PHYSICS

The following question given below consist of an "Assertion" (A) and "Reason" (R) Type questions. Use the following Key to choose the appropriate answer.

(A) If both (A) and (R) are true, and (R) is the correct explanation of (A).

(B) If both (A) and (R) are true but (R) is not the correct explanation of (A).

(C) If (A) is true but (R) is false.

(D) If (A) is false but (R) is true.

Q.1 **Assertion :** A body may be accelerated even when it is moving uniformly.

Reason : Acceleration is rate at which speed of body changes. **[A]**

Q.2 **Assertion :** When a car take turn, then a new type of force called centripetal force act on the car.

Reason : Centripetal force is necessary for circular motion. **[D]**

Q.3 **Assertion :** $S = ut + \frac{1}{2}at^2$, do not apply to the case of uniform circular motion.

Reason : In circular motion, acceleration is not uniform. **[C]**

Q.4 **Assertion :** When a particle is moving in a circular path, both centripetal force and centrifugal force acts on the particle.

Reason : Centripetal force and centrifugal force depend on frame of reference. **[D]**

Q.5 **Assertion :** A particle is tied to a string is projected in a vertical circle.

When the initial speed of particle is $\sqrt{6gr}$, then particle completes vertical circle of radius r.

Reason : The minimum speed of particle required to complete vertical circle is $\sqrt{4gr}$.

[C]

Q.6 **Assertion** : On a banked curved track, vertical components of normal reaction provides the necessary centripetal force.

Reason : Centripetal force is always required for turning. **[D]**

Q.7 **Assertion** : The tendency of skidding/overturning is quadrupled, when a cyclist doubles his speed of turning.

Reason : $\tan\theta = \frac{v^2}{Rg}$

$\Rightarrow$ becomes 4 times as v is doubled. **[A]**

Q.8 **Assertion :** In uniform circular motion speed of body is constant but its velocity is variable.

Reason : In uniform circular motion tangential acceleration of body is zero, but body has normal acceleration. **[A]**

Q.9 **Assertion :** On a banked curved track, horizontal components of normal reaction may provides the necessary centripetal force.

Reason : When a car take turn centripetal force is necessary. **[B]**

Q.10 **Assertion :** The kinematic equation for uniform acceleration do not apply to the case of uniform circular motion.

Reason : In uniform circular motion magnitude of acceleration is constant but its direction is changing. **[A]**

Q.11 **Statement - I :** A cyclist always bends in wards while negotiating a curve.

Statement - II : By bending, he lowers his centre of gravity **[B]**

Q.12 **Statement I :** The maximum speed at which a car can turn on level curve of radius 40 m, is 11 m/s ; $\mu = 0.3$.

Statement II : $v = \sqrt{\mu Rg} \Rightarrow \mu = \frac{v^2}{Rg}$

$= \frac{11 \times 11}{40 \times 10} = 0.3.$ **[A]**

Q.13 **Statement I :** On banked curved road, vertical component of normal reaction provides the necessary centripetal force.

Statement II : Centripetal force is always required for turning. **[D]**

Q.14 **Statement I :** The tendency to overturn of skidding/overturning is quadrupled, when a cyclist doubles his speed of turning.

Statement II : $\tan \theta = \frac{v^2}{Rg} \Rightarrow$ becomes 4 times as v doubled. **[A]**

Q.15 **Statement - I** In circular motion, work done by the centripetal force is always zero.

Statement - II Centripetal force is always perpendicular to the instantaneous displacement.

(A) A (B) B

(C) C (D) D

[A]

For a body moving in a circular path of radius R = 1m in anticlockwise direction with constant speed V.

Q.1 **Column-I** **Column-II**

(A) Angle betweeen instantaneous velocity and instantaneous acceleration

(P) None-zero

(B) Angle made by are at centre has moved in the time the which magnitude of displacement is equal

(Q) zero

(C) Total acceleration of the body

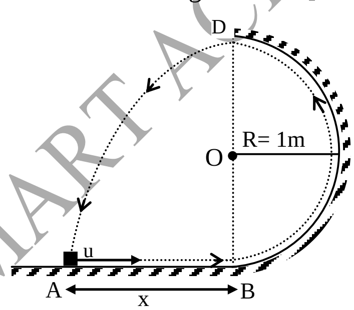
(R) $\pi/2$

(D) Tangencial acceleration of the body

(S) $\pi/3$

(A) $\rightarrow$ R (B) $\rightarrow$ S (C) $\rightarrow$ P (D) $\rightarrow$ Q

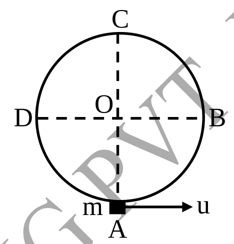
Q.2 A small body of mass m = 2 kg is thrown with speed u from point A along a smooth circular track as shown. The body after moving through the points B, C and D comes back at hits point A. Length AB is x. When x = 3 R then $u = v_0$ and normal reaction at point C is N_1. The minimum value of $x = x_0$ and in this case normal reaction at point C is N_2 then, [if R = 1 m, Data in column II are rounded off and $g = 10\ m/s^2$]



Column I	Column II [In SI units]
(A) v_0	(P) 85
(B) x_0	(Q) 8
(C) N_1	(R) 2
(D) N_2	(S) 60

(A) $\rightarrow$ Q (B) $\rightarrow$R (C) $\rightarrow$ P (D) $\rightarrow$ S

Q.3 A particle suspended from a string of length ℓ is given a horizontal speed $u = 3\sqrt{g\ell}$ at the bottom. Then for the particle match the following column -



Column – I	Column – II
(A) Speed at B	(P) 7 mg
(B) Speed at C	(Q) $\sqrt{5g\ell}$
(C) Tension in string at B	(R) $\sqrt{7g\ell}$
(D) Tension in string at C	(S) 4 mg

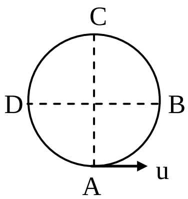
Sol. **A $\rightarrow$ R, B $\rightarrow$ Q, C $\rightarrow$ P, D $\rightarrow$ S**

Q.4 A particle is moving along a circular path and motion is uniform circular motion.

Column – I	Column - II
(A) Velocity	(P) Constant
(B) Speed	(Q) Variable
(C) Acceleration	(R) Zero
(D) Magnitude of radial acceleration	(S) None

A $\rightarrow$ Q; B $\rightarrow$ P; C $\rightarrow$ Q ; D $\rightarrow$ P

Q.5 A particle is suspended from a string of length 'R'. It is given a velocity $u = 3\sqrt{Rg}$. Match the following



Column-I	Column-II
(A) Velocity at B	(P) 7 mg
(B) Velocity at C	(Q) $\sqrt{5gR}$
(C) Tension at B	(R) $\sqrt{7gR}$
(D) Tension at C	(S) 4 mg

Ans. $A \rightarrow R$; $B \rightarrow Q$; $C \rightarrow P$; $D \rightarrow S$

Q.6 The bob of a simple pendulum is given a velocity 10 m/s at its lowest point. Mass of the bob is 1 kg and string length is 1 m.

Column – I	Column - II
(A) Minimum tension in string (in Newton)	(P) 50
(B) Magnitude of acceleration of bob when the string is horizontal (in m/s^2)	(Q) 60
(C) Minimum magnitude of acceleration of bob (in m/s^2)	(R) zero
(D) Tangential acceleration at the highest point (in m/s^2)	(S) $10\sqrt{65}$

Ans. $A \rightarrow P$; $B \rightarrow S$; $C \rightarrow Q$; $D \rightarrow R$

Q.7 A car of mass 500 kg is moving in a circular road of radius $35/\sqrt{3}$. Angle of banking of road is 30^o. Coefficient of friction between road and tyres is $\mu = \frac{1}{2\sqrt{3}}$. Match the following:

Column-I	Column-II
(A) Maximum speed (in m/s) of car for safe turning	(P) $5\sqrt{2}$
(B) Minimum speed (in m/s) of car for safe turning	(Q) 12.50
(C) Speed (in m/s) at which friction force between tyres and road is zero	(R) $\sqrt{210}$
(D) Friction force (in 10^2 Newton) between tyres and road if speed is $\sqrt{\frac{350}{6}}$ m/s	(S) $\sqrt{\frac{350}{3}}$

Ans. $A \rightarrow R$; $B \rightarrow P$; $C \rightarrow S$; $D \rightarrow Q$

Q.8 A pendulum of length 3.2 m is free to rotate in a vertical circle. Let the velocity of pendulum at its lowest position be v_0 then match the following-

Column I	Column II
(A) If $v_0 = 4\sqrt{7}$ m/s, maximum height attained by pendulum (in meter)	(P) Zero
(A) If $v_0 = 4\sqrt{7}$ m/s, minimum velocity of pendulum (in meter/sec)	(Q) 2
(C) If v_0 = 8 m/s, maximum height attained by pendulum (in meter)	(R) 3.2
(D) If v_0 = 8 m/s, minimum velocity of pendulum (in meter/sec)	(S) 5.4

Sol. **$A \rightarrow S$; $B \rightarrow Q$; $C \rightarrow R$; $D \rightarrow P$**

Q.9 For a body moving in a circular path of radius R = 1m in anticlockwise direction with constant speed V.

Column-I **Column-II**

(A) Angle betweeen instantaneous velocity and instantaneous acceleration

(P) None-zero

(B) Angle made by arc at centre that has moved in the time in which magnitude of displacement is equal to radius

(Q) zero

(C) Total acceleration of the body

(R) $\pi/2$

(D) Tangencial acceleration of the body

(S) $\pi/3$

(T) $\pi/6$

Ans. **$A \rightarrow R$; $B \rightarrow S$; $C \rightarrow P$; $D \rightarrow Q$**

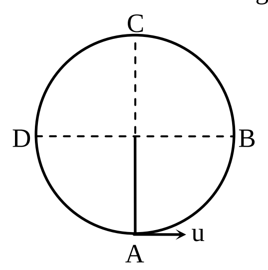
Q.10 The bob of a simple pendulum is given a velocity 10 m/s at its lowest point. Mass of the bob is 1 kg and string length is 1 m.

Column – I	Column - II
(A) Minimum tension in string (in Newton)	(P) 50

Column-I	Column-II
(B) Magnitude of acceleration of bob when the string is horizontal (in m/s^2)	(Q) 60
(C) Minimum magnitude of acceleration of bob (in m/s^2)	(R) zero
(D) Tangential acceleration at the highest point (in m/s^2)	(S) $10\sqrt{65}$

Sol. $\mathbf{A \rightarrow P ; B \rightarrow S ; C \rightarrow Q ; D \rightarrow R}$

Q.11 A particle of 1 kg suspended from a string of length 1 m. It is given a velocity $u = \sqrt{7g\ell}$ at the bottom. Match the following. ($g = 10\ m/s^2$)



Column-I	Column-II
(A) Velocity at B	(P) 80 SI unit
(B) Velocity at C	(Q) 5.5 SI unit
(C) Tension in string at A	(R) 7.07 SI unit
(D) Tension in string at D	(S) None

Sol. $\mathbf{A \rightarrow R ; B \rightarrow Q ; C \rightarrow P ; D \rightarrow S}$

Q.12 Match the following **:**

Column-I	Column-II
(A) Constant positive acceleration	(P) Speed may decrease
(B) Constant negative acceleration	(Q) Speed must increase
(C) Angle between acceleration and velocity is 90º	(R) Speed is constant
(D) Angle between acceleration and velocity is less than 90º	(S) None

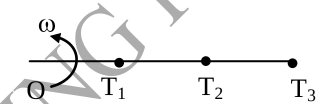
Ans. $\mathbf{A \rightarrow Q ; B \rightarrow P ; C \rightarrow R ; D \rightarrow Q}$

Q.13 A particle is rotating in a circle of radius 1m with constant speed 4 m/s. In times 1 s, match the following (in SI units):

Column-I	Column-II
(A) Displacement	(P) 8 sin 2
(B) Distance	(Q) 4
(C) Average velocity	(R) 2 sin 2
(D) Average acceleration	(S) 4 sin 2

Ans. $A \rightarrow R; B \rightarrow Q; C \rightarrow P; D \rightarrow Q$

Q.14 Three balls each of mass 1 kg are attached with three strings each of length 1m as shown in figure. They are rotated in a horizontal circle with angular velocity ω = 4 rad/s about point O. Match the following:



Column-I	Column-II
(A) T_1	(P) Maximum
(B) T_2	(Q) Minimum
(C) T_3	(R) 80 N
	(T) 48 N
	(U) 90 N

Ans. $A \rightarrow P; B \rightarrow R; C \rightarrow Q,T$

Q.15 Match the following -

Column-I	Column-II
(A) A cone resting its slant surface touching against smooth horizontal floor	(P) Stable equilibrium
(B) A car moving on smooth circular track of banking angle 'θ' with constant speed without its tyre slipping	(Q) Unstable equilibrium
(C) A rigid body suspended in laboratory in such a manner that its centre of gravity vertically above point of suspension & its circular motion lies vertically below point of suspension	(R) Neutral equilibrium
(D) A uniform cube balanced on a horizontal floor on one its edge (only a force	(S) None of the above

parallel to horizontal plane can be applied)

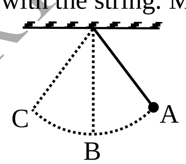
Sol. **A → R ; B → S ; C → Q; D → Q**

Q.16 Here $\vec{r}$ represents the position vector of a particle at time t and ω and a are non-zero.

	Column -I		**Column -II**
(A)	$\vec{r} = \cos \omega t\ \hat{i} + \sin \omega t\ \hat{j} + at\ \hat{k}$	(P)	constant speed
(B)	$\vec{r} = 5 \cos \omega t\ \hat{i} + 5 (\sin \omega t + t)\ \hat{j}$	(Q)	helical motion
(C)	$\vec{r} = 5\ at^2\ \hat{i} + 2at\ \hat{j}$	(R)	constant non- zero magnitude of tangential of acceleration
(D)	$\vec{r} = 5[(\cos \omega t)\ \hat{i} + (\sin \omega t)\ \hat{j}]$	(S)	constant magnitude of total acceleration
		(T)	circular motion

Sol.2 **A → P, Q, R, S; B → S; C → S; D → P, S, T**

Q.17 A pendulum is released from point A as shown. At some instant net force on the bob is making an angle θ with the string. Match the following.

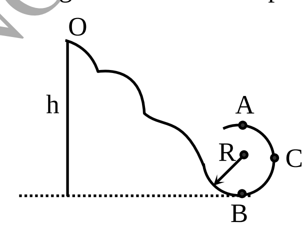


	Column -I		**Column -II**
(A)	For θ = 30º	(P)	Particle may be moving between B and A
(B)	For θ = 120º	(Q)	Particle may be moving between C and B
(C)	For θ = 90º	(R)	Particle is at A
(D)	For θ = 0º	(S)	Particle is at B
		(T)	None of these

Sol. **A → P,Q ; B → T ; C →R ; D → S**

Q.18 A particle is released from height h on a smooth track terminating in a circular path of radius R. A and C are points at top and at horizontal level respectively of the circular path.

Column I represents the different values of height of inclined plane and column II gives the conditions during the motion of the particle.



	Column I		**Column II**
(A)	If h = 3.2 R	(P)	The particle is able to complete vertical circular motion
(B)	If h = 2.7 R	(Q)	The force exerted by particle on track at point A is zero
(C)	If h = 2.5 R	(R)	The force exerted by particle on track at point A is more than its weight
(D)	If h = 4 R	(S)	The force exerted by particle on track at point C is more than its weight.
		(T)	The force exerted by particle on track at point A is less then its weight

Sol. **A →** P,R,S; **B →** P,S,T; **C →** P,Q,S; **D →** P,R,S

Q.1 Speed of a body moving in a circular path changes with time as v = 2t, then -

(A) Magnitude of acceleration remains constant
(B) Magnitude of acceleration increases
(C) Angle between velocity and acceleration remains constant
(D) Angle between velocity and acceleration increases

Sol.[B,D] As v = 2t and let radius of circular path is r then,

$$a_T = \frac{dv}{dt} = 2 \Rightarrow \quad a_r = \frac{v^2}{r} = \frac{4t^2}{r}$$

Therefore,

$$a = \sqrt{a_T^2 + a_r^2} \;\Rightarrow a = \sqrt{4 + \frac{16t^4}{r^2}}$$

$\therefore$ (B) and (D) are correct.

Q.2 A body is connected to a string of length r and revolved in vertical circle with one end of string as the centre of circle. Its velocity at bottom most point v_L is twice that of its value v_H at the top most point. Then –

(A) Ratio of maximum tension to minimum tension in string is 10/9
(B) Velocity at highest point is $\sqrt{4gr/3}$
(C) Tension at bottom most point is 6 mg
(D) $v_L^2 - v_H^2$ is equal to 4gr **[B,D]**

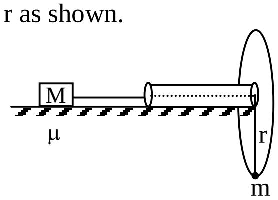
Sol. As $V_H^2 = V_L^2 - 2gh$ where h = 2r

$\therefore$ $V_H^2 = V_L^2 - 4gr$

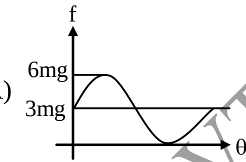
Now, $V_L = 2V_H$ (given)

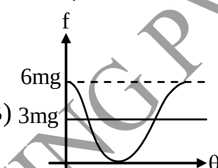
$\therefore$ $V_H = \sqrt{\frac{4gr}{3}}$

Q.3 The block M is connected by an ideal string which passes through a thin fixed smooth pipe. A mass m is now connected to the other end of string and it is revolved in the vertical circle of radius r as shown.



If block M is at rest and friction coefficient between M and surface is μ then friction force on M is f. Let at t = 0 mass m is at its lowest point moving with speed u = $\sqrt{5gr}$ and θ is angular displacement of string connecting m then,

(A) 

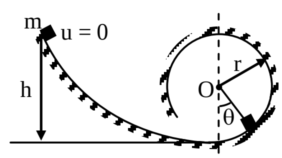
(B) 

(C) force applied by surface on M varies with the period of π
(D) force applied by surface on M varies with a period of 2π **[B,C]**

Sol. $T = f = mg\cos\theta + \frac{mv^2}{r}$

where $v^2 = 5gr - 2gr(1 - \cos\theta)$

Q.4 A particle of mass m is released from height h on a smooth curved surface which ends into a vertical loop of radius r as shown. If h = 2r then,



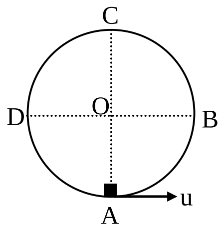
(A) The particle reaches the top of the loop with zero velocity
(B) The particle cannot reach the top of the loop
(C) The particle breaks off at a height h = r from base
(D) The particle breaks off at a height r < h < 2r **[B,D]**

Sol. To reach the top of loop particle must have a minimum speed of v = $\sqrt{5gr}$ at the bottom of the loop.

but $v^2 = 2gh = 4gr$

Q.5 ABCD is a smooth fixed vertical circular track. A small particle is projected tangentially from the lower most point A of the track with speed

$u = \sqrt{4gr}$ where r is the radius of track. AC is the vertical diameter of track, then-



(A) The particle leaves the track somewhere between B and C on the path of track

(B) The particle cannot hit the point C when it is moving in air

(C) The particle cannot cross the line AC when it moving in horizontal direction

(D) The particle can cross the line AC moving horizontally **[A,B,C]**

Q. 6 Which of the following statements are true for a moving body ?

(A) if its speed changes, its velocity must change and it must have some acceleration

(B) if its velocity changes, its speed must change and it must have some acceleration

(C) if its velocity changes, its speed may or may not change, and it must have some acceleration

(D) if its speed changes, but direction of motion does not change, its velocity may remain constant

Sol. **[A,C]**

(A) magnitude of velocity is changing hence acceleration is present

(C) Velocity is changing hence it can happen by change in direction also as in a uniform circular motion. Hence acceleration is present.

Q. 7 Which of the following statements are true for a moving body ?

(A) if its speed changes, its velocity must change and it must have some acceleration

(B) if its velocity changes, its speed must change and it must have some acceleration

(C) if its velocity changes, its speed may or may not change, and it must have some acceleration

(D) if its speed changes, but direction of motion does not change, its velocity may remain constant

Sol. **[A,C]**

(A) magnitude of velocity is changing hence acceleration is present

(C) Velocity is changing hence it can happen by change in direction also as in a uniform circular motion. Hence acceleration is present.

Q.8 A body moves in a circular path of radius R with deceleration so that at any moment of time its tangential and normal acceleration are equal in magnitude. At the initial moment t = 0, the velocity of body is v_0 then the velocity of body at any time will be –

(A) $v = \dfrac{v_0}{\left(1+\dfrac{v_0 t}{R}\right)}$ at time t

(B) $v = v_0 e^{-\frac{S}{R}}$ after it has moved S meter

(C) $v = v_0 e^{-SR}$ after it has moved S meter

(D) None of these

Sol **[A,B]**

As $a_T = a_N$

$\therefore \dfrac{vdv}{ds} = \dfrac{-v^2}{R}$ which can also be written as $\dfrac{dv}{dt} = -\dfrac{v^2}{R}$

Integrating the above equations answer is obtained.

Q.9 A body is connected to a string of length r and revolved in vertical circle with one end of string as the centre of circle. Its velocity at bottom most point v_L is twice that of its value v_H at the top most point. Then –

(A) Ratio of maximum tension to minimum tension in string is 10/9

(B) Velocity at highest point is $\sqrt{4gr/3}$

(C) Tension at bottom most point is 6 mg

(D) $v_L^2 - v_H^2$ is equal to 4gr

Sol. **[B,D]**

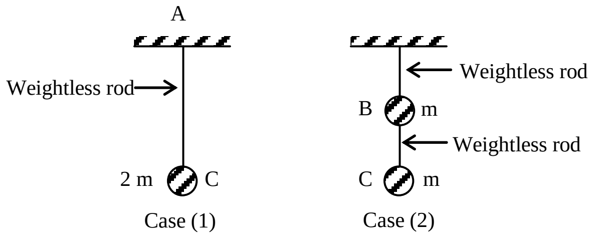
As $V_H^2 = V_L^2 - 2gh$ where h = 2r

$\therefore \quad V_H^2 = V_L^2 - 4gr$

Now, $V_L = 2V_H$ (given)

$\therefore \quad V_H = \sqrt{\dfrac{4gr}{3}}$

Q.10 Which of the following is/are correct ?



(A) Horizontal velocity imparted to end C of rod to deflect it to the horizontal in first case is $\sqrt{2g\ell}$

(B) Horizontal velocity imparted to end C of rod to deflect it to the horizontal in second case is $\sqrt{\frac{12}{5}g\ell}$

(C) Horizontal velocity imparted to end C of rod to deflect it to horizontal in first case is $\sqrt{4g\ell}$

(D) Horizontal velocity imparted to end C of rod to deflect it to the horizontal in second case is $\sqrt{\frac{36}{5}g\ell}$ **[A, B]**

Q.11 Speed of a body moving in a circular path changes with time as v = 2t, then –

(A) Magnitude of acceleration remains constant

(B) Magnitude of acceleration increases

(C) Angle between velocity and acceleration remains constant

(D) Angle between velocity and acceleration increases **[B,D]**

Sol. As v = 2t and let radius of circular path is r then,

$$a_T = \frac{dv}{dt} = 2$$

$$a_r = \frac{v^2}{r} = \frac{4t^2}{r}$$

Therefore,

$$a = \sqrt{a_T^2 + a_r^2}$$

$$a = \sqrt{4 + \frac{16t^4}{r^2}}$$

$\therefore$ (B) and (D) are correct.

Q.12 A body moves in a circular path of radius R with deceleration so that at any moment of time its tangential and normal accelerations are equal in magnitude. At the initial moment t = 0, the velocity of body is v_0 then the velocity of body will be-

(A) $v = \frac{v_0}{1+\left(\frac{v_0 t}{R}\right)}$ at time t

(B) $v = v_0^{e^{-S/R}}$ after it has moved S meter

(C) $v = v_0 e^{-SR}$ after it has moved S meter

(D) None of these **[A,B]**

Sol. Given $a_r = a_t$

$$\frac{v^2}{R} = a_t$$

$$a_t = \frac{v^2}{R}$$

$$\frac{dv}{dt} = -\frac{v^2}{R}$$

$$dv = -\frac{v^2}{R}dt$$

or $$\int_{v_0}^{v} \frac{dv}{v^2} = -\frac{1}{R}\int_0^t dt$$

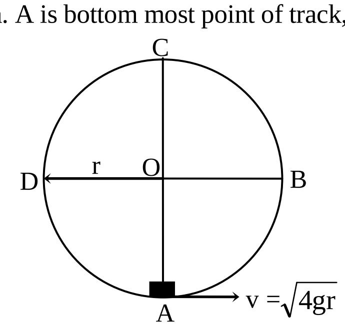
Again,

$$a_t = \frac{v^2}{R}$$

$$v\frac{dv}{dS} = -\frac{v^2}{R}$$

$$\int_{v_0}^{v} \frac{dv}{v} = -\frac{1}{R}\int_0^S dS$$

Q.13 ABCD is a vertical circular fixed smooth track in which a small particle is projected with speed $v = \sqrt{4gr}$ from the point A in tangential direction. A is bottom most point of track, then –



(A) The particle leaves contact somewhere between B and C path of track

(B) The particle can not cross the vertical line AC moving horizontally
(C) The particle can hit point C while moving in air
(D) All of the above **[B,A]**

Q.14 An object follows a curved path. The following quantities may remain constant during the motion-
(A) speed
(B) velocity
(C) acceleration
(D) magnitude of acceleration **[A,D]**

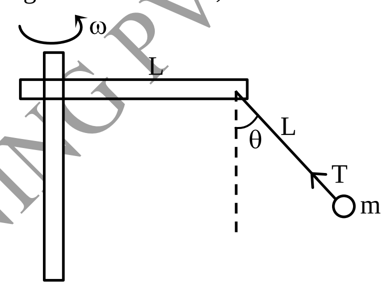
Q.15 The position vector of a particle in a circular motion about the origin sweeps out equal area in equal times-
(A) velocity remains constant
(B) speed remains constant
(C) acceleration remains constant
(D) tangential acceleration remains constant
[B,D]

Q.16 A car of mass M is moving on a horizontal circular path of radius r. At an instant its speed is v and is increasing at a rate a -
(A) the acceleration of the car is towards the centre of the path
(B) the magnitude of the frictional force on the car is greater than mv^2/R
(C) the friction coefficient between the ground and the car is not less than a/g
(D) the friction coefficient between the ground and the car is $\mu = \tan^{-1} v^2/Rg$ **[B,C]**

Q.17 A circular road of radius r is banked for a speed of v = 40 km/h. A car of mass m attempts to go on the circular road. The friction coefficient between the tyre and the road is negligible. Then-
(A) the car cannot make a turn without skidding
(B) if the car turn at a speed less than 40 km/h, it will slip down.
(C) if the car turn at the correct speed of 40 km/h the force by the road on the car is equal to mv^2/r
(D) if the car turn at the correct speed of 40 km/h, the force by the road on the car is greater than mg as well as greater than mv^2/r **[B,D]**

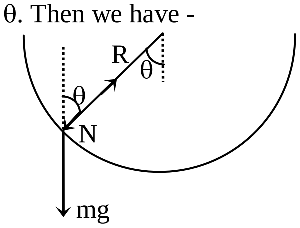
Q.18 A person applies a constant force $\vec{F}$ on a particle of mass m and finds that the particle move in a circle of radius r with a uniform speed v.
(A) this is not possible
(B) there are other forces also on the particle
(C) the resultant of other forces is mv^2/r towards centre
(D) the resultant of the other forces varies in magnitude as well as direction **[B,D]**

Q.19 Figure shows a rod of length L pivoted near an end and which is made to rotate in a horizontal plane with a constant angular speed. A ball of mass m is suspended by a string also of length L from the other end of the rod. If the θ is made by string with the vertical, then-



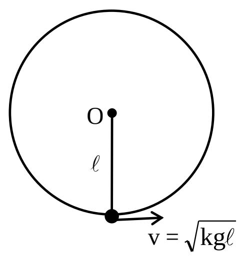
(A) $T \sin\theta = m\omega^2 L(1 + \sin\theta)$
(B) $T \cos\theta = mg$
(C) $\tan\theta = \dfrac{\omega^2 L(1+\sin\theta)}{g}$
(D) none of above **[A,B,C]**

Q.20 A hemispherical bowl of radius R is set rotating about its axis of symmetry which is kept vertical. A small block kept in the bowl rotates with the bowl without slipping on its surface. If the surface of bowl is smooth, and the angle made by the radius through the block with the vertical is θ. Then we have -



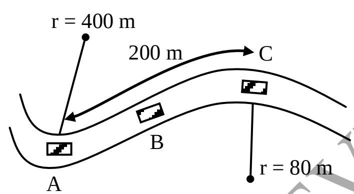
(A) $N \sin\theta = m\omega^2 R \sin\theta$
(B) $N \cos\theta = mg$
(C) $N = m\omega^2 R$
(D) $\omega = \sqrt{\dfrac{g}{R\cos\theta}}$ **[A,B,D]**

Q.1 A pendulum of length ℓ is given a horizontal velocity $\sqrt{kg\ell}$ at the lowest point of vertical circular path as shown. In the subsequent motion the string gets slag at a certain point and the pendulum bob strikes the point of suspensión then the value of k is –



[0004]

Q.2 A 1500 kg car enters a section of curved road in the horizontal plane and slows down at a uniform rate from a speed of 100 km/hr at A to a speed of 50 km/hr as it passes C. The radius of curvature of the road at A is 400 m and at C is 80 m. The total horizontal force exerted by the road on tyres at position C is ...... N.



[4220]

Sol. $v_C^2 = v_A^2 + 2a_t S$

Tangential acceleration :

$a_t = \dfrac{v_C^2 - v_A^2}{2s}$ = 1.447 m/s^2

Normal acceleration at C is

$a_n = \dfrac{v^2}{r_C}$ = 2.41 m/s^2

Tangential force at C

$F_t = ma_t$

= 1500 × 1.447

= 2170 N

Normal force at C

$F_n = ma_n$

= 1500 (2.41)

= 3620 N

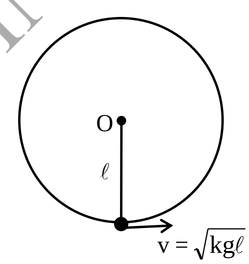
Total force at C

$F = \sqrt{F_n^2 + F_t^2}$

$F = \sqrt{(2170)^2 + (3620)^2}$

F = 4220 N

Q.3 A pendulum of length ℓ is given a horizontal velocity $\sqrt{kg\ell}$ at the lowest point of vertical circular path as shown. In the subsequent motion the string gets slag at a certain point and the pendulum bob strikes the point of suspensión then the value of k is -



Sol. **[0004]**

Q.4 A sphere of mass m = 0.5 kg carrying positive charge q = 110 μC is connected with a light, flexible and inextensible spring of length r = 60cm and whirled in a vertical circle. If a vertically upwards electric field of strength E = 10^5 N/C exists in the space then the minimum velocity of sphere in m/s required at highest point so that it may just complete the circle is (g = 10 m/s^2)

Sol. **[6]**

$F_E = qE = 11$ N

$F_g = mg = 5$N

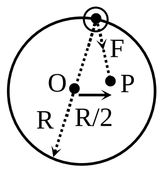
So Net force = F = 6N upward

$g_{eff} = \dfrac{F}{m} = \dfrac{6}{0.5}$ 12 m/s^2

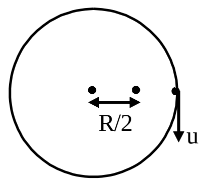
so $V_{min} = \sqrt{5g_{eff}\,\ell} = \sqrt{5\times 12\times(60\times 10^{-2})}$

so V_{min} = 6 m/sec

Q.5 A small bead of mass m can move on a smooth circular wire (radius R) under the action of a force $F = \frac{Km}{r^2}$ directed (r = position of bead from P & K = constant) towards a point P within the circle at a distance R/2 from the centre. What should be the minimum velocity (in m/s) of bead at the point of the wire nearest the centre of force (P) so that bead will complete the circle (Take $\frac{k}{3R}$ = 8 unit)



Sol.[8] $U = -\int \vec{F}.\vec{dr}$



$U = -\frac{km}{r}$

$K_i + U_i = K_f + U_f$

$$\frac{1}{2}mv^2 - \frac{Km}{\left(\frac{R}{2}\right)} = 0 - \frac{Km}{3R/2}$$

$$\frac{mv^2}{2} = \frac{2Km}{R} - \frac{-2Km}{3R}$$

$$\frac{mv^2}{2} = \frac{4Km}{3R}$$

$$V = \sqrt{\frac{8K}{3R}}, V = 8 \text{ m/s}$$

Q.6 A highway curve with a radius of 750 m is banked properly for a car traveling 120 kph. If a 1590 kg car takes the turn at a speed of 230 kph, how much sideways force must the tires exert against the road if the car does not skid?

Sol. 6230

Q.7 What is the minimum radius of a circle along which a cyclist can ride with a velocity 18 km/hr if the coefficient of friction between the tyres and the road is $\mu = 0.5$ (take $g = 10$ m/s^2)

Sol.[5] $R = \frac{v^2}{\mu g} = \frac{5\times5}{0.5\times10} = 5$ m

Q.1 A particle is moving along a circular path with a constant speed. The acceleration of the particle is constant in -

(A) magnitude

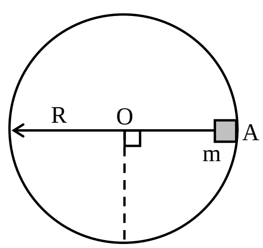
(B) direction

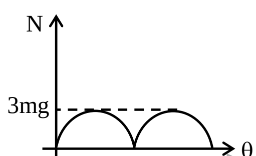
(C) both magnitude and direction

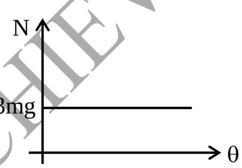
(D) neither magnitude nor direction **[A]**

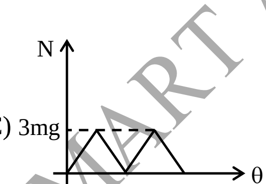
Sol. Only magnitude remain constant and direction changes

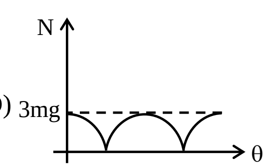
Q. 2 A particle of mass m is released from point A on smooth fixed circular track as shown. If the particle is released from rest at t = 0, then variation of normal reaction N with (θ) angular displacement from initial position is –



(A)


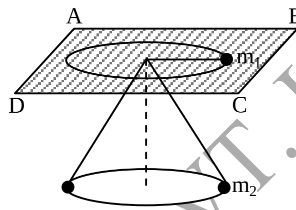
(B)


(C)


(D)


[A]

`**Q.3** ABCD is a smooth horizontal fixed plane on which mass m_1 = 0.1 kg is moving in a circular path of radius r = 1 m. It is connected by an ideal string which is passing through a smooth hole and connects of mass $m_2 = \frac{1}{\sqrt{2}}$ kg at the other end as shown. m_2 also moves in a horizontal circle of same radius of 1 m with a speed of $\sqrt{10}$ m/s. If g = 10 m/s^2 then the speed of m_1 is-

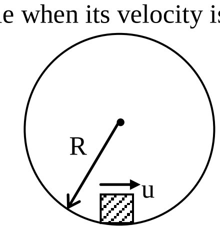


(A) $\sqrt{10}$ m/s (B) 10 m/s

(C) $\frac{1}{\sqrt{10}}$ m/s (D) None of these

[B]

Q.4 A particle is given an initial speed u inside a smooth spherical shell of radius R = 1 m that it is just able to complete the circle. Acceleration of the particle when its velocity is vertical is -



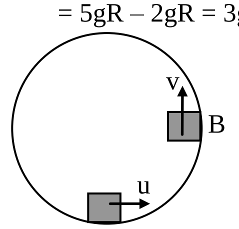
(A) g $\sqrt{10}$ (B) g

(C) g $\sqrt{2}$ (D) 3g **[A]**

Sol. **[A]** $u^2 = 5gR$

$\therefore v^2 = u^2 - 2gR$

$= 5gR - 2gR = 3gR$



Tangential acceleration at B is

$a_t = g$ (downwards)

Centripetal acceleration at B is

$a_C = \frac{v^2}{R} = 3g$

$\therefore$ Total acceleration will be

$a = \sqrt{a_C^2 + a_t^2} = g\sqrt{10}$

Q. 5 A particle moves in x-y plane. The position vector of particle at any time t is $\vec{r} = \{(2t)\hat{i} + (2t^2)\hat{j}\}$ m. The rate of change of θ at time t = 2s. (where θ is the angle which its velocity vector makes with positive x-axis) is

(A) $\frac{2}{17}$ rad/s (B) $\frac{1}{14}$ rad/s

(C) $\frac{4}{7}$ rad/s (D) $\frac{6}{5}$ rad/s

Sol. **[A]**

$x = 2t \quad \Rightarrow V_x = \frac{dx}{dt} = 2$

$y = 2t^2 \quad \Rightarrow v_y = \frac{dy}{dt} = 4t$

$\therefore \quad \tan\theta = \frac{v_y}{v_x} = \frac{4t}{2} = 2t$

Differentiating with respect to time we get,

$(\sec^2\theta)\,\frac{d\theta}{dt} = 2$

or $(1 + \tan^2\theta)\,\frac{d\theta}{dt} = 2$

or $(1 + 4t^2)\,\frac{d\theta}{dt} = 2$

or $\frac{d\theta}{dt} = \frac{2}{1+4t^2}$

$\frac{d\theta}{dt}$ at t = 2 s is $\frac{d\theta}{dt} = \frac{2}{1+4(2)^2} = \frac{2}{17}$ rad/s

Q. 6 A particle is moving in a circular path. The acceleration and momentum of the particle at a certain moment are $\vec{a} = (4\hat{i} + 3\hat{j})$ m/s² and $\vec{p} = (8\hat{i} - 6\hat{j})$ kg-m/s. The motion of the particle is

(A) Uniform circular motion

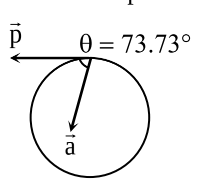
(B) accelerated circular motion

(C) decelerated circular motion

(D) We cannot say anything with $\vec{a}$ and $\vec{p}$ only

Sol. **[B]**

Angle between $\vec{a}$ and $\vec{p}$ is :



$\theta = \cos^{-1}\frac{\vec{a}.\vec{p}}{|\vec{a}||\vec{p}|}$

$= \cos^{-1}\left\{\frac{32-18}{\sqrt{(16+9)}\sqrt{(64+36)}}\right\}$

$= \cos^{-1}\left(\frac{14}{50}\right)$

θ = 73.73°

Since 0° < 90°, the motion is an acceleration one.

Q.7 A stone hanging from a massless string of length 15 m is projected horizontally with speed 147 m/s. Then the speed of the particle at the point where tension in string equals the weight of particle is –

(A) 10 m/s (B) 7 m/s

(C) 12 m/s (D) None of these

Sol. **[B]**

$T - mg\cos\theta = \frac{mv^2}{\ell}$ and $v^2 - u^2 = -2g\ell\,(1 - \cos\,\theta)$

also T = mg

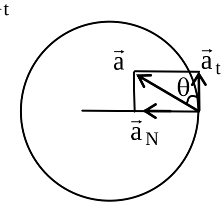
Q. 8 A point on the periphery of rotating disc has its acceleration vector making on angle 30º with velocity vector then the ration of magnitude of centripetal acceleration to tangential acceleration is -

(A) sin30º (B) cos 30º

(C) tan 30º (D) None of these

Sol. **[C]**

$\tan\theta = \frac{a_N}{a_t}$



Q.9 Check up the only correct statement in the following-

(A) A body has a constant velocity and still it can have a varying speed

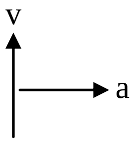
(B) A body has a constant speed but it can have a varying velocity

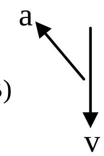
(C) A body having constant speed cannot have any acceleration

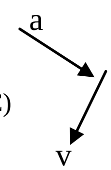
(D) A body in motion under a force acting upon it must always have work done upon it

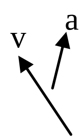
[B]

Q.10 Shown here are the velocity and acceleration vectors for an object in several different types of motion. In which case is the object slowing down and turning to the right ?

(A) 

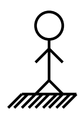
(B) 

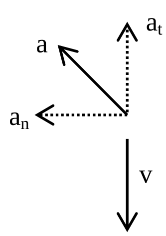
(C) 

(D) 

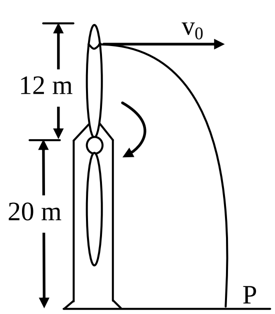
[B]

Sol. From observer point of view a_t decreases v and a_n makes the path of object curved turning to the right.





`Q.11 A wind farm generator uses a two-bladed propeller mounted on a pylon at a height of 20 m. The length of each propeller blade is 12 m. A tip of the propeller breaks off when the propeller is vertical. At that instant, the period of the motion of the propeller is 1.2 second. The fragment files off horizontally, falls and strikes the ground at point P.

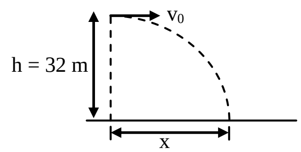


In figure, the distance from the base of the pylon to the point where the fragment strikes the ground is closest to -

(A) 120 m (B) 130 m

(C) 140 m (D) 160 m **[D]**

Sol.



$x = v_0 t$

$h = \frac{1}{2} gt^2$

$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2 \times 32}{10}} = \frac{8}{\sqrt{10}}$

$v_0 = \omega r = \frac{2\pi}{T} \times 12 = \frac{2\pi}{1.2} \times 12 = 20\pi$

$x = 20\pi \times \frac{8}{\sqrt{10}} = \frac{160 \times 3.14}{3.162}$

$x = 160$ m

Q.12 A circular disc of radius r = 5 m is rotating in horizontal plane about y-axis. y-axis a vertical axis passing through the centre of disc and x-z is the horizontal plane at ground. The height of disc above ground is h = 5 m. Small particles are ejecting from disc in horizontal direction with speed 12 m/s from the circumference of disc then the distance of these particles from origin when they hits x – z plane is -

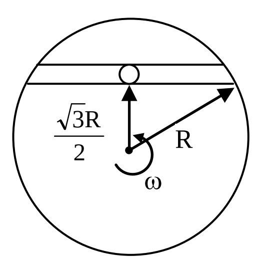
(A) 5 m (B) 12 m

(C) 13 m (D) None of these **[C]**

Sol. $R = u\sqrt{\frac{2h}{g}} = 12\sqrt{\frac{2 \times 5}{10}} = 12$ m

$\therefore$ Distance from origin = $\sqrt{5^2 + (12)^2} = 13$ m

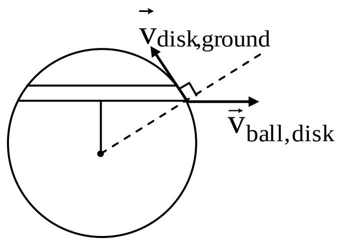
Q.13 A horizontal disk is rotating with angular velocity 'ω' about a vertical axis passing through its centre. A ball is placed at the centre of groove and pushed slightly. The velocity of ball when it comes out of the groove –

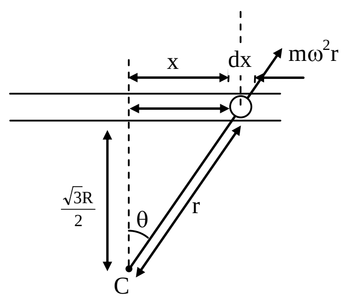


(A) $\frac{\sqrt{3}}{2}\omega R$ (B) $\frac{\omega R}{2}$

(C) ωR (D) $\frac{\omega R}{\sqrt{2}}$ **[A]**

Sol. Let us consider motion of ball with respect to disk





Net force along groove $= m\omega^2 r \sin\theta$

$= m\omega^2 r\, \frac{x}{r}$

$= m\omega^2 x$

$\therefore \quad ma = m\omega^2 x$

$\Rightarrow v\,\frac{dv}{dx} = \omega^2 x$

$\Rightarrow \quad v = \frac{\omega R}{2}$

$\vec{v}_{Ball,Ground} = \vec{v}_{Ball,Disk} + \vec{v}_{Ball,Ground}$

$\therefore \quad \vec{v}_{Ball,Ground}$

$$= \left\{(\omega R)^2 + \left(\frac{\omega R}{2}\right)^2 + 2(\omega R)\left(\frac{\omega R}{2}\right)\cos 120°\right\}^{\frac{1}{2}}$$

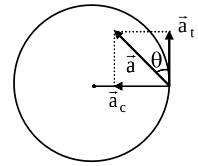
$$= \frac{\sqrt{3}}{2}\omega R$$

Q.14 A particle is moving in a circular path and its acceleration vector is making an angle of 30° with the velocity vector, then the ratio of centripetal acceleration to its tangential acceleration is –

(A) $\frac{1}{2}$ (B) $\frac{\sqrt{3}}{2}$

(C) $\frac{1}{\sqrt{3}}$ (D) $\sqrt{3}$ **[C]**

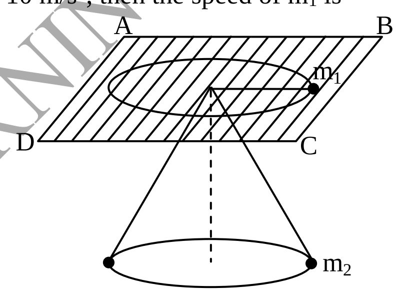
Sol.



$\tan\theta = \frac{a_c}{a_t}$

$\therefore \quad \frac{a_c}{a_t} = \tan 30° = \frac{1}{\sqrt{3}}$

Q. 15 ABCD is a smooth horizontal fixed plane on which mass $m_1 = 0.1$ kg is moving in a circular path of radius 1 m. It is connected by an ideal string which is passing through a smooth hole and connects mass $m_2 = \frac{1}{\sqrt{2}}$ kg at the other end as shown. m_2 also moves in a horizontal circle of same radius of 1 m with a speed of $\sqrt{10}$ m/s. If g = 10 m/s^2, then the speed of m_1 is –

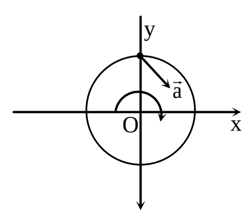


(A) $\sqrt{10}$ m/s (B) 10 m/s

(C) $\frac{1}{\sqrt{10}}$ m/s (D) None of these **[B]**

Sol. $T = m_2\sqrt{g^2 + \left(\frac{v_2^2}{r}\right)^2} = \frac{m_1 v_1^2}{r}$

Q.16 A body is moving is x-y plane as shown in a circular path of radius 2 m. At a certain instant when the body is crossing the positive y-axis its acceleration is $(6\hat{i} - 8\hat{j})$ m/s^2. Then its angular acceleration and angular velocity at this instant will be -



(A) $-\,3\hat{k}$ rad/s^2 and $-2\hat{k}$ rad/s respectively

(B) $+3\hat{k}$ rad/s^2 and $+2\hat{k}$ rad/s respectively

(C) $-4\hat{k}$ rad/s^2 and $-\sqrt{3}\hat{k}$ rad/s respectively

(D) $+4\hat{k}$ rad/s^2 and $+\sqrt{3}\hat{k}$ rad/s respectively

[A]

Sol. $\vec{a} = 6\hat{i} - 8\hat{j}$

$\therefore$ $a_r = 8$ and $a_t = 6$

$r\omega^2 = 8$ and $r\alpha = 6$

Q.17 Position vector of a particle moving in x-y plane at time t is $\vec{r} = a\,(1 - \cos \omega t)\ \hat{\mathbf{i}} + a \sin \omega t\ \hat{\mathbf{j}}$. The path of the particle is :

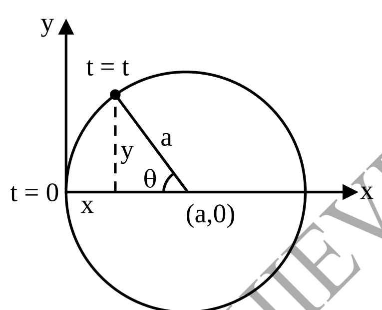
(A) a circle of radius **a** and centre at (a, 0)

(B) a circle of radius **a** and centre at (0, 0)

(C) an ellipse

(D) neither a circle nor an ellipse **[A]**

Sol. Particle is moving in a circle of radius **a** and centre (a, 0) with constant angular velocity ω. At time t = 0 particle is at origin and it starts rotating clockwise. At time t it has rotated an angle θ given by :



$\theta = \omega t$

$y = a \sin \theta = a \sin \omega t$

and $x = a - a \cos \theta = a\,(1 - \cos \omega t)$

$\therefore\ \vec{r} = a\,(1 - \cos \omega t)\ \hat{\mathbf{i}} + a \sin \omega t\ \hat{\mathbf{j}}$

Q.18 A simple pendulum consisting of a mass M attached in a string of length L is released from rest at an angle **α**. A pin is located at a distance ***l*** below the pivot point. When the pendulum swings down, the string hits the pin as shown in the figure. The maximum angle θ which string makes with the vertical after hitting the pin is –

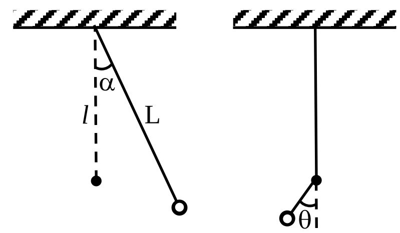


Fig.

(A) $\cos^{-1}\left[\dfrac{L\cos\alpha + l}{L + l}\right]$

(B) $\cos^{-1}\left[\dfrac{L\cos\alpha + l}{L - l}\right]$

(C) $\cos^{-1}\left[\dfrac{L\cos\alpha - l}{L - l}\right]$

(D) $\cos^{-1}\left[\dfrac{L\cos\alpha - l}{L + l}\right]$ **[C]**

Sol. At the bottom most point, square of speed of bob,

$v^2 = 2\,gL(1 - \cos \alpha)$

It will rise further to a height,

$h = \dfrac{v^2}{2g} = L(1 - \cos \alpha)$

or $(L - l)\,(1 - \cos \theta) = L(1 - \cos \alpha)$

$\therefore\ \theta = \cos^{-1}\left[\dfrac{L\cos\alpha - l}{L - l}\right]$

Q.19 A stone tied to a string of length L is whirled in a vertical circle with the other end of the string at the centre. At a certain instant of time, the stone is at its lowest position, and has a speed **u**. The magnitude of the change in its velocity as it reaches a position where the string is horizontal is –

(A) $\sqrt{u^2 - 2gL}$ (B) $\sqrt{2gL}$

(C) $\sqrt{u^2 - gL}$ (D) $\sqrt{2(u^2 - gL)}$

[D]

Sol. From energy conservation

$v^2 = u^2 - 2gL$ … (1)

Now since the two velocity vectors shown in figure are mutually perpendicular, hence the magnitude of change of velocity will be given by

$|\Delta \vec{v}| = \sqrt{u^2 + v^2}$

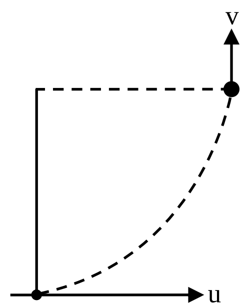


Fig.

Substituting value of v^2 from Eq. (1)

$$|\Delta \vec{v}| = \sqrt{u^2 + u^2 - 2gL}$$

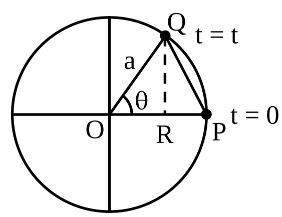
$$|\Delta \vec{v}| = \sqrt{2(u^2 - gL)}$$

Q.20 The magnitude of displacement of a particle moving in a circle of radius a with constant angular speed ω varies with time t as –

(A) $2a \sin \omega t$ (B) $2a \sin \frac{\omega t}{2}$

(C) $2a \cos \omega t$ (D) $2a \cos \frac{\omega t}{2}$ **[B]**

Sol. In time t particle has rotated an angle $\theta = \omega t$. Displacement

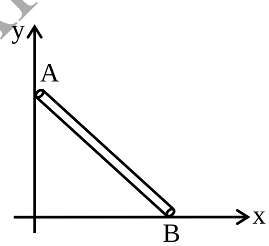


$$s = PQ = \sqrt{QR^2 + PR^2}$$

$$= \sqrt{(a \sin \omega t)^2 + (a - a \cos \omega t)^2}$$

$$s = 2a \sin \frac{\omega t}{2}$$

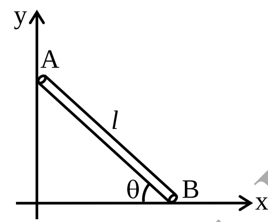
Q.21 A rigid rod leans against a vertical wall (y-axis) as shown in figure. The other end of the rod is on the horizontal floor. Point A is pushed downwards with constant velocity. Path of the centre of the rod is –



(A) a straight line passing through origin
(B) a straight line not passing through origin
(C) a circle of radius $l/2$ and centre at origin
(D) a circle of radius $l/2$ but centre not at origin

[C]

Sol. Let l be the length of the rod and θ the angle of rod with x-axis (horizontal) at some instant of time. Co-ordinates of the centre of rod at this instant of time are



$$x = \frac{l}{2} \cos \theta$$

and $$y = \frac{l}{2} \sin \theta$$

Squaring and adding Eqs. (1) and (2), we get:

$$x^2 + y^2 = \frac{l^2}{4}$$

Which is an equation of a circle of radius $\frac{l}{2}$ and centre at origin.

Q.22 A solid body rotates about a stationary axis so that its angular velocity depends on the rotation angle ϕ as $\omega = \omega_0 - k\phi$, where ω_0 and k are positive constants. At the moment t = 0, the angle $\phi = 0$. Find the time dependence of rotation angle-

(A) $K.\ \omega_0 e^{-kt}$ (B) $\frac{\omega_0}{K}\ [e^{-kt}]$

(C) $\frac{\omega_0}{K}\ [1 - e^{-kt}]$ (D) $\frac{K}{\omega_0}\ [e^{-kt} - 1]$

[C]

Q.23 A point moves along a circle with velocity v = at where a = 0.5 m/sec^2. Then the total acceleration of the point at the moment when it covered $(1/10)^{th}$ of the circle after beginning of motion-

(A) 0.5 m/sec^2 (B) 0.6 m/sec^2

(C) 0.7 m/sec^2 (D) 0.8 m/sec^2 **[D]**

Q.24 Two cars having masses m_1 and m_2 move in circles of radius r_1 and r_2. If they complete the circle in equal time. The ratio of their angular speeds ω_1/ω_2 is-

(A) $\frac{m_1}{m_2}$ (B) $\frac{r_1}{r_2}$

(C) $\frac{m_1 r_1}{m_2 r_2}$ (D) 1 **[D]**

Q.25 When a particle moves in a circle with a uniform speed -

(A) its velocity and acceleration are both constants

(B) its velocity is constant but the acceleration changes

(C) its acceleration is constant but the velocity changes

(D) its velocity and acceleration both change **[D]**

Q.26 A stone of mass m tied to a string of length ℓ is rotated in a circle with the other end of the string as the centre. The speed of stone is v. If the string breaks, the stone will move -

(A) towards centre (B) away from centre

(C) along tangent (D) will stop **[C]**

Q.27 Angular position of a line of a disc of radius r = 6 cm is given by $\theta = 10 - 5t + 4t^2$ rad. the average angular speed between 1 and 3 s is-

(A) π rad/s (B) 11 rad/s

(C) 22 rad/s (D) 5.5 rad/s **[B]**

Q.28 In the above question linear speed of a point on the rim at 2s is-

(A) 0.33 m/s (B) 0.66 m/s

(C) 1 m/s (D) 1.32 m/s **[B]**

Q.29 At t = 0 a fly wheel is rotating at 50 rpm. A motor gives it a constant angular acceleration of 0.5 rad/s^2 until it reaches 100 rpm. the motor is then disconnected. How many revolutions are completed at t = 20 s ?

(A) 25 rev (B) 29 rev

(C) 20 rev (D) 15 rev **[B]**

Q.30 A 30 cm diameter turn table starts from rest and takes 2 s to reach its final rotation rate of 33.5 rpm; the angular acceleration is-

(A) 1.75 rad/s^2 (B) 1.25 rad/s^2

(C) 2 rad/s^2 (D) 1 rad/s^2 **[A]**

Q.31 A stone is moved round a horizontal circle with a 20 cm long string tied to it. If centripetal acceleration is 9.8 m/s^2, then its angular velocity will be-

(A) 7 rad/s (B) 22/7 rad/s

(C) 49 rad/s (D) 14 rad/s **[A]**

Q.32 A car is moving in a circular path of radius 500m with a speed of 30m/sec. If its speed is increasing at the rate of 2m/sec^2, the resultant acceleration will be -

(A) 2 m/sec^2 (B) 2.5 m/sec^2

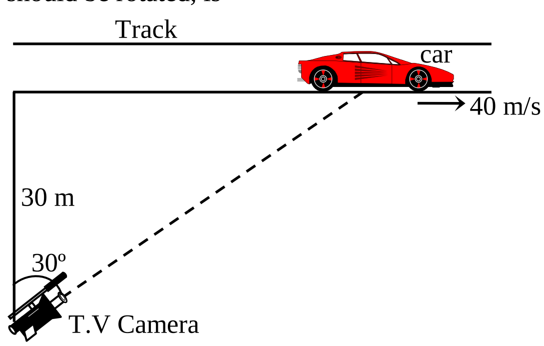
(C) 2.7 m/sec^2 (D) 4 m/sec^2 **[C]**

Q.33 An electric fan has blades of length 30 cm as measured from the axis of rotation. If the fan is rotating at 1200 r.p.m. The acceleration of a point on the tip of the blade is about-

(A) 1600 m/sec^2 (B) 4740 m/sec^2

(C) 2370 m/sec^2 (D) 5055 m/sec^2 **[B]**

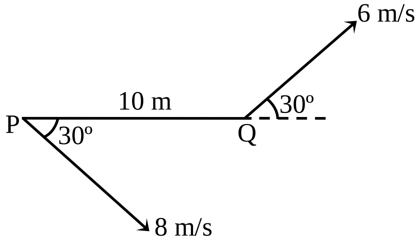
Q.34 A racing car is travelling along a track at a constant speed of 40 m/s. A T.V. camera men is recording the event from a distance of 30m directly away from the track as shown in figure. In order to keep the car under view in the position shown, the angular speed with which the camera should be rotated, is-



(A) 4/3 rad/sec (B) 3/4 rad/sec

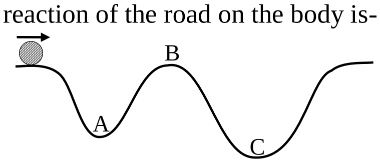
(C) $8/3\sqrt{3}$ rad/sec (D) 1 rad/sec **[B]**

`Q.35 Two moving particles P and Q are 10 m apart at a certain instant. The velocity of P is 8m/s making an angle 30º with the line joining P and Q and that of Q is 6m/s making an angle 30º with PQ as shown in the figure. Then angular velocity of P with respect to Q is-



(A) Zero (B) 0.1 rad/sec
(C) 0.4 rad/sec (D) 0.7 rad/sec **[D]**

Q.36 A body moves along an uneven horizontal road surface with constant speed at all points. The normal reaction of the road on the body is-



(A) Maximum at A
(B) Maximum at B
(C) Minimum at C
(D) The same at A,B and C **[A]**

Q.37 A particle of mass m rotates in a circle of radius a with a uniform angular speed ω. It is viewed from a frame rotating about the Z-axis with a uniform angular speed ω_o. The centrifugal force on the particle is-

(A) $m\omega^2 a$ (B) $m\omega_0^2 a$

(C) $m\left(\frac{\omega+\omega_0}{2}\right)^2 a$ (D) $m\omega\,\omega_o\, a$ **[B]**

Q.38 A uniform circular ring of mass per unit length λ and radius R is rotating with angular velocity ω about its own axis in a gravity free space. Tension in the ring is-

(A) Zero (B) $\frac{1}{2}\lambda R^2 \omega^2$

(C) $\lambda R^2 \omega^2$ (D) $\lambda R \omega^2$ **[C]**

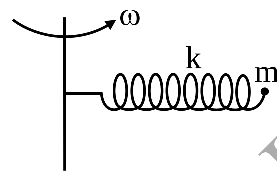
Q.39 A uniform rod of mass m and length ℓ rotates in a horizontal plane with an angular velocity ω about a vertical axis passing through one end. The tension in the rod at distance x from the axis is-

(A) $\frac{1}{2}m\omega^2 x$ (B) $\frac{1}{2}m\omega^2\frac{x^2}{\ell}$

(C) $\frac{1}{2}m\omega^2\ell\left(1-\frac{x^2}{\ell}\right)$ (D) $\frac{1}{2}\cdot\frac{m\omega^2}{\ell}[\ell^2-x^2]$

[D]

Q.40 A particle of mass m is fixed to one end of a light spring of force constant k and unstretched length ℓ. The system is rotated about the other end of the spring with an angular velocity ω, in gravity free space. The increase in length of the spring will be-



(A) $\frac{m\omega^2\ell}{k}$ (B) $\frac{m\omega^2\ell}{k-m\omega^2}$

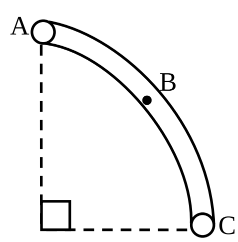
(C) $\frac{m\omega^2\ell}{k+m\omega^2}$ (D) None of these **[B]**

Q.41 A railway track is banked for a speed v, by making the height of the outer rail (h) higher than that of the inner rail. The distance between the rails is d. The radius of curvature of the track is r-

(A) $\frac{h}{d}=\frac{v^2}{rg}$ (B) $\tan\left(\sin^{-1}\frac{h}{d}\right)=\frac{v^2}{rg}$

(C) $\tan^{-1}\left(\frac{h}{d}\right)=\frac{v^2}{rg}$ (D) $\frac{h}{r}=\frac{v^2}{dg}$ **[A]**

Q.42 The tube AC forms a quarter circle in a vertical plane. The ball B has an area of cross-section slightly smaller than that of the tube, and can move without friction through it. B is placed at A and displaced slightly. It will-



(A) always be in contact with the inner wall of the tube
(B) always be in contact with the outer wall of the tube
(C) initially be in contact with the inner wall and later with the outer wall
(D) initially be in contact with the outer wall and later with the inner wall **[C]**

Q.43 A particle is acted upon by a constant force always normal to the direction of motion of the particle. It is therefore inferred that-

(i) Its velocity is constant

(ii) It moves in a straight line

(iii) Its speed is constant

(iv) It moves in circular path

(A) i , iv (B) iii, iv

(C) i, ii (D) i, ii, iii **[B]**

Q.44 A particle of mass m is observed from an inertial frame of reference and is found to move in a circle of radius r with a uniform speed v. The centrifugal force on it is-

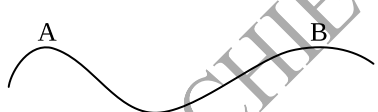
(A) $\frac{mv^2}{R}$ towards centre

(B) $\frac{mv^2}{R}$ away from centre

(C) $\frac{mv^2}{R}$ along tangent

(D) zero **[D]**

Q.45 A car moves at a constant speed on a road as shown in figure. The normal force by the road on the car is N_A and N_B when it is at the points A and B -



(A) $N_A = N_B$

(B) $N_A > N_B$

(C) $N_A < N_B$

(D) insufficient information **[C]**

Q.46 A motorcycle is going on an over bridge of radius R. The driver maintain a constant speed. As the motorcycle is ascending on the over bridge, the normal force on it -

(A) increases (B) decreases

(C) remains same (D) fluctuates **[A]**

Q.47 A rod of length L is pivoted at one end and is rotated with a uniform angular velocity in a horizontal plane. Let T_1 and T_2 be the tension at the points L/4 and 3L/4 away from the pivoted ends, then-

(A) $T_1 > T_2$

(B) $T_2 > T_1$

(C) $T_1 = T_2$

(D) inadequate information **[A]**

Q.48 Let θ denote the angular displacement of a simple pendulum oscillating in a vertical plane. If the mass of the bob is m. The tension in the string is mg cos θ -

(A) always (B) never

(C) at extreme position (D) at mean position

[C]

Q.49 Water in a bucket is whirled in a vertical circle with a string attached to it. The water does not fall down even when the bucket is inverted at the top of its path. We conclude that-

(A) $mg = \frac{mv^2}{R}$ (B) $mg > \frac{mv^2}{R}$

(C) $mg < \frac{mv^2}{R}$ (D) none of these **[C]**

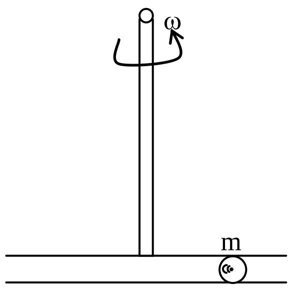
Q.50 Three identical cars A, B and C are moving at the same speed on three bridges. The car A goes on plane bridge. B on a bridge convex upwards and car C on a bridge concave upwards. Let F_A, F_B and F_C be the normal forces exerted by the cars on the bridges when they are at the middle of bridge -

(A) F_A is maximum (B) F_B is maximum

(C) F_C is maximum (D) $F_A = F_B = F_C$ **[C]**

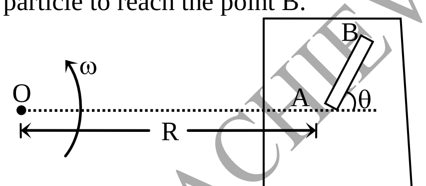
PHYSICS

Q.1 A particle of mass m is constrained to move along a smooth groove which is being rotated about a vertical axis through its centre with a constant angular velocity ω. If it starts at a distance R from the axis at t = 0, find its velocity relative to the groove when it is at a distance r from the centre



Sol. $v = \omega\sqrt{r^2 - R^2}$

Q.2 A table with smooth horizontal surface is fixed in a cabin that rotates with a uniform angular velocity ω in a circular path of radius R. A smooth groove AB of length L<<R is made on the surface of the table. The groove makes an angle θ with the radius OA of the circle in which the cabin rotates. A small particle is kept at the point A in the groove and is released to move along AB. Find the time taken by the particle to reach the point B.



Ans. $\sqrt{\dfrac{2L}{\omega^2 R\cos\theta}}$

Q.3 A chain of mass m forming a circle of radius R is slipped on a smooth round cone with half-angle θ. Find the tension of the chain if it rotates with a constant angular velocity ω about a vertical axis coinciding with the symmetry axis of the cone.

Ans. $T = \left[\cot\theta + \dfrac{R\omega^2}{g}\right]\dfrac{mg}{2\pi}$

Q.4 A car goes on a horizontal circular road of radius R, the speed increasing at a constant rate $\dfrac{dv}{dt} = a$. The friction coefficient between the road and the tyre is μ. Find the speed at which the car will skid.

Sol. $[(\mu^2 g^2 - a^2)R^2]^{1/4}$

Q.5 A person stands on a spring balance at the equator. **(a)** By what fraction is the balance reading less than his true weight ? **(b)** If the speed of earth's rotation is increased by such an amount that the balance reading is half the true weight, what will be the length of the day in this case ?

Sol. (a) 3.5×10^{-3} (b) 2.0 hrs.

Q.6 A particle is projected with a speed u at angle θ with the horizontal. Consider a small part near the highest position and take it approximately to be a circular arc. What is the radius of this circle ? This radius is called the radius of curvature of the curve at the point.

Sol. $\dfrac{u^2\cos^2\theta}{g}$

Q.7 A particle moves in a circle of radius 1.0 cm at a speed given by v = 2.0 t where v is in cm/s and t in second.

(a) Find the radial acceleration of the particle at t = 1 s.

(b) Find the tangential acceleration at t = 1 s.

(c) Find the magnitude of the acceleration at t = 1 s.

Ans. (a) 4.0 cm/s^2 (b) 2.0 cm/s^2 (c) $\sqrt{20}$ cm/s^2

Q.8 A spaceman in training is rotated in a seat at the end of horizontal rotating arm of length 5 m. If he can withstand acceleration up to 9 g, what is the maximum number of revolutions per second permissible ? Take g = 10 m/s^2

Ans. 0.675 rev/s

Q.9 A small sphere of mass 1g is attached to a rubber cord of initial length 50 cm and rotated in a horizontal plane uniformly at the rate of 600 rev min^{-1}. Find the length of the cord at this speed and the tension along it. Given that a force of 50 gf stretches the rubber cord by 1 cm $g = 980$ cm s^{-2}.

Ans. 54.44 cm, 217.7×10^4 dyne

Q.10 A stone is fastened to one end of a string and is whirled in a vertical circle of radius R. Find the minimum speed the stone can have at the highest point of the circle.

Ans. $\sqrt{Rg}$

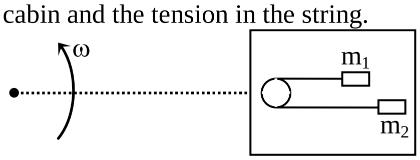
Q.11 A circular automobile test track has a radius of 200 m. The track is so designed that when a car travels at a speed of 100 kilometer per hour, the force between the automobile and the track is normal to the surface of track. Find the angle of the bank.

Ans. 21º29'

Q.12 Two bodies A and B separated by a distance 2 R are moving counterclockwise along the circular path of radius R each with uniform speed v. At time t = 0; A is given a constant tangential acceleration $a = \dfrac{72v^2}{25\pi R}$. Find (i) the time lapse for the two bodies to collide; (ii) the angle covered by A; (iii) angular velocity of A; (iv) radial acceleration of A at this time.

Ans. (i) $\dfrac{5\pi R}{6v}$ sec, (ii) $\dfrac{11\pi}{6}$ (iii) $\dfrac{17v}{5R}$ (iv) $\dfrac{289v^2}{25R^2}$

Q.13 A table with smooth horizontal surface is placed in a cabin which moves in a circle of a large radius R. A smooth pulley of small radius is fastened to the table. Two masses of m and 2m are placed on the table connected through a string going over the pulley. Initially the masses were at rest. Find the magnitude of the initial acceleration of the masses as seen from the cabin and the tension in the string.



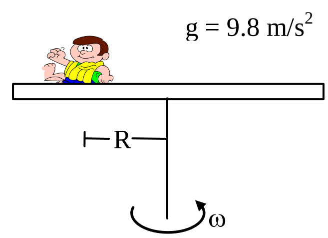
Ans. $\dfrac{\omega^2 R}{3}$, $\dfrac{4}{3}m\omega^2 R$

Q.14 A spring which obeys Hooke's law is found to be extended by one centimetre when a mass is hung on it. It extends by three more centimetre when the attached mass is moving uniformly in a horizontal circle making two revolutions per second. Find the inclination of the spring to the vertical, the length of the unstretched spring and the radius of the circle.

Ans. $\cos^{-1}(0.25)$, 20.5 cm, 23.72 cm

Q.15 In an amusement park there is a rotating horizontal disk. A child can sit on it at any radius (Shown in figure). As the disk begins to "speed up", the child may slide off if the frictional force is insufficient. The mass of the child is 50 kg and the coefficient of friction is 0.4. The angular velocity is 2 rad/s. What is the maximum radius R where he can sit and still remain on the disk ?

Sol.



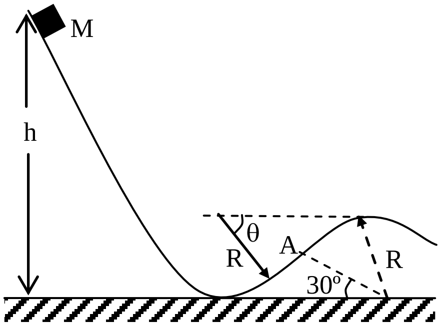
Under the critical circumstance that the child just starts to slide,

$mR\omega^2 = \mu mg$.

Hence $R = \dfrac{\mu g}{\omega^2} = \dfrac{0.4 \times 9.8}{2^2} = 0.98$ m

As the centrifugal force is proportional to the radius, this is the maximum radius for no-sliding.

Q.16 A mass **M** slides without friction on the roller coaster track shown in figure. The curved sections of the track have radius of curvature R. The mass begins its descent from the height **h**. At some value of h, the mass will begin to lose contact with the track. Indicate on the diagram where the mass loses contact with the track and calculate the minimum value of **h** for which happens.



Sol. Before the inflection point A of the track, the normal reaction of track on the mass N, is

$$N = \frac{mv^2}{R} + mg\sin\theta,$$

Where v is the velocity of the mass. After the inflection point,

$$N + \frac{mv^2}{R} = mg\sin\theta,$$

For which $\sin\theta = \frac{R}{2R}$, or $\theta = 30º$.

The mass loses contact with the track if $N \le 0$. This can only happen for the second part of the track and only if

$$\frac{mv^2}{R} \ge mg\sin\theta$$

The conservation of mechanical energy

$$Mg[h-(R-R\sin\theta)] = \frac{1}{2}mv^2$$

Then requires

$$h - R + R\sin\theta \ge \frac{R\sin\theta}{2},$$

or $$h \ge R - \frac{R\sin\theta}{2}$$

The earliest the mass can start to lose contact with the track is at A for which $\theta = 30º$. Hence the minimum h required is $\mathbf{\frac{3R}{4}}$.

Q.17 A small mass **m** rests at the edge of a horizontal disk of radius **R**, the coefficient of static friction between the mass and the disk is **μ**. The disk is rotated about its axis at an angular velocity such that the mass slides off the disk and lands on the floor **h** meters below. What was its horizontal distance of travel from the point that is left the disk ?

Sol. The maximum static friction between the mass and the disk is **f = μmg**. When the small mass slides off the disk, its horizontal velocity **v** is given by

$$\frac{mv^2}{R} = \mu mg$$

Thus $v = \sqrt{\mu Rg}$.

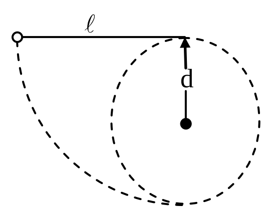
The time required to descend h from rest is

$$t = \sqrt{\frac{2h}{g}}$$

Therefore the horizontal distance of travel before landing on the floor is equal to

$$\mathbf{vt = \sqrt{2\mu Rh}}$$

Q.18 A pendulum of mass **m** and length ℓ is released from rest in a horizontal position. A nail a distance **d** below the pivot causes the mass to move along the path indicated by the doted line. Find the minimum distance **d** in terms of ℓ such that the mass will swing completely round in the circle shown in figure..



Sol. Take the mass m as a point mass. At the instant when the pendulum collides with the nail, m has a velocity $\mathbf{v = \sqrt{2g\ell}}$. The angular momentum of the mass with respect to the point at which the nail locates is conserved during the collision. Then the velocity of the mass is still **v** at the instant after the collision and the motion thereafter is such that the mass is constrained to rotate around the nail. Under the critical condition that the mass can just swing completely round in a circle, the gravitational force when the mass is at the top of the circle. Let the velocity of the mass at this instant be $\mathbf{v_1}$, and we have

$$\frac{mv_1^2}{\ell - d} = mg,$$

or $\quad v_1^2 = (\ell - d)g.$

The energy equation

$$\frac{mv^2}{2} = \frac{mv_1^2}{2} + 2mg(\ell - d),$$

or $\quad 2g\ell = (\ell - d)g + 4(\ell - d)g$

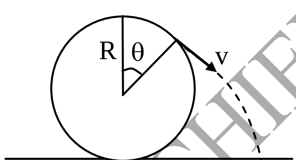
then gives the minimum distance as

$$\mathbf{d = \frac{3\ell}{5}}.$$

Q.19 Find the acceleration of the moon with respect to the earth from the following data: Distance between the earth and the moon = 3.85×10^5 km and the time taken by the moon to complete one revolution around the earth = 27.3 day.

Ans. 2.73×10^{-3} m/s^2

Q.20 A smooth sphere rests on a horizontal plane. A point particle slides frictionlessly down the sphere, starting at the top. Let **R** be the radius of the sphere. Describe the particle's path up to the time it strikes the plane.



Sol. A shown in fig. conservation of energy gives

$$\frac{1}{2}mv^2 = mg\,R\,(1 - \cos\theta).$$

The radial force the sphere exerts on the particle is

$$F = mg\cos\theta - \frac{mv^2}{R}.$$

When F = 0, the constraint vanishes and the particle leaves the sphere. At this instant, we have $\quad \frac{v^2}{R} = g\cos\theta,$

$$v^2 = 2gR\,(1 - \cos\theta)$$

giving $\quad \cos\theta = \frac{2}{3}, \quad$ or $\quad q = 48.2^o,$

$$v = \sqrt{\frac{2gR}{3}}.$$

The particle leaves the sphere with a speed $v = \sqrt{2gR/3}$ at an angle $\theta = 48.2^o$. After leaving the sphere **the particle follows a parabolic trajectory until it hits the plane.**