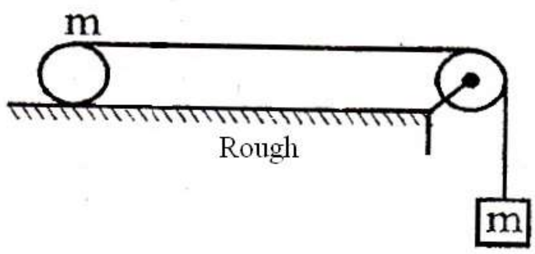
PHYSICS: **Max.Marks : 60**

SECTION I

Single Correct Answer Type

This section contains **10 multiple choice questions.** Each question has four choices (A), (B), (C) and (D) out of which **ONLY ONE is correct.**

1. In the given figure a ring of mass m and radius r is kept on a sufficiently rough horizontal surface while a block of equal mass 'm' is attached through a string, which is tightly wounded on the ring. When the system is released from rest the ring rolls without slipping. Consider the following statements and choose the correct options (Pulley is ideal)



i) Acceleration of the centre of mass of ring is $\frac{2g}{3}$

ii) Acceleration of the block is $\frac{4g}{3}$

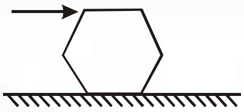
iii) Frictional force on the ring is zero

iv) Frictional force (on the ring) acts along backward direction

A) Statement (i) and (ii) only B) Statement (ii) and (iii) only

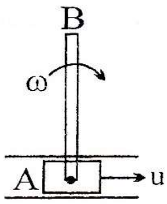
C) Statement (i) and (iv) only D) Statement (iii) only

2. In the figure a constant horizontal force is applied at the corner of a regular hexagon. The hexagon starts to rotate in vertical plane and does not slide during the motion. Initially the angular acceleration of the body is α_0 and magnitude of friction force is f_0. After the body had rotated through 5 degree, the angular acceleration is α and magnitude of friction is f. Then



A) $\alpha = \alpha_0,\ f = f_0$ B) $\alpha > \alpha_0,\ f > f_0$ C) $\alpha < \alpha_0,\ f < f_0$ D) $\alpha > \alpha_0,\ f < f_0$

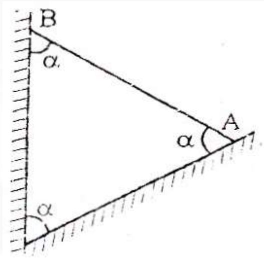
3. A mechanism consists of a part which is translated with a velocity u and a rod AB of length L and mass M hinged at A. The rod rotates about axis A with angular velocity ω. The kinetic energy of rod when it is vertical as shown is



A) $\frac{1}{2}Mu^2 + \frac{1}{6}ML^2\omega^2$ B) $\frac{1}{2}Mu^2 + \frac{1}{6}ML\omega u$

C) $\frac{1}{2}Mu^2 + \frac{1}{6}ML^2\omega^2 + \frac{1}{2}ML\omega u$ D) $\frac{1}{2}Mu^2 + \frac{1}{6}ML^2\omega^2 + \frac{1}{8}ML\omega u$

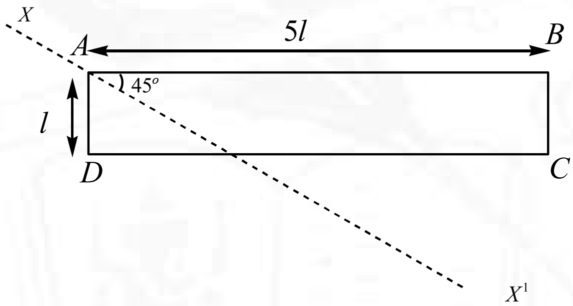
4. In the figure shown, the end A of the rod of length L is being pushed down parallel to the inclined surface with a velocity =v. Let the velocity of end B = u and the angular velocity of the rod = ω. Then ,



A) $u = v\cos\alpha, upward$ B) $u = v, downwards$

C) $\omega = v\sin\alpha / L$ D) $\omega = 2v\sin\alpha / L$

5. The moment of inertia of a thin uniform rectangular plate ABCD about the axis xx^1 lying in the plane of the plate is [Mass per unit area = σ]

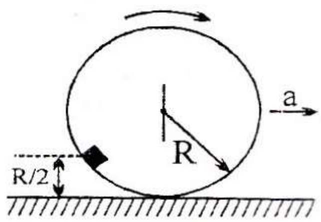


A) $\frac{185}{12}\sigma l^4$ B) $\sigma l^4\left(\frac{130}{3}\right)$ C) $\frac{5\sqrt{2}}{3}\sigma l^4$ D) $\frac{\sigma l^4}{24}$

6. A ring of radius R is rolling purely on the outer surface of a pipe of radius 4R. At some instant, the center of the ring has a constant speed =v. Then, the acceleration of the point on the ring which is in contact with the surface of the pipe is

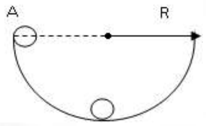
A) $4v^2/5R$ B) v^2/R C) $v^2/4R$ D) Zero

7. Inside a uniformly accelerating thin-walled spherical shell of radius R, which is undergoing pure rolling on horizontal surface, there is small body slipping around. Angle of friction between body and inner surface of sphere is 23^o. Which of the following can be the acceleration 'a' of the center of sphere to ensure that the small body stays at R/2 distance from the surface?



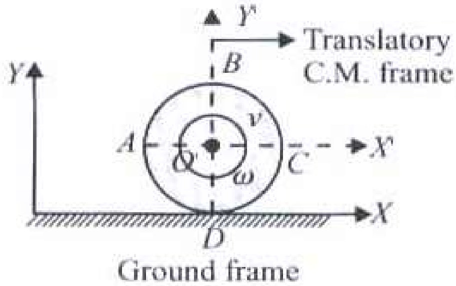
A) $\frac{g}{\sqrt{3}}$ B) $\frac{3g}{4}$ C) $g\tan 23^o$ D) $\frac{g\sqrt{3}}{2}$

8. A small solid sphere A of radius r and mass m rolls without slipping inside a large fixed hemispherical bowl of radius R as shown in figure. The sphere 'A' starts from rest at the top point on the rim of the hemisphere. Find the normal force exerted by small sphere on the hemisphere when it touches the bottom of hemisphere. [g – acceleration due to gravity]



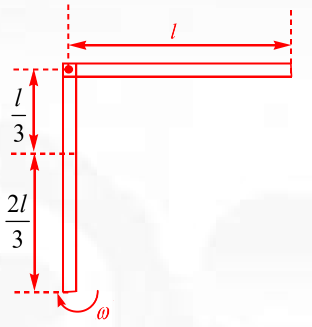
A) $\frac{10}{2}mg$ B) $\frac{9}{7}mg$ C) $\frac{17}{7}mg$ D) $\frac{3}{7}mg$

9. A thin rigid uniform circular disc rolls without slipping on a horizontal rigid surface (or the ground). At a certain instant, its position w.r.t. ground frame is as shown in the figure. Select the **incorrect** statement:



A) sector ABC has greater kinetic energy than sector ADC w.r.t. ground frame.
B) sector $BO'C$ has greater kinetic energy than sector $CO'D$ w.r.t ground frame.
C) sector $BO'C$ has the same kinetic energy as sector $AO'B$ w.r.t. ground frame.
D) all the sectors $AO'B, BO'C, CO'D$ and $AO'D$ have same momentum w.r.t. the centre of mass frame.

10. A thin uniform rod of mass M and length L is hinged at an end and released from rest in the horizontal position. The tension at a point located at a distance L/3 from the hinge point, when the rod becomes vertical, will be



A) $\frac{22Mg}{27}$ B) $\frac{11Mg}{13}$ C) $\frac{6Mg}{11}$ D) $2Mg$

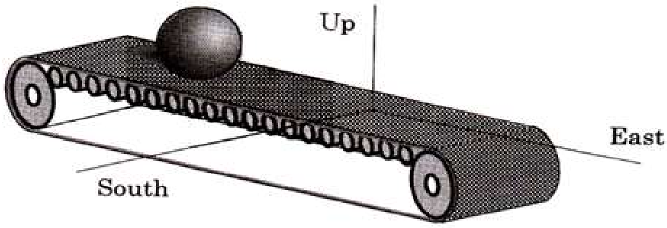
SECTION II

Multiple Correct Answer(s) Type

This section contains **5 multiple choice questions.** Each question has four choices (A), (B), (C) and (D) out of which **ONE or MORE are correct.**

11. A simplified model of a conveyor belt used to transport luggage is shown in the figure. It consists of a flexible strip that moves on rollers. The rollers are kept close enough to prevent any vertical movement of the luggage placed on it. The upper surface of the strip is rough so that objects placed on it are dragged due to frictional forces. A stationary homogeneous sphere of radius R and mass M is

placed on the conveyor belt which moving with constant speed v_0 due east. Assume the coefficient of static and kinetic friction to be μ_s and μ_k respectively. Initially the sphere slides on the conveyor belt and force of kinetic friction provides necessary torque to increase its angular velocity. This condition persists until the sphere starts rolling without slipping on the conveyor belt.



Which of the following statements correctly describe motion of the sphere?

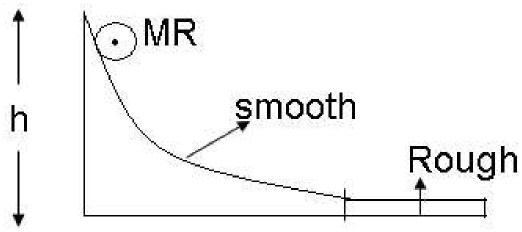
A) Its linear speed relative to the ground increases and relative to the belt decreases

B) Its linear speed relative to the ground and also relative to the belt decreases.

C) It rotates in anticlockwise sense when looked facing due north.

D) It rotates in clockwise sense when looked facing due north.

12. A small solid cylinder of mass M and radius R slides down a smooth curve of height 'h' from rest and gets onto the plank of mass M which is resting on a smooth surface as shown in the figure. Take μ as the coefficient of friction between plank and the cylinder. For this situation mark out the correct statement(s).[plank is free to move]



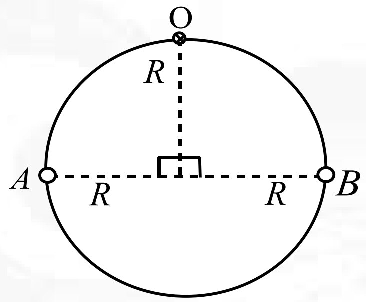
A) The cylinder is performing impure rolling motion initially on the plank and finally performs pure rolling motion

B) The direction of frictional force on the cylinder while rolling on plank is initially in backward direction and finally it attains zero value.

C) The velocity of the centre of mass of the plank + cylinder systems, after the cylinder starts pure rolling, is $V_0/2$

D) The minimum length of the plank required for pure rolling of the cylinder over the plank $3V_0^2/16\mu g$. Where $V_0 = \sqrt{2gh}$

13. A light rigid ring of radius R= 1m has two identical beads A & B each of mass m = 1kg. The ring is hinged at its top point O in such a way that it can rotate in the vertical plane freely about a horizontal axis into the plane of the diagram shown. Bead A is rigidly attached to ring and bead B is free to slide along the ring without friction. Immediately after the bead B is released



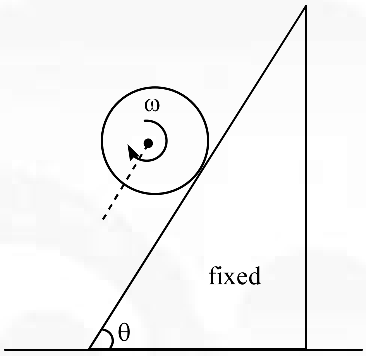
A) The acceleration of bead B has a magnitude of $\left(\sqrt{10}\right)\left(\frac{g}{3}\right)$ m/s^2

B) The ratio of magnitudes of hinge reaction at the point O along x and y axis is equal to 1.

C) The acceleration of bead A is $\left(\sqrt{2}\right)\left(\frac{g}{3}\right)$m/s^2

D) The net reaction force from the hinge O is $\left(\sqrt{2}\right)\left(\frac{20}{3}\right)$ N

14. A solid sphere is given an angular velocity ω and kept on a rough fixed incline plane.



Then choose the correct statement(s):

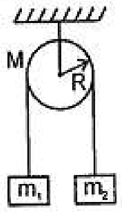
A) If $\mu = tan\theta$ then sphere will be in linear equilibrium for some time and after that pure rolling down the plane will start.

B) If $\mu = tan\theta$ then sphere will move up the plane and frictional force acting all the time will be $2mg\,sin\theta$.

C) If $\mu = \frac{tan\theta}{2}$ there will never be pure rolling (consider inclined plane to be long enough).

D) If incline plane is not fixed and it is on smooth horizontal surface then linear momentum of the system (wedge and sphere) can be conserved in horizontal direction.

15. In the shown figure, the pulley of mass M and radius R can rotate about its fixed horizontal axis (axle) without friction. Friction between light inextensible string and pulley is sufficient to prevent slipping of string over pulley. The masses of blocks are m_1 and m_2 such that $m_2 > m_1$. The system is initially released from rest as shown. Before the block of mass m_1 touches the pulley, pick up the correct statements.



A The magnitude of acceleration of any small length dl of string is constant throughout the motion

B) Magnitude of force exerted by string on mass m_2 is larger as compared to that exerted by string on mass m_1.

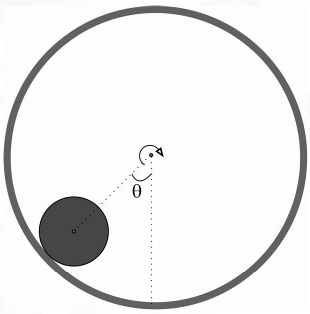
C) Accelerations of both blocks are same.

D) The Acceleration of small length dl of string in contact with block of mass m_2 remains constant

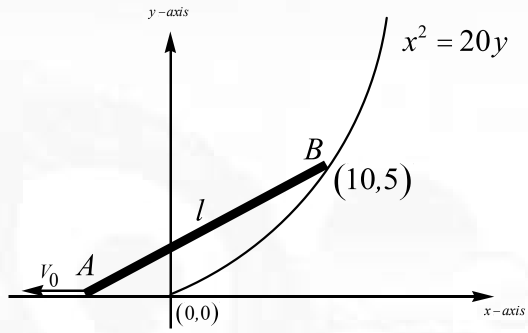
SECTION III
Integer Answer Type

This section contains **5 questions.** The answer to each question is single digit integer, ranging from 0 to 9 (*both inclusive*).

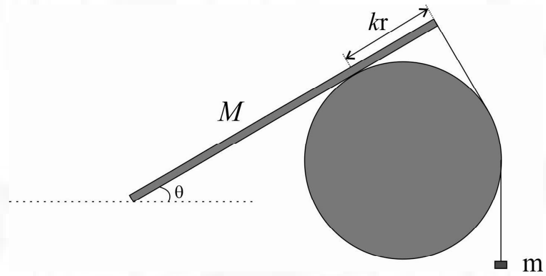
16. A hollow cylinder of radius R=2.0 m is rotating at constant angular acceleration about its stationary horizontal axis into the plane of the paper as shown in the figure. If a uniform solid cylinder is placed horizontally with its axis parallel to the axis of hollow cylinder at an angular position of $\theta = 30°$, the solid cylinder starts rolling with its axis motionless. The angular acceleration α (in rad/s^2) of the hollow cylinder is x. Find x



17. A uniform rod has mass m = 2 kg and length l = 13m. One end of the rod is pulled with a constant velocity of v_0 = 34 m/s along a frictionless horizontal floor in the negative x direction. The other end is moving along a parabolic fixed curve. The equation of the parabola is $x^2 = 20y$. Find the angular velocity of the rod (in rad/s) when the end point 'B' is at (10,5)



18. A block of mass m is attached to one end of a uniform rod of mass M=10 kg with the help of a light inextensible thin cord. This arrangement is placed on a fixed horizontal frictionless cylinder of radius r as shown in the Figure. In equilibrium, the rod leans at an angle $\theta = 30°$ with horizontal and the distance between the point of contact of the rod with cylinder and top end of the rod is $k = \frac{1}{\sqrt{2}}$. The mass of the block m is 3(n), then the value of n is



19. Consider the following statements

(a) The angular velocity of all points on the rigid body as seen from any other point on it is the same.

(b) A rigid uniform disc rolls without slipping on a fixed rough horizontal surface, the velocity of the lowest point is zero and hence the acceleration of the lowest point is also zero

(c) If two different axes are at the same distance from centre of mass of a rigid body, then moment of inertia of the given rigid body about both the axis will always be same.

(d) When a cylinder is rolling with slipping on a rough horizontal surface the work done by friction on the surface is negative.

(e) Friction acting on a cylinder without sliding on an inclined surface could be positive, negative or zero depending on the external force acting on it.

(f) A rigid body cannot roll on a smooth horizontal surface.

(g) In the centre of mass frame a rigid body can have only rotational motion.

(h) $\tau_{net} = I_{cm}\alpha$ is valid in all frames of reference.

(i) A sphere is rotating uniformly about an axis passing through its centre then, all the particles on the surface have same linear speed.

Mark the total number of correct statements in the OMR sheet.

20. An ideal string is wrapped several times on a solid cylinder of mass 4 kg and radius 1 m. The pulleys are ideal and massless; the surface between block and ground is smooth. There is no slipping between the top surface of the block and the cylinder. If the angular acceleration of the cylinder is $\frac{10x}{9}$ rad/s^2, then find the value of x.