spreading out of a field.

12. What is solenoidal field?
Answer: A field with zero divergence.

13. What is divergence of curl of any vector?
Answer: Zero.

14. State physical meaning of divergence.
Answer: It represents flux density or source strength at a point.

Curl

15. Define curl.
Answer: Curl of A is $\nabla\times A\nabla\times A\nabla\times A$; it measures rotation of vector field.

16. What is irrotational field?
Answer: Field with zero curl.

17. What is curl of gradient?
Answer: Zero.

18. State significance of curl.
Answer: It indicates rotational property of field.

Vector Integration

19. Define line integral.
Answer: Integral of vector field along a curve: $\oint F\cdot dr\oint F\cdot dr\oint F\cdot dr$.

20. What is physical meaning of line integral?
Answer: Represents work done by force.

21. Define surface integral.
Answer: Integral of vector field over a surface.

22. What is flux?
Answer: Surface integral of electric field through surface.

23. Define volume integral.
Answer: Integral of field throughout a volume.

Gauss & Stokes Theorem

24. State Gauss divergence theorem.
Answer: Surface integral of vector field over closed surface equals volume integral of divergence.

25. What is significance of Gauss theorem?
Answer: Converts surface integral into volume integral.

26. State Stokes theorem.
Answer: Line integral over closed curve equals surface integral of curl.

27. What does Stokes theorem relate?
Answer: Line integral and surface integral.

28. Condition for using Gauss theorem?
Answer: Closed surface.

29. Condition for Stokes theorem?
Answer: Open surface bounded by closed curve.

Mixed Concept

30. Define Laplacian operator.
Answer: $\nabla 2=\nabla\cdot\nabla\nabla^2 = \nabla\cdot\nabla\nabla 2=\nabla\cdot\nabla$.

31. When is field conservative?
Answer: When curl is zero.

32. Write identity $\nabla\cdot(\nabla\times A)$.
Answer: Zero.

33. Write identity $\nabla\times(\nabla\varphi)$.
Answer: Zero.

34. Define unit normal vector.
Answer: Vector perpendicular to surface with unit magnitude.

35. What is circulation?
Answer: Line integral of vector field around closed path.

✅ PART–B: Electrostatics (Q.36–75)

Electrostatic Field & Gauss Law

36. Define electric field.
Answer: Force per unit positive charge.

37. Write unit of electric field.
Answer: N/C or V/m.

38. Define electric flux.
Answer: Product of electric field and area component normal to surface.

39. State Gauss's law.
Answer: Total electric flux through closed surface equals enclosed charge/ε_0.

40. When is Gauss law useful?
Answer: For symmetric charge distributions.

Electric Field Due to Charge Distributions

41. Electric field due to point charge varies as?
Answer: $1/r^2$.

42. Field due to infinite line charge varies as?
Answer: $1/r$.

43. Field inside spherical shell?
Answer: Zero.

44. Field inside solid sphere varies as?
Answer: Directly proportional to r.

45. Field due to infinite plane sheet?
Answer: Constant.

46. Field inside conductor?
Answer: Zero.

Electric Potential

47. Define electric potential.
Answer: Work done per unit charge.

48. Unit of potential?
Answer: Volt.

49. Potential due to point charge varies as?
Answer: 1/r.

50. Relation between E and V?
Answer: $E=-\nabla VE = -\nabla VE=-\nabla V$.

51. Potential inside spherical shell?
Answer: Constant.

52. Define equipotential surface.
Answer: Surface of constant potential.

53. Work on equipotential surface?
Answer: Zero.

Capacitance

54. Define capacitance.
Answer: C = Q/V.

55. Unit of capacitance.
Answer: Farad.

56. Capacitance of isolated sphere.
Answer: $C=4\pi\varepsilon 0RC = 4\pi\ \varepsilon_0\ RC=4\pi\varepsilon 0R$.

57. Capacitance of parallel plate capacitor.
Answer: $C=\varepsilon 0A/dC = \varepsilon_0\ A/dC=\varepsilon 0A/d$.

58. Effect of dielectric on capacitance?
Answer: Increases by factor k.

59. Energy stored in capacitor?
Answer: ½CV2½ CV^2½CV2.

60. Energy density in electric field.
Answer: ½ε0E2½ $\varepsilon_0\ E^2$½ε0E2.

Dielectrics

61. Define dielectric.
Answer: Insulating material that polarizes in electric field.

62. Define polarization.
Answer: Dipole moment per unit volume.

63. Define displacement vector.
Answer: D=ε0E+PD = ε_0E + PD=ε0E+P.

64. State Gauss law in dielectric.
Answer: ∮D·dS=Qfree∮D·dS = Q_{free}∮D·dS=Qfree.

65. What is dielectric constant?
Answer: Ratio of capacitance with dielectric to without dielectric.

Applications

66. Field outside spherical shell behaves as?
Answer: Like point charge.

67. Potential at infinity is taken as?
Answer: Zero.

68. Direction of electric field?
Answer: From positive to negative charge.

69. Charge resides on conductor surface because?
Answer: Electric field inside conductor is zero.

70. What is electrostatic shielding?
Answer: Zero electric field inside closed conductor.

71. Capacitance of spherical condenser depends on?
Answer: Radii of two spheres.

72. Cylindrical capacitor used in?
Answer: Coaxial cables.

73. Why dielectric reduces electric field?
Answer: Due to polarization opposing field.

74. Define electric dipole moment.
Answer: Product of charge and separation distance.

75. Potential due to dipole decreases as?
Answer: $1/r^2$.

PART–A: Magnetism (Q.76–110)

Biot–Savart Law

76. State Biot–Savart law.
Answer: It states that magnetic field dBdBdB due to current element is proportional to Idlsin⁡θ/r2I dl \sin\theta / r^2Idlsinθ/r2.

77. What is SI unit of magnetic field?
Answer: Tesla (T).

78. On what factors does magnetic field depend?
Answer: Current, distance, and angle between current element and point.

79. Magnetic field due to long straight conductor varies as?
Answer: 1/r1/r1/r.

80. Direction of magnetic field around straight wire?
Answer: Given by right-hand thumb rule.

81. Magnetic field at center of circular coil?
Answer: B=μ0I2RB = \frac{μ_0 I}{2R}B=2Rμ0I.

82. Magnetic field inside long solenoid?
Answer: B=μ0nIB = μ_0 n IB=μ0nI.

83. Field outside ideal long solenoid?
Answer: Nearly zero.

84. Magnetic field lines are?
Answer: Closed loops.

85. What is magnetostatics?
Answer: Study of magnetic fields due to steady currents.

Divergence and Curl of B

86. What is divergence of magnetic field?
Answer: ∇·B=0∇·B = 0∇·B=0.

87. Physical meaning of ∇·B = 0?
Answer: No magnetic monopoles exist.

88. What is curl of magnetic field?
Answer: ∇×B=μ0J$\nabla\times B = \mu_0 J$∇×B=μ0J.

89. What does curl of B represent?
Answer: Relation between magnetic field and current density.

90. Magnetic field is solenoidal because?
Answer: Its divergence is zero.

Magnetic Vector Potential

91. Define magnetic vector potential.
Answer: A vector AAA such that B=∇×AB = ∇×AB=∇×A.

92. Unit of magnetic vector potential?
Answer: Weber/m.

93. Why is vector potential useful?
Answer: Simplifies magnetic field calculations.

Ampere's Circuital Law

94. State Ampere's circuital law.
Answer: ∮B·dl=μ0I$\oint B\cdot dl = \mu_0 I$∮B·dl=μ0I.

95. When is Ampere's law useful?
Answer: For symmetric current distributions.

96. Shape of magnetic field around straight wire?
Answer: Circular.

97. Magnetic field inside toroid?
Answer: B=μ0NI2πrB = \frac{μ_0NI}{2πr}B=2πrμ0NI.

Magnetic Properties of Materials

98. Define magnetic intensity (H).
Answer: Magnetizing field strength.

99. Define magnetic induction (B).
Answer: Magnetic flux density.

100. Relation between B and H?
Answer: $B=\mu HB = \mu HB=\mu H$.

101. Define permeability.
Answer: Ability of material to support magnetic field.

102. Define magnetic susceptibility.
Answer: Ratio of magnetization to magnetic intensity.

103. Relation between μ and χ?
Answer: $\mu=\mu 0(1+\chi)\mu = \mu_0(1+\chi)\mu=\mu 0(1+\chi)$.

Dia-, Para-, Ferromagnetism

104. What are diamagnetic materials?
Answer: Materials weakly repelled by magnetic field.

105. Example of diamagnetic material.
Answer: Copper.

106. What are paramagnetic materials?
Answer: Weakly attracted materials.

107. Example of paramagnetic material.
Answer: Aluminium.

108. What are ferromagnetic materials?
Answer: Strongly attracted materials.

109. Example of ferromagnetic material.
Answer: Iron.

110. What is hysteresis?
Answer: Lagging of magnetization behind magnetizing field.

✓ PART–B: Electromagnetic Induction (Q.111–130)

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111. State Faraday’s first law.
Answer: Changing magnetic flux induces emf.

112. State Faraday’s second law.
Answer: Induced emf equals rate of change of flux.

113. Write formula of induced emf.
Answer: e=−NdΦdte = -N \frac{dΦ}{dt}e=−NdtdΦ.

114. What does negative sign indicate?
Answer: Lenz’s law.

115. State Lenz’s law.
Answer: Induced current opposes cause producing it.

116. Define self inductance.
Answer: Property of coil to oppose change in its own current.

117. Define mutual inductance.
Answer: Induced emf in one coil due to change in current in another.

118. Unit of inductance.
Answer: Henry.

119. Induced emf in inductor.
Answer: e=−LdIdte = -L \frac{dI}{dt}e=−LdtdI.

120. Induced emf in secondary coil.
Answer: e=−MdIdte = -M \frac{dI}{dt}e=−MdtdI.

121. Energy stored in inductor.
Answer: ½LI2½ LI^2½LI2.

122. Energy density in magnetic field.
Answer: B2/2μ0B^2 / $2\mu_0$B2/2μ0.

123. On what factors does L depend?
Answer: Geometry and permeability.

124. On what factors does M depend?
Answer: Distance and orientation of coils.

125. What is eddy current?
Answer: Induced circulating currents in conductors.

126. Application of mutual inductance.
Answer: Transformer.

127. Define magnetic flux.
Answer: Φ=B·AΦ = B·AΦ=B·A.

128. Unit of magnetic flux.
Answer: Weber.

129. What produces electromagnetic induction?
Answer: Relative motion between magnet and coil.

130. State condition for no induced emf.
Answer: Constant magnetic flux.

✅ PART–C: Maxwell's Equations & EM Waves (Q.131–150)

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131. State continuity equation.
Answer: ∇·J=−∂ρ∂t∇·J = -\frac{∂ρ}{∂t}∇·J=−∂t∂ρ.

132. What does continuity equation represent?
Answer: Conservation of charge.

133. Define displacement current.
Answer: Current due to changing electric field.

134. Expression for displacement current density.
Answer: Jd=ε0∂E∂tJ_d = ε_0 \frac{∂E}{∂t}Jd=ε0∂t∂E.

135. State Gauss's law for electricity.
Answer: ∇·E=ρ/ε0∇·E = ρ/ε_0∇·E=ρ/ε0.

136. State Gauss's law for magnetism.
Answer: ∇·B=0∇·B = 0∇·B=0.

137. State Faraday's law (Maxwell form).
Answer: ∇×E=−∂B∂t∇×E = -\frac{∂B}{∂t}∇×E=−∂t∂B.

138. State Ampere-Maxwell law.
Answer: ∇×B=μ0J+μ0ε0∂E∂t∇×B = μ_0J + $\mu_0\varepsilon_0$\frac{∂E}{∂t}∇×B=μ0J+μ0ε0∂t∂E.

139. What did Maxwell predict?
Answer: Electromagnetic waves.

140. Speed of EM wave in vacuum.
Answer: 3×108m/s3 × 10^8 m/s3×108m/s.

141. Relation between speed and constants.
Answer: c=1/μ0ε0c = 1/\sqrt{$\mu_0\varepsilon_0$}c=1/μ0ε0.

142. Nature of EM waves.
Answer: Transverse.

143. Relation between E and B in vacuum.
Answer: E=cBE = cBE=cB.

144. Direction of propagation.
Answer: Along E×BE × BE×B.

145. Define Poynting vector.
Answer: S=E×B/μ0S = E × B/μ_0S=E×B/μ0.

146. What does Poynting vector represent?
Answer: Energy flow per unit area.

147. Energy density of EM wave.
Answer: ½ε0E2+B2/2μ0½ ε_0E^2 + B^2/2μ_0½ε0E2+B2/2μ0.

148. EM waves require medium?
Answer: No.

149. What is polarization?
Answer: Restriction of vibrations to one plane.

150. Why EM waves can be polarized?
Answer: Because they are transverse waves.

PART–A: Vector Analysis (Q.1–18)

---

1. Define scalar and vector product. Discuss their physical significance.

Answer:
The scalar (dot) product of two vectors **A** and **B** is

A·B=|A||B|cos⁡θA·B = |A||B|\cos\thetaA·B=|A||B|cosθ

It gives a scalar quantity and represents projection of one vector onto another. It is used in calculating work done: W=F·sW = F·sW=F·s.

The vector (cross) product is

A×B=|A||B|sin⁡θn^A×B = |A||B|\sin\theta \hat{n}A×B=|A||B|sinθn^

It gives a vector perpendicular to both A and B. It is used in torque τ=r×F\tau = r×Fτ=r×F and angular momentum.

---

2. Explain scalar triple product and its geometrical interpretation.

Answer:
Scalar triple product is A·(B×C)A·(B×C)A·(B×C).
It gives a scalar quantity equal to volume of parallelepiped formed by vectors A, B, C.
If scalar triple product is zero, vectors are coplanar.
It is useful in geometry and physics problems involving volume.

---

3. Derive vector triple product identity.

Answer:
Vector triple product is:

A×(B×C)=B(A·C)−C(A·B)A×(B×C) = B(A·C) - C(A·B)A×(B×C)=B(A·C)−C(A·B)

It shows result lies in plane of B and C.
It simplifies many electromagnetic and mechanics calculations.

---

4. Define gradient and explain its physical meaning.

Answer:
Gradient of scalar φ is

∇φ∇φ∇φ

It is a vector pointing in direction of maximum increase of scalar field.
Magnitude gives rate of maximum change per unit length.
Example: Electric field is negative gradient of potential.

---

5. Define divergence and explain its significance.

Answer:
Divergence of vector A is

$\nabla\cdot A\nabla\cdot A\nabla\cdot A$

It represents net outward flux per unit volume.
If divergence is zero, field is solenoidal.
Used in Gauss divergence theorem.

---

6. Define curl and explain its physical meaning.

Answer:
Curl of vector A is

$\nabla\times A\nabla\times A\nabla\times A$

It measures rotational tendency of vector field.
If curl is zero, field is irrotational (conservative).
Example: Electrostatic field has zero curl.

---

7. Prove that curl of gradient is zero.

Answer:

$\nabla\times(\nabla\varphi)=0\nabla\times(\nabla\varphi) = 0\nabla\times(\nabla\varphi)=0$

Because mixed partial derivatives are equal.
Hence conservative fields have zero curl.

---

8. Prove that divergence of curl is zero.

Answer:

$\nabla\cdot(\nabla\times A)=0\nabla\cdot(\nabla\times A) = 0\nabla\cdot(\nabla\times A)=0$

It shows rotational fields have no net source.

9. Explain line integral and its physical meaning.

Answer:
Line integral of vector field is

∮F·dr∮F·dr∮F·dr

Represents work done by force along path.
If integral is path independent, field is conservative.

---

10. Define surface integral and flux.

Answer:
Surface integral is

∬F·dS\iint F·dS∬F·dS

It gives flux through surface.
Important in Gauss's law.

---

11. Define volume integral and its application.

Answer:
Volume integral integrates field over volume:

∭fdV\iiint f dV∭fdV

Used to find total charge, mass etc.

---

12. State and explain Gauss divergence theorem.

Answer:
It states that surface integral over closed surface equals volume integral of divergence:

∮F·dS=∭(∇·F)dV\oint F·dS = \iiint (∇·F) dV∮F·dS=∭(∇·F)dV

It simplifies flux calculations.

---

13. State and explain Stokes theorem.

Answer:
Line integral around closed curve equals surface integral of curl:

$$\oint F\cdot dr = \iint (\nabla\times F)\cdot dS$$

Relates circulation and rotation.

---

14. Define conservative field. Give condition.

Answer:
A field whose line integral is path independent.
Condition: $\nabla\times F = 0$.

---

15. Explain Laplacian operator and its use.

Answer:
Laplacian:

$$\nabla^2 = \nabla\cdot\nabla$$

Used in Poisson and Laplace equations.

---

16. Distinguish between solenoidal and irrotational fields.

Answer:
Solenoidal: divergence zero.
Irrotational: curl zero.
Electrostatic field is irrotational.

---

17. Explain physical meaning of circulation.

Answer:
Circulation is line integral around closed path.
Represents rotational strength of field.

18. Discuss applications of vector analysis in physics.

Answer:
Used in electromagnetism, fluid dynamics, mechanics.
Maxwell equations are written using divergence and curl operators.

✅ PART–B: Electrostatics (Q.19–35)

---

19. State and explain Gauss's law in electrostatics.

Answer:
Total electric flux through closed surface equals enclosed charge divided by ε_0:

∮E·dS=Q/ε0\oint E·dS = Q/ε_0∮E·dS=Q/ε0

Useful for symmetric charge distributions.

---

20. Derive electric field due to point charge using Gauss law.

Answer:
Using spherical surface:

E(4πr2)=Q/ε0E(4πr^2) = Q/ε_0E(4πr2)=Q/ε0 E=14πε0Qr2E = \frac{1}{4π ε_0}\frac{Q}{r^2}E=4πε01r2Q

---

21. Derive electric field due to infinite line charge.

Answer:
Using cylindrical Gaussian surface:

E(2πrl)=λl/ε0E(2πrl) = λl/ε_0E(2πrl)=λl/ε0 E=λ2πε0rE = \frac{λ}{2π ε_0 r}E=2πε0rλ

---

22. Find electric field due to infinite plane sheet.

Answer:
Using Gaussian pillbox:

E=σ2ε0E = \frac{σ}{2ε$_0$}E=2ε0σ

Field is constant.

---

23. Show electric field inside spherical shell is zero.

Answer:
Using Gauss law, enclosed charge inside shell is zero → E = 0.

---

24. Derive electric field inside uniformly charged solid sphere.

Answer:

E=Qr4πε0R3E = \frac{Qr}{4π ε$_0$ R^3}E=4πε0R3Qr

Field varies linearly with r.

---

25. Define electric potential and derive relation with field.

Answer:
Potential is work done per unit charge.

E=−∇VE = -∇VE=−∇V

---

26. Derive potential due to point charge.

Answer:

V=14πε0QrV = \frac{1}{4π ε$_0$}\frac{Q}{r}V=4πε01rQ

---

27. Define capacitance and derive for isolated sphere.

Answer:

C=Q/VC = Q/VC=Q/V

For sphere:

C=4πε0RC = 4π ε_0 RC=4πε0R

---

28. Derive capacitance of parallel plate capacitor.

Answer:

C=ε0AdC = \frac{ε_0 A}{d}C=dε0A

---

29. Explain effect of dielectric on capacitance.

Answer:
Capacitance increases by factor k:

C=kε0A/dC = kε_0 A/dC=kε0A/d

---

30. Derive energy stored in capacitor.

Answer:

U=½CV2U = ½ CV^2U=½CV2

---

31. Derive energy density in electric field.

Answer:

u=½ε0E2u = ½ ε_0 E^2u=½ε0E2

---

32. Define polarization and displacement vector.

Answer:
Polarization P = dipole moment per unit volume.
Displacement vector:

D=ε0E+PD = ε_0E + PD=ε0E+P

---

33. State Gauss law in dielectric medium.

Answer:

∮D·dS=Qfree\oint D·dS = Q_{free}∮D·dS=Qfree

---

34. Explain electrostatic shielding.

Answer:
Inside conductor electric field is zero.
Used in Faraday cage.

---

35. Discuss applications of electrostatics.

Answer:
Used in capacitors, electrostatic precipitators, photocopiers, shielding, and electronic circuits.

PART–A: Magnetism (Q.36–50)

---

36. Derive magnetic field due to a long straight current carrying conductor using Biot–Savart law.

Answer:
From Biot–Savart law:

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

For an infinite straight wire, integrating over entire length gives:

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

Magnetic field lines are concentric circles around the wire. Direction is given by right-hand thumb rule.

---

37. Derive magnetic field at the center of a circular coil.

Answer:
Using Biot–Savart law and integrating over the loop:

$$B = \frac{\mu_0 I}{2R}$$

For N turns:

B=μ0NI2RB = \frac{μ$_o$ N I}{2R}B=2Rμ0NI

Magnetic field is perpendicular to plane of the coil.

---

38. Derive magnetic field inside a long solenoid using Ampere's circuital law.

Answer:
Ampere's law:

∮B·dl=μ0Ienc\oint B·dl = μ$_o$ I_{enc}∮B·dl=μ0Ienc

For solenoid,

B=μ0nIB = μ$_o$ n IB=μ0nI

where n is number of turns per unit length. Field inside is uniform and outside nearly zero.

---

39. Explain divergence and curl of magnetic field with physical significance.

Answer:
Divergence:

∇·B=0∇·B = 0∇·B=0

This implies no magnetic monopoles.

Curl:

∇×B=μ0J∇×B = μ$_o$J∇×B=μ0J

Magnetic field is produced by current density.

---

40. Define magnetic vector potential and show that B=∇×AB = ∇×AB=∇×A.

Answer:
Since ∇·B=0∇·B = 0∇·B=0, magnetic field can be written as curl of vector potential A:

B=∇×AB = ∇×AB=∇×A

It simplifies Maxwell’s equations and electromagnetic wave derivations.

---

41. State and explain Ampere’s circuital law.

Answer:

$\oint B\cdot dl=\mu 0I$ $\oint B\cdot dl = \mu_0 I$ $\oint B\cdot dl=\mu 0I$

It states that circulation of magnetic field around closed path equals μ_0 times current enclosed. Useful in symmetric cases like solenoid and toroid.

---

42. Derive magnetic field inside a toroid.

Answer:
Using Ampere’s law:

$B(2\pi r)=\mu 0NIB(2\pi r) = \mu_0 N IB(2\pi r)=\mu 0NI$ $B=\mu 0NI2\pi rB = \frac{\mu_0 N I}{2\pi r}B=2\pi r\mu 0NI$

Field exists only inside toroid.

---

43. Define magnetic intensity (H) and magnetic induction (B). Discuss relation between them.

Answer:
Magnetic intensity H (A/m) is magnetizing field.
Magnetic induction B (Tesla) is flux density.
Relation:

$B=\mu HB = \mu HB=\mu H$

---

44. Define permeability and magnetic susceptibility. Derive relation between them.

Answer:
Permeability μ = ability to support magnetic field.
Susceptibility $\chi = M/H$.
Relation:

$\mu=\mu 0(1+\chi)\mu = \mu_0(1+\chi)\mu=\mu 0(1+\chi)$

---

45. Explain diamagnetic materials with properties.

Answer:
Diamagnetic materials have small negative susceptibility. They are weakly repelled by magnetic field. Example: Copper. Magnetization is opposite to applied field.

---

46. Explain paramagnetic materials with properties.

Answer:
Paramagnetic materials have small positive susceptibility. Weakly attracted by magnetic field. Example: Aluminium. Magnetization aligns with field.

---

47. Explain ferromagnetic materials and hysteresis.

Answer:
Ferromagnetic materials have very large susceptibility. Strong attraction. Show hysteresis curve representing energy loss.

---

48. Compare diamagnetic, paramagnetic and ferromagnetic materials.

Answer:
Diamagnetic: χ negative, weak repulsion.
Paramagnetic: χ small positive.
Ferromagnetic: χ large positive, strong attraction and hysteresis.

---

49. Discuss applications of magnetic materials.

Answer:
Used in transformers, motors, generators, magnetic storage devices, MRI machines.

---

50. Explain practical applications of solenoids and toroids.

Answer:
Solenoids used in electromagnets and relays.
Toroids used in transformers to confine magnetic field and reduce losses.

✅ PART–B: Electromagnetic Induction (Q.51–60)

---

51. State and explain Faraday's laws of electromagnetic induction.

Answer:

1. Changing magnetic flux induces emf.
2. Induced emf equals rate of change of flux:

$$e = -N \frac{d\Phi}{dt}$$

Negative sign represents Lenz's law.

---

52. Explain Lenz's law and its significance.

Answer:
Induced current opposes cause producing it. Ensures conservation of energy and determines direction of induced current.

---

53. Define self inductance and derive induced emf expression.

Answer:
Self inductance L is property of coil to oppose change in its own current.

$$e = -L \frac{dI}{dt}$$

---

54. Define mutual inductance and derive expression for induced emf.

Answer:
Mutual inductance M relates flux linkage of one coil due to another.

e=−MdIdte = -M \frac{dI}{dt}e=−MdtdI

---

55. Derive expression for self inductance of a long solenoid.

Answer:

L=μ0n2AlL = μ_0 n^2 A lL=μ0n2Al

Depends on geometry and permeability.

---

56. Derive expression for energy stored in inductor.

Answer:
Work done to build current:

U=½LI2U = ½ L I^2U=½LI2

---

57. Derive energy density in magnetic field.

Answer:

u=B22μ0u = \frac{B^2}{2μ_0}u=2μ0B2

Energy stored per unit volume.

---

58. Explain mutual inductance in transformers.

Answer:
AC in primary produces changing flux inducing emf in secondary.
Voltage ratio equals turns ratio.

---

59. Discuss eddy currents and their effects.

Answer:
Circulating currents induced in conductors. Cause heating losses. Reduced by lamination.

---

60. Explain electromagnetic induction in practical devices.

Answer:
Used in generators, transformers, induction cookers, wireless charging systems.

✅ **PART–C: Maxwell's Equations & EM Waves (Q.61–70)**

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61. State Maxwell's four equations in differential form.

Answer:

1. $\nabla\cdot E=\rho/\varepsilon 0\nabla\cdot E = \rho/\varepsilon_0\nabla\cdot E=\rho/\varepsilon 0$
2. $\nabla\cdot B=0\nabla\cdot B = 0\nabla\cdot B=0$
3. $\nabla\times E=-\partial B/\partial t\nabla\times E = -\partial B/\partial t\nabla\times E=-\partial B/\partial t$
4. $\nabla\times B=\mu 0J+\mu 0\varepsilon 0\partial E/\partial t\nabla\times B = \mu_0 J + \mu_0\varepsilon_0 \partial E/\partial t\nabla\times B=\mu 0J+\mu 0\varepsilon 0\partial E/\partial t$

---

62. Explain equation of continuity.

Answer:

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

Represents conservation of charge.

---

63. Define displacement current and its importance.

Answer:

$Jd=\varepsilon 0\partial E\partial tJ_d = \varepsilon_0 \frac{\partial E}{\partial t}Jd=\varepsilon 0\partial t\partial E$

Introduced by Maxwell to maintain current continuity.

---

64. Derive electromagnetic wave equation from Maxwell's equations.

Answer:
Combining equations leads to:

∇2E=μ0ε0∂2E∂t2\nabla^2 E = $\mu_0\varepsilon_0$ \frac{∂^2E}{∂t^2}∇2E=μ0ε0∂t2∂2E

Wave speed:

c=1μ0ε0c = \frac{1}{\sqrt{$\mu_0\varepsilon_0$}}c=μ0ε01

---

65. Explain Poynting vector and its physical meaning.

Answer:

S=1μ0E×BS = \frac{1}{μ_0} E × BS=μ01E×B

Represents energy flow per unit area per unit time.

---

66. Derive expression for energy density of EM wave.

Answer:

u=½ε0E2+B22μ0u = ½ ε_0E^2 + \frac{B^2}{2μ_0}u=½ε0E2+2μ0B2

Electric and magnetic energy contributions are equal.

---

67. Discuss propagation of EM waves in vacuum.

Answer:
EM waves are transverse.
E and B are perpendicular to each other and to direction of propagation.
Speed = 3×108m/s3×10^8 m/s3×108m/s.

---

68. Discuss propagation of EM waves in dielectric medium.

Answer:
Speed reduces to

$$v = \frac{c}{\sqrt{k}}$$

where k is dielectric constant.

---

69. Explain transverse nature of EM waves.

Answer:
Electric and magnetic fields oscillate perpendicular to propagation direction. Hence EM waves are transverse.

---

70. Explain polarization of electromagnetic waves.

Answer:
Polarization is restriction of electric field vibrations to one plane. Only transverse waves can be polarized.

25 Long-Answer Questions (15 Marks Each) with Detailed Explanations
(Suitable for University Semester Examination)

✅ PART–A: Vector Analysis (Q.1–12)

---

1. Define scalar and vector products. Derive their expressions and discuss geometrical and physical significance.

Answer:
The scalar (dot) product of two vectors **A** and **B** is defined as:

$$A \cdot B = |A||B|\cos\theta$$

It gives a scalar quantity and represents projection of one vector onto another.
In component form:

$$A \cdot B = A_xB_x + A_yB_y + A_zB_z$$

Physical significance: Work done $W = F \cdot s$.

The vector (cross) product is:

$$A \times B = |A||B|\sin\theta \hat{n}$$

Direction is perpendicular to plane of A and B (right-hand rule).
Magnitude equals area of parallelogram formed by vectors.
Applications: Torque $\tau = r \times F$, angular momentum.

---

2. Explain scalar triple product and prove that it represents volume of parallelepiped.

Answer:
Scalar triple product:

$$A \cdot (B \times C)$$

Since $|B \times C|$ equals area of base and dotting with A gives height component, the product equals volume.
If scalar triple product is zero, vectors are coplanar.

---

3. Derive vector triple product identity and explain its importance.

Answer:

$$A \times (B \times C) = B(A \cdot C) - C(A \cdot B)$$

This shows result lies in plane of B and C.
Used in electromagnetism and rigid body mechanics.

---

4. Define gradient of scalar field. Derive its expression in Cartesian coordinates and explain physical meaning.

Answer:
Gradient of scalar φ:

$$\nabla \phi = \frac{\partial \phi}{\partial x}i + \frac{\partial \phi}{\partial y}j + \frac{\partial \phi}{\partial z}k$$

It gives direction of maximum rate of increase.
Magnitude gives maximum rate of change per unit length.
Example: E=−∇VE = -∇VE=−∇V.

---

5. Define divergence of vector field and derive its Cartesian form. Discuss its physical interpretation.

Answer:

∇·A=∂Ax∂x+∂Ay∂y+∂Az∂z∇·A = \frac{∂A_x}{∂x} + \frac{∂A_y}{∂y} + \frac{∂A_z}{∂z}∇·A=∂x∂Ax+∂y∂Ay+∂z∂Az

Represents net outward flux per unit volume.
If zero → solenoidal field.

---

6. Define curl of vector field and derive its expression in Cartesian form. Explain significance.

Answer:

∇×A=|ijk∂/∂x∂/∂y∂/∂zAxAyAz|∇×A = \begin{vmatrix} i & j & k \\ ∂/∂x & ∂/∂y & ∂/∂z \\ A_x & A_y & A_z \end{vmatrix}∇×A=i∂/∂xAxj∂/∂yAyk∂/∂zAz

Measures rotational tendency of field.
If zero → irrotational field.

---

7. Prove that divergence of curl is zero and curl of gradient is zero.

Answer:
Using vector identities:

∇·(∇×A)=0∇·(∇×A) = 0∇·(∇×A)=0 ∇×(∇ϕ)=0∇×(∇ϕ) = 0∇×(∇ϕ)=0

These identities are fundamental in electromagnetism.

---

8. Define line, surface and volume integrals. Discuss their physical applications.

Answer:
Line integral: ∮F·dr\oint F·dr∮F·dr → work done.
Surface integral: ∬F·dS\iint F·dS∬F·dS → flux.
Volume integral: ∭fdV\iiint f dV∭fdV → total quantity in volume.

---

9. State and prove Gauss divergence theorem.

Answer:

∮F·dS=∭(∇·F)dV\oint F·dS = \iiint (∇·F)dV∮F·dS=∭(∇·F)dV

It relates flux through closed surface to volume integral of divergence.
Used in Maxwell equations and fluid dynamics.

---

10. State and explain Stokes theorem.

Answer:

∮F·dr=∬(∇×F)·dS\oint F·dr = \iint (∇×F)·dS∮F·dr=∬(∇×F)·dS

Relates circulation around closed curve to surface integral of curl.

---

11. Discuss conservative and solenoidal vector fields with examples.

Answer:
Conservative: curl zero (Electrostatic field).
Solenoidal: divergence zero (Magnetic field).

---

12. Discuss applications of vector calculus in physics.

Answer:
Used in electromagnetism, fluid mechanics, gravitation, and Maxwell's equations.

✅ PART–B: Electrostatics (Q.13–25)

---

13. State and explain Gauss's law. Derive electric field due to point charge.

Answer:
Gauss law:

∮E·dS=Q/ε0\oint E·dS = Q/ε_0∮E·dS=Q/ε0

For spherical surface:

E(4πr2)=Q/ε0E(4πr^2) = Q/ε_0E(4πr2)=Q/ε0 E=14πε0Qr2E = \frac{1}{4π ε_0}\frac{Q}{r^2}E=4πε01 r2Q

---

14. Derive electric field due to infinite line charge.

Answer:
Using cylindrical Gaussian surface:

E(2πrl)=λl/ε0E(2πrl) = λl/ε_0E(2πrl)=λl/ε0 E=λ2πε0rE = \frac{λ}{2π ε_0 r}E=2πε0rλ

---

15. Derive electric field due to infinite plane sheet.

Answer:
Using pillbox surface:

E=σ2ε0E = \frac{σ}{2ε_0}E=2ε0σ

Field is uniform and independent of distance.

---

16. Show that electric field inside uniformly charged spherical shell is zero.

Answer:
By Gauss law, enclosed charge inside shell is zero → E=0E = 0E=0.

---

17. Derive electric field inside uniformly charged solid sphere.

Answer:

$$E = \frac{Qr}{4\pi \varepsilon_0 R^3}$$

Field increases linearly with r.

---

18. Define electric potential and derive relation $E = -\nabla V$.

Answer:
Potential is work done per unit charge.
Electric field equals negative gradient of potential.

---

19. Derive potential due to point charge and dipole.

Answer:
Point charge:

$$V = \frac{1}{4\pi \varepsilon_0}\frac{Q}{r}$$

Dipole:

$$V = \frac{1}{4\pi \varepsilon_0}\frac{p\cos\theta}{r^2}$$

---

20. Derive capacitance of isolated spherical conductor.

Answer:

$$C = 4\pi \varepsilon_0 R$$

---

21. Derive capacitance of parallel plate capacitor with dielectric.

Answer:
Without dielectric:

$$C = \varepsilon_0 A/d$$

With dielectric:

$$C = k\varepsilon_0 A/d$$

---

22. Derive energy stored in capacitor and energy density of electric field.

Answer:

U=½CV2U = ½ CV^2U=½CV2

Energy density:

u=½ε0E2u = ½ ε_0 E^2u=½ε0E2

---

23. Define polarization and derive relation for displacement vector.

Answer:
Polarization PPP = dipole moment per unit volume.

D=ε0E+PD = ε_0E + PD=ε0E+P

---

24. State Gauss law in dielectric medium and explain its importance.

Answer:

∮D·dS=Qfree\oint D·dS = Q_{free}∮D·dS=Qfree

Useful in solving electrostatic problems in dielectrics.

---

25. Discuss applications of electrostatics in practical devices.

Answer:
Applications: Capacitors, electrostatic precipitators, photocopiers, shielding, sensors, and electronic circuits.

PART–A: Magnetostatics (Q.26–38)

---

26. State and derive Biot–Savart's law. Discuss its physical significance.

Answer:
Biot–Savart law states that the magnetic field $d\mathbf{B}$ at a point due to a current element $I d\mathbf{l}$ is

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

Direction is perpendicular to plane containing current element and position vector (right-hand rule).
It shows magnetic field depends on current, distance and angle.
It is analogous to Coulomb's law in electrostatics and forms basis of magnetostatics.

---

27. Derive magnetic field due to a long straight current carrying conductor using Biot–Savart law.

Answer:
Using symmetry and integrating over infinite length:

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

Field lines are concentric circles.
Magnitude decreases inversely with distance.
Direction by right-hand thumb rule.

---

28. Derive magnetic field at the center of a circular current carrying coil.

Answer:
Applying Biot–Savart law and integrating over circular loop:

$$B = \frac{\mu_0 I}{2R}$$

For N turns:

$$B = \frac{\mu_0 N I}{2R}$$

Field is perpendicular to plane of coil.

---

29. Derive magnetic field inside a long solenoid using Ampere's circuital law.

Answer:
Ampere's law:

∮B·dl=μ0Ienc\oint B·dl = μ_0 I_{enc}∮B·dl=μ0Ienc

For solenoid:

B=μ0nIB = μ_0 n IB=μ0nI

where n = turns per unit length.
Field inside uniform; outside nearly zero.

---

30. Discuss divergence and curl of magnetic field and their physical meaning.

Answer:
Divergence:

∇·B=0∇·B = 0∇·B=0

Implies no magnetic monopoles.

Curl:

∇×B=μ0J∇×B = μ_0 J∇×B=μ0J

Indicates magnetic field produced by current density.

---

31. Define magnetic vector potential and derive relation B=∇×AB = ∇×AB=∇×A.

Answer:
Since ∇·B=0∇·B = 0∇·B=0, magnetic field can be expressed as curl of vector A:

B=∇×AB = ∇×AB=∇×A

Vector potential simplifies electromagnetic field calculations.

---

32. State and explain Ampere's circuital law with applications.

Answer:

∮B·dl=μ0I\oint B·dl = μ_0 I∮B·dl=μ0I

Useful in finding magnetic field of straight wire, solenoid, toroid.
Applies to steady currents.

---

33. Derive magnetic field inside a toroid.

Answer:
Applying Ampere’s law:

B(2πr)=μ0NIB(2\pi r) = μ_0 N IB(2πr)=μ0NI B=μ0NI2πrB = \frac{μ_0 N I}{2\pi r}B=2πrμ0NI

Field confined inside toroid.

---

34. Define magnetic intensity (H), magnetic induction (B), permeability and susceptibility. Derive relation among them.

Answer:
Magnetic intensity H (A/m) is magnetizing force.
Magnetic induction B (Tesla) is flux density.
Permeability μ relates B and H:

B=μHB = μHB=μH

Susceptibility:

χ=MHχ = \frac{M}{H}χ=HM

Relation:

μ=μ0(1+χ)μ = μ_0(1+χ)μ=μ0(1+χ)

---

35. Explain diamagnetic, paramagnetic and ferromagnetic materials with properties and examples.

Answer:
Diamagnetic: χ negative, weak repulsion (Copper).
Paramagnetic: χ small positive (Aluminium).
Ferromagnetic: χ large positive, strong attraction and hysteresis (Iron).

---

36. Discuss hysteresis curve and energy loss in ferromagnetic materials.

Answer:
Hysteresis loop shows lag between magnetization and magnetizing field.
Area of loop represents energy loss per cycle.
Important in transformer core design.

---

37. Compare solenoid and toroid with applications.

Answer:
Solenoid: uniform field inside, used in electromagnets.
Toroid: confined field, used in transformers to reduce leakage.

---

38. Discuss practical applications of magnetostatics in engineering.

Answer:
Used in motors, generators, transformers, MRI machines, magnetic storage and sensors.

✅ PART–B: Electromagnetic Induction (Q.39–45)

---

39. State and explain Faraday's laws of electromagnetic induction with derivation.

Answer:
First law: Changing magnetic flux induces emf.
Second law:

e=−NdΦdte = -N\frac{dΦ}{dt}e=−NdtdΦ

Negative sign from Lenz's law.

---

40. Explain Lenz's law and prove that it obeys conservation of energy.

Answer:
Induced current opposes change causing it.
If it aided change, energy would be created.
Thus ensures conservation of energy.

---

41. Define self inductance and derive expression for induced emf.

Answer:
Self inductance L relates flux linkage to current:

Φ=LIΦ = LIΦ=LI

Induced emf:

e=−LdIdte = -L\frac{dI}{dt}e=−LdtdI

---

42. Define mutual inductance and derive expression for induced emf in secondary coil.

Answer:

Φ=MIΦ = MIΦ=MI e=−MdIdte = -M\frac{dI}{dt}e=−MdtdI

Used in transformers.

---

43. Derive expression for self inductance of a long solenoid.

Answer:

L=μ0n2AlL = μ_0 n^2 A lL=μ0n2Al

Depends on geometry and permeability.

---

44. Derive expression for energy stored in magnetic field and its energy density.

Answer:
Energy stored:

U=½LI2U = ½ L I^2U=½LI2

Energy density:

u=B22μ0u = \frac{B^2}{2μ_0}u=2μ0B2

---

45. Discuss working principle of transformer based on mutual inductance.

Answer:
AC in primary produces varying flux inducing emf in secondary.
Voltage ratio:

VsVp=NsNp\frac{V_s}{V_p} = \frac{N_s}{N_p}VpVs=NpNs

✅ **PART–C: Maxwell's Equations & EM Waves (Q.46–50)**

---

46. State Maxwell's equations in differential form and explain their physical meaning.

Answer:

1. ∇·E=ρ/ε0∇·E = ρ/ε_0∇·E=ρ/ε0 (Gauss law)
2. ∇·B=0∇·B = 0∇·B=0 (No monopoles)
3. ∇×E=−∂B/∂t∇×E = -∂B/∂t∇×E=−∂B/∂t (Faraday's law)
4. ∇×B=μ0J+μ0ε0∂E/∂t∇×B = μ_0J + μ_0ε_0 ∂E/∂t∇×B=μ0J+μ0ε0∂E/∂t (Ampere-Maxwell law)

---

47. Derive electromagnetic wave equation from Maxwell's equations.

Answer:
Combining equations gives:

∇2E=μ0ε0∂2E∂t2\nabla^2 E = μ_0ε_0 \frac{∂^2E}{∂t^2}∇2E=μ0ε0∂t2∂2E

Wave speed:

c=1μ0ε0c = \frac{1}{\sqrt{μ_0ε_0}}c=μ0ε01

---

48. Explain displacement current and its importance in Maxwell's theory.

Answer:
Displacement current density:

Jd=ε0∂E∂tJ_d = ε_0 \frac{∂E}{∂t}Jd=ε0∂t∂E

Completes Ampere's law and explains EM wave propagation.

---

49. Define Poynting vector and derive expression for energy density of EM wave.

Answer:

S=1μ0E×BS = \frac{1}{μ_0} E×BS=μ01E×B

Energy density:

u=½ε0E2+B22μ0u = ½ε_0E^2 + \frac{B^2}{2μ_0}u=½ε0E2+2μ0B2

---

50. Discuss propagation of electromagnetic waves in vacuum and dielectric medium. Explain transverse nature and polarization.

Answer:
EM waves are transverse; E and B are perpendicular to each other and propagation direction.
Speed in vacuum:

c=3×108m/sc = 3×10^8 m/sc=3×108m/s

In dielectric:

v=ckv = \frac{c}{\sqrt{k}}v=kc

Polarization restricts electric field vibrations to one plane.