MECHANICS – MCQs (1–50)

◆ **UNIT–1: VECTORS (1–25)**

1. A vector quantity has:

A) Only magnitude
B) Only direction
C) Both magnitude and direction
D) Neither magnitude nor direction
Answer: C

---

2. If A = 3i + 4j, then |A| equals:

A) 5
B) 7
C) 25
D) 1
Answer: A

---

3. The dot product of two perpendicular vectors is:

A) 1
B) -1
C) 0
D) Infinite
Answer: C

---

4. The cross product of two parallel vectors is:

A) 0
B) 1
C) -1
D) Undefined
Answer: A

---

5. The unit vector in the direction of vector A is:

A) $A \times A$
B) $A / |A|$
C) $|A| A$
D) A^2
Answer: B

---

6. The scalar product of two vectors gives:

A) Vector
B) Scalar
C) Tensor
D) Matrix
Answer: B

---

7. The vector product of two vectors gives:

A) Scalar
B) Vector
C) Constant
D) Function
Answer: B

---

8. If $A \cdot B = |A||B| \cos\theta$, then θ is:

A) Angle between vectors
B) Magnitude
C) Unit vector
D) Direction ratio
Answer: A

---

9. $i \times j$ equals:

A) i
B) j
C) k
D) 0
Answer: C

---

10. j × i equals:

A) k
B) -k
C) i
D) 0
Answer: B

---

11. If A = ai + bj + ck, then A·A equals:

A) $a^2 + b^2 + c^2$
B) a + b + c
C) abc
D) 0
Answer: A

---

12. The angle between identical vectors is:

A) 0°
B) 90°
C) 180°
D) 60°
Answer: A

---

13. If two vectors are orthogonal, then:

A) Cross product is zero
B) Dot product is zero
C) Both are zero
D) None
Answer: B

---

14. The derivative of position vector gives:

A) Acceleration
B) Velocity

C) Force
D) Displacement
Answer: B

---

15. The second derivative of position vector gives:

A) Velocity
B) Acceleration
C) Momentum
D) Work
Answer: B

---

16. If r = xi + yj + zk, then dr/dt equals:

A) xi + yj + zk
B) dx/dt i + dy/dt j + dz/dt k
C) x^2i
D) 0
Answer: B

---

17. Scalar triple product gives:

A) Area
B) Length
C) Volume
D) Speed
Answer: C

---

18. A × B is perpendicular to:

A) A only
B) B only
C) Both A and B
D) None
Answer: C

---

19. If A × B = 0, then vectors are:

A) Perpendicular
B) Parallel
C) Random
D) Unit
Answer: B

---

20. |A × B| equals:

A) |A||B| sinθ
B) |A||B| cosθ
C) A·B
D) |A| + |B|
Answer: A

---

21. If A·B = 0 and both are non-zero, then:

A) Parallel
B) Perpendicular
C) Equal
D) Opposite
Answer: B

---

22. The gradient of a scalar function is:

A) Scalar
B) Vector
C) Matrix
D) Constant
Answer: B

---

23. The time derivative of a constant vector is:

A) 1
B) Same vector
C) Zero

D) Infinite
Answer: C

---

24. Work done = F · s represents:

A) Cross product
B) Dot product
C) Scalar triple product
D) Vector triple product
Answer: B

---

25. Torque is defined as:

A) F·r
B) r × F
C) F/r
D) r·r
Answer: B

◆ UNIT–2: ORDINARY DIFFERENTIAL EQUATIONS (26–50)

---

26. A first order homogeneous differential equation is of form:

A) dy/dx = f(y/x)
B) dy/dx = x + y
C) dy/dx = x^2
D) dy/dx = constant
Answer: A

---

27. The substitution used in homogeneous equation is:

A) y = vx
B) x = vy
C) y = v
D) x = v
Answer: A

---

28. The general form of second order linear differential equation:

A) $ay'' + by' + cy = 0$
B) $y' + y = 0$
C) $y'' = 0$
D) $dy/dx = y$
Answer: A

---

29. The auxiliary equation of $ay'' + by' + cy = 0$ is:

A) $ar^2 + br + c = 0$
B) $r^2 + y = 0$
C) $y^2 = 0$
D) None
Answer: A

---

30. If roots are real and distinct, solution is:

A) $e^{(r_1x)} + e^{(r_2x)}$
B) sinx
C) cosx
D) x^2
Answer: A

---

31. If roots are equal, solution is:

A) $C_1e^{(rx)} + C_2xe^{(rx)}$
B) $C_1 + C_2$
C) sinx
D) None
Answer: A

---

32. If roots are complex $\alpha \pm i\beta$, solution is:

A) $e^{(\alpha x)}(C_1 \cos\beta x + C_2 \sin\beta x)$
B) x^2

C) e^x
D) None
Answer: A

---

33. Order of equation $d^2y/dx^2 + dy/dx + y = 0$:

A) 1
B) 2
C) 3
D) 0
Answer: B

---

34. Degree of equation $(d^2y/dx^2)^2 + y = 0$:

A) 1
B) 2
C) 3
D) 4
Answer: B

---

35. dy/dx = y/x is:

A) Homogeneous
B) Linear
C) Exact
D) None
Answer: A

---

36. Solution of dy/dx = y:

A) $y = Ce^x$
B) $y = Cx$
C) $y = x^2$
D) None
Answer: A

---

37. The integrating factor of dy/dx + Py = 0:

A) e^∫Pdx
B) x
C) y
D) 1
Answer: A

---

38. Complementary function depends on:

A) RHS
B) Homogeneous part
C) Constant
D) None
Answer: B

---

39. Particular integral depends on:

A) Homogeneous part
B) RHS
C) Degree
D) None
Answer: B

---

40. If equation is y'' − 4y = 0, roots are:

A) ±2
B) ±4
C) 0
D) 1
Answer: A

---

41. General solution of y'' − 4y = 0:

A) $C_1e^{2x} + C_2e^{-2x}$
B) Cx
C) x^2

D) None
Answer: A

---

42. The equation dy/dx = x + y is:

A) Homogeneous
B) Linear
C) Non-linear
D) Exact
Answer: B

---

43. Second order equation describes:

A) Linear motion
B) Oscillation
C) Exponential growth
D) None
Answer: B

---

44. Simple harmonic motion equation:

A) $d^2x/dt^2 + \omega^2x = 0$
B) $dx/dt = x$
C) $x = t$
D) None
Answer: A

---

45. Solution of SHM equation is:

A) $A \cos\omega t + B \sin\omega t$
B) e^t
C) t^2
D) None
Answer: A

---

46. If auxiliary equation has imaginary roots, motion is:

A) Oscillatory
B) Linear
C) Constant
D) Divergent
Answer: A

---

47. The equation dy/dx = f(y/x) can be solved by:

A) Substitution y = vx
B) Integration by parts
C) Laplace transform
D) None
Answer: A

---

48. y'' + 9y = 0 has roots:

A) ±3i
B) ±3
C) 0
D) 9
Answer: A

---

49. General solution of y'' + 9y = 0:

A) $C_1\cos 3x + C_2\sin 3x$
B) e^{3x}
C) x^2
D) None
Answer: A

---

50. Differential equations in mechanics are mainly used to study:

A) Motion
B) Color
C) Shape
D) Density
Answer: A

LAWS OF MOTION (51–75)

---

51. Newton’s First Law is also called:

A) Law of Gravitation
B) Law of Inertia
C) Law of Acceleration
D) Law of Energy
Answer: B

---

52. An inertial frame is one in which:

A) Newton’s laws are valid
B) Body accelerates without force
C) Energy is not conserved
D) Velocity is zero
Answer: A

---

53. A non-inertial frame requires introduction of:

A) Gravitational force
B) Magnetic force
C) Pseudo force
D) Electric force
Answer: C

---

54. Newton’s Second Law states:

A) $F = mv$
B) $F = ma$
C) $F = m/a$
D) $F = m^2a$
Answer: B

---

55. The SI unit of force is:

A) Joule
B) Newton
C) Watt
D) Pascal
Answer: B

---

56. Newton's Third Law deals with:

A) Acceleration
B) Inertia
C) Action and Reaction
D) Gravity
Answer: C

---

57. The reaction force acts:

A) On same body
B) On different body
C) In same direction
D) With smaller magnitude
Answer: B

---

58. Linear momentum is defined as:

A) mv^2
B) ma
C) mv
D) m/v
Answer: C

---

59. The rate of change of momentum equals:

A) Velocity
B) Acceleration
C) Force
D) Work
Answer: C

60. If net force is zero, momentum is:

A) Increasing
B) Decreasing
C) Constant
D) Infinite
Answer: C

---

61. Centre of mass of two equal masses lies:

A) Closer to heavier mass
B) At midpoint
C) Outside system
D) At origin
Answer: B

---

62. Position of centre of mass is given by:

A) $\Sigma m_i r_i / \Sigma m_i$
B) $\Sigma r_i / m$
C) Σm_i
D) r/m
Answer: A

---

63. Motion of centre of mass depends on:

A) Internal forces
B) External forces
C) Shape
D) Volume
Answer: B

---

64. Internal forces in a system:

A) Change total momentum
B) Do not change total momentum

C) Increase energy
D) Decrease mass
Answer: B

---

65. For an isolated system:

A) Momentum not conserved
B) Momentum conserved
C) Energy zero
D) Force infinite
Answer: B

---

66. A body of mass m moving with velocity v has kinetic energy:

A) mv
B) mv^2
C) $\frac{1}{2}mv^2$
D) $2mv^2$
Answer: C

---

67. Impulse equals:

A) F
B) Ft
C) mv^2
D) m
Answer: B

---

68. Impulse is equal to change in:

A) Energy
B) Velocity
C) Momentum
D) Mass
Answer: C

---

69. If no external torque acts, angular momentum:

A) Changes
B) Conserved
C) Zero
D) Infinite
Answer: B

---

70. In circular motion, required force is:

A) Centrifugal
B) Centripetal
C) Gravitational
D) Magnetic
Answer: B

---

71. Pseudo force acts in:

A) Inertial frame
B) Non-inertial frame
C) Vacuum
D) Stationary frame
Answer: B

---

72. Weightlessness occurs when:

A) $g = 0$
B) Normal reaction = 0
C) Mass = 0
D) Velocity = 0
Answer: B

---

73. If two bodies collide and stick together, collision is:

A) Elastic
B) Inelastic
C) Perfectly elastic

D) None
Answer: B

---

74. For elastic collision:

A) Only momentum conserved
B) Only energy conserved
C) Both conserved
D) None
Answer: C

---

75. Centre of mass of a uniform rod lies at:

A) End
B) 1/4 length
C) Midpoint
D) Outside
Answer: C

◆ **MOMENTUM & ENERGY (76–100)**

---

76. Work done is defined as:

A) F × s
B) F · s
C) F/s
D) s/F
Answer: B

---

77. SI unit of work is:

A) Watt
B) Newton
C) Joule
D) Pascal
Answer: C

78. Power is:

A) Work × time
B) Work/time
C) Force
D) Energy
Answer: B

---

79. SI unit of power:

A) Watt
B) Joule
C) Newton
D) Volt
Answer: A

---

80. Potential energy due to gravity:

A) mgh
B) ½mv²
C) mv
D) mg
Answer: A

---

81. Work-energy theorem states:

A) Work = KE
B) Work = Change in KE
C) Work = PE
D) Work = Force
Answer: B

---

82. Mechanical energy is sum of:

A) KE + PE
B) KE only

C) PE only
D) Heat
Answer: A

---

83. In conservative force field:

A) Energy conserved
B) Energy lost
C) Work depends on path
D) None
Answer: A

---

84. Gravitational force is:

A) Non-conservative
B) Conservative
C) Frictional
D) Magnetic
Answer: B

---

85. Rocket propulsion works on:

A) Newton’s First Law
B) Newton’s Second Law
C) Newton’s Third Law
D) Gravitation
Answer: C

---

86. Rocket motion is based on conservation of:

A) Energy
B) Momentum
C) Power
D) Mass
Answer: B

---

87. Thrust of rocket equals:

A) v dm/dt
B) m dv/dt
C) mg
D) mv
Answer: A

---

88. If external force is zero:

A) Energy conserved only
B) Momentum conserved
C) Velocity zero
D) Acceleration zero
Answer: B

---

89. Escape velocity depends on:

A) Mass of planet
B) Radius of planet
C) Both A and B
D) Velocity of light
Answer: C

---

90. Work done in lifting object upward increases:

A) KE
B) PE
C) Mass
D) Momentum
Answer: B

---

91. If velocity doubles, kinetic energy becomes:

A) Double
B) Four times
C) Half

D) Same
Answer: B

---

92. In perfectly elastic collision:

A) KE decreases
B) KE conserved
C) Momentum not conserved
D) Mass changes
Answer: B

---

93. If no external force acts on system:

A) COM accelerates
B) COM moves with constant velocity
C) COM at rest only
D) Energy zero
Answer: B

---

94. The dimensional formula of momentum:

A) ML^2T^{-2}
B) MLT^{-1}
C) ML^2T^{-1}
D) MT^{-2}
Answer: B

---

95. Work done in circular motion (centripetal force):

A) Positive
B) Negative
C) Zero
D) Infinite
Answer: C

---

96. If force and displacement are perpendicular:

A) Work maximum
B) Work zero
C) Work negative
D) Work positive
Answer: B

---

97. Kinetic energy depends on:

A) Mass only
B) Velocity only
C) Both mass and velocity
D) Time
Answer: C

---

98. Total energy in SHM remains:

A) Increasing
B) Decreasing
C) Constant
D) Zero
Answer: C

---

99. Momentum is a:

A) Scalar
B) Vector
C) Constant
D) Tensor
Answer: B

---

100. Rocket velocity increases because:

A) Mass increases
B) Fuel expelled backward
C) Gravity zero
D) Energy destroyed
Answer: B

MECHANICS – MCQs (101–150)

◆ ROTATIONAL MOTION (101–120)

---

101. Angular velocity is defined as:

A) $d\theta/dt$
B) θ/t
C) $r\omega$
D) v/r
Answer: A

---

102. SI unit of angular velocity is:

A) m/s
B) rad/s
C) N·m
D) kg·m²
Answer: B

---

103. Angular momentum of a particle is:

A) mv
B) $r \times p$
C) $r \cdot p$
D) $I\omega^2$
Answer: B

---

104. SI unit of angular momentum:

A) kg·m/s
B) kg·m²/s
C) N
D) J
Answer: B

105. Torque is defined as:

A) $r \times F$
B) $r \cdot F$
C) F/r
D) $m\omega$
Answer: A

---

106. SI unit of torque:

A) N
B) J
C) N·m
D) kg
Answer: C

---

107. Relation between torque and angular momentum:

A) $\tau = L$
B) $\tau = dL/dt$
C) $\tau = \omega L$
D) $\tau = I$
Answer: B

---

108. If net external torque is zero:

A) L increases
B) L decreases
C) L conserved
D) L zero
Answer: C

---

109. Moment of inertia depends on:

A) Mass distribution
B) Shape

C) Axis of rotation
D) All of these
Answer: D

---

110. Angular momentum of rigid body is:

A) $I\omega$
B) $I\omega^2$
C) mv
D) F
Answer: A

---

111. Kinetic energy of rotating body:

A) $\frac{1}{2}mv^2$
B) $\frac{1}{2}I\omega^2$
C) $I\omega$
D) mgh
Answer: B

---

112. If a skater pulls arms inward, angular velocity:

A) Decreases
B) Increases
C) Zero
D) Constant
Answer: B

---

113. Angular acceleration is:

A) $d\omega/dt$
B) ω/t
C) θ/t
D) $I\omega$
Answer: A

---

114. Relation between linear and angular velocity:

A) $v = r\omega$
B) $v = \omega/r$
C) $v = r/\omega$
D) $v = r^2\omega$
Answer: A

---

115. Direction of angular momentum is given by:

A) Left-hand rule
B) Right-hand rule
C) Fleming's rule
D) None
Answer: B

---

116. If radius doubles, moment of inertia:

A) Doubles
B) Halves
C) Increases by factor 4
D) No change
Answer: C

---

117. Rotational analogue of force is:

A) Work
B) Torque
C) Momentum
D) Energy
Answer: B

---

118. Rotational analogue of mass is:

A) Torque
B) Inertia
C) Moment of inertia

D) Energy
Answer: C

---

119. Areal velocity is:

A) dA/dt
B) rω
C) ω^2
D) L^2
Answer: A

---

120. Areal velocity remains constant due to:

A) Energy conservation
B) Torque
C) Angular momentum conservation
D) Mass conservation
Answer: C

◆ **GRAVITATION (121–150)**

---

121. Newton's law of gravitation states:

A) $F \propto r$
B) $F \propto 1/r$
C) $F \propto 1/r^2$
D) $F \propto r^2$
Answer: C

---

122. Gravitational force between two masses is:

A) Gm_1m_2/r
B) Gm_1m_2/r^2
C) m_1m_2/r^2
D) G/r^2
Answer: B

123. Value of gravitational constant G:

A) 6.67×10^{-11} Nm^2/kg^2
B) 9.8 m/s^2
C) 3×10^8
D) 1
Answer: A

---

124. Central force always acts:

A) Tangentially
B) Radially
C) Vertically
D) Horizontally
Answer: B

---

125. Motion under central force is:

A) 3D
B) In a plane
C) Random
D) Linear
Answer: B

---

126. In central force motion:

A) Linear momentum conserved
B) Angular momentum conserved
C) Energy zero
D) Torque non-zero
Answer: B

---

127. Kepler's First Law states:

A) Planets move in circles
B) Planets move in ellipses

C) Planets stationary
D) None
Answer: B

---

128. Kepler's Second Law relates to:

A) Force
B) Period
C) Equal areas in equal time
D) Gravity
Answer: C

---

129. Kepler's Third Law:

A) $T^2 \propto r^3$
B) $T \propto r^2$
C) $T^3 \propto r^2$
D) $T \propto r$
Answer: A

---

130. Escape velocity from Earth:

A) 7.9 km/s
B) 11.2 km/s
C) 9.8 km/s
D) 3 km/s
Answer: B

---

131. Orbital velocity of satellite near Earth:

A) 7.9 km/s
B) 11.2 km/s
C) 3 km/s
D) 1 km/s
Answer: A

---

132. Time period of geostationary satellite:

A) 12 hours
B) 24 hours
C) 48 hours
D) 6 hours
Answer: B

---

133. Geostationary satellite orbits in:

A) Polar plane
B) Equatorial plane
C) Any plane
D) Inclined plane
Answer: B

---

134. Height of geostationary orbit ≈

A) 1000 km
B) 20000 km
C) 36000 km
D) 500 km
Answer: C

---

135. GPS works using:

A) Radio waves
B) Sound waves
C) Light only
D) Magnetic waves
Answer: A

---

136. Minimum number of satellites for GPS:

A) 1
B) 2
C) 3

D) 4
Answer: D

---

137. Weightlessness occurs due to:

A) No gravity
B) Free fall condition
C) Zero mass
D) Zero velocity
Answer: B

---

138. Astronauts feel weightless because:

A) Gravity absent
B) They are in free fall
C) Mass zero
D) No oxygen
Answer: B

---

139. Prolonged weightlessness causes:

A) Bone density loss
B) Muscle weakening
C) Fluid redistribution
D) All of these
Answer: D

---

140. Gravitational potential energy:

A) $-GMm/r$
B) GMm/r
C) mgh
D) $\frac{1}{2}mv^2$
Answer: A

---

141. If distance doubles, gravitational force becomes:

A) Double
B) Half
C) One-fourth
D) Four times
Answer: C

---

142. Angular momentum in planetary motion:

A) Zero
B) Conserved
C) Increasing
D) Decreasing
Answer: B

---

143. Areal velocity equals:

A) L/2m
B) L/m
C) mL
D) L^2
Answer: A

---

144. Satellite in circular orbit experiences:

A) No force
B) Centripetal force
C) Magnetic force
D) Friction
Answer: B

---

145. If satellite speed increases:

A) Moves to lower orbit
B) Moves to higher orbit
C) Stops
D) Falls immediately
Answer: B

146. Gravitational field intensity equals:

A) F/m
B) m/F
C) F
D) m
Answer: A

---

147. Value of g decreases with:

A) Height
B) Depth
C) Both
D) None
Answer: C

---

148. Satellite remains in orbit due to:

A) Balance of gravity & centripetal force
B) No gravity
C) Zero velocity
D) Zero acceleration
Answer: A

---

149. Planetary orbits are elliptical due to:

A) Central inverse square force
B) Linear force
C) Magnetic force
D) Friction
Answer: A

---

150. Total mechanical energy of satellite in orbit is:

A) Positive
B) Zero

C) Negative
D) Infinite
Answer: C

OSCILLATIONS (151–170)

---

151. The restoring force in SHM is:

A) Constant
B) Proportional to displacement
C) Proportional to velocity
D) Zero
Answer: B

---

152. Differential equation of SHM is:

A) $d^2x/dt^2 + \omega^2x = 0$
B) $dx/dt = x$
C) $d^2x/dt^2 = 0$
D) $x = at^2$
Answer: A

---

153. Solution of SHM equation is:

A) Ae^(ωt)
B) A cos(ωt + φ)
C) At
D) A/t
Answer: B

---

154. Time period of SHM is:

A) $2\pi/\omega$
B) $\omega/2\pi$
C) $1/\omega$
D) ω
Answer: A

155. Frequency of SHM:

A) $\omega/2\pi$
B) $2\pi/\omega$
C) ω
D) $1/2\pi$
Answer: A

---

156. Maximum velocity in SHM occurs at:

A) Mean position
B) Extreme position
C) Anywhere
D) None
Answer: A

---

157. Potential energy in SHM at extreme position is:

A) Zero
B) Maximum
C) Minimum
D) Infinite
Answer: B

---

158. Kinetic energy in SHM at mean position is:

A) Zero
B) Maximum
C) Minimum
D) Half
Answer: B

---

159. Total energy in SHM is:

A) Variable
B) Zero

C) Constant
D) Infinite
Answer: C

---

160. Total energy in SHM equals:

A) ½kA²
B) kA
C) ½mv
D) mgh
Answer: A

---

161. Time average of kinetic energy over one cycle:

A) Zero
B) Equal to total energy
C) Half of total energy
D) Double
Answer: C

---

162. In damped oscillation amplitude:

A) Increases
B) Decreases with time
C) Constant
D) Zero
Answer: B

---

163. Critical damping occurs when system:

A) Oscillates forever
B) Returns to equilibrium fastest without oscillation
C) Never stops
D) None
Answer: B

---

164. Underdamped motion:

A) No oscillation
B) Oscillatory with decreasing amplitude
C) Constant amplitude
D) Infinite amplitude
Answer: B

---

165. Overdamped motion:

A) Oscillatory
B) Non-oscillatory slow return
C) Infinite frequency
D) None
Answer: B

---

166. Phase difference between velocity and displacement in SHM:

A) 0°
B) 90°
C) 180°
D) 45°
Answer: B

---

167. Acceleration in SHM is:

A) Constant
B) Proportional to displacement
C) Proportional to velocity
D) Zero
Answer: B

---

168. Angular frequency of mass-spring system:

A) √(k/m)
B) k/m
C) m/k

D) km
Answer: A

---

169. For simple pendulum, time period:

A) $2\pi\sqrt{(l/g)}$
B) $2\pi\sqrt{(g/l)}$
C) l/g
D) g/l
Answer: A

---

170. Damping force is proportional to:

A) Displacement
B) Velocity
C) Acceleration
D) Time
Answer: B

◆ **ELASTICITY (171–185)**

---

171. Hooke's Law states:

A) Stress ∝ Strain
B) Stress ∝ Length
C) Strain ∝ Area
D) None
Answer: A

---

172. Young's modulus is:

A) Stress/Strain
B) Strain/Stress
C) Force/Area
D) Area/Force
Answer: A

173. SI unit of Young's modulus:

A) N
B) N/m
C) N/m^2
D) J
Answer: C

---

174. Poisson's ratio is:

A) Longitudinal strain / lateral strain
B) Lateral strain / longitudinal strain
C) Stress/strain
D) None
Answer: B

---

175. Range of Poisson's ratio:

A) 0 to 0.5
B) 1 to 2
C) 0 to 1
D) Negative only
Answer: A

---

176. Bulk modulus relates to:

A) Volume change
B) Length change
C) Angle change
D) Area change
Answer: A

---

177. Shear modulus is also called:

A) Young's modulus
B) Rigidity modulus

C) Bulk modulus
D) Elastic limit
Answer: B

---

178. Relation between elastic constants:

A) $Y = 2\eta(1 + \sigma)$
B) $Y = \eta\sigma$
C) $Y = 2\sigma$
D) $Y = \eta$
Answer: A

---

179. Work done in stretching a wire:

A) ½ × Stress × Strain × Volume
B) Stress only
C) Strain only
D) None
Answer: A

---

180. Twisting couple on cylinder:

A) Proportional to angle of twist
B) Independent of twist
C) Zero
D) Infinite
Answer: A

---

181. Torsional pendulum is used to determine:

A) Young's modulus
B) Rigidity modulus
C) Bulk modulus
D) Density
Answer: B

---

182. Time period of torsional pendulum:

A) $2\pi\sqrt{(I/C)}$
B) $2\pi\sqrt{(C/I)}$
C) I/C
D) C/I
Answer: A

---

183. Searle's method is used to determine:

A) Young's modulus
B) Poisson's ratio
C) Rigidity modulus
D) Gravity
Answer: A

---

184. Elastic limit is:

A) Maximum stress
B) Maximum strain
C) Limit up to which Hooke's law holds
D) Breaking point
Answer: C

---

185. If stress exceeds elastic limit:

A) Permanent deformation
B) No change
C) Oscillation
D) None
Answer: A

◆ SPECIAL THEORY OF RELATIVITY (186–200)

---

186. Speed of light in vacuum is:

A) 3×10^8 m/s
B) 3×10^6 m/s
C) 3×10^5 m/s
D) 9.8 m/s
Answer: A

---

187. According to relativity, speed of light is:

A) Variable
B) Depends on observer
C) Constant for all observers
D) Zero
Answer: C

---

188. Einstein proposed Special Relativity in:

A) 1900
B) 1905
C) 1915
D) 1920
Answer: B

---

189. Length contraction formula:

A) $L = L_0\sqrt{(1 - v^2/c^2)}$
B) $L = L_0/(1 - v^2/c^2)$
C) $L = L_0 v$
D) $L = L_0$
Answer: A

---

190. Time dilation formula:

A) $t = t_0\sqrt{(1 - v^2/c^2)}$
B) $t = t_0/\sqrt{(1 - v^2/c^2)}$
C) $t = vt_0$
D) $t = t_0$
Answer: B

191. Moving clocks run:

A) Faster
B) Slower
C) Same
D) Stop
Answer: B

---

192. Proper time is measured in:

A) Moving frame
B) Rest frame
C) Any frame
D) None
Answer: B

---

193. Relativistic velocity addition formula ensures:

A) $v > c$ possible
B) $v < c$ always
C) $v = c$ always
D) None
Answer: B

---

194. If $v << c$, relativistic formulas reduce to:

A) Quantum mechanics
B) Newtonian mechanics
C) Thermodynamics
D) Optics
Answer: B

---

195. Mass increases with:

A) Speed
B) Time

C) Temperature
D) Height
Answer: A

---

196. Relativistic mass formula:

A) $m = m_0/\sqrt{(1 - v^2/c^2)}$
B) $m = m_0$
C) $m = m_0v$
D) $m = cv$
Answer: A

---

197. Energy-mass relation:

A) $E = mc$
B) $E = mc^2$
C) $E = m/c$
D) $E = m^2c$
Answer: B

---

198. If object moves at speed of light:

A) Mass finite
B) Mass zero
C) Mass infinite
D) No change
Answer: C

---

199. Length contraction occurs along:

A) Perpendicular direction
B) Direction of motion
C) Vertical direction
D) All directions
Answer: B

---

200. Special relativity deals with:

A) Accelerated frames
B) Inertial frames
C) Gravity
D) Quantum field
Answer: B

PART–1: VECTORS (1–15)

---

1. What is a vector quantity?

Answer: A physical quantity having both magnitude and direction.

---

2. What is vector algebra?

Answer: Branch of mathematics dealing with operations on vectors.

---

3. Define scalar product.

Answer: Dot product of two vectors giving a scalar: $A \cdot B = |A||B|\cos\theta$.

---

4. When is dot product zero?

Answer: When vectors are perpendicular ($\theta = 90°$).

---

5. Define vector product.

Answer: Cross product of two vectors giving a vector: $A \times B = |A||B|\sin\theta\ \hat{n}$.

---

6. When is cross product zero?

Answer: When vectors are parallel.

7. What is a unit vector?

Answer: A vector of magnitude 1 in a given direction.

---

8. Define scalar triple product.

Answer: A·(B×C), gives volume of parallelepiped.

---

9. What is vector triple product?

Answer: A×(B×C).

---

10. Define position vector.

Answer: Vector representing position of a point from origin.

---

11. What is derivative of position vector?

Answer: Velocity.

---

12. What is second derivative of position vector?

Answer: Acceleration.

---

13. Define gradient.

Answer: Rate of change of scalar field; it is a vector.

---

14. What is angular velocity vector direction?

Answer: Along axis of rotation (right-hand rule).

---

15. What is torque in vector form?

Answer: $\tau = r \times F$.

◆ **PART–2: ORDINARY DIFFERENTIAL EQUATIONS (16–30)**

---

16. Define differential equation.

Answer: Equation involving derivatives of a function.

---

17. What is order of a differential equation?

Answer: Highest order derivative present.

---

18. What is degree of differential equation?

Answer: Power of highest order derivative.

---

19. Define homogeneous first order DE.

Answer: DE of form $dy/dx = f(y/x)$.

---

20. What substitution solves homogeneous DE?

Answer: $y = vx$.

---

21. Write general form of 2nd order linear DE.

Answer: ay'' + by' + cy = 0.

---

22. What is auxiliary equation?

Answer: $ar^2 + br + c = 0$.

---

23. When roots are real and distinct?

Answer: Discriminant > 0.

---

24. Solution for equal roots?

Answer: $(C_1 + C_2x)e^{(rx)}$.

---

25. Solution for complex roots?

Answer: $e^{(\alpha x)}(C_1\cos\beta x + C_2\sin\beta x)$.

---

26. What describes SHM mathematically?

Answer: $d^2x/dt^2 + \omega^2x = 0$.

---

27. Define complementary function.

Answer: Solution of homogeneous equation.

---

28. Define particular integral.

Answer: Specific solution satisfying non-homogeneous part.

---

29. What is linear DE?

Answer: DE where dependent variable and derivatives are first degree.

---

30. Application of 2nd order DE in mechanics?

Answer: Describes oscillations and vibrations.

◆ **PART–3: LAWS OF MOTION (31–45)**

---

31. State Newton's First Law.

Answer: A body remains at rest or uniform motion unless acted upon by force.

---

32. What is inertia?

Answer: Resistance to change in state of motion.

---

33. State Newton's Second Law.

Answer: F = ma.

---

34. State Newton's Third Law.

Answer: For every action, equal and opposite reaction.

---

35. Define inertial frame.

Answer: Frame where Newton's laws hold.

---

36. What is non-inertial frame?

Answer: Accelerating frame requiring pseudo force.

---

37. Define momentum.

Answer: Product of mass and velocity ($p = mv$).

---

38. What is impulse?

Answer: Change in momentum.

---

39. Define centre of mass.

Answer: Point where total mass of system is assumed concentrated.

---

40. Formula for centre of mass?

Answer: $\Sigma m_i r_i / \Sigma m_i$.

---

41. Does internal force change total momentum?

Answer: No.

---

42. What is isolated system?

Answer: System with no external force.

---

43. Condition for conservation of momentum?

Answer: Net external force = 0.

44. Define pseudo force.

Answer: Apparent force in non-inertial frame.

---

45. What is centripetal force?

Answer: Force toward center in circular motion.

◆ **PART–4: MOMENTUM & ENERGY (46–60)**

---

46. Define work.

Answer: $W = F \cdot s$.

---

47. Define kinetic energy.

Answer: $\frac{1}{2}mv^2$.

---

48. Define potential energy.

Answer: Energy due to position.

---

49. State work-energy theorem.

Answer: Work done equals change in kinetic energy.

---

50. Define power.

Answer: Work done per unit time.

---

51. State conservation of energy.

Answer: Energy cannot be created or destroyed.

---

52. Define mechanical energy.

Answer: Sum of kinetic and potential energy.

---

53. What is elastic collision?

Answer: Both momentum and KE conserved.

---

54. What is inelastic collision?

Answer: KE not conserved.

---

55. Rocket propulsion is based on?

Answer: Conservation of momentum.

---

56. What is thrust?

Answer: Rate of change of momentum of exhaust gases.

---

57. Define escape velocity.

Answer: Minimum speed to escape gravitational field.

---

58. Work done by centripetal force?

Answer: Zero.

---

59. Define conservative force.

Answer: Work independent of path.

---

60. Give example of conservative force.

Answer: Gravitational force.

◆ **PART–5: ROTATIONAL MOTION (61–75)**

---

61. Define angular velocity.

Answer: Rate of change of angular displacement.

---

62. Define angular acceleration.

Answer: Rate of change of angular velocity.

---

63. Relation between linear & angular velocity?

Answer: $v = r\omega$.

---

64. Define angular momentum.

Answer: $L = r \times p$.

---

65. Angular momentum of rigid body?

Answer: $L = I\omega$.

---

66. Define torque.

Answer: $\tau = r \times F$.

---

67. Relation between torque and angular momentum?

Answer: $\tau = dL/dt$.

---

68. When is angular momentum conserved?

Answer: When external torque is zero.

---

69. Define moment of inertia.

Answer: Rotational inertia of a body.

---

70. KE of rotating body?

Answer: $\frac{1}{2}I\omega^2$.

---

71. What is areal velocity?

Answer: Area swept per unit time.

---

72. Why is areal velocity constant in central force?

Answer: Due to conservation of angular momentum.

---

73. Rotational analogue of mass?

Answer: Moment of inertia.

---

74. Rotational analogue of force?

Answer: Torque.

---

75. Example of conservation of angular momentum?

Answer: Ice skater spinning faster by pulling arms inward.

GRAVITATION (76–95)

---

76. Define gravitational field intensity.

Answer: Gravitational force per unit mass ($g = F/m$).

---

77. What is gravitational potential?

Answer: Work done in bringing unit mass from infinity to a point.

---

78. Expression for gravitational potential energy?

Answer: $U = -GMm/r$.

---

79. Why is gravitational potential energy negative?

Answer: Because gravitational force is attractive.

---

80. What happens to g with increase in height?

Answer: It decreases.

---

81. What happens to g inside Earth?

Answer: It decreases with depth.

---

82. Define orbital period of satellite.

Answer: Time taken to complete one revolution.

---

83. Formula for orbital velocity.

Answer: $v = \sqrt{(GM/r)}$.

---

84. Condition for satellite to remain in orbit.

Answer: Gravitational force = Centripetal force.

---

85. Define escape velocity formula.

Answer: $v_e = \sqrt{(2GM/R)}$.

---

86. Why astronauts float in spacecraft?

Answer: Due to continuous free fall.

---

87. One health problem in space?

Answer: Muscle atrophy.

---

88. What is microgravity?

Answer: Condition of very small apparent gravity.

---

89. Why planetary orbits are elliptical?

Answer: Due to inverse square central force.

---

90. What is centripetal acceleration in orbit?

Answer: v^2/r.

---

91. Define gravitational binding energy.

Answer: Energy required to separate a system to infinity.

---

92. What is polar satellite?

Answer: Satellite orbiting over poles.

---

93. Application of geostationary satellite?

Answer: Communication and weather forecasting.

---

94. GPS determines position using?

Answer: Time delay of radio signals.

---

95. Why is angular momentum constant in planetary motion?

Answer: Because external torque is zero.

◆ **OSCILLATIONS (96–110)**

96. What is amplitude in SHM?

Answer: Maximum displacement from mean position.

97. Define phase of SHM.

Answer: Quantity $(\omega t + \varphi)$ determining state of motion.

98. What is phase constant?

Answer: Initial phase angle.

99. Acceleration in SHM equals?

Answer: $a = -\omega^2 x$.

100. What is restoring force formula in SHM?

Answer: $F = -kx$.

101. At extreme position velocity is?

Answer: Zero.

102. At mean position acceleration is?

Answer: Zero.

103. Define periodic motion.

Answer: Motion repeating at equal intervals of time.

---

104. Define frequency.

Answer: Number of oscillations per second.

---

105. SI unit of frequency?

Answer: Hertz (Hz).

---

106. Energy transformation in SHM?

Answer: Between KE and PE.

---

107. What causes damping?

Answer: Friction or resistive forces.

---

108. Equation of damped oscillation includes?

Answer: Damping term proportional to velocity.

---

109. In absence of damping, motion is?

Answer: Undamped SHM.

---

110. Total energy in damped oscillation?

Answer: Decreases with time.

◆ **ELASTICITY (111–130)**

---

111. Define longitudinal stress.

Answer: Stress along length of material.

---

112. Define shear stress.

Answer: Stress parallel to surface.

---

113. Define volumetric strain.

Answer: Change in volume/original volume.

---

114. What is bulk modulus formula?

Answer: K = Pressure / Volumetric strain.

---

115. Relation between bulk modulus and compressibility?

Answer: Compressibility = 1/K.

---

116. Define elastic fatigue.

Answer: Loss of elasticity due to repeated stress.

---

117. Define resilience.

Answer: Energy stored per unit volume.

---

118. What is breaking stress?

Answer: Maximum stress before fracture.

---

119. What determines rigidity of material?

Answer: Shear modulus.

---

120. What is angle of twist?

Answer: Angular displacement due to torsion.

---

121. Twisting couple formula?

Answer: $\tau \propto \theta$.

---

122. Define torsional oscillation.

Answer: Oscillation due to twisting motion.

---

123. In torsional pendulum restoring torque is proportional to?

Answer: Angular displacement.

---

124. SI unit of rigidity modulus?

Answer: N/m^2.

---

125. Young's modulus measures?

Answer: Stiffness of material.

---

126. What happens to length under tension?

Answer: Increases.

---

127. What happens to lateral dimension under tension?

Answer: Decreases.

---

128. Why Poisson's ratio less than 0.5?

Answer: For material stability.

---

129. What is ductile material?

Answer: Material that undergoes large deformation before breaking.

---

130. Example of brittle material?

Answer: Glass.

◆ **SPECIAL THEORY OF RELATIVITY (131–150)**

---

131. What is inertial frame?

Answer: Frame moving with constant velocity.

---

132. What is Lorentz factor (γ)?

Answer: $\gamma = 1/\sqrt{(1 - v^2/c^2)}$.

---

133. What happens to time as speed increases?

Answer: It dilates (increases).

---

134. What happens to length as speed increases?

Answer: It contracts.

---

135. What is relativistic momentum?

Answer: $p = \gamma mv$.

---

136. What is rest mass?

Answer: Mass measured in rest frame.

---

137. Can any object reach speed of light?

Answer: No.

---

138. What happens to mass near speed of light?

Answer: It increases significantly.

---

139. What is simultaneity in relativity?

Answer: Events simultaneous in one frame may not be in another.

140. What is relativistic energy?

Answer: $E = \gamma mc^2$.

---

141. What is rest energy?

Answer: $E_0 = m_0c^2$.

---

142. Why classical mechanics fails at high speed?

Answer: Because relativistic effects become significant.

---

143. Does light require medium to travel?

Answer: No.

---

144. What is spacetime?

Answer: Combination of space and time dimensions.

---

145. What is proper interval?

Answer: Invariant quantity between events.

---

146. If v = 0, Lorentz factor equals?

Answer: 1.

---

147. If v approaches c, Lorentz factor becomes?

Answer: Very large.

---

148. Does relativity violate conservation laws?

Answer: No.

---

149. What ensures velocity never exceeds c?

Answer: Relativistic velocity addition formula.

---

150. Special relativity applies to which motions?

Answer: Uniform (non-accelerated) motion.

Explain Scalar and Vector Products of Two Vectors.

Answer:

Let **A** and **B** be two vectors.

(a) Scalar (Dot) Product

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

- Result is a **scalar**.
- Measures projection of one vector onto another.
- If θ = 90°, A·B = 0 (vectors perpendicular).

Applications: Work done (W = F·s)

(b) Vector (Cross) Product

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

- Result is a **vector** perpendicular to plane of A and B.
- Direction by **Right-hand rule**.
- If vectors are parallel → cross product = 0.

Applications: Torque ($\tau = r \times F$)

---

2. Derive Expression for Scalar Triple Product and Its Physical Meaning.

A·(B×C)A \cdot (B \times C)A·(B×C)

- Represents **volume of parallelepiped** formed by three vectors.
- If scalar triple product = 0 → vectors are coplanar.

Determinant form:

|AxAyAzBxByBzCxCyCz|\begin{vmatrix} A_x & A_y & A_z \\ B_x & B_y & B_z \\ C_x & C_y & C_z \end{vmatrix}AxBxCxAyByCyAzBzCz

---

3. Derivative of a Vector with Respect to Time.

If position vector:

r=xi+yj+zkr = xi + yj + zkr=xi+yj+zk

Velocity:

v=drdtv = \frac{dr}{dt}v=dtdr

Acceleration:

a=d2rdt2a = \frac{d^2 r}{dt^2}a=dt2d2r

Important rules:

- Derivative of constant vector = 0
- Product rule applies for vector functions

---

4. Prove that A × B is Perpendicular to Both A and B.

Since:

A·(A×B)=0A \cdot (A \times B) = 0A·(A×B)=0

Thus cross product is perpendicular to both vectors.

---

5. Explain Gradient of a Scalar Function.

Gradient:

∇φ\nabla \phi∇φ

- Direction of maximum increase.
- It is a vector.
- Used in mechanics and electromagnetism.

---

6. Explain Physical Applications of Vector Algebra in Mechanics.

- Velocity and acceleration are vectors.
- Work = Dot product.
- Torque = Cross product.
- Angular momentum = r × p.

Vector algebra simplifies 3D motion problems.

■ SECTION–2: ORDINARY DIFFERENTIAL EQUATIONS (7–12)

---

7. Solve First Order Homogeneous Differential Equation.

Given:

dydx=f(y/x)\frac{dy}{dx} = f(y/x)dxdy=f(y/x)

Substitute:

y=vxy = vxy=vx

Then:

dydx=v+xdvdx\frac{dy}{dx} = v + x\frac{dv}{dx}dxdy=v+xdxdv

Reduce to separable form and integrate.

---

8. Derive Solution of Second Order Linear Homogeneous Equation.

Given:

ay′′+by′+cy=0ay'' + by' + cy = 0ay′′+by′+cy=0

Auxiliary equation:

ar2+br+c=0ar^2 + br + c = 0ar2+br+c=0

Cases:

1. Real distinct roots → C1er1x+C2er2xC_1e^{r_1x} + C_2e^{r_2x}C1er1x+C2er2x
2. Equal roots → (C1+C2x)erx(C_1 + C_2x)e^{rx}(C1+C2x)erx
3. Complex roots → eαx(C1cosβx+C2sinβx)e^{\alpha x}(C_1\cos\beta x + C_2\sin\beta x)eαx(C1cosβx+C2sinβx)

---

9. Application of 2nd Order DE in SHM.

Equation:

d2xdt2+ω2x=0\frac{d^2x}{dt^2} + \omega^2 x = 0dt2d2x+ω2x=0

Solution:

x=Acos⁡(ωt+φ)x = A\cos(\omega t + \phi)x=Acos(ωt+φ)

Describes oscillatory motion.

---

10. Define Order and Degree of Differential Equation with Example.

Order: Highest derivative.
Degree: Power of highest derivative.

Example:

(d2y/dx2)2+y=0(d^2y/dx^2)^2 + y = 0(d2y/dx2)2+y=0

Order = 2
Degree = 2

---

11. Explain Auxiliary Equation Method.

Convert differential equation into algebraic equation in r.
Solve roots and write general solution.

---

12. Physical Significance of Differential Equations in Mechanics.

Used in:

- Motion under force
- Oscillations
- Wave motion
- Electric circuits

📘 SECTION–3: LAWS OF MOTION (13–18)

---

13. State and Explain Newton's Three Laws of Motion.

1. Law of Inertia
2. F = ma
3. Action = −Reaction

They form foundation of classical mechanics.

---

14. Explain Inertial and Non-Inertial Frames.

Inertial frame → Newton's laws valid.
Non-inertial → Pseudo force introduced.

Example: Rotating frame.

---

15. Define Centre of Mass and Derive Expression.

R=∑miri∑miR = \frac{\sum m_i r_i}{\sum m_i}R=∑mi∑miri

Motion of COM depends only on external force.

---

16. Prove Conservation of Momentum.

From Newton's 3rd law:
Internal forces cancel → total momentum constant if no external force.

---

17. Explain Dynamics of System of Particles.

Total force = rate of change of total momentum.

Internal forces do not change total momentum.

---

18. Explain Pseudo Force with Example.

In accelerating frame, fictitious force:

Fp=−maF_p = -maFp=−ma

Example: Passenger in accelerating bus.

■ SECTION–4: MOMENTUM & ENERGY (19–24)

---

19. Derive Work-Energy Theorem.

W=∫Fdx=ΔKEW = \int F dx = \Delta KEW=∫Fdx=ΔKE

Thus work done equals change in kinetic energy.

---

20. State and Prove Conservation of Energy.

Total energy:

E=KE+PEE = KE + PEE=KE+PE

If force conservative → E constant.

---

21. Explain Elastic and Inelastic Collisions.

Elastic → KE & momentum conserved.
Inelastic → Only momentum conserved.

---

22. Derive Expression for Escape Velocity.

Using energy conservation:

12mv2=GMmR\frac{1}{2}mv^2 = \frac{GMm}{R}21mv2=RGMm v=2GMRv = \sqrt{\frac{2GM}{R}}v=R2GM

---

23. Explain Rocket Propulsion.

Based on conservation of momentum.

Thrust:

F=vedmdtF = v_e \frac{dm}{dt}F=vedtdm

Rocket gains velocity by expelling mass backward.

---

24. Explain Conservative and Non-Conservative Forces.

Conservative:

- Path independent
- PE defined

Non-conservative:

- Path dependent (friction)

📘 SECTION–5: ROTATIONAL MOTION (25–30)

---

25. Define Angular Velocity and Angular Acceleration.

ω=dθdt\omega = \frac{d\theta}{dt}ω=dtdθ α=dωdt\alpha = \frac{d\omega}{dt}α=dtdω

---

26. Define Angular Momentum and Derive Relation L = Iω.

L=r×pL = r \times pL=r×p

For rigid body:

L=IωL = I\omegaL=Iω

---

27. Prove Conservation of Angular Momentum.

If external torque = 0:

dLdt=0\frac{dL}{dt} = 0dtdL=0

Hence L constant.

---

28. Define Torque and Its Relation with Angular Momentum.

τ=r×F\tau = r \times Fτ=r×F τ=dLdt\tau = \frac{dL}{dt}τ=dtdL

---

29. Derive Rotational Kinetic Energy.

KE=12Iω2KE = \frac{1}{2}I\omega^2KE=21Iω2

---

30. Explain Areal Velocity and Its Significance.

dAdt=L2m\frac{dA}{dt} = \frac{L}{2m}dtdA=2mL

Constant in central force motion.

📓 SECTION–6: GRAVITATION (31–40)

---

31. State and Explain Newton's Law of Gravitation.

F=Gm1m2r2F = \frac{Gm_1m_2}{r^2}F=r2Gm1m2

Force always attractive and central.

---

32. Prove Motion in Central Force is Planar.

Since torque = 0 → L conserved → motion in plane.

---

33. State Kepler's Three Laws.

1. Elliptical orbits
2. Equal areas in equal time
3. T2∝r3T^2 \propto r^3T2∝r3

---

34. Derive Orbital Velocity of Satellite.

GMmr2=mv2r\frac{GMm}{r^2} = \frac{mv^2}{r}r2GMm=rmv2 v=GMrv = \sqrt{\frac{GM}{r}}v=rGM

---

35. Explain Geostationary Orbit.

- Period = 24 hr
- Equatorial plane
- Height ≈ 36,000 km
- Used for communication

---

36. Explain Working Principle of GPS.

- Uses time delay of signals.
- Minimum 4 satellites.
- Determines position via trilateration.

---

37. Define Weightlessness.

Occurs in free fall when normal reaction = 0.

---

38. Physiological Effects on Astronauts.

- Bone density loss
- Muscle weakening
- Fluid redistribution
- Space sickness

---

39. Define Gravitational Potential Energy.

U=−GMmrU = -\frac{GMm}{r}U=−rGMm

Negative due to attractive force.

---

40. Derive Relation Between Areal Velocity and Angular Momentum.

dAdt=L2m\frac{dA}{dt} = \frac{L}{2m}dtdA=2mL

Hence constant due to conservation of L.

41. Define Simple Harmonic Motion (SHM) and derive its Differential Equation.

Answer:

SHM is oscillatory motion in which restoring force is directly proportional to displacement and directed towards mean position.

F=−kxF = -kxF=−kx

Using Newton's Second Law:

md2xdt2=−kxm\frac{d^2x}{dt^2} = -kxmdt2d2x=−kx d2xdt2+kmx=0\frac{d^2x}{dt^2} + \frac{k}{m}x = 0dt2d2x+mkx=0

Let ω2=k/m\omega^2 = k/mω2=k/m

d2xdt2+ω2x=0\frac{d^2x}{dt^2} + \omega^2 x = 0dt2d2x+ω2x=0

This is the differential equation of SHM.

---

42. Obtain the Solution of SHM Differential Equation.

Equation:

d2xdt2+ω2x=0\frac{d^2x}{dt^2} + \omega^2 x = 0dt2d2x+ω2x=0

Auxiliary equation:

r2+ω2=0r^2 + \omega^2 = 0r2+ω2=0 r=±iωr = \pm i\omegar=±iω

Solution:

x=Acos⁡(ωt+ϕ)x = A\cos(\omega t + \phi)x=Acos(ωt+ϕ)

---

43. Derive Expression for Velocity and Acceleration in SHM.

x=Acos⁡(ωt+ϕ)x = A\cos(\omega t + \phi)x=Acos(ωt+ϕ)

Velocity:

v=−Aωsin⁡(ωt+ϕ)v = -A\omega \sin(\omega t + \phi)v=−Aωsin(ωt+ϕ)

Acceleration:

a=−ω2xa = -\omega^2 xa=−ω2x

Thus acceleration is proportional to displacement.

---

44. Derive Expression for Kinetic Energy in SHM.

KE=12mv2KE = \frac{1}{2}mv^2KE=21mv2 KE=12mA2ω2sin⁡2(ωt+ϕ)KE = \frac{1}{2}mA^2\omega^2 \sin^2(\omega t + \phi)KE=21mA2ω2sin2(ωt+ϕ)

Maximum KE occurs at mean position.

---

45. Derive Expression for Potential Energy in SHM.

PE=12kx2PE = \frac{1}{2}kx^2PE=21kx2 PE=12kA2cos⁡2(ωt+ϕ)PE = \frac{1}{2}kA^2\cos^2(\omega t + \phi)PE=21kA2cos2(ωt+ϕ)

Maximum at extreme positions.

---

46. Show that Total Energy in SHM is Constant.

E=KE+PEE = KE + PEE=KE+PE E=12kA2E = \frac{1}{2}kA^2E=21kA2

Hence total energy remains constant.

---

47. Find Time Average of Kinetic and Potential Energy in SHM.

Over one complete cycle:

⟨KE⟩=⟨PE⟩=12E\langle KE \rangle = \langle PE \rangle = \frac{1}{2}E⟨KE⟩=⟨PE⟩=21E

Average kinetic energy equals average potential energy.

---

48. Explain Damped Oscillations.

Equation:

md2xdt2+bdxdt+kx=0m\frac{d^2x}{dt^2} + b\frac{dx}{dt} + kx = 0mdt2d2x+bdtdx+kx=0

Types:

1. Underdamped
2. Critically damped
3. Overdamped

Amplitude decreases exponentially.

---

49. Explain Condition for Critical Damping.

Critical damping when:

b2=4mkb^2 = 4mkb2=4mk

System returns to equilibrium without oscillation in shortest time.

---

50. Compare Undamped and Damped Oscillations.

Undamped → Constant amplitude
Damped → Amplitude decreases with time

Energy remains constant in undamped, decreases in damped motion.

---

51. Derive Time Period of Simple Pendulum.

T=2πlgT = 2\pi \sqrt{\frac{l}{g}}T=2πgl

Valid for small oscillations.

---

52. Explain Energy Transformation in SHM.

Energy continuously transforms between kinetic and potential energy while total remains constant.

◆ ELASTICITY (53–66)

---

53. State and Explain Hooke's Law.

Within elastic limit:

Stress∝StrainStress \propto StrainStress∝Strain Stress=Y×StrainStress = Y \times StrainStress=Y×Strain

---

54. Explain Stress-Strain Diagram.

Regions:

- Linear (Hooke's law)
- Elastic limit
- Yield point
- Breaking point

Shows mechanical behavior of material.

---

55. Define Young's Modulus and Derive Expression.

Y=F/AΔL/LY = \frac{F/A}{\Delta L/L}Y=ΔL/LF/A

Measures stiffness of material.

---

56. Define Bulk Modulus.

K=PressureVolumetric StrainK = \frac{Pressure}{Volumetric \ Strain}K=Volumetric StrainPressure

Measures resistance to volume change.

---

57. Define Rigidity Modulus.

η=Shear StressShear Strain\eta = \frac{Shear \ Stress}{Shear \ Strain}η=Shear StrainShear Stress

Measures resistance to shape change.

---

58. Derive Relation Between Elastic Constants.

$Y=2\eta(1+\sigma)Y = 2\eta(1 + \sigma)Y=2η(1+σ)$

Where σ = Poisson's ratio.

---

59. Define Poisson's Ratio.

$\sigma=\text{Lateral Strain}\text{Longitudinal Strain}\sigma = \frac{\text{Lateral Strain}}{\text{Longitudinal Strain}}\sigma=\text{Longitudinal Strain}\text{Lateral Strain}$

Range: 0 to 0.5

---

60. Derive Expression for Work Done in Stretching a Wire.

$\text{Work}=12\times\text{Stress}\times\text{Strain}\times\text{Volume}\text{Work} = \frac{1}{2} \times \text{Stress} \times \text{Strain} \times \text{Volume}\text{Work}=21\times\text{Stress}\times\text{Strain}\times\text{Volume}$

Energy stored as elastic potential energy.

---

61. Explain Twisting Couple on a Cylinder.

Torque proportional to angle of twist:

$\tau=C\theta\tau = C\theta\tau=Cθ$

Where C = torsional rigidity.

---

62. Describe Static Torsion Method.

Used to determine rigidity modulus by measuring twist under applied torque.

---

63. Explain Torsional Pendulum and Its Time Period.

T=2πICT = 2\pi \sqrt{\frac{I}{C}}T=2πCI

Used to determine rigidity modulus and moment of inertia.

---

64. Determine Rigidity Modulus Using Torsional Pendulum.

η=8πIlT2r4\eta = \frac{8\pi I l}{T^2 r^4}η=T2r48πIl

Where l = length, r = radius.

---

65. Explain Searle's Method.

Used to determine Young's modulus by measuring extension under load.

---

66. Explain Determination of η, Y and σ by Searle's Method.

Using experimental measurements of stress and strain and elastic constant relations.

◆ SPECIAL THEORY OF RELATIVITY (67–75)

---

67. State Postulates of Special Theory of Relativity.

1. Laws of physics same in all inertial frames.
2. Speed of light constant for all observers.

---

68. Explain Constancy of Speed of Light.

Speed of light in vacuum is independent of motion of source or observer.

---

69. Derive Time Dilation Formula.

t=t01−v2/c2t = \frac{t_0}{\sqrt{1 - v^2/c^2}}t=1−v2/c2t0

Moving clock runs slower.

---

70. Derive Length Contraction Formula.

L=L01−v2/c2L = L_0 \sqrt{1 - v^2/c^2}L=L01−v2/c2

Length contracts along direction of motion.

---

71. Define Lorentz Factor.

γ=11−v2/c2\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}γ=1−v2/c21

---

72. Explain Relativistic Addition of Velocities.

u′=u+v1+uvc2u' = \frac{u + v}{1 + \frac{uv}{c^2}}u′=1+c2uvu+v

Ensures velocity never exceeds c.

---

73. Explain Relativistic Momentum.

p=γmvp = \gamma mvp=γmv

Momentum increases with velocity.

---

74. Derive Mass-Energy Relation.

E=mc2E = mc^2E=mc2

Shows equivalence of mass and energy.

---

75. Compare Newtonian and Relativistic Mechanics.

Newtonian valid for v≪cv \ll cv≪c.
Relativistic required for speeds near light.

SECTION–1: VECTORS

---

1. Explain Scalar and Vector Product of Two Vectors with Geometrical Interpretation.

Scalar (Dot) Product

A·B=ABcos⁡θ\mathbf{A}\cdot \mathbf{B} = AB\cos\thetaA·B=ABcosθ

- Result is **scalar**
- Measures projection of one vector on another
- If θ = 90°, dot product = 0

Vector (Cross) Product

A×B=ABsin⁡θn^\mathbf{A} \times \mathbf{B} = AB\sin\theta \hat{n}A×B=ABsinθn^

- Result is **vector**
- Direction by **Right-hand rule**

Diagram

Applications

- Work = F·s
- Torque = r×F

---

2. Derive and Explain Scalar Triple Product and Its Physical Significance.

A·(B×C)\mathbf{A}\cdot(\mathbf{B}\times \mathbf{C})A·(B×C)

Represents **volume of parallelepiped**

Determinant form:

|AxAyAzBxByBzCxCyCz|\begin{vmatrix} A_x & A_y & A_z \\ B_x & B_y & B_z \\ C_x & C_y & C_z \end{vmatrix}AxBxCxAyByCyAzBzCz

If zero → vectors are coplanar.

---

3. Derivative of a Vector with Respect to Time and Its Applications.

Let:

r=xi+yj+zk\mathbf{r} = xi + yj + zkr=xi+yj+zk

Velocity:

v=drdt\mathbf{v} = \frac{d\mathbf{r}}{dt}v=dtdr

Acceleration:

a=d2rdt2\mathbf{a} = \frac{d^2\mathbf{r}}{dt^2}a=dt2d2r

Used in:

- Circular motion
- Projectile motion
- Rotational dynamics

📘 SECTION–2: ORDINARY DIFFERENTIAL EQUATIONS

---

4. Solve First Order Homogeneous Differential Equation.

Given:

dydx=f(y/x)\frac{dy}{dx} = f(y/x)dxdy=f(y/x)

Substitute:

y=vxy = vxy=vx

Then solve separable equation and integrate.

Used in growth, decay, mechanical motion problems.

---

5. Solve Second Order Linear Homogeneous Differential Equation.

ay′′+by′+cy=0ay'' + by' + cy = 0ay′′+by′+cy=0

Auxiliary equation:

ar2+br+c=0ar^2 + br + c = 0ar2+br+c=0

Three cases:

1. Distinct real roots
2. Equal roots
3. Complex roots

General solution depends on nature of roots.

---

6. Application of Second Order Differential Equation in SHM.

d2xdt2+ω2x=0\frac{d^2x}{dt^2} + \omega^2 x = 0dt2d2x+ω2x=0

Solution:

x=Acos⁡(ωt+ϕ)x = A\cos(\omega t + \phi)x=Acos(ωt+ϕ)

Describes oscillatory motion.

📘 SECTION–3: LAWS OF MOTION

---

7. State and Explain Newton's Three Laws with Applications.

1. Law of inertia
2. F = ma
3. Action-reaction

Applications:

- Recoil of gun
- Rocket propulsion
- Collision problems

---

8. Explain Inertial and Non-Inertial Frames with Example.

In non-inertial frame, pseudo force introduced:

Fp=−maF_p = -maFp=−ma

Example: Rotating frame.

---

9. Define and Derive Expression for Centre of Mass of System of Particles.

R=∑miri∑mi\mathbf{R} = \frac{\sum m_i \mathbf{r_i}}{\sum m_i}R=∑mi∑miri

Motion depends only on external force.

---

10. Prove Conservation of Linear Momentum.

Using Newton's Third Law:

Internal forces cancel → total momentum constant.

📓 SECTION–4: MOMENTUM & ENERGY

---

11. Derive Work-Energy Theorem.

W=∫Fdx=ΔKEW = \int F dx = \Delta KEW=∫Fdx=ΔKE

Thus:

Work done = change in kinetic energy.

---

12. Prove Conservation of Mechanical Energy.

For conservative force:

KE+PE=constantKE + PE = constantKE+PE=constant

Example: Free fall motion.

---

13. Derive Expression for Escape Velocity.

Using energy conservation:

12mv2=GMmR\frac{1}{2}mv^2 = \frac{GMm}{R}21mv2=RGMm v=2GMRv = \sqrt{\frac{2GM}{R}}v=R2GM

---

14. Explain Rocket Propulsion and Derive Rocket Equation.

Based on conservation of momentum.

F=vedmdtF = v_e \frac{dm}{dt}F=vedtdm

Rocket gains velocity by expelling gases backward.

📓 SECTION–5: ROTATIONAL MOTION

---

15. Define Angular Momentum and Prove Its Conservation.

L=r×p\mathbf{L} = \mathbf{r} \times \mathbf{p}L=r×p

If external torque = 0:

dLdt=0\frac{d\mathbf{L}}{dt} = 0dtdL=0

Thus L conserved.

---

16. Define Torque and Derive Relation τ = dL/dt.

τ=r×F\tau = \mathbf{r} \times \mathbf{F}τ=r×F τ=dLdt\tau = \frac{d\mathbf{L}}{dt}τ=dtdL

---

17. Derive Rotational Kinetic Energy.

KE=12Iω2KE = \frac{1}{2}I\omega^2KE=21Iω2

Rotational analogue of translational energy.

📓 SECTION–6: GRAVITATION

---

18. State and Explain Newton's Law of Gravitation.

F=Gm1m2r2F = \frac{Gm_1m_2}{r^2}F=r2Gm1m2

Force always attractive and central.

---

19. Prove Motion in Central Force Field is Planar.

Since torque = 0 → L conserved → motion confined to plane.

---

20. Derive Expression for Areal Velocity and Show It Is Constant.

dAdt=L2m\frac{dA}{dt} = \frac{L}{2m}dtdA=2mL

Thus constant due to conservation of angular momentum.

---

21. State Kepler's Three Laws and Explain Their Significance.

1. Elliptical orbits
2. Equal areas in equal time
3. T2∝r3T^2 \propto r^3T2∝r3

Explains planetary motion.

---

22. Derive Orbital Velocity of Satellite.

GMmr2=mv2r\frac{GMm}{r^2} = \frac{mv^2}{r}r2GMm=rmv2 v=GMrv = \sqrt{\frac{GM}{r}}v=rGM

---

23. Explain Geostationary Satellite and Its Applications.

Conditions:

- Period = 24 hours
- Equatorial orbit
- Height ≈ 36,000 km

Used for communication & weather.

---

24. Explain Working Principle of GPS.

Uses time delay of signals from at least 4 satellites.

Determines:

- Latitude
- Longitude
- Altitude

---

25. Explain Weightlessness and Physiological Effects on Astronauts.

Weightlessness occurs during free fall.

Effects:

- Bone density loss
- Muscle atrophy
- Fluid redistribution
- Space motion sickness

OSCILLATIONS, ELASTICITY & SPECIAL RELATIVITY

◆ **(26–50)**

◆ **OSCILLATIONS**

---

26. Define Simple Harmonic Motion (SHM) and Derive Its Differential Equation.

Definition:
Simple Harmonic Motion is periodic motion in which restoring force is directly proportional to displacement and directed towards mean position.

F=−kxF = -kxF=−kx

Using Newton's Second Law:

md2xdt2=−kxm\frac{d^2x}{dt^2} = -kxmdt2d2x=−kx d2xdt2+kmx=0\frac{d^2x}{dt^2} + \frac{k}{m}x = 0dt2d2x+mkx=0

Let ω2=k/m\omega^2 = k/mω2=k/m

d2xdt2+ω2x=0\frac{d^2x}{dt^2} + \omega^2 x = 0dt2d2x+ω2x=0

This is the differential equation of SHM.

Diagram

---

27. Solve the Differential Equation of SHM.

Equation:

d2xdt2+ω2x=0\frac{d^2x}{dt^2} + \omega^2 x = 0dt2d2x+ω2x=0

Auxiliary equation:

r2+ω2=0r^2 + \omega^2 = 0r2+ω2=0 r=±iωr = \pm i\omegar=±iω

General solution:

x=Acos⁡(ωt+ϕ)x = A\cos(\omega t + \phi)x=Acos(ωt+ϕ)

Where A = amplitude, φ = phase constant.

---

28. Derive Expressions for Velocity and Acceleration in SHM.

x=Acos⁡(ωt+ϕ)x = A\cos(\omega t + \phi)x=Acos(ωt+ϕ)

Velocity:

v=−Aωsin⁡(ωt+ϕ)v = -A\omega \sin(\omega t + \phi)v=−Aωsin(ωt+ϕ)

Acceleration:

a=−ω2xa = -\omega^2 xa=−ω2x

Acceleration proportional to displacement.

---

29. Derive Expression for Kinetic Energy in SHM.

KE=12mv2KE = \frac{1}{2}mv^2KE=21mv2 KE=12mA2ω2sin⁡2(ωt+ϕ)KE = \frac{1}{2}mA^2\omega^2 \sin^2(\omega t + \phi)KE=21mA2ω2sin2(ωt+ϕ)

Maximum at mean position.

---

30. Derive Expression for Potential Energy in SHM.

PE=12kx2PE = \frac{1}{2}kx^2PE=21kx2 PE=12kA2cos⁡2(ωt+ϕ)PE = \frac{1}{2}kA^2 \cos^2(\omega t + \phi)PE=21kA2cos2(ωt+ϕ)

Maximum at extreme positions.

---

31. Prove that Total Energy in SHM is Constant.

E=KE+PEE = KE + PEE=KE+PE E=12kA2E = \frac{1}{2}kA^2E=21kA2

Total energy remains constant throughout motion.

---

32. Find Time Average of Kinetic and Potential Energy in SHM.

Over one cycle:

⟨KE⟩=⟨PE⟩=12E\langle KE \rangle = \langle PE \rangle = \frac{1}{2}E⟨KE⟩=⟨PE⟩=21E

Average KE equals average PE.

---

33. Explain Damped Oscillations and Derive Equation.

Equation:

md2xdt2+bdxdt+kx=0m\frac{d^2x}{dt^2} + b\frac{dx}{dt} + kx = 0mdt2d2x+bdtdx+kx=0

Solution:

x=Ae−bt/2mcos⁡(ω′t)x = Ae^{-bt/2m}\cos(\omega' t)x=Ae−bt/2mcos(ω′t)

Amplitude decreases exponentially.

---

34. Discuss Underdamped, Critically Damped and Overdamped Cases.

1. Underdamped → Oscillatory
2. Critical damping → Fastest return without oscillation
3. Overdamped → Slow non-oscillatory motion

Condition:

b2=4mkb^2 = 4mkb2=4mk

---

35. Derive Time Period of Simple Pendulum.

For small oscillations:

T=2πlgT = 2\pi \sqrt{\frac{l}{g}}T=2πgl

Independent of mass.

◆ **ELASTICITY**

---

36. State and Explain Hooke's Law with Stress-Strain Diagram.

Hooke's Law:

Stress∝StrainStress \propto StrainStress∝Strain

Linear region in stress-strain curve.

Diagram

---

37. Define Young's Modulus and Derive Its Expression.

Y=F/AΔL/LY = \frac{F/A}{\Delta L/L}Y=ΔL/LF/A

Measures stiffness of material.

---

38. Define Bulk Modulus and Rigidity Modulus.

Bulk modulus:

K=PressureVolumetric StrainK = \frac{Pressure}{Volumetric \ Strain}K=Volumetric StrainPressure

Rigidity modulus:

η=Shear StressShear Strain\eta = \frac{Shear \ Stress}{Shear \ Strain}η=Shear StrainShear Stress

---

39. Derive Relation Between Elastic Constants.

Y=2η(1+σ)Y = 2\eta(1+\sigma)Y=2η(1+σ)

Where σ = Poisson's ratio.

---

40. Define Poisson's Ratio and Derive Its Expression.

σ=Lateral StrainLongitudinal Strain\sigma = \frac{Lateral \ Strain}{Longitudinal \ Strain}σ=Longitudinal StrainLateral Strain

Range: 0 to 0.5

---

41. Derive Work Done in Stretching a Wire.

Work=12×Stress×Strain×VolumeWork = \frac{1}{2} \times Stress \times Strain \times VolumeWork=21×Stress×Strain×Volume

Stored as elastic potential energy.

---

42. Explain Twisting Couple on a Cylinder.

$\tau = C\theta$

Torque proportional to angle of twist.

---

43. Describe Static Torsion Method for Rigidity Modulus.

Apply known torque and measure twist.

$\eta = \frac{2l\tau}{\pi r^4 \theta}$

---

44. Explain Torsional Pendulum and Determine Time Period.

$T = 2\pi \sqrt{\frac{I}{C}}$

Used to determine rigidity modulus.

---

45. Determine Rigidity Modulus Using Torsional Pendulum.

$\eta = \frac{8\pi I l}{T^2 r^4}$

---

46. Explain Searle's Method for Young's Modulus.

Measure extension produced by known load.

$Y = \frac{FL}{A\Delta L}$

◆ SPECIAL THEORY OF RELATIVITY

---

47. State and Explain Postulates of Special Theory of Relativity.

1. Laws of physics same in all inertial frames

2. Speed of light constant in vacuum

---

48. Derive Time Dilation Formula.

t=t01−v2/c2t = \frac{t_0}{\sqrt{1 - v^2/c^2}}t=1−v2/c2t0

Moving clock runs slower.

---

49. Derive Length Contraction Formula.

L=L01−v2/c2L = L_0\sqrt{1 - v^2/c^2}L=L01−v2/c2

Length contracts along direction of motion.

---

50. Explain Relativistic Addition of Velocities and Its Significance.

u′=u+v1+uvc2u' = \frac{u+v}{1+\frac{uv}{c^2}}u′=1+c2uvu+v

Ensures velocity never exceeds speed of light.