विध्न विचारत भीरु जन, नहीं आरम्भे काम,
विपति देख छोड़े तुरंत मध्यम मन कर श्याम।
पुरुष सिंह संकल्प कर, सहते विपति अनेक,
'बना' न छोड़े ध्येय को, रघुबर राखे टेक।।

रचितः मानव धर्म प्रणेता
सद्गुरु श्री रणछोड़दासजी महाराज

ROTATIONAL MOTION (ROTATION)

Some questions (Assertion–Reason type) are given below. Each question contains STATEMENT – 1 (Assertion) and STATEMENT – 2 (Reason). Each question has 4 choices (A), (B), (C) and (D) out of which **ONLY ONE** is correct. So select the correct choice :

Choices are :

(A) Statement – 1 is True, Statement – 2 is True; Statement – 2 **is** a correct explanation for Statement – 1.
(B) Statement – 1 is True, Statement – 2 is True; Statement – 2 **is NOT** a correct explanation for Statement – 1.
(C) Statement – 1 is True, Statement – 2 is False.
(D) Statement – 1 is False, Statement – 2 is True.

144. **STATEMENT – 1**
The torque can be applied only about two points
(i) centre of mass and
(ii) point about which the body is rolling.

STATEMENT – 2
The equation $a = r\alpha$ can always be applied in case of rolling.

145. **STATEMENT – 1**
In case of rolling friction force can act in forward and backward direction both.

STATEMENT – 2
The angular momentum of a system will be conserved only about that point about which external angular impulse is zero.

146. **STATEMENT – 1**
For the purpose of calculation of moment of inertia, a body's mass can be thought to be concentrated at its centre of mass.

STATEMENT – 2
Moment of inertia is a measure of how the mass is distributed about a certain axis.

147. **STATEMENT – 1**
Many great rivers flow toward the equator. The sediments that they carry, increases the time of rotation of the earth about its own axis.

STATEMENT – 2
The angular momentum of the earth about its rotation axis is conserved.

148. **STATEMENT – 1**
The mass of a body cannot be considered to be concentrated at the centre of mass of the body for the purpose of computing its moment of inertia.

STATEMENT – 2
For then the moment of inertia of every body about an axis passing through its centre of mass would be zero.

149. **STATEMENT – 1**
A ladders is more likely to slip when a person is near the top than when he is near the bottom.

STATEMENT – 2
The friction between the ladder and floor decreases as he climbs up.

150. **STATEMENT – 1**
If a body (ball) is rolling on a surface without slipping, no frictional force acts on it.

STATEMENT – 2
In the case of rolling without slipping point of contacts are relatively at rest.

151. **STATEMENT – 1**

Torque $(\vec{\tau})$ acting on a rigid body is defined as $\vec{\tau} = \vec{A} \times \vec{L}$, where $\vec{A}$ is a constant vector and $\vec{L}$ is the angular momentum of the body. The magnitude of the angular momentum of the body remains same.

STATEMENT – 2
$\vec{\tau}$ is perpendicular to $\vec{L}$ and hence torque does not deliver any power to the body.

152. **STATEMENT – 1**

For a rigid body angular momentum $\vec{L}$ and $\vec{\omega}$ have same direction.

STATEMENT – 2

For rigid body about a symmetrical axis $\vec{L}$ and $\vec{\omega}$ have same direction.

153. **STATEMENT – 1**
The moment of inertia of a rigid body is not unique; about a given axis.

STATEMENT – 2
The moment of inertia of a rigid body depends on axis about which it has to be calculated.

154. **STATEMENT – 1**
A sphere rolling on a rough horizontal surface with constant velocity then it start going up on a smooth inclined plane. Rotational KE of sphere decreases continuously on horizontal and inclined surface.

STATEMENT – 2
Rotational KE decreases if torque due to friction opposes angular velocity of sphere.

155. **STATEMENT – 1**
Minimum moment of inertia of a uniform body is I about an axis. The axis must be passing through COM of body.

STATEMENT – 2
Moment of inertia depends on distribution of mass about axis of rotation.

156. **STATEMENT – 1 :** A solid sphere rolling on a rough horizontal surface. Acceleration of contact point is zero.

STATEMENT – 2 : A solid sphere can roll on the smooth surface.

157. **STATEMENT – 1 :** A disc is rolling on an inclined plane without slipping. The velocity of centre of mass is V. These other points on the disc lie on a circular arc having same speed as centre of mass.

STATEMENT – 2 : When a disc is rolling on an inclined plane. The magnitude of velocities of all the point from the contact point is same, having distance equal to radius r.

158. **STATEMENT – 1 :** A sphere is performing pure rolling on a rough horizontal surface with constant angular velocity. Frictional force acting on the sphere is zero.

STATEMENT – 2 : Velocity of contact point is zero.

159. **STATEMENT – 1 :** A non–uniform sphere is placed such that its centre is at the origin of co–ordinate system. If I_x and I_y be moment of inertia about x axis and y axis respectively then moment of inertia about z axis is $I_x + I_y$.

STATEMENT – 2 : According to perpendicular axis theory $I_z = I_x + I_y$ when object is lying in x–y plane.

160. **STATEMENT – 1 :** Torque is equal to rate of change of angular momentum.

STATEMENT – 2 : Angular momentum depends on moment of inertia and angular velocity.

161. **STATEMENT – 1 :** If earth shrink (without change in mass) to half it's present size. Length of the day would become 6 hours.

STATEMENT – 2 : As size of earth changes its moment of inertia changes.

162. **STATEMENT – 1 :** A disc is rolling on a rough horizontal surface. The instantaneous speed of the point of contact during perfect rolling is zero with respect to ground.

STATEMENT – 2 : The force of friction can help in achieving pure rolling condition.

163. **STATEMENT – 1 :** When a diver dives, the rotational kinetic energy of diver increases, during several somersaults.

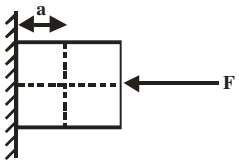
STATEMENT – 2 : When diver pulls his limbs, the moment of inertia decreases and on account of conservation of angular momentum his angular speed increases.

164. **STATEMENT – 1 :** A ring moving down on a smooth inclined plane will be in slipping motion.

STATEMENT – 2 : Work done by friction in pure rolling motion is zero.

165. **STATEMENT – 1 :** A horizontal force F is applied such that the block remains stationary because N will produce torque

STATEMENT – 2 : The torque produced by friction force is equal and opposite the torque produce due to normal reaction (N).



166. **STATEMENT – 1 :** The velocity of a body at the bottom of an inclined place of given height, is more when it slides down the plane, compared to, when it rolling down the same plane.

STATEMENT – 2 : In rolling down, a body acquires both, kinetic energy of translation and rotation.

167. **STATEMENT – 1 :** If momentum of system is zero than kinetic energy must be zero.

STATEMENT – 2 : If kinetic energy of system is zero than momentum must be zero.

168. **STATEMENT – 1 :** If rod is thrown upward with initial angular velocity and velocity of centre of mass then its momentum changes but angular velocity remains same.

STATEMENT – 2 : Torque on rod about centre of mass due to gravitational force is zero.

169. **STATEMENT – 1 :** Moment of inertial of uniform disc and solid cylinder of equal mass and equal radius about an axis passing through centre and perpendicular to plane will be same.

STATEMENT – 2 : Moment of inertia depends upon distribution of mass from the axis of rotation i.e., perpendicular distance from the axis.

170. **STATEMENT – 1 :** For a particle moving along circular path, centripetal force cancel centrifugal force.

STATEMENT – 2 : They are equal in magnitude and opposite in direction.

171. **STATEMENT – 1 :** The force of friction in the case of a disc rolling without slipping down on inclined plane is $\frac{1}{3} g \sin\alpha$.

STATEMENT – 2 : When the disc rolls without slipping, friction is required because for rolling condition velocity of point of contact is zero.

Hint & Solution

144. (C)

145.	(B)	146.	(D)	147.	(A)	148.	(A)
149.	(C)	150.	(D)	151.	(A)	152.	(D)
153.	(D)	154.	(D)	155.	(B)	156.	(D)
157.	(A)	158.	(B)	159.	(D)	160.	(B)
161.	(A)	162.	(B)	163.	(A)	164.	(B)
165.	(A)	166.	(A)	167.	(D)	168.	(A)
169.	(A)	170.	(D)	171.	(B)		

144. (i) Conceptual.
(ii) It can be applied only if body rolls and the surface has zero acceleration.

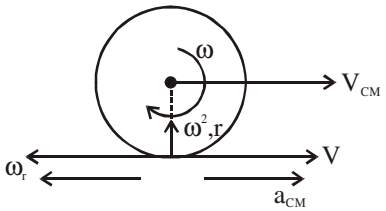
145. Conceptual.

147. $\because$ Sediment deposited at the equator (away from axis of rotation) increases the moment of inertia (not mass) of the Earth. Since $I\omega$ = constant, ω decreases and thus $I = \frac{2\pi}{\omega}$ increases.

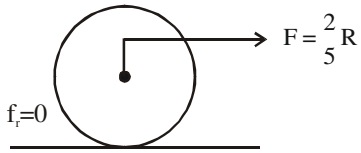
148. Moment of inertia is then sum of m r^2 terms. We cannot change all the r's, keep m's the same, and expect $\Sigma m_i r_i^2$ to remain unchanged.

149. As the person climbs up, normal reaction and friction between the ladder and the wall both increase. This decreases normal reaction from the floor, decreasing limiting value of friction there. This increases the possibility of the ladder slipping.

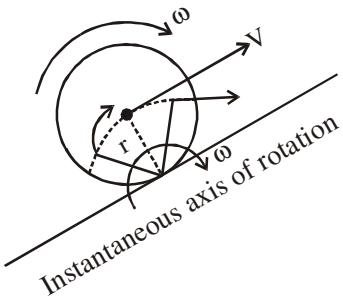
156.



During the motion of rolling there is radial acceleration toward the centre. Hence contact point moves vertically upward.



157.



158. If angular velocity is constant then frictional force acting on sphere is zero. In case of pure rolling velocity of contact point is zero.

159. Perpendicular axis theorem is not valid for a sphere.

160. $\vec{\tau} = \frac{d\vec{L}}{dt}$ and $L = I\omega$.

161. When earth shrinks its angular momentum remains constant i.e.,

$$L = I\omega = \frac{2}{5}mR^2 \times \frac{2\pi}{T} = \text{constant}.$$

$T \propto I \propto R^2$ it means if size of earth changes then it's moment of inertia changes.
If radius is half so time period will become T/4. Hence 24/4 = 6 Hr.

162. Velocity of point of contact
$V = (V_{CM} - \omega R)$
When pure rolling occurs $V_{CM} = \omega R$.
Hence V = 0.
Also frictional force can provide torque which further helps in achieving the pure rolling condition.

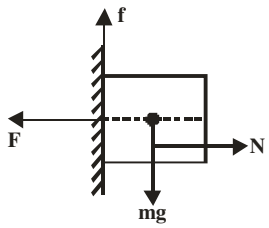
163. $I_1 \omega_1 = I_2 \omega_2$
$\because$ $I_2 < I_1$
$\therefore$ $\omega_2 > \omega_1$
The diver does work by pulling his limps and thus, ω increases or rotational kinetic energy increases.

164. In the case of smooth surface. fr = 0, whereas in pure rolling motion friction can be present or absent.

165. As the block remains stationary
$\Sigma fx = 0$ i.e., F = N
$\Sigma fy = 0$ i.e., f = mg

and $\Sigma\tau = 0$ i.e., $\therefore$ $\vec{\tau}_f + \vec{\tau}_N = 0$

As $\vec{\tau}_f \neq 0$ $\therefore$ $\vec{\tau}_N \neq 0$ and torque by friction and normal reaction will be in opposite.

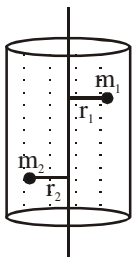


166. In sliding down, the entire potential energy is converted into kinetic energy. While in rolling down same part of potential energy is converted into K.E. of rotation, therefore linear velocity acquired is less.

167. If system has only rotational kinetic energy than momentum may be zero.

168. Since net torque is zero angular velocity remains constant.

169.



$I = \Sigma mr^2$.

170. Centripetal force is real while centrifugal force is Pseudo.

171. Frictional force on an inclined plane.

$= \frac{1}{3} g \sin\alpha$ (for a disc).