Circular Motion

Question1

A stone of mass ' m ' kg is tied to a string of length ' L ' m and moved in a vertical circle of radius 49 cm in a vertical plane. If it completes 30 revolutions per minute, the tension in the string when it is at the lowermost point is nearly [Take $\pi^2 = 10$ and acceleration due to gravity, $\mathrm{g} = 10 \mathrm{~m/s^2}$]

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Options:

A.

$(90 \mathrm{~m}) \mathrm{N}$

B.

$(60 \mathrm{~m}) \mathrm{N}$

C.

$(45 m) \mathrm{N}$

D.

$(15 m) \mathrm{N}$

Answer: D

Solution:

Tension in the string at the lowermost point is given by

$$T = mg + m\omega^2 r = m\{g + 4\pi^2 n^2 r\} \quad \ldots.[\omega = 2\pi n]$$

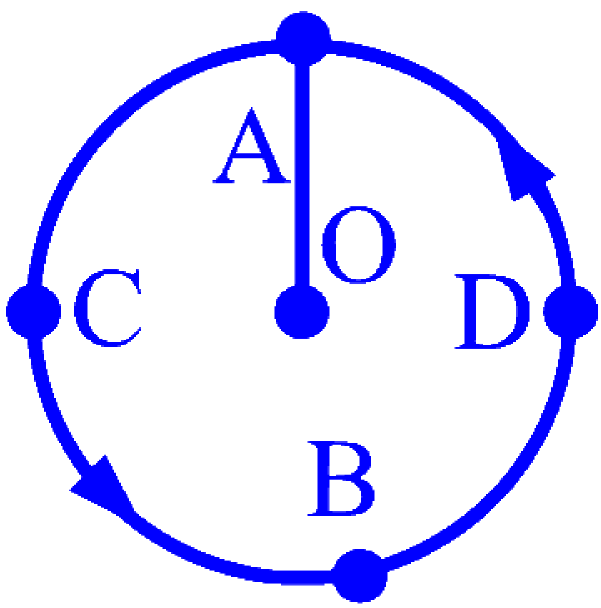
$$T = m\left[g + \left(4\pi^2\left(\frac{n}{60}\right)^2 r\right)\right] = m\left[g + \left(\frac{\pi^2 n^2 r}{900}\right)\right]$$

$$T = m\left[10 + \left(\frac{10 \times 30^2 \times 0.49}{900}\right)\right] = (15m)N$$

Question2

A point mass ' m ' attached at one end of a massless, inextensible string of length ' l ' performs a vertical circular motion and the string rotates in vertical plane, as shown in the diagram. The increase in the centripetal acceleration of the point mass when it moves from point A to point C is

[g = acceleration due to gravity.]



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Options:

A. 3 g

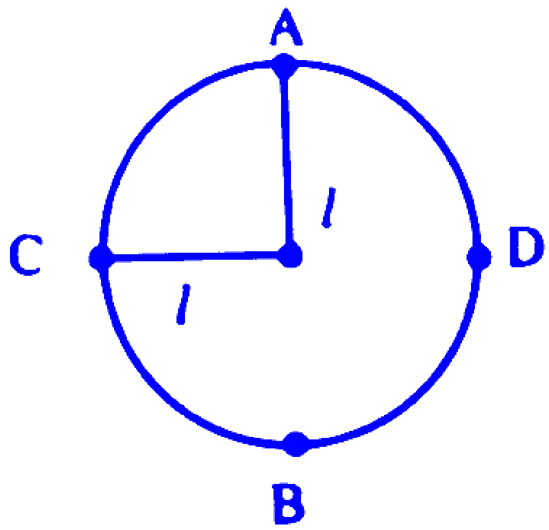
B. 2 g

C. g

D. $\frac{g}{2}$

Answer: B

Solution:



By Conservation of energy,

$$KE_A + PE_A = KE_C + PE_C$$

$$\therefore \quad 2mgl = \frac{1}{2}mv_c^2 + mgl \quad \ldots(\because \text{At A}, v_A = 0)$$

$$\therefore \quad v_C^2 = 2gl$$

We know,

Centripetal acceleration $= \frac{v^2}{r}$

$\ldots(r = \text{radius of circular motion })$

$\therefore$ At point A ,

$a_A = \frac{v_A^2}{l} \Rightarrow a_A = 0 \ldots(\because v_A = 0)$

$\therefore$ At point C ,

$a_C = \frac{v_C^2}{l} \Rightarrow a_C = 2\text{ g}$

$\therefore$ Increase in the centripetal acceleration of the point mass from point A to point C is 2 g

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Question3

An inextensible string of length ' l ' fixed at one end, carries a mass ' m ' at the other end. If the string makes $\frac{1}{\pi}$ revolutions per second around the vertical axis through the fixed end, the tension in the string is [The string makes an angle θ with the vertical]

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Options:

A. 16 ml

B. 8 ml

C. 4 ml

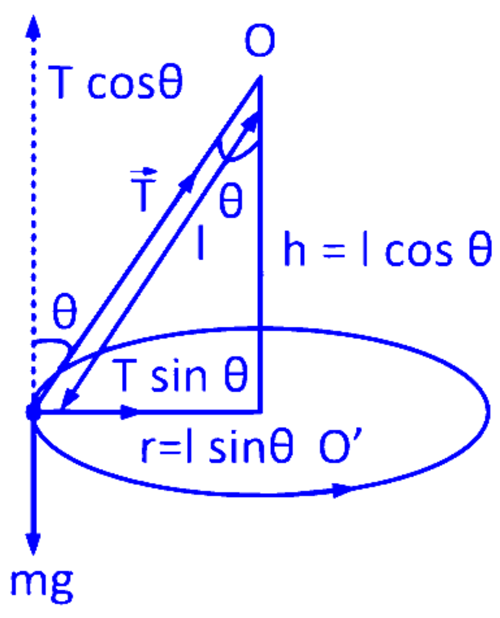
D. 2 ml

Answer: C

Solution:

Given that, $\mathrm{f}=\frac{1}{\pi} \mathrm{rps}$,

$\therefore \quad \omega=2 \pi \mathrm{f}=2 \pi \times \frac{1}{\pi}=2 \mathrm{rad} / \mathrm{s}$



The centripetal force is provided by the horizontal component of the tension i.e., ($T \sin \theta$).

$\therefore \quad \mathrm{T} \sin \theta = m r \omega^2$

But $r = l \sin \theta$ and

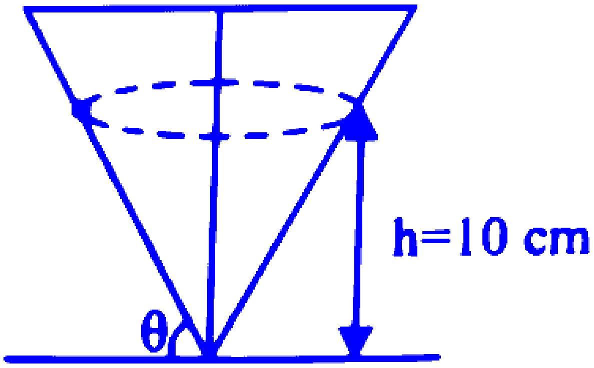
$\omega^2 = 4$

$\therefore \quad T \sin \theta = m \times (l \sin \theta) \times 4$

$\therefore \quad T = 4 m l$

Question4

A particle describes a horizontal circle on smooth inner surface of a cone as shown in figure. If the height of the circle above the vertex is 10 cm . The speed of the particle is $\left(\mathrm{g}\right.$, acceleration due to gravity $\left.= 10 \mathrm{~m} / \mathrm{s}^2\right)$



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Options:

A. $2 \mathrm{~m} / \mathrm{s}$

B. $1.5 \mathrm{~m} / \mathrm{s}$

C. $1 \mathrm{~m} / \mathrm{s}$

D. $0.5 \mathrm{~m} / \mathrm{s}$

Answer: C

Solution:

From figure,

$$N \sin \theta = mg$$

$$N \cos \theta = \frac{mV^2}{R}$$

$$\therefore \quad \tan \theta = \frac{Rg}{V^2}$$

$$\therefore \quad \frac{R}{h} = \frac{Rg}{V^2}$$

$$\therefore \quad h = \frac{V^2}{g}$$

$$\therefore \quad V = \sqrt{hg} = \sqrt{0.1 \times 10} = 1 \mathrm{~m/s}$$

Question5

Two stones of masses m and 3 m are whirled in horizontal circles, the heavier one in a radius $\left(\frac{\mathrm{r}}{3}\right)$ and lighter one in a radius r . The tangential speed of lighter stone is ' n ' times the value of heavier stone. When the magnitude of centripetal force becomes equal the value of n is

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Options:

A. 4

B. 3

C. 2

D. 1

Answer: B

Solution:

We have **two stones**:

- Stone A (lighter): mass = m, radius of circular motion = r, tangential speed = v_A.
- Stone B (heavier): mass = $3m$, radius of circular motion = $\frac{r}{3}$, tangential speed = v_B.

It is given:

$v_A = n\, v_B$

We need: condition when centripetal forces are equal in magnitude.

Step 1. Write centripetal force formula

$F = \frac{mv^2}{R}$

Step 2. Forces for two stones

- For Stone A:

$F_A = \frac{mv_A^2}{r}$

- For Stone B:

$F_B = \frac{(3m)v_B^2}{\frac{r}{3}} = \frac{3mv_B^2}{(r/3)} = \frac{9mv_B^2}{r}$

Step 3. Equating forces

$F_A = F_B$

$\frac{mv_A^2}{r} = \frac{9mv_B^2}{r}$

Cancel m and r:

$v_A^2 = 9v_B^2$

$\frac{v_A}{v_B} = 3$

So:

$v_A = 3v_B$

That means $n = 3$.

✅ **Answer: 3 (Option B)**

Question6

A motor cyclist has to rotate in horizontal circles inside the cylindrical wall of inner radius ' R ' metre. If the coefficient of friction between the wall and the tyres is ' μ_s ', then the minimum speed required is ($\mathrm{g} =$ acceleration due to gravity)

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Options:

A. $\sqrt{\mu_r \mathrm{Rg}}$

B. $\sqrt{\frac{\mathrm{Rg}}{\mu_s}}$

C. $\sqrt{\frac{\mu_s}{\mathrm{Rg}}}$

D. $\sqrt{\frac{R^2 g}{\mu_s}}$

Answer: B

Solution:

Step 1: Forces on the motorcyclist

- Suppose the motorcyclist is moving in a horizontal circle inside the vertical cylindrical wall of radius R.
- The normal reaction N of the wall acts **horizontally**, towards the center.
- The weight mg acts **downward**.
- The static friction force f acts **upward**, opposing the weight. For equilibrium in vertical direction, friction provides balance to gravity.

Step 2: Force equations

- Vertical balance:

$f = mg$

But maximum available friction is:

$f \leq \mu_s N$

Thus the condition:

$mg \leq \mu_s N$

- Horizontal direction (centripetal force):

$N = \frac{mv^2}{R}$

Step 3: Combine conditions

Substitute N:

$mg \leq \mu_s \cdot \frac{mv^2}{R}$

Cancel m:

$g \leq \mu_s \cdot \frac{v^2}{R}$

So:

$v^2 \geq \frac{gR}{\mu_s}$

Step 4: Minimum speed

$v_{\min} = \sqrt{\frac{gR}{\mu_s}}$

Final Answer:

The correct option is:

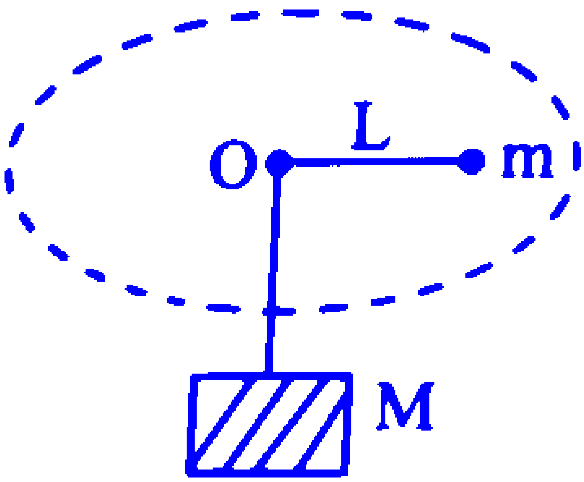
Option B: $\sqrt{\frac{Rg}{\mu_s}}$ ✅

Question7

The figure shows two masses ' m ' and ' M ' connected by a light string that passes through $_a$ small hole ' O ' at the centre of the table. Mass ' m ' is moved round in a horizontal circle with ' O ' as the

centre. The frequency with which ' m ' should be revolved so that ' M ' remains stationary is

(g $=$ gravitational acceleration)



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Options:

A. $\frac{1}{\pi}\sqrt{\frac{\mathrm{ML}}{\mathrm{mg}}}$

B. $\frac{1}{2\pi}\sqrt{\frac{\mathrm{Mg}}{\mathrm{mL}}}$

C. $\frac{1}{\pi}\sqrt{\frac{\mathrm{Mg}}{\mathrm{mL}}}$

D. $\frac{1}{2\pi}\sqrt{\frac{\mathrm{ML}}{\mathrm{mg}}}$

Answer: B

Solution:

Step 1: Forces Acting on the Masses

When m moves in a circle, it pulls on the string with a force. That same force pulls up on mass M, balancing its weight (Mg).

Step 2: Centripetal Force for Mass m

To keep moving in a circle of radius L, mass m needs a force equal to $mr\omega^2$, where $r = L$ and ω is the angular speed.

Step 3: Set Forces Equal

The upward force on M from the string is the same as the force needed by m to move in a circle.
$mr\omega^2 = Mg$

Step 4: Substitute $r = L$

$mL\omega^2 = Mg$So,$\omega^2 = \frac{Mg}{mL}$

Step 5: Relate ω (angular speed) to f (frequency)

We use $\omega = 2\pi f.\omega^2 = (2\pi f)^2 = 4\pi^2 f^2$

Step 6: Solve for f

Set the expressions for ω^2 equal:$4\pi^2 f^2 = \frac{Mg}{mL}$So,$f = \frac{1}{2\pi}\sqrt{\frac{Mg}{mL}}$

Question8

Radius of curved road is ' R ', width of road is ' b '. The outer edge of road is raised by ' h ' with respect to inner edge so that a car with velocity ' V ' can pass safe over it, then value of ' h ' is ($\mathrm{g} =$ acceleration due to gravity)

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Options:

A. $\frac{\mathrm{V}^2\ \mathrm{b}}{\mathrm{Rg}}$

B. $\frac{\mathrm{V}}{\mathrm{Rgb}}$

C. $\frac{V^2R}{g}$

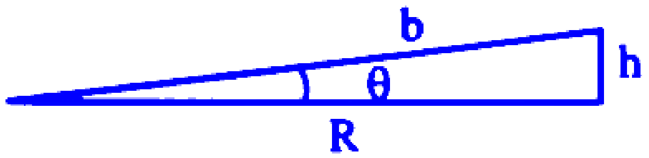
D. $\frac{V^2b}{g}$

Answer: A

Solution:

Banking of roads helps vehicles take turns safely by tilting the road surface. The required angle is given by $\tan \theta=\frac{\mathrm{v}^2}{\mathrm{Rg}}$

Where, ' h ' is height of the outer edge from the inner edge and ' b ' is the distance between the tracks or width of the road.



$\tan \theta=\frac{h}{\left(b^2-h^2\right)^{1/2}} \approx \frac{h}{b}$

$\left(l^2 \gg \mathrm{h}^2\right)$

$\therefore \frac{\mathrm{h}}{\mathrm{b}}=\frac{\mathrm{V}^2}{\mathrm{Rg}}$

$\therefore \mathrm{h}=\frac{\mathrm{V}^2 \mathrm{~b}}{\mathrm{Rg}}$

Question9

Two bodies of mass 10 kg and 5 kg are moving in concentric circular orbits of radii ' R ' and ' r ' respectively such that their periods are same. The ratio between their centripetal acceleration is

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Options:

A. R/r

B. r/R

C. $\mathrm{R}^2/\mathrm{r}^2$

D. r^2/R^2

Answer: A

Solution:

Step 1: Formula for centripetal acceleration

Centripetal acceleration is

$a_c = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$

where T is the time period, r is radius.

Step 2: Since the time period is the same

$a_c \propto r$

So the centripetal acceleration is directly proportional to the orbit radius if the period is the same.

Step 3: Ratio

For body of mass 10 kg with orbit radius R:

$a_1 = \frac{4\pi^2 R}{T^2}$

For body of mass 5 kg with orbit radius r:

$a_2 = \frac{4\pi^2 r}{T^2}$

Hence their ratio:

$\frac{a_1}{a_2} = \frac{R}{r}$

Final Answer:

$\boxed{\frac{R}{r}}$

Correct option: A (R/r)

Question10

A car is driven on the banked road of radius of curvature 20 m with maximum safe speed. In order to increase its safety speed by 20%, without changing the angle of banking, the increase in the radius of curvature will be [Assume friction is same on the road]

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Options:

A. 28.8 m

B. 14.4 m

C. 8.8 m

D. 4.8 m

Answer: C

Solution:

$$v_{\max} = \sqrt{rg\left(\frac{\tan\theta+\mu_s}{1-\mu_s\tan\theta}\right)}$$

$$v_{\max} \propto \sqrt{r}$$

$$\therefore \quad \frac{v_2}{v_1} = \sqrt{\frac{r_2}{r_1}}$$

$$\therefore \quad \left(\frac{v_2}{v_1}\right)^2 = \frac{r_2}{r_1}$$

$$\therefore \quad r_2 = \left(\frac{v_2}{v_1}\right)^2 r_1.$$

When safety speed is increased by 20%,

$v_2 = 1.2v_1$

Also given that, $\mathrm{r}_1 = 20$ m

$\therefore \quad r_2 = (1.2)^2 \times 20 = 1.44 \times 20 = 28.8$ m

$\therefore \quad$ Increase in radius $= 28.8 - 20 = 8.8$ m

Question11

A vehicle is moving with uniform speed along 3 different shaped roads as horizontal, concave and convex. The surface of road on which, the normal reaction on vehicle is maximum is

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Options:

A. convex

B. concave

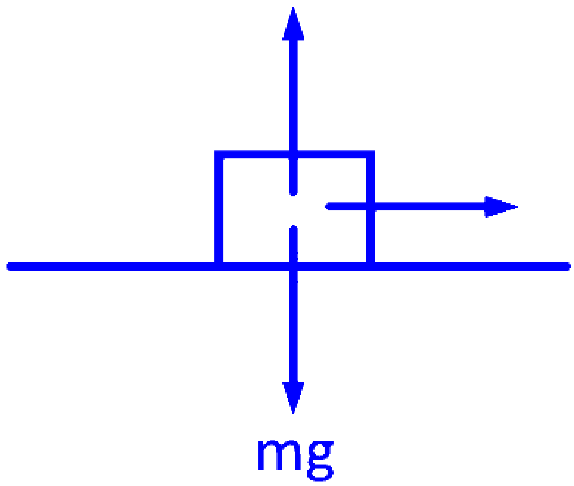
C. horizontal

D. same on all the 3 surface

Answer: B

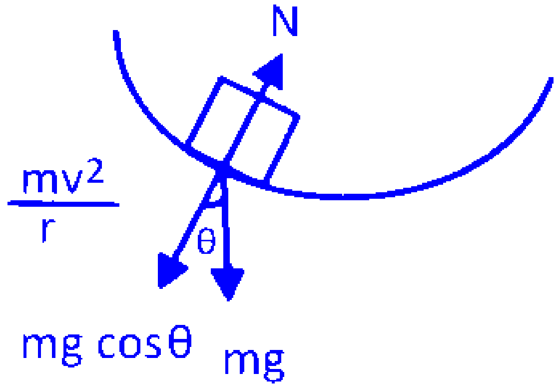
Solution:

Horizontal road



$\mathrm{N} = \mathrm{mg} \qquad \ldots (i)$

Concave road

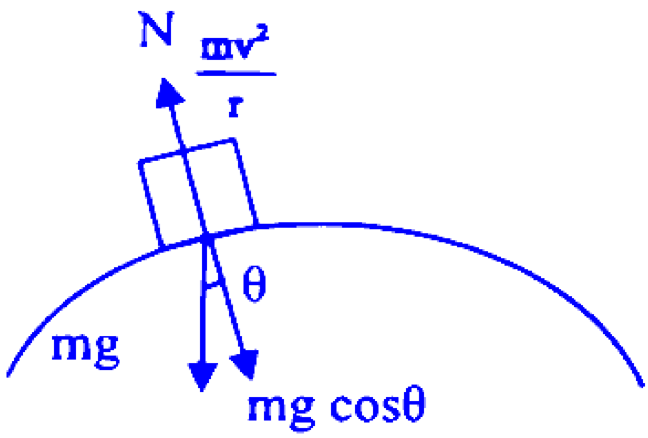


$N = \frac{mv^2}{r} + mg\cos\theta$

$\therefore \quad N_{max} = \frac{mv^2}{r} + mg \quad \ldots$ (ii)

.... (When $\cos\theta = 1$)

Convex road



$$N + \frac{mv^2}{r} = mg\cos\theta$$

$$\therefore N = mg\cos\theta - \frac{mv^2}{r}$$

$$\therefore \quad N_{max} = mg - \frac{mv^2}{r} \quad \ldots \text{(iii)}$$

$\ldots$(When $\cos\theta = 1$)

From equations (i), (ii) and (iii), we get: Normal reaction on the vehicle is maximum for a concave shaped road.

Question12

A vehicle is moving with a constant speed of $10\ \mathrm{m/s}$ in a circular horizontal track of radius 20 m . A bob is suspended from the roof of a vehicle by a massless string. The angle made by the string with the vertical will be (acceleration due to gravity, $g = 10\ \mathrm{m/s^2}$)

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Options:

A. $\tan^{-1}(0.5)$

B. $\tan^{-1}(0.6)$

C. $\tan^{-1}(0.7)$

D. $\tan^{-1}(0.8)$

Answer: A

Solution:

Step 1: Acceleration of the vehicle

The vehicle moves in a circular horizontal track with

- Speed: $v = 10\,\text{m/s}$
- Radius: $R = 20\,\text{m}$

Centripetal acceleration of the vehicle (and therefore of the bob inside it):

$a_c = \frac{v^2}{R} = \frac{10^2}{20} = \frac{100}{20} = 5\,\text{m/s}^2$

Step 2: Forces on the bob

- Weight: mg downward.
- String tension has vertical and horizontal components:
- Vertical component balances gravity
- Horizontal component provides centripetal acceleration (in the non-inertial frame of the vehicle, this is due to pseudo force).

So, if the string makes angle θ with the vertical, then

$\tan\theta = \frac{\text{horizontal acceleration}}{\text{vertical acceleration}} = \frac{a_c}{g}$

Step 3: Substitute values

$\tan\theta = \frac{5}{10} = 0.5$

$\theta = \tan^{-1}(0.5)$

Final Answer:

$\boxed{\tan^{-1}(0.5)}$ (Option A)

Question13

A body of mass 100 gram is tied to a spring of spring constant $8 \mathrm{~N/m}$, while the other end of a spring is fixed. If the body moves in a circular path on smooth horizontal surface with constant angular speed $8 \mathrm{rad/s}$ then the ratio of extension in the spring to its natured length will be

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Options:

A. 1 : 1

B. 8 : 1

C. 2 : 1

D. 4 : 1

Answer: D

Solution:

- Mass: $m = 100\,\text{g} = 0.1\,\text{kg}$
- Spring constant: $k = 8\,\text{N/m}$
- Angular speed: $\omega = 8\,\text{rad/s}$
- Motion: Mass is moving in circle on smooth surface, spring attached to center.

We are asked: ratio of **extension** (x) to **natural length** (l).

Step 1: Force Balance

Centripetal force is provided by spring force:

$kx = m\omega^2 r$

Here r is radius of circular motion = natural length l + extension x:

$r = l + x$

So:

$kx = m\omega^2(l + x)$

Step 2: Plug Known Values

Substitute $m = 0.1$, $\omega = 8$, $k = 8$:

$8x = (0.1)(64)(l + x)$

$8x = 6.4(l + x)$

Step 3: Rearrange

$8x - 6.4x = 6.4l$

$1.6x = 6.4l$

$\frac{x}{l} = \frac{6.4}{1.6} = 4$

Final Answer:

$\frac{\text{extension}}{\text{natural length}} = 4 : 1$

✅ Correct Option: **D (4:1)**

Question14

A simple pendulum oscillates with an angular amplitude θ. If the maximum tension in the string is 4 times the minimum tension then the value of θ is

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Options:

A. $\cos^{-1}(0.75)$

B. $\cos^{-1}(0.5)$

C. $\sin^{-1}(0.5)$

D. $\sin^{-1}(0.75)$

Answer: B

Solution:

In simple pendulum,

$T = mg\cos\phi + \frac{mv^2}{l}$

At lowest point (Tension is maximum):

$T_{max} = mg + \frac{mv^2}{l} \quad \ldots.(\phi = 0^\circ)$

At highest point (Tension is minimum):

$T_{min} = mg\cos\theta$

$\ldots.($ angular amplitude $= \theta$ and $v = 0)$

By energy conservation,

$$
\begin{aligned}
& \frac{1}{2}mv^2 = mgl(1-\cos\theta) \\
\therefore \quad & \frac{mv^2}{l} = 2mg(1-\cos\theta) \qquad \ldots(i) \\
& \text{But, } T_{max} = 4\,T_{min} \\
\therefore \quad & mg + \frac{mv^2}{l} = 4mg\cos\theta \\
\therefore \quad & mg + 2mg(1-\cos\theta) = 4mg\cos\theta \\
\therefore \quad & 1 + 2 - 2\cos\theta = 4\cos\theta \\
\therefore \quad & 3 = 6\cos\theta \\
\Rightarrow \quad & \cos\theta = \frac{1}{2} \\
\therefore \quad & \theta = \cos^{-1}(0.5)
\end{aligned}
$$

Question15

A pendulum bob has a speed $4\ m/s$ at its lowest position. The pendulum is 1 m long. When the length of the string makes an angle of 60° with the vertical, the speed of the bob at that position is (acceleration due to gravity, $g = 10\ m/s^2$, $\cos 60^\circ = 0.5$)

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Options:

A. $6 \mathrm{~m/s}$

B. $\sqrt{3} \mathrm{~m/s}$

C. $\sqrt{6} \mathrm{~m/s}$

D. $3 \mathrm{~m/s}$

Answer: C

Solution:

Step 1. Known values:

- Length of pendulum: $L = 1 \mathrm{~m}$
- Speed at lowest position: $v_{\text{lowest}} = 4 \mathrm{~m/s}$
- $g = 10 \mathrm{~m/s}^2$
- Position of interest: string at 60° with vertical.

Step 2. Use energy conservation

At lowest point, potential energy is minimum.

At another position, some kinetic energy is converted into potential energy:

$\frac{1}{2}mv^2 + mgh = \frac{1}{2}mv_{\text{lowest}}^2$

Here h is the rise in height of bob above lowest position.

Step 3. Calculate vertical rise h

At lowest: vertical position = $-L$).

At angle $\theta = 60^\circ$, vertical height relative to pivot = $-L\cos\theta = -L\cos 60^\circ$.

So rise:

$h = L - L\cos\theta = L(1 - \cos\theta)$

$h = 1 \times (1 - 0.5) = 0.5 \mathrm{~m}$

Step 4. Apply energy conservation

$\frac{1}{2}mv^2 + mg(0.5) = \frac{1}{2}m(4^2)$

$\frac{1}{2}v^2 + 5 = \frac{1}{2}(16) = 8$

$\frac{1}{2}v^2 = 3$

$v^2 = 6 \quad \Rightarrow \quad v = \sqrt{6}\,\text{m/s}$

✅ **Final Answer:**

The speed of the bob at the 60° position is:

Option C: $\sqrt{6}\,\text{m/s}$

Question16

A wheel initially at rest, begins to rotate about its axis with constant angular acceleration. If it rotates through an angle θ_1 in first 2 s and a further angle θ_2 in the next 2 s , the ratio $\theta_1 : \theta_2$ is

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Options:

A. $1 : 6$

B. $6 : 1$

C. $3 : 1$

D. $1 : 3$

Answer: D

Solution:

Let the **initial angular velocity** be $\omega_0 = 0$ (since the wheel is initially at rest).

Let the **angular acceleration** be α.

Angular displacement in time t is:

$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$

First 2 seconds ($t = 2$ s)

$\theta_1 = 0 \cdot 2 + \frac{1}{2}\alpha(2)^2 = \frac{1}{2}\alpha \cdot 4 = 2\alpha$

Next 2 seconds ($t = 4$ s total, $t = 2$ s extra)

Total angle covered in 4 seconds:

$\theta_{\text{total}} = 0 \cdot 4 + \frac{1}{2}\alpha(4)^2 = \frac{1}{2}\alpha \cdot 16 = 8\alpha$

So, **angle covered in the next 2 seconds** (θ_2):

$\theta_2 = \theta_{\text{total}} - \theta_1 = 8\alpha - 2\alpha = 6\alpha$

Ratio $\theta_1 : \theta_2$

$\theta_1 : \theta_2 = 2\alpha : 6\alpha = 1 : 3$

Correct option: D

Question17

For a particle moving in a circle with constant angular speed, which of the following statements is 'false'?

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Options:

A. The velocity vector is tangent to the circle.

B. The acceleration vector is tangent to the circle.

C. The velocity and acceleration vectors are perpendicular to each other.

D. The acceleration vector points to the centre of the circle.

Answer: B

Solution:

We first recall some basic facts from **Uniform Circular Motion (UCM):**

- The particle is moving with **constant angular speed**.
- Its **velocity** is always **tangent to the circle**.
- The **acceleration** is called centripetal acceleration, and it always points **towards the centre of the circle**.
- The acceleration is **perpendicular** to the velocity.

Now let us check each option:

Option A:

“The velocity vector is tangent to the circle.”

→ This is **true**.

Option B:

“The acceleration vector is tangent to the circle.”

→ This is **false**, because acceleration is directed towards the centre, not tangent.

Option C:

“The velocity and acceleration vectors are perpendicular to each other.”

→ This is **true**.

Option D:

“The acceleration vector points to the centre of the circle.”

→ This is **true**.

Correct Answer: Option B

Question18

A particle performing uniform circular motion of radius $\frac{\pi}{2}$ m makes x revolutions in time t. Its tangential velocity is

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Options:

A. $\frac{x}{\pi t}$

B. $\frac{\pi^2}{xt}$

C. $\frac{\pi^2 x}{t}$

D. $\frac{\pi x}{t}$

Answer: C

Solution:

Step 1: Write the formula for tangential velocity.

The tangential velocity v for a particle in uniform circular motion is given by:

$v = \frac{\text{distance travelled}}{\text{time}}$

Step 2: Find the distance travelled in x revolutions.

- In 1 revolution, distance = circumference of circle $= 2\pi r$
- For x revolutions, distance $= x \times 2\pi r$

The radius is given as $r = \frac{\pi}{2}$ m.

So,

distance $= x \times 2\pi\left(\frac{\pi}{2}\right)$

distance $= x \times \pi \times \pi = x\pi^2$

Step 3: Divide total distance by total time.

Total time taken $= t$

$v = \frac{x\pi^2}{t}$

Step 4: Match with the given options.

Option C

$$\boxed{\frac{\pi^2 x}{t}}$$

This is the correct answer.

Question19

A weightless thread can bear tension up to 3.7 kg wt. A stone of mass 500 gram is tied to it and revolved in circular path of radius 4 m in vertical plane. Maximum angular velocity of the stone will be (acceleration due to gravity, $\mathrm{g} = 10 \mathrm{~m/s^2}$)

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Options:

A. $16 \mathrm{rad/s}$

B. 4rad/s

C. 2rad/s

D. 8rad/s

Answer: B

Solution:

Given:

- Maximum tension in thread, $T_{\max} = 3.7 \text{ kg wt} = 3.7 \times 10 \text{ N} = 37 \text{ N}$
- Mass of stone, $m = 500 \text{ g} = 0.5 \text{ kg}$
- Radius of circle, $r = 4 \text{ m}$
- Acceleration due to gravity, $g = 10 \text{ m/s}^2$

Step 1: Identify the location of maximum tension

- In the vertical circular motion, the tension will be maximum at the **lowest point**.

Step 2: Write the equation for tension at the lowest point

At the lowest point,

$T_{\max} = m\omega^2 r + mg$

Where,

- $m\omega^2 r$ is the centripetal force,
- mg is the weight (acting downwards).

Step 3: Substitute the given values

$37 = 0.5\omega^2 \times 4 + 0.5 \times 10$

$37 = 2\omega^2 + 5$

Step 4: Solve for ω

Subtract 5 from both sides:

$37 - 5 = 2\omega^2$

$32 = 2\omega^2$

$\omega^2 = \frac{32}{2} = 16$

$\omega = \sqrt{16} = 4 \text{ rad/s}$

Answer:

Option B (4 rad/s) is correct.

Question20

When a ceiling fan is switched off, its angular velocity falls to $\left(\frac{1}{3}\right)^{\text{rd}}$ while it makes 24 rotations. How many more rotations will it make before coming to rest?

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Options:

A. 3

B. 6

C. 9

D. 12

Answer: A

Solution:

Let the initial angular velocity be ω_0.

Final angular velocity after 24 rotations is $\omega_1 = \frac{\omega_0}{3}$.

Let the angular retardation (deceleration) be α (negative value, since fan is slowing down).

Number of rotations made during retardation is n.

Step 1: Use rotational motion equation

The relation between angular velocities, angular acceleration, and angular displacement is:

$\omega_1^2 = \omega_0^2 + 2\alpha\theta$

where θ is the angle rotated (in radians).

1 rotation = 2π radians

After 24 rotations:

$\theta_1 = 24 \times 2\pi = 48\pi$ radians

So,

$\left(\frac{\omega_0}{3}\right)^2 = \omega_0^2 + 2\alpha \times 48\pi$

$\frac{\omega_0^2}{9} = \omega_0^2 + 96\pi\alpha$

Bring like terms together:

$\frac{\omega_0^2}{9} - \omega_0^2 = 96\pi\alpha$

$\left(\frac{1}{9} - 1\right)\omega_0^2 = 96\pi\alpha$

$-\frac{8}{9}\omega_0^2 = 96\pi\alpha$

$\alpha = -\frac{8\omega_0^2}{9 \times 96\pi}$

$\alpha = -\frac{\omega_0^2}{108\pi}$

Step 2: Find total rotations till rest

Let total number of rotations before coming to rest be N.

At rest, final angular velocity $\omega = 0$.

Apply same formula:

$\omega^2 = \omega_0^2 + 2\alpha\theta_{\text{total}}$

$0 = \omega_0^2 + 2\alpha\theta_{\text{total}}$

$2\alpha\theta_{\text{total}} = -\omega_0^2$

$\theta_{\text{total}} = \frac{-\omega_0^2}{2\alpha}$

Substitute α from earlier:

$\theta_{\text{total}} = \frac{-\omega_0^2}{2 \times \left(-\frac{\omega_0^2}{108\pi}\right)}$

$\theta_{\text{total}} = \frac{-\omega_0^2}{-\frac{2\omega_0^2}{108\pi}}$

$\theta_{\text{total}} = \frac{-\omega_0^2 \times 108\pi}{-2\omega_0^2}$

$\theta_{\text{total}} = \frac{108\pi}{2}$

$\theta_{\text{total}} = 54\pi$ radians

Number of total rotations:

$N = \frac{\theta_{\text{total}}}{2\pi} = \frac{54\pi}{2\pi} = 27$

Step 3: Find required answer

Rotations still to be made after first 24 rotations:

$N - 24 = 27 - 24 = 3$

Final Answer:

$\boxed{3}$

Option A is correct.

Question21

The linear speed of a particle at the equator of the earth due to its spin motion is ' V '. The linear speed of the particle at latitude 30° is

$$\begin{bmatrix} \sin 30^{\circ} = \cos 60^{\circ} = 1/2 \\ \cos 30^{\circ} = \sin 60^{\circ} = \sqrt{3}/2 \end{bmatrix}$$

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Options:

A. $\frac{\mathrm{V}}{\sqrt{2}}$

B. $\frac{\mathrm{V}}{2}$

C. $\frac{\sqrt{3}}{2}\mathrm{v}$

D. V

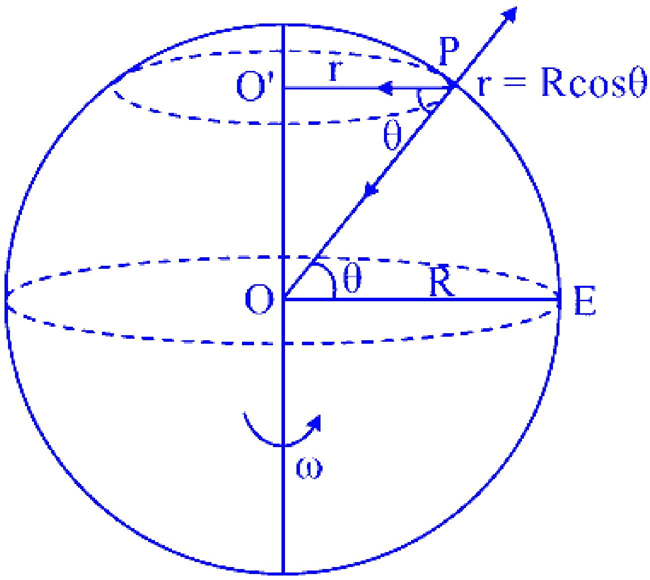
Answer: C

Solution:

The particle on the equator of the earth has linear speed V.

$\Rightarrow \mathrm{V} = \mathrm{R}\omega \quad$ .... (i)

where R is the radius of the earth.



If the particle is now at 30° latitude, the particle will move in a circle of smaller radius.

Let the radius of this smaller circle be r .

$\Rightarrow \mathrm{r}=\mathrm{R} \cos \theta$

$\therefore$ The linear velocity of the particle at 30°,

$V^{\prime}=r \omega$

$$=R \cos \theta \omega=R \cos 30^{\circ} \omega=\frac{\sqrt{3}}{2} R \omega \quad \text{.... (ii)}$$

Dividing equation (ii) by (i),

$$\frac{V^{\prime}}{V}=\frac{\frac{\sqrt{3}}{2} R \omega}{R \omega}$$

$$\therefore \quad V^{\prime}=V \frac{\sqrt{3}}{2}$$

Question22

Two objects of masses ' m_1 ' and ' m_2 ' are moving in the circles of radii ' r_1 ' and ' r_2 ' respectively. Their respective angular speeds ' ω_1 ' and ' ω_2 ' are such that they both complete one revolution in the same time ' t '. The ratio of linear speed of ' m_2 ' to that of ' m_1 ' is

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Options:

A. $\omega_1 : \omega_2$

B. $T_2 : T_1$

C. $m_1 : m_2$

D. $r_2 : r_1$

Answer: D

Solution:

We know that the linear speed v for an object in circular motion is given by:

$v = r\omega,$

where r is the radius of the circle and ω is the angular speed.

Given that both objects complete one revolution in the same time t, their angular speeds are equal. In fact, the angular speed for one complete revolution is:

$\omega = \frac{2\pi}{t}.$

For the two objects:

For mass m_1 with radius r_1:

$v_1 = r_1\omega_1 = r_1\left(\frac{2\pi}{t}\right)$

For mass m_2 with radius r_2:

$v_2 = r_2\omega_2 = r_2\left(\frac{2\pi}{t}\right)$

Taking the ratio of the linear speeds $\frac{v_2}{v_1}$:

$\frac{v_2}{v_1} = \frac{r_2\left(\frac{2\pi}{t}\right)}{r_1\left(\frac{2\pi}{t}\right)} = \frac{r_2}{r_1}.$

Thus, the ratio of the linear speed of m_2 to that of m_1 is:

$\frac{v_2}{v_1} = \frac{r_2}{r_1}.$

The correct answer is therefore Option D.

Question23

A body performing uniform circular motion of radius ' R ' has frequency ' n '. Its centripetal acceleration per unit radius is

proportional to $(n)^x$. The value of x is

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Options:

A. 1

B. 2

C. -1

D. -2

Answer: B

Solution:

Let's break down the problem step by step:

For a body in uniform circular motion, the tangential speed is given by:

$v = 2\pi Rn$

where:

R is the radius,

n is the frequency (number of revolutions per unit time).

The centripetal acceleration is given by:

$a = \frac{v^2}{R}.$

Substituting the expression for v into the acceleration formula:

$a = \frac{(2\pi Rn)^2}{R} = \frac{4\pi^2R^2n^2}{R} = 4\pi^2n^2R.$

The centripetal acceleration per unit radius is therefore:

$\frac{a}{R} = \frac{4\pi^2n^2R}{R} = 4\pi^2n^2.$

This shows that the centripetal acceleration per unit radius is directly proportional to n^2. Hence, the exponent x is 2.

So, the answer is: Option B (2).

Question24

A particle starting from rest moves along the circumference of a circle of radius ' r ' with angular acceleration ' α '. The magnitude of the average velocity in time it completes the small angular displacement ' θ ' is

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Options:

A. $\frac{r^2}{2\alpha\theta}$

B. $\frac{\mathrm{r}}{2\alpha\theta}$

C. $\frac{\mathrm{r}\alpha\theta}{2}$

D. $\frac{\mathrm{r}}{\sqrt{2}}\sqrt{\alpha\theta}$

Answer: D

Solution:

Using kinematic equation,

$$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$$

$$\theta = \frac{1}{2}\alpha t^2 \quad \ldots (\because \text{ particle was at rest, } \omega_0 = 0)$$

$$\therefore \quad t = \left(\frac{2\theta}{\alpha}\right)^{1/2} \quad \text{.... (i)}$$

Angular displacement of the particle $= r\theta$ .... (iii)

$$\therefore \quad \text{Average velocity} = \frac{\text{Angular displacement}}{\text{time}}$$

$$\mathrm{v}_{\text{avenge}} = \frac{\mathrm{r}\theta}{\mathrm{t}} = \frac{\mathrm{r}\theta}{\left(\frac{2\theta}{\alpha}\right)^{1/2}} = \frac{\mathrm{r}}{\sqrt{2}}\sqrt{\alpha\theta}$$

Question25

A particle is moving in a circle with uniform speed. It has constant

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Options:

A. velocity.

B. acceleration.

C. kinetic energy.

D. displacement.

Answer: C

Solution:

A particle moving in a circle with uniform speed has constant **kinetic energy**.

When a particle moves in a circular path with constant speed, the magnitude of its velocity remains unchanged. However, the direction changes constantly, which means that the particle is accelerating towards the center of the circle. This acceleration is called centripetal acceleration. Therefore:

Velocity is not constant because its direction changes continuously.

Acceleration is present because of the change in direction, but it is not constant because its direction continually changes along the circle.

Kinetic energy is constant as the speed (magnitude of velocity) is uniform. Kinetic energy is given by the formula:

$KE = \frac{1}{2} m v^2$

since the speed v is constant, kinetic energy is constant.

Displacement is not constant because the particle continues to move around the circle.

Hence, the correct choice is **Option C: kinetic energy**.

Question26

A particle of mass ' m ' is performing uniform circular motion along a circular path of radius ' r '. Its angular momentum about the axis

passing through the centre and perpendicular to the plane is ' L '. The kinetic energy of the particle is

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Options:

A. $\frac{L^2}{2Mr^2}$

B. $\frac{2\,\mathrm{L}^2}{\mathrm{mr}^2}$

C. $\frac{\mathrm{L}^2}{\mathrm{mr}^2}$

D. $\frac{2\,\mathrm{L}^2}{3\mathrm{mr}^2}$

Answer: A

Solution:

$$\mathrm{E}=\frac{1}{2}\mathrm{I}\omega^2$$
$$\mathrm{L}=\mathrm{I}\omega \Rightarrow \mathrm{L}^2=\mathrm{I}^2\omega^2$$
$$\therefore \quad \mathrm{E}=\frac{1}{2}\frac{\mathrm{L}^2}{\mathrm{I}}$$
$$\text{But } \mathrm{I}=\mathrm{Mr}^2$$
$$\therefore \quad \mathrm{E}=\frac{1}{2}\frac{\mathrm{L}^2}{\mathrm{Mr}^2}=\frac{\mathrm{L}^2}{2\mathrm{Mr}^2}$$

Question27

A particle of mass ' m ' performs uniform circular motion of radius ' r ' with linear speed ' v ' under the application of force ' F '. If ' m ', ' v ' and $'\mathrm{r}$ ' are all increased by 20% the necessary change in force required to maintain the particle in uniform circular motion, is

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Options:

A. 12%

B. 44%

C. 14%

D. 144%

Answer: B

Solution:

In uniform circular motion, the centripetal force required to maintain the motion is given by the formula:

$F = \frac{mv^2}{r}$

Let's denote the initial values of mass, velocity, and radius as m, v, and r, respectively. The initial force is:

$F_{\text{initial}} = \frac{mv^2}{r}$

Now, if mass, velocity, and radius each increase by 20%, the new values will be:

New mass = $m' = 1.2m$

New velocity = $v' = 1.2v$

New radius = $r' = 1.2r$

The new force required, F_{new}, is:

$F_{\text{new}} = \frac{m'(v')^2}{r'} = \frac{(1.2m)(1.2v)^2}{1.2r}$

Calculating the new force, we have:

$F_{\text{new}} = \frac{1.2m \times (1.44v^2)}{1.2r}$

Simplifying the expression:

$F_{\text{new}} = \frac{1.2 \times 1.44 \times m \times v^2}{1.2 \times r}$

$F_{\text{new}} = \frac{1.44mv^2}{r}$

The change in force can be calculated as:

Change in force $= F_{\text{new}} - F_{\text{initial}}$

Substituting the expressions for F_{new} and F_{initial} :

Change in force $= \frac{1.44mv^2}{r} - \frac{mv^2}{r}$

Simplifying the change in force expression:

Change in force $= (1.44 - 1)\frac{mv^2}{r}$

Change in force $= 0.44\frac{mv^2}{r}$

The percentage change in force is:

Percentage change $= \left(\frac{\text{Change in force}}{F_{\text{initial}}}\right) \times 100\%$

Percentage change $= \left(\frac{0.44\frac{mv^2}{r}}{\frac{mv^2}{r}}\right) \times 100\%$

Percentage change $= 0.44 \times 100\%$

Percentage change $= 44\%$

Therefore, the necessary change in force required is **44%**. The correct answer is **Option B:** 44%.

Question28

A particle rotates in a horizontal circle of radius 'R' in a conical funnel with constant speed 'V'. The inner surface of the funnel is smooth. The height of the plane of the circle from the vertex of the funnel is (g-acceleration due to gravity)

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Options:

A. $\frac{V}{g}$

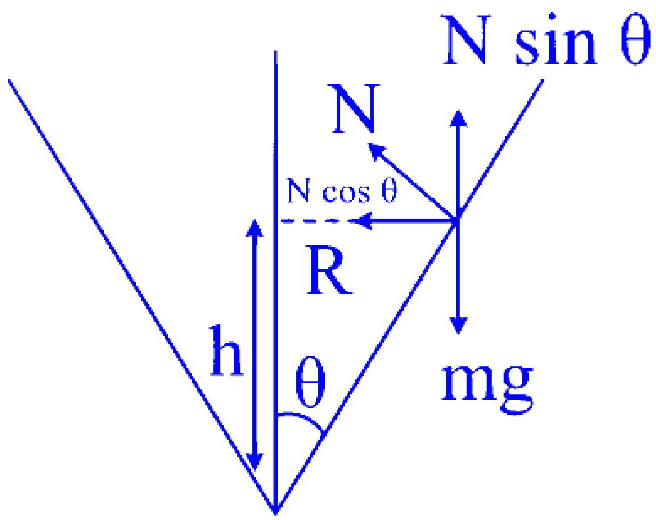
B. $\frac{\mathrm{V}}{2\mathrm{~g}}$

C. $\frac{\mathrm{V}^2}{2\mathrm{~g}}$

D. $\frac{\mathrm{V}^2}{\mathrm{g}}$

Answer: D

Solution:



From figure,

$N \sin \theta = mg$

$N \cos \theta = \frac{mV^2}{R}$

$\therefore \quad \tan \theta = \frac{\mathrm{Rg}}{\mathrm{V}^2}$

$\therefore \quad \frac{\mathrm{R}}{\mathrm{h}} = \frac{\mathrm{Rg}}{\mathrm{V}^2}$

$\therefore \quad \mathrm{h} = \frac{\mathrm{V}^2}{\mathrm{g}}$

Question29

For a particle in uniform circular motion

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Options:

A. linear velocity always radial to the circular path, without change in its magnitude

B. linear velocity always tangential to the circular path, without change in its magnitude

C. linear acceleration always tangential to the circular path

D. linear acceleration always along the axis of the circular path

Answer: B

Solution:

Answer: Option B

Explanation:

In uniform circular motion, the speed (magnitude of the linear velocity) remains constant, but the direction of the velocity continuously changes. The linear velocity at any point along the circular path is always directed **tangentially** to the circle. Since the speed is constant, its magnitude does not change.

Key points to note:

Linear velocity:

For a particle moving in a circle, the instantaneous linear velocity vector is directed along the tangent to the circle at the particle's position. The magnitude of this velocity remains constant in uniform circular motion.

Linear acceleration (centripetal acceleration):

Although not asked directly in the correct option, the acceleration in uniform circular motion is directed radially inward (towards the center of the circle), not tangentially or along any axis perpendicular to the plane of the circle.

Thus, the only correct statement given the options is that the linear velocity is always tangential to the circular path and its magnitude remains unchanged in uniform circular motion.

Question30

A disc at rest is subjected to a uniform angular acceleration about its axis. Let θ and θ_1 be the angle made by the disc in 2^{nd} and 3^{rd} second of its motion. The ratio $\frac{\theta}{\theta_1}$ is

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Options:

A. 2 : 3

B. 1 : 2

C. 2 : 3

D. 4 : 5

Answer: D

Solution:

Kinematic equation for rotational motion,

$\theta=\omega_0 t+\frac{1}{2} \alpha t^2$

Disk is initially at rest, $\omega_0=0$

$\Rightarrow \theta=\frac{1}{2} \alpha t^2 \quad \text{.... (i)}$

Angle described in 2^{nd} second is,

$\theta_1=\frac{1}{2} \alpha(2)^2=2 \alpha \quad \text{... [From (i)]}$

Angle described in first 3 seconds will be,

$\theta_2=\frac{1}{2} \alpha(3)^2=4.5 \alpha \quad \text{.... [From (i)]}$

Angle described in 3^{rd} second will be,

$$\begin{aligned} \theta^{\prime} & =\theta_2-\theta_1 \\ & =4.5 \alpha-2 \alpha=2.5 \alpha \end{aligned}$$

$\therefore \quad \frac{\theta}{\theta^{\prime}}=\frac{2}{2.5}=\frac{4}{5}$

Question31

A body moves along a circular path of radius 15 cm . It starts from a point on the circular path and reaches the end of diameter in 3 second, The angular speed of the body in $\mathrm{rad/s}$ is

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Options:

A. $\frac{\pi}{2}$

B. $\frac{\pi}{3}$

C. $\frac{\pi}{4}$

D. $\frac{\pi}{5}$

Answer: B

Solution:

Let r be radius,

Circumference $= 2\pi$,

Half the circle is covered,

$\therefore \quad \text{Distance covered} = \pi \mathrm{r} = 15\mathrm{r}$

... (given, $\mathrm{r} = 15$ cm)

Speed $= \frac{\text{distance}}{\text{time}} = \frac{15\pi}{3} = 5\pi$

Angular speed, $\theta = \frac{v}{r} = \frac{5\pi}{15} = \frac{\pi}{3}$ rad/s

----

Question32

A wheel of radius 1 m rolls through 180° over a plane surface. The magnitude of the displacement of the point of the wheel initially in contact with the surface is.

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Options:

A. 2π

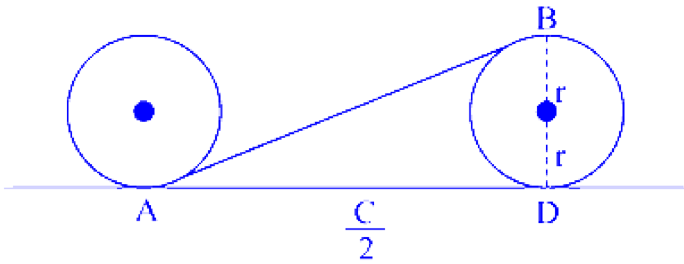
B. π

C. $\sqrt{\pi^2 + 4}$

D. 3π

Answer: C

Solution:



Distance travelled by the wheel in half revolution $= \frac{C}{2} = \frac{2\pi r}{2} = \pi r$

Where C is the circumference of the wheel.

$\therefore$ From figure,

Displacement of initial point of contact after half revolution $= AB$

$\therefore \quad AB^2 = AD^2 + DB^2$
$AB^2 = (\pi r)^2 + (2r)^2 = r^2\left(\pi^2 + 4\right)$
$\therefore \quad AB = r\sqrt{(\pi^2 + 4)}$
$\therefore \quad AB = \sqrt{(\pi^2 + 4)}$ .... (given)

Question33

The string of pendulum of length ' L ' is displaced through 90° from the vertical and released. Then the maximum strength of the string in order to withstand the tension, as the pendulum passes through the mean position is ($m =$ mass of pendulum, $g =$ acceleration due to gravity)

MHT CET 2024 2nd May Evening Shift

Options:

A. mg

B. 3 mg

C. 5 mg

D. 6 mg

Answer: B

Solution:

By conservation of energy

K.E. $= \frac{1}{2}\mathrm{mv}^2 = \mathrm{mg}l$

$\mathrm{v} = \sqrt{2\,\mathrm{g}l}$ .... (i)

The forces acting on the pendulum at mean position are tension in string, centripetal force and weight of pendulum.

$$\mathrm{T} - \frac{\mathrm{mv}^2}{\mathrm{l}} = \mathrm{mg}$$

$$\mathrm{T} - \frac{\mathrm{m}(\sqrt{2\,\mathrm{g}})^2}{l} = \mathrm{mg} \quad \text{...[From (i)]}$$

$$\therefore \quad \mathrm{T} = 3\,\mathrm{mg}$$

Question34

A particle at rest starts moving with a constant angular acceleration of $4\ \mathrm{rad/s^2}$ in a circular path. The time at which magnitudes of its centripetal acceleration and tangential acceleration will be equal, is (in second)

MHT CET 2024 2nd May Morning Shift

Options:

A. $\frac{1}{4}$

B. $\frac{1}{3}$

C. $\frac{1}{2}$

D. $\frac{2}{3}$

Answer: C

Solution:

Given that, $\alpha = 4\ \mathrm{rad/s^2}$

Centripetal (radial) acceleration, $a_r = r\omega^2$

Tangential acceleration, $a_t = r\alpha$

If $a_r = a_t$, then $r\omega^2 = r\alpha$

$\therefore \quad \omega^2 = \alpha = 4$

$\therefore \quad \omega = \sqrt{4} = 2 \mathrm{rad/s}$

But, $\omega = \omega_0 + \alpha t = 0 + \alpha t = \alpha t$

$\therefore \quad 2 = 4t$

$\therefore \quad t = \frac{1}{2} s$

Question35

A particle is performing uniform circular motion along the circumference of the circle of diameter 1 m with frequency 4 Hz . The acceleration of the particle in $\mathrm{m/s^2}$ is

MHT CET 2024 2nd May Morning Shift

Options:

A. $8\pi^2$

B. $16\pi^2$

C. $24\pi^2$

D. $32\pi^2$

Answer: D

Solution:

In uniform circular motion, the acceleration of a particle, also called the centripetal acceleration, is given by the formula:

$a = \omega^2 r$

where ω is the angular velocity and r is the radius of the circle.

Find the radius, r:

Since the diameter is given as 1 m, the radius r is:

$r = \frac{\text{diameter}}{2} = \frac{1}{2}\text{ m}$

Determine the angular velocity, ω:

The angular velocity ω can be calculated using the relation between angular velocity and frequency:

$\omega = 2\pi f$

where f is the frequency. Given $f = 4\,\text{Hz}$,

$\omega = 2\pi \times 4 = 8\pi\,\text{rad/s}$

Calculate the centripetal acceleration, a:

Substitute ω and r into the centripetal acceleration formula:

$a = \omega^2 r = (8\pi)^2 \times \frac{1}{2}$

Simplify the expression:

$a = 64\pi^2 \times \frac{1}{2} = 32\pi^2\text{ m/s}^2$

Thus, the acceleration of the particle is $32\pi^2\text{ m/s}^2$, which corresponds to **Option D**.

Question36

A particle moves around a circular path of radius 'r' with uniform speed 'V'. After moving half the circle, the average acceleration of the particle is

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Options:

A. $\frac{\mathrm{V}^2}{\mathrm{r}}$

B. $\frac{2V^2}{r}$

C. $\frac{2V^2}{\pi r}$

D. $\frac{\mathrm{V}^2}{\pi \mathrm{r}}$

Answer: C

Solution:

At end points of the half revolution magnitude of the velocity is same but it directs in opposite direction.

$\therefore \quad \Delta V = V - (-V)$

$\therefore \quad \Delta V = 2\ V$

Time taken to complete the half revolution is

$t = \frac{\pi r}{V}$

Average acceleration is, $a = \frac{\Delta V}{t} = \frac{2V}{\frac{\pi r}{V}}$

$\therefore \quad a = \frac{2V^2}{\pi r}$

Question37

On dry road, the maximum speed of a vehicle along a circular path is 'V'. When the road becomes wet, maximum speed becomes $\frac{V}{2}$. If coefficient of friction of dry road is 'μ' then that of wet road is

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Options:

A. $\frac{2\mu}{3}$

B. $\frac{\mu}{4}$

C. $\frac{\mu}{3}$

D. $\frac{3\mu}{4}$

Answer: B

Solution:

The equation for maximum velocity is

$V = \sqrt{\mu r g}$ .... (i)

When the road becomes wet the equation becomes

$\frac{V}{2} = \sqrt{\mu' r g}$ ..... (ii)

Dividing equation (i) with equation (ii),

$$\frac{V}{\frac{V}{2}} = \frac{\sqrt{\mu rg}}{\sqrt{\mu' rg}}$$

$$\therefore \quad 2 = \frac{\sqrt{\mu}}{\sqrt{\mu'}}$$

$$\therefore \quad \mu' = \frac{\mu}{4}$$

Question38

A string of length 'L' fixed at one end carries a body of mass 'm' at the other end. The mass is revolved in a circle in the horizontal plane about a vertical axis passing through the fixed end of the string. The string makes angle 'θ' with the vertical. The angular frequency of the body is 'ω'. The tension in the string is

MHT CET 2023 14th May Morning Shift

Options:

A. $\mathrm{mL}^2\omega$

B. $\mathrm{mL}\omega^2$

C. $\frac{\omega^2}{\mathrm{mL}}$

D. $\frac{\mathrm{m}\omega^2}{\mathrm{L}}$

Answer: B

Solution:

In case of conical pendulum, the tension in the string provides the necessary centripetal force.

$$\therefore \quad \mathrm{T} = \mathrm{mr}\omega^2 = \mathrm{mL}\omega^2 \quad .... \text{(Here, r = L)}$$

Question39

A stone is projected at angle θ with velocity u. If it executes nearly a circular motion at its maximum point for short time, then the radius of the circular path will be ($g =$ acceleration due to gravity)

MHT CET 2023 13th May Evening Shift

Options:

A. $\frac{u^2}{g}$

B. $\frac{u^2 \cos^2 \theta}{g}$

C. $\frac{u^2 \sin^2 \theta}{g}$

D. $\frac{u^2 \cos^2 \theta}{2g}$

Answer: B

Solution:

Since, the particle experiences a downward acceleration due to gravity at peak (highest point), and traces a circular arc, it has no component of acceleration in x-direction.

Let, radius of circle be R.

Horizontal velocity of the particle of height point.

$v_x = u \cos \theta \quad (\because a_x = 0)$

$\therefore a = \frac{v_x^2}{R}$ (for circular motion centripetal acceleration$= \frac{v^2}{R}$)

$\Rightarrow R = \frac{v_x^2}{a} = \frac{u^2 \cos^2 \theta}{g} \quad (\because a = g)$

Question40

A particle is moving in a circle with uniform speed 'v'. In moving from a point to another diametrically opposite point

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Options:

A. the momentum changes by mv

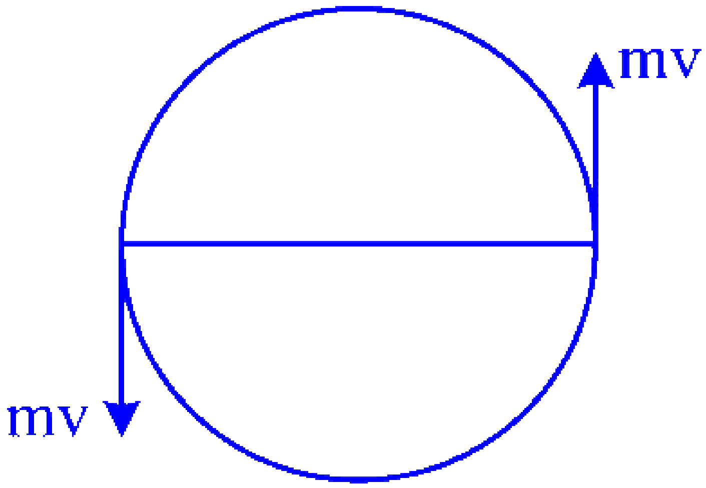
B. the momentum changes by 2 mv

C. the kinetic energy changes by $\frac{1}{2}mv^2$

D. the kinetic energy changes by mv^2

Answer: B

Solution:



At both points, the momentum will be mv, but will be in opposite directions.

$\therefore \quad \Delta P = mv - (-mv)$
$\therefore \quad \Delta P = 2\ mv$

The momentum changes by 2 mv.

Question41

A body of mass 'm' attached at the end of a string is just completing the loop in a vertical circle. The apparent weight of the body at the lowest point in its path is (g = gravitational acceleration)

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Options:

A. zero

B. mg

C. 3 mg

D. 6 mg

Answer: D

Solution:

The tension at the lowest point is $\mathrm{T}=\frac{\mathrm{mv}^2}{\mathrm{r}}+\mathrm{mg}$

To complete the vertical circle, the minimum velocity should be $\mathrm{v}=\sqrt{5 \mathrm{gr}}$

$$\begin{aligned} \therefore \quad & \mathrm{T}=\frac{\mathrm{m}(\sqrt{5 \mathrm{gr}})^2}{\mathrm{r}}+\mathrm{mg} \\ & \mathrm{R}=5 \mathrm{mg}+\mathrm{mg} \\ \therefore \quad & \mathrm{T}=6 \mathrm{mg}\end{aligned}$$

Question42

A railway track is banked for a speed ',v' by elevating outer rail by a height 'h' above the inner rail. The distance between two rails is 'd' then the radius of curvature of track is ($\mathrm{g}=$ gravitational acceleration)

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Options:

A. $\frac{\mathrm{v}^2 \mathrm{~d}}{\mathrm{gh}}$

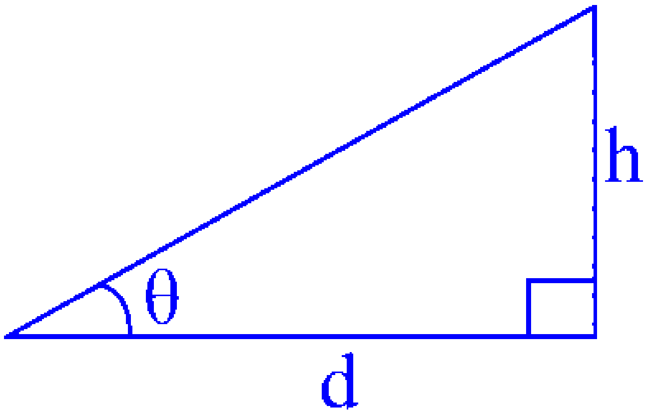
B. $\frac{2 \mathrm{v}^2}{\mathrm{gdh}}$

C. $\frac{\mathrm{gd}}{2 \mathrm{v}^2 \mathrm{h}}$

D. $\frac{v^2}{2ghd}$

Answer: A

Solution:



From figure,

$$\begin{aligned} & \tan \theta=\frac{h}{d} \\ \therefore \quad & \frac{v^2}{rg}=\frac{h}{d} \quad \ldots .\left(\because \tan \theta=\frac{v^2}{rg}\right) \\ \therefore \quad & r=\frac{v^2 d}{gh} \end{aligned}$$

Question43

Two particles having mass 'M' and 'm' are moving in a circular path with radius 'R' and 'r' respectively. The time period for both the particles is same. The ratio of angular velocity of the first particle to the second particle will be

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Options:

A. 1 : 1

B. 1 : 2

C. 2 : 3

D. 3 : 4

Answer: A

Solution:

$$\mathrm{T} = \frac{2\pi}{\omega}$$

$$\text{Hence, } \mathrm{T}_1 = \mathrm{T}_2$$

$$\Rightarrow \omega_1 = \omega_2$$

$$\therefore \quad \frac{\omega_1}{\omega_2} = \frac{1}{1}$$

Question44

In a conical pendulum the bob of mass 'm' moves in a horizontal circle of radius 'r' with uniform speed 'V'. The string of length 'L' describes a cone of semi vertical angle 'θ'. The centripetal force acting on the bob is ($\mathrm{g}=$ acceleration due to gravity)

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Options:

A. $\frac{\mathrm{mgr}}{\sqrt{\mathrm{L}^2-\mathrm{r}^2}}$

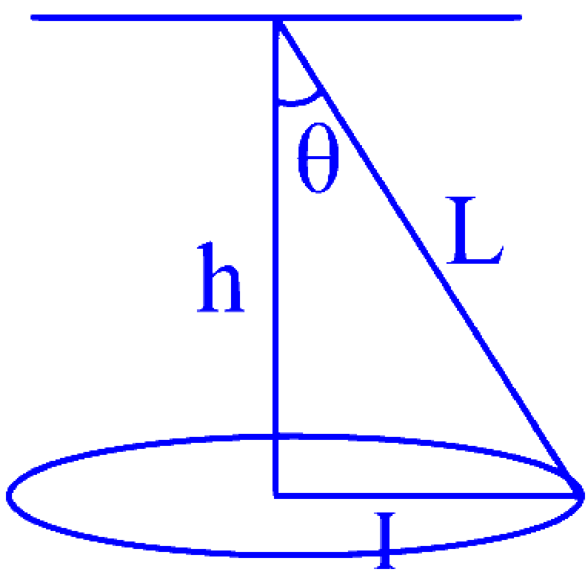
B. $\frac{\mathrm{mgr}}{(\mathrm{L}^2-\mathrm{r}^2)}$

C. $\frac{\sqrt{\mathrm{L}^2-\mathrm{r}^2}}{\mathrm{mgL}}$

D. $\frac{\mathrm{mgL}}{\sqrt{\mathrm{L}^2-\mathrm{r}^2}}$

Answer: A

Solution:



$$T\cos\theta = mg$$
$$\sin\theta = \frac{r}{L}$$
$$\cos\theta = \frac{\sqrt{L^2 - r^2}}{L}$$
$$\therefore \quad T = \frac{mg}{\cos\theta} = \frac{mgL}{\sqrt{L^2 - r^2}}$$
$$mr\omega^2 = T\sin\theta$$
$$\frac{T \times r}{L} = m\omega^2 \quad \ldots (\sin\theta = \frac{r}{L})$$
$$\omega^2 = \frac{g}{\sqrt{L^2 - r^2}}$$

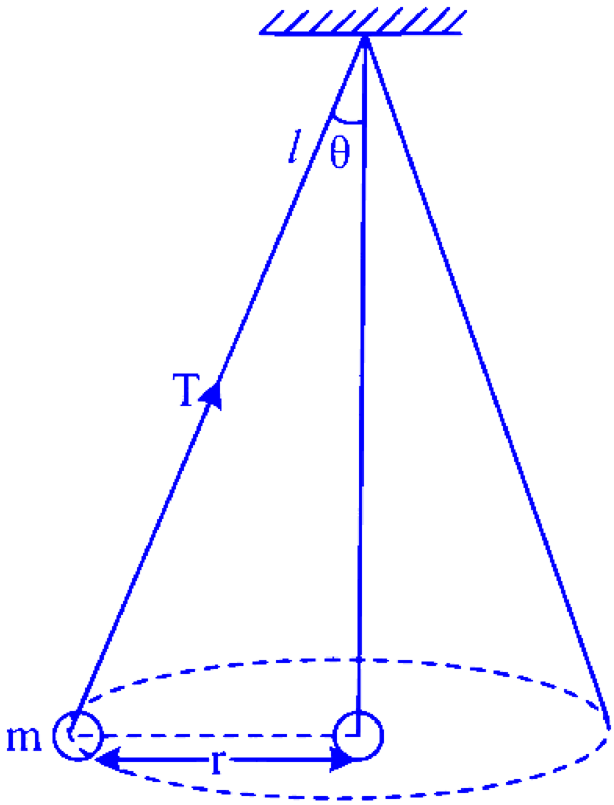
$\therefore$ The centripetal force is

$$F = \frac{mgr}{\sqrt{L^2 - r^2}}$$

Question45

A ball of mass 'm' is attached to the free end of a string of length 'l'. The ball is moving in horizontal circular path about the vertical axis as shown in the diagram.

The angular velocity 'ω' of the ball will be [$T =$ Tension in the string.]



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Options:

A. $\sqrt{\frac{Tl}{m}}$

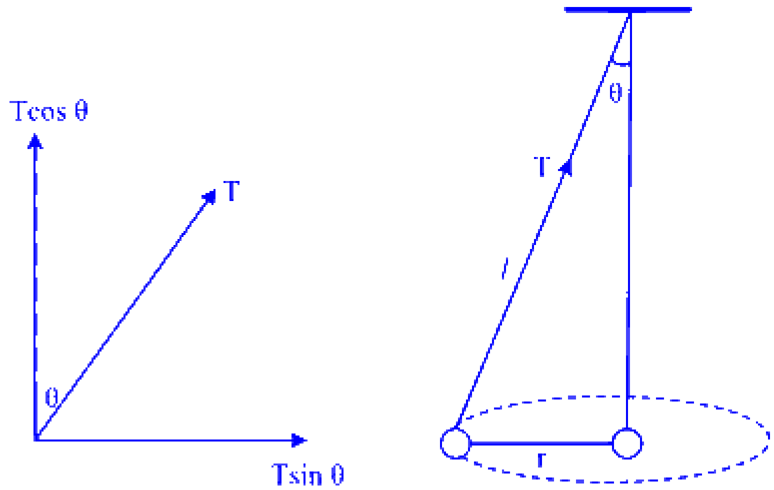
B. $\sqrt{\frac{Tm}{l}}$

C. $\sqrt{\frac{ml}{T}}$

D. $\sqrt{\frac{T}{mll}}$

Answer: D

Solution:



The tension in the string can be resolved in two components along the perpendicular axis. The gravitational force is acting downwards and the centrifugal force is acting in $-x$ direction $T \sin \theta = mr\omega^2$

$\therefore \quad \omega^2 = \frac{T \sin \theta}{\mathrm{mr}}$

$\therefore \quad \omega = \sqrt{\frac{T \sin \theta}{\mathrm{mr}}}$

From figure, $\sin \theta = \frac{r}{l}$

$$\therefore \quad \omega = \sqrt{\frac{\mathrm{Tr}}{\mathrm{mr}l}}$$

$$\therefore \quad \omega = \sqrt{\frac{\mathrm{T}}{\mathrm{m}l}}$$

Using dimensional analysis, dimensions of only option (D) matches with the dimensions of angular velocity.

Question46

A particle performing uniform circular motion of radius $\frac{\pi}{2}$ m makes 'x' revolutions in time 't'. Its tangential velocity is

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Options:

A. $\frac{\pi \mathrm{x}}{\mathrm{t}}$

B. $\frac{\pi x^2}{t}$

C. $\frac{\pi^2 x^2}{t}$

D. $\frac{\pi^2 \mathrm{x}}{\mathrm{t}}$

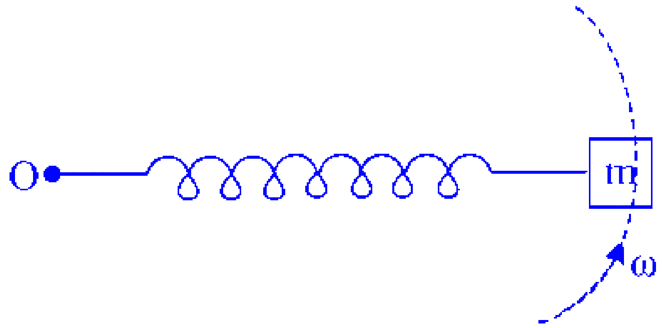
Answer: D

Solution:

$$\begin{aligned} \text{Circumference of the circle } & = 2\pi \mathrm{r} \\ & = 2\pi \times \frac{\pi}{2} = \pi^2 \\ \therefore \quad \text{Tangential velocity } & = \frac{\text{Distance Travelled}}{\text{Time}} \\ & = \frac{\pi^2 \times x}{t} \\ & = \frac{\pi^2 x}{t} \end{aligned}$$

Question47

A body of mass 200 gram is tied to a spring of spring constant $12.5 \mathrm{~N} / \mathrm{m}$, while other end of spring is fixed at point 'O'. If the body moves about 'O' in a circular path on a smooth horizontal surface with constant angular speed $5 \mathrm{rad} / \mathrm{s}$ then the ratio of extension in the spring to its natural length will be



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Options:

A. 1 : 2

B. 1 : 1

C. 2 : 3

D. 2 : 5

Answer: C

Solution:

Let the normal length be L and the extension be x.

$\therefore \quad$ Restoring Force = Centripetal Force

$$\mathrm{kx} = \mathrm{m}(\mathrm{L}+\mathrm{x})\omega^2$$
$$12.5\mathrm{x} = 0.2(\mathrm{~L}+\mathrm{x})25 \quad \ldots(\because \omega = 5 \text{ rad/s})$$

$$12.5x = 5(L+x)$$
$$7.5x = 5L$$
$$\therefore \quad \frac{x}{L} = \frac{5}{7.5} = \frac{2}{3} = 2:3$$

Question48

A particle of mass 'm' moves along a circle of radius 'r' with constant tangential acceleration. If K.E. of the particle is 'E' by the end of third revolution after beginning of the motion, then magnitude of tangential acceleration is

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Options:

A. $\frac{\mathrm{E}}{2\pi \mathrm{rm}}$

B. $\frac{\mathrm{E}}{6\pi \mathrm{rm}}$

C. $\frac{\mathrm{E}}{8\pi \mathrm{rm}}$

D. $\frac{\mathrm{E}}{4\pi \mathrm{rm}}$

Answer: B

Solution:

Using 3^{rd} equation of motion,

$v^2 = u^2 + 2as$

$\therefore \quad v^2 = 2a_t s$ .... (For u = 0)

$\therefore \quad a_t = \frac{v^2}{2s}$

By the end of 3^{rd} revolution, distance covered, $s = 3(2\pi r) = 6\pi r$

$\therefore \quad a_t = \frac{v^2}{2 \times 6\pi r}$ .... (i)

Also, $\frac{1}{2}mv^2 = E$

$\therefore \quad v^2 = \frac{2E}{m}$ ..... (ii)

Substituting equation (ii) in equation (i),

$a_t = \frac{2E}{2 \times 6\pi r \times m} = \frac{E}{6\pi rm}$

Question49

A simple pendulum of length $2 \mathrm{~m}$ is given a horizontal push through angular displacement of 60°. If the mass of bob is 200 gram, the angular velocity of the bob will be (Take Acceleration due to gravity $= 10 \mathrm{~m/s^2}$) $\left(\sin 30^{\circ} = \cos 60^{\circ} = 0.5, \cos 30^{\circ} = \sin 60^{\circ} = \sqrt{3}/2\right)$

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Options:

A. $2\sqrt{2} \mathrm{~rad/s}$

B. $3\sqrt{2} \mathrm{~rad/s}$

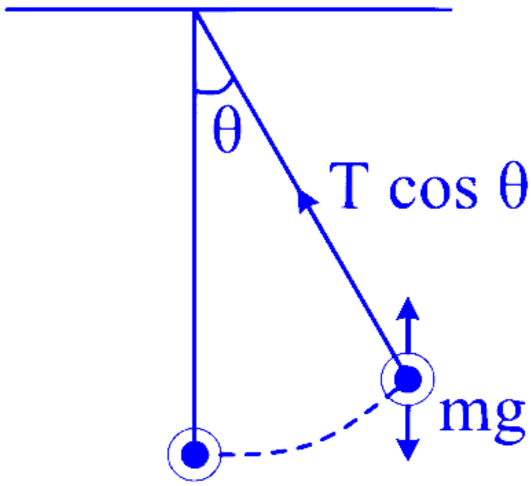
C. $2\sqrt{2.5} \mathrm{~rad/s}$

D. $3\sqrt{2.5} \mathrm{~rad/s}$

Answer: C

Solution:

Given : $l = 2$ m, $\theta = 60^{\circ}$, m = 200 g = 2g



From the figure,

$T = mr\omega^2$ ..... (i)

also $T\cos\theta = mg$ ..... (ii)

putting (i) into (ii)

$mr\omega^2 - \cos\theta = mg$ ..... (iii)

putting the given values into equation (iii)

$$2 \times 2 \times \omega^2 \frac{1}{2} = 2 \times 10 \quad \ldots \left(\because \cos 60 = \frac{1}{2}\right)$$

$$\omega^2 = 10$$

$$\Rightarrow \omega = \sqrt{10} \quad \ldots . (\because \sqrt{10} = \sqrt{2 \times 2 \times 2.5})$$

$$= 2\sqrt{2.5} \text{ rad/s}$$

Question50

A particle at rest starts moving with constant angular acceleration 4 rad/s^2 in circular path. At what time the magnitudes of its tangential acceleration and centrifugal acceleration will be equal?

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Options:

A. 0.4 s

B. 0.5 s

C. 0.8 s

D. 1.0 s

Answer: B

Solution:

In rotational motion,

$\omega = \omega_0 + \alpha t$
$\omega = \alpha t$

...... ($\because \omega_0 = 0$; particle at rest.)

$\therefore$ Centrifugal acceleration $\mathrm{a} = \omega^2 \mathrm{r}$

$\therefore$ $\mathrm{a} = \alpha^2 \mathrm{t}^2 \mathrm{r}$

Tangential acceleration $a_t = \alpha \times r$

Given: $a = a_t$

$\Rightarrow \alpha^2 t^2 r = \alpha r$

$t^2 = \frac{1}{\alpha} = \frac{1}{4}$

$\therefore$ $\mathrm{t} = \frac{1}{2} = 0.5$ s

Question51

A bucket containing water is revolved in a vertical circle of radius r. To prevent the water from falling down, the minimum frequency of revolution required is

(g = acceleration due to gravity)

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Options:

A. $2\pi\sqrt{\frac{\mathrm{r}}{\mathrm{g}}}$

B. $\frac{1}{2\pi}\sqrt{\frac{\mathrm{r}}{\mathrm{g}}}$

C. $\frac{1}{2\pi}\sqrt{\frac{\mathrm{g}}{\mathrm{r}}}$

D. $2\pi\sqrt{\frac{\mathrm{g}}{\mathrm{r}}}$

Answer: C

Solution:

To answer this question, we need to consider the forces in action when the bucket is at the topmost point in its circular path. At that point, the centripetal force required to keep the water moving in a circular path must be greater than or equal to the gravitational force acting on the water, to prevent it from falling out of the bucket.

The centripetal force (F_c) can be described by the following equation, where m is the mass of water, v is the linear velocity of the bucket, and r is the radius of the circle:

$F_c = \frac{mv^2}{r}$

At the minimum velocity needed to keep the water in the bucket, this centripetal force is provided entirely by the weight of the water, which is mg, where g is the acceleration due to gravity. Therefore, we can set $F_c = mg$ and solve for the velocity:

$mg = \frac{mv^2}{r}$

dividing both sides by m and then multiplying by r gives us:

$v^2 = rg$

Now, velocity can also be related to the frequency of revolution (f) and the circumference of the circle (C) using the relation:

$v = f \times C$

The circumference of the circle is given by:

$C = 2\pi r$

Let's substitute this into the velocity equation and solve for frequency:

$\sqrt{rg} = f \times 2\pi r$

dividing both sides by $2\pi r$ gives us:

$\frac{\sqrt{rg}}{2\pi r} = f$

To isolate f, since r is in a square root in the numerator and is not in a square root in the denominator, we can simplify:

$f = \frac{1}{2\pi}\sqrt{\frac{g}{r}}$

So the correct answer to the minimum frequency required to prevent the water from falling out of the bucket is Option C:

$\frac{1}{2\pi}\sqrt{\frac{g}{r}}$

Question52

A body moving in a circular path with a constant speed has constant

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Options:

A. momentum

B. velocity

C. acceleration

D. kinetic energy

Answer: D

Solution:

A body moving in a circular path at constant speed has constant kinetic energy. The directions of momentum, velocity and acceleration change from point to points. Hence they do not remain constant. K.E. is a scalar. Others are vectors.

Question53

Two bodies of masses 'm' and '3 m' are rotating in horizontal speed of the body of mass 'm' is n times that of the value of heavier body;

while the centripetal force is same for both. The value of n is

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Options:

A. 3

B. 1

C. 9

D. 6

Answer: A

Solution:

For body A, mass $=$ m, radius of the circle $=$ r

For body B, mass $=$ 3 m and radius of the circle $= \frac{r}{3}$ and v and v' are the tangential speeds

For A, C.P. force $= \frac{mv^2}{r}$ .... (1)

For B, C.P. force $= \frac{3\ m \cdot v'^2}{r/3} = \frac{9mv'^2}{r}$ .... (2)

and it is given that $v = nv'$

Since the C.P. force is same for both

$$\therefore \frac{mv^2}{r} = \frac{9mv'^2}{r}$$
$$\therefore v^2 = 9v'^2 \text{ but } v = nv'$$
$$\therefore n^2v'^2 = 9v'^2$$
$$\therefore n^2 = 9 \quad \therefore n = 3$$

Question54

A particle is moving along the circular path with constant speed and centripetal acceleration 'a'. If the speed is doubled, the ratio of its acceleration after and before the change is

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Options:

A. 3 : 1

B. 1 : 4

C. 2 : 1

D. 4 : 1

Answer: D

Solution:

To determine the ratio of the particle's acceleration after and before the change in speed, let's start with the formula for centripetal acceleration.

The centripetal acceleration of a particle moving with a constant speed v along a circular path of radius r is given by:

$a = \frac{v^2}{r}$

If the speed of the particle is doubled, the new speed v' will be:

$v' = 2v$

The new centripetal acceleration a' for this doubled speed is:

$a' = \frac{v'^2}{r}$

Substituting $v' = 2v$ into the equation for a':

$a' = \frac{(2v)^2}{r} = \frac{4v^2}{r}$

The initial centripetal acceleration a is:

$a = \frac{v^2}{r}$

Now, the ratio of the new centripetal acceleration a' to the initial centripetal acceleration a is:

$\frac{a'}{a} = \frac{\frac{4v^2}{r}}{\frac{v^2}{r}} = \frac{4v^2}{v^2} = 4$

Thus, the ratio of the particle's acceleration after doubling the speed to the acceleration before the speed change is:

4 : 1

Therefore, the correct option is:

Option D: 4: 1

Question55

A body of mass 'm' is moving with speed 'V' along a circular path of radius 'r'. Now the speed is reduced to $\frac{V}{2}$ and radius is increased to '3r'. For this change, initial centripetal force needs to be

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Options:

A. increased by $\frac{7}{12}$ times

B. increased by $\frac{10}{12}$ times

C. decreased by $\frac{11}{12}$ times

D. decreased by $\frac{1}{12}$ times

Answer: C

Solution:

Centripetal force $\mathrm{F}=\frac{\mathrm{mv}^2}{\mathrm{r}}$

$\mathrm{F}_1=\frac{\mathrm{mv}_1^2}{\mathrm{r}_1}$ and $\mathrm{F}_2=\frac{\mathrm{mv}_2^2}{\mathrm{r}_2}$

$$\therefore \frac{F_2}{F_1}=\frac{v_2^2}{v_1^2}\cdot\frac{r_1}{r_2}$$

$$v_2=\frac{v_1}{2} \text{ and } r_2=3r_1$$

$$\therefore \frac{F_2}{F_1}=\left(\frac{1}{2}\right)^2\cdot\frac{1}{3}=\frac{1}{12}$$

$$\therefore F_2=\frac{F_1}{12} \quad \therefore F_2<F_1$$

$$\therefore F_1-F_2=F_1-\frac{F_1}{12}=\frac{11}{12}F_1$$

Question56

A body attached to one end of a string performs motion along a vertical circle. Its centripetal acceleration, when the string is horizontal, will be [g = acceleration due to gravity]

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Options:

A. zero

B. 5g

C. 3g

D. g

Answer: C

Solution:

When string is horizontal its speed is given by

$V = \sqrt{3gr}$

Centripetal acceleration $= \frac{V^2}{r} = 3$ g

Question57

A projectile is thrown with an initial velocity $(a\hat{i} + b\hat{j})\mathrm{m/s}$, where $\hat{i}$ and $\hat{j}$ are unit vectors along horizontal and vertical directions respectively. If the range of the projectile is twice the maximum height reached by it, then

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Options:

A. b = 2a

B. $b = 4a$

C. $b = \frac{a}{2}$

D. $b = a$

Answer: A

Solution:

$u_x = a =$ Horizontal component of the velocity

$u_y = b =$ Vertical component of the velocity

Maximum height $H = \frac{u_y^2}{2g} = \frac{b^2}{2g}$

$$\text{Range } R = \frac{2u_y u_x}{g} = \frac{2ba}{g}$$

$$R = 2H \quad \therefore \frac{2ba}{g} = \frac{2b^2}{2g}$$

$$\therefore \quad b = 2a$$

Question58

A particle is performing U.C.M. along the circumference of a circle of diameter 50 cm with frequency 2 Hz. The acceleration of the particle in m/s^2 is

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Options:

A. $2\pi^2$

B. $4\pi^2$

C. $8\pi^2$

D. π^2

Answer: B

Solution:

To find the acceleration of the particle performing uniform circular motion (U.C.M.), we will use the formula for centripetal acceleration:

$a = \omega^2 r$

where ω is the angular velocity and r is the radius of the circle.

First, we need to determine the angular velocity ω. The formula for angular velocity in terms of frequency f is:

$\omega = 2\pi f$

Given the frequency $f = 2$ Hz, we have:

$\omega = 2\pi \times 2 = 4\pi \text{ rad/s}$

Next, we need to find the radius r of the circle. Given the diameter as 50 cm, the radius r is:

$r = \frac{50 \text{ cm}}{2} = 25 \text{ cm} = 0.25 \text{ m}$

Now we can calculate the centripetal acceleration:

$a = \omega^2 r = (4\pi)^2 \times 0.25 = 16\pi^2 \times 0.25 = 4\pi^2 \text{ m/s}^2$

Therefore, the acceleration of the particle is:

Option B

$4\pi^2 \text{ m/s}^2$

Question59

If ω_1 is angular velocity of hour hand of clock and ω_2 is angular velocity of the earth, then the ratio $\omega_1 : \omega_2$ is

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Options:

A. 1 : 2

B. 2 : 3

C. 3 : 2

D. 2 : 1

Answer: D

Solution:

To determine the ratio of the angular velocities of the hour hand of a clock (ω_1) and the Earth (ω_2), let's first understand the angular velocities involved:

The hour hand of a clock completes one full revolution in 12 hours. Therefore, the angular velocity ω_1 can be calculated as follows:

$$\omega_1 = \frac{2\pi \text{ radians}}{12 \text{ hours}} = \frac{\pi}{6} \text{ radians per hour}$$

The Earth completes one full revolution (360 degrees or 2π radians) in about 24 hours. Hence, the angular velocity ω_2 of the Earth is:

$$\omega_2 = \frac{2\pi \text{ radians}}{24 \text{ hours}} = \frac{\pi}{12} \text{ radians per hour}$$

Now, to find the ratio $\omega_1 : \omega_2$, we divide ω_1 by ω_2:

$$\frac{\omega_1}{\omega_2} = \frac{\frac{\pi}{6}}{\frac{\pi}{12}} = \frac{\pi}{6} \times \frac{12}{\pi} = 2$$

Thus, the ratio $\omega_1 : \omega_2$ is:

$2 : 1$

So, the correct answer is:

Option D: 2 : 1

Question60

The angular displacement of body performing circular motion is given by $\theta = 5 \sin \frac{\pi t}{6}$. The angular velocity of the body at $t = 3$ second will be $\left[\sin \frac{\pi}{2} = 1, \cos \frac{\pi}{2} = 0\right]$

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Options:

A. $5 \frac{\text{rad}}{\text{s}}$

B. $1 \frac{\text{rad}}{\text{s}}$

C. $2.5 \frac{\mathrm{rad}}{\mathrm{s}}$

D. zero $\frac{\mathrm{rad}}{\mathrm{s}}$

Answer: D

Solution:

The given angular displacement of the body performing circular motion is expressed as:

$\theta = 5 \sin \frac{\pi t}{6}$

To determine the angular velocity, we need to differentiate the angular displacement θ with respect to time t. The angular velocity ω is given by:

$\omega = \frac{d\theta}{dt}$

Let's find the derivative of $\theta = 5 \sin \frac{\pi t}{6}$ with respect to t.

First, apply the chain rule to differentiate the sine function:

$\frac{d\theta}{dt} = 5 \cdot \frac{d}{dt}\left(\sin \frac{\pi t}{6}\right)$

Next, differentiate $\sin \frac{\pi t}{6}$ with respect to t. Using the chain rule:

$\frac{d}{dt}\left(\sin \frac{\pi t}{6}\right) = \cos \frac{\pi t}{6} \cdot \frac{d}{dt}\left(\frac{\pi t}{6}\right)$

$= \cos \frac{\pi t}{6} \cdot \frac{\pi}{6}$

Now, substituting this back into the expression for $\frac{d\theta}{dt}$:

$\frac{d\theta}{dt} = 5 \cdot \cos \frac{\pi t}{6} \cdot \frac{\pi}{6}$

$\frac{d\theta}{dt} = \frac{5\pi}{6} \cos \frac{\pi t}{6}$

We need to evaluate the angular velocity at $t = 3$ seconds:

$\omega(t = 3) = \frac{5\pi}{6} \cos\left(\frac{\pi \cdot 3}{6}\right)$

$\omega(t = 3) = \frac{5\pi}{6} \cos\left(\frac{\pi}{2}\right)$

Given that $\cos \frac{\pi}{2} = 0$:

$\omega(t = 3) = \frac{5\pi}{6} \cdot 0$

$\omega(t = 3) = 0$

Therefore, the angular velocity of the body at $t = 3$ seconds is:

Option D: zero $\frac{\mathrm{rad}}{\mathrm{s}}$

Question61

A body performing uniform circular motion of radius 'R' has frequency 'n'. It centripetal acceleration is

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Options:

A. 8 $\pi^2 nR^2$

B. 4 $\pi^2 n^2 R$

C. 4 $\pi^2 n^2 R^2$

D. 8 $\pi^2 n^2 R$

Answer: B

Solution:

The correct answer is **Option B: 4 $\pi^2 n^2 R$**.

Here's why:

Understanding Centripetal Acceleration

Centripetal acceleration is the acceleration that keeps an object moving in a circular path. It always points towards the center of the circle. The magnitude of centripetal acceleration (a_c) is given by:

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

Where:

- v is the object's speed
- R is the radius of the circular path

Relating Frequency and Speed

Frequency (n) represents the number of revolutions the object completes per second. We can relate frequency to speed (v) as follows:

In one revolution, the object covers a distance equal to the circumference of the circle (2πR). So, the speed is:

$v = 2\pi Rn$

Putting it Together

Substituting the expression for v in the centripetal acceleration formula, we get:

$a_c = \frac{(2\pi Rn)^2}{R}$

$a_c = \frac{4\pi^2 R^2 n^2}{R}$

$a_c = \boxed{4\pi^2 n^2 R}$

Therefore, the centripetal acceleration of a body performing uniform circular motion is $4\pi^2 n^2 R$.

Question62

The angle of banking 'θ' for a meter gauge railway line is given by $\theta = \tan^{-1}\left(\frac{1}{20}\right)$. What is the elevation of the outer rail above the inner rail?

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Options:

A. 20 cm

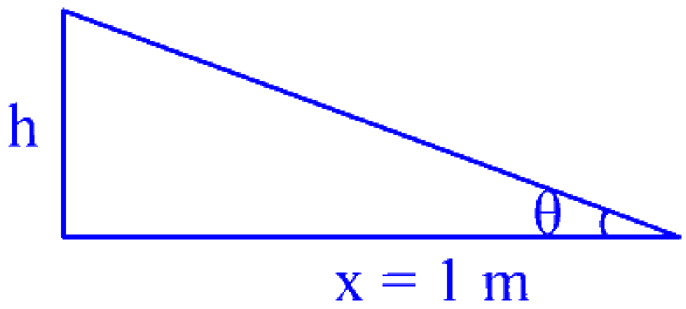
B. 10 cm

C. 0.2 cm

D. 5 cm

Answer: D

Solution:



$\tan\theta = \frac{1}{20} = \frac{h}{1}$

$\therefore \mathrm{h}=\frac{1}{20} \mathrm{~m}=0.05 \mathrm{~m}=5 \mathrm{~cm}$

Question63

A particle moves in a circular orbit of radius 'r' under a central attractive force, $F=-\frac{k}{r}$, where k is a constant. The periodic time of its motion is proportional to

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Options:

A. $r^{\frac{1}{2}}$

B. $\mathrm{r}^{\frac{2}{3}}$

C. r

D. $r^{\frac{3}{2}}$

Answer: C

Solution:

$$
\begin{aligned}
& \mathrm{mr} \omega^2=\frac{\mathrm{k}}{\mathrm{r}} \\
& \therefore \omega^2=\frac{\mathrm{k}}{\mathrm{mr}^2} \quad \therefore \omega^2 \propto \frac{1}{\mathrm{r}^2} \\
& \therefore \quad \omega \propto \frac{1}{\mathrm{r}}, \mathrm{T}=\frac{2 \pi}{\omega} \quad \therefore \mathrm{T} \propto \mathrm{r}
\end{aligned}
$$

Question64

A particle at rest starts moving with a constant angular acceleration of $4 \mathrm{~rad} / \mathrm{s}^2$ in a circular path. At what time the magnitude of its centripetal acceleration and tangential acceleration will be equal?

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Options:

A. $\frac{1}{4}$ S

B. $\frac{2}{3}$ S

C. $\frac{1}{2}$ S

D. $\frac{1}{3}$ S

Answer: C

Solution:

$\alpha = 4 \text{ rad/s}^2$

Centripatal (radial) acceleration, $a_r = r\omega^2$

Tangential acceleration, $a_t = r\alpha$

If $a_r = a_t$, then $r\omega^2 = r\alpha$

$$\therefore \quad \omega^2 = \alpha = 4$$
$$\omega = \sqrt{4} = 2\text{rad/s}$$
$$\omega = \omega_0 = \alpha t \quad = 0 + \alpha t = \alpha t$$
$$\therefore 2 = 4t$$
$$\text{or } t = \frac{1}{2} \text{ s}$$

Question65

A child starts running from rest along a circular track of radius r with constant tangential acceleration a. After time t he feels that slipping of shoes on the ground has started. The coefficient of friction between shoes and the ground is

[g = acceleration due to gravity]

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Options:

A. $\frac{\left[a^4 t^4+a^2 r^2\right]^{\frac{1}{2}}}{g r}$

B. $\frac{\left[a^4 t^4+a^2 r^2\right]}{r g}$

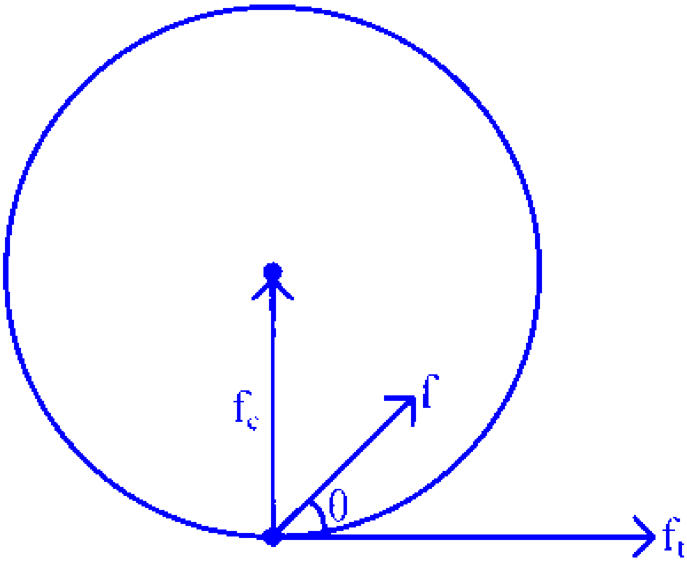
C. $\frac{\left[a^2 t^2+a^4 r^4\right]}{r g}$

D. $\frac{\left[a^4 t^4-a^2 r^2\right]^{\frac{1}{2}}}{r g}$

Answer: A

Solution:

When child moves in a circular track, he is acted upon by two force as shown below,



Here, $f_c=f \sin \theta$ and $f_t=f \cos \theta$.

As, f_c is the centripetal force and f_t is the tangential force. So,

$$f_c=\frac{m v^2}{r}=f \sin \theta$$

and $\quad f_t=m a=f \cos \theta$

$\therefore$ Resultant force, $f_R=\sqrt{(f \sin \theta)^2+(f \cos \theta)^2}$

$$=\sqrt{\left(\frac{m v^2}{r}\right)^2+(m a)^2}$$

Also, when the shoes starts slipping, the friction becomes equal to resultant force.

$\therefore \qquad f = f_R$

$\Rightarrow \qquad \mu mg = \sqrt{\left(\frac{mv^2}{r}\right)^2 + (ma)^2}$

$\Rightarrow \qquad \mu^2 m^2 g^2 = \frac{m^2 v^4}{r^2} + m^2 a^2$

$\Rightarrow \qquad \mu^2 g^2 = \frac{(at)^4 + a^2 r^2}{r^2} \qquad \left(\because a = \frac{v}{t}\right)$

or $\qquad \mu = \frac{\left(a^4 t^4 + a^2 r^2\right)^{\frac{1}{2}}}{gr}$

Question66

A body is moving along a circular track of radius 100 m with velocity $20 \mathrm{~m/s}$. Its tangential acceleration is $3 \mathrm{~m/s^2}$, then its resultant acceleration will be

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Options:

A. $5 \mathrm{~m/s^2}$

B. $4 \mathrm{~m/s^2}$

C. $2 \mathrm{~m/s^2}$

D. $3 \mathrm{~m/s^2}$

Answer: A

Solution:

The resultant acceleration of a body moving along a circular track can be determined by combining its tangential acceleration with its centripetal acceleration vectorially.

Tangential Acceleration (a_t):

Given as $3 \mathrm{~m/s}^2$.

Centripetal Acceleration (a_c):

This is required to maintain the circular motion and is given by the formula:

$a_c = \frac{v^2}{r}$

where $v = 20\,\mathrm{m/s}$ is the velocity and $r = 100\,\mathrm{m}$ is the radius of the circular path.

$a_c = \frac{(20)^2}{100} = \frac{400}{100} = 4\,\mathrm{m/s}^2$

Resultant Acceleration (a_r):

Since the centripetal and tangential accelerations are perpendicular to each other, the resultant acceleration can be calculated using the Pythagorean theorem:

$a_r = \sqrt{a_t^2 + a_c^2}$

$a_r = \sqrt{(3)^2 + (4)^2}$

$a_r = \sqrt{9 + 16}$

$a_r = \sqrt{25}$

$a_r = 5\,\mathrm{m/s}^2$

Thus, the resultant acceleration of the body is $\boxed{5\,\mathrm{m/s}^2}$.

Question67

A particle starting from rest moves along the circumference of a circle of radius r with angular acceleration α. The magnitude of the average velocity, in the time it completes the small angular displacement θ is

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Options:

A. $r\left(\frac{2}{\alpha\theta}\right)^2$

B. $r\left(\frac{\alpha\theta}{2}\right)^2$

C. $\rho\left(\frac{\alpha\theta}{2}\right)$

D. $r\left(\frac{\alpha\theta}{2}\right)^{\frac{1}{2}}$

Answer: D

Solution:

To find the magnitude of the average velocity of a particle moving along a circular path with angular acceleration, we first consider the kinematics of rotational motion.

The angular displacement, θ, is given by the rotational kinematics equation for a particle starting from rest:

$\theta = \frac{1}{2}\alpha t^2$

Solving for the time t:

$t = \sqrt{\frac{2\theta}{\alpha}}$

The tangential velocity v at any time t for a particle traveling along the circumference of a circle with angular velocity ω is related by:

$v = r\omega$

Since the angular velocity ω is related to angular acceleration α by:

$\omega = \alpha t$

Substituting $t = \sqrt{\frac{2\theta}{\alpha}}$:

$\omega = \alpha\sqrt{\frac{2\theta}{\alpha}} = \sqrt{2\alpha\theta}$

Therefore, the tangential velocity v becomes:

$v = r\sqrt{2\alpha\theta}$

Average velocity $\overline{v}$ over the time interval during which the particle covers the angular displacement θ is computed as the total arc length traveled divided by the time taken. The arc length s is given by:

$s = r\theta$

Thus, the average velocity is:

$\overline{v} = \frac{s}{t} = \frac{r\theta}{\sqrt{\frac{2\theta}{\alpha}}}$

Simplifying:

$\overline{v} = r\theta \cdot \sqrt{\frac{\alpha}{2\theta}} = r\sqrt{\frac{\alpha\theta}{2}}$

Therefore, the correct choice is:

Option D: $r\left(\frac{\alpha\theta}{2}\right)^{\frac{1}{2}}$

Question68

A particle of mass m is performing UCM along a circle of radius r. The relation between centripetal acceleration a and kinetic energy E is given by

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Options:

A. $a = \frac{2E}{mr}$

B. $a = 2Em$

C. $a = \frac{E}{mr}$

D. $a = \left(\frac{2E}{mr}\right)^2$

Answer: A

Solution:

To find the relation between centripetal acceleration a and kinetic energy E for a particle of mass m performing uniform circular motion of radius r, we start by expressing the centripetal acceleration and the kinetic energy in terms of the velocity v of the particle.

The centripetal acceleration a is given by:

$a = \frac{v^2}{r}$

The kinetic energy E of the particle is given by:

$E = \frac{1}{2}mv^2$

From the expression for kinetic energy, we can solve for v^2:

$v^2 = \frac{2E}{m}$

Substitute v^2 from the kinetic energy expression into the centripetal acceleration expression:

$a = \frac{v^2}{r} = \frac{\frac{2E}{m}}{r} = \frac{2E}{mr}$

Therefore, the correct relation between centripetal acceleration a and kinetic energy E is:

Option A

$a = \frac{2E}{mr}$

Question69

In non-uniform circular motion, the ratio of tangential to radial acceleration is ($r =$ radius, $\alpha =$ angular acceleration and $v =$ linear velocity)

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Options:

A. $\frac{r\alpha}{v}$

B. $\frac{v^2}{ra}$

C. $\frac{r\alpha^2}{v^2}$

D. $\frac{r^2\alpha}{v^2}$

Answer: D

Solution:

In non-uniform circular motion, two types of acceleration components are present: the tangential acceleration (which is responsible for the change in the speed of the particle moving along the circular path) and the radial (or centripetal) acceleration (which is responsible for the change in direction of the velocity of the particle). The tangential acceleration, a_t, is given by $a_t = r\alpha$, where α is the angular acceleration, and r is the radius of the circle. The radial (centripetal) acceleration, a_r, is given by $a_r = \frac{v^2}{r}$, where v is the linear (tangential) velocity of the particle.

The question asks for the ratio of tangential to radial acceleration, which is:

$\frac{a_t}{a_r} = \frac{r\alpha}{\frac{v^2}{r}} = \frac{r^2\alpha}{v^2}$

Therefore, the correct option is:

Option D: $\frac{r^2\alpha}{v^2}$

Question70

A particle is moving in a radius R with constant speed v. The magnitude of average acceleration after half revolution is

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Options:

A. $\frac{2\pi}{Rv^2}$

B. $\frac{2R}{\pi v}$

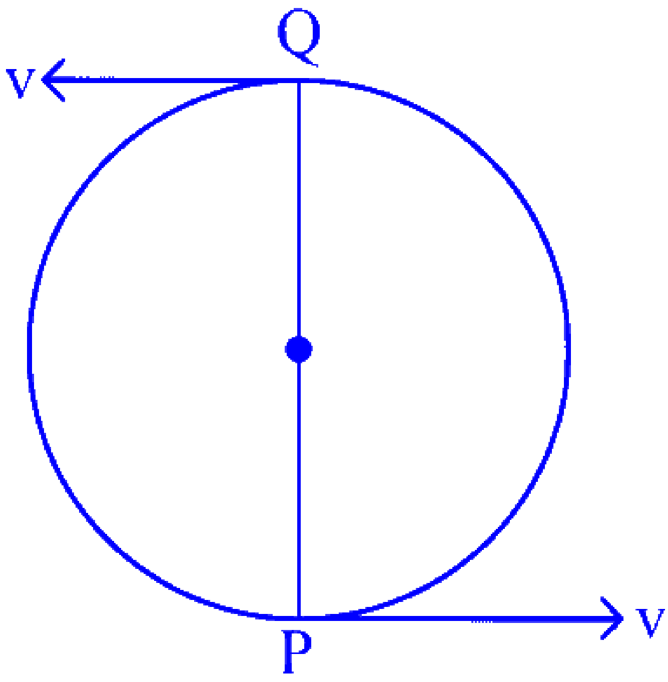
C. $\frac{2v^2}{\pi R}$

D. $\frac{2V}{\pi R^2}$

Answer: C

Solution:

The given situation is shown in the figure.



Change in momentum of particel in half-revolution

$\Delta p = mv - m(-v) = 2mv$ .... (i)

Time taken by the particle to complete half-revolution,

$t = \frac{\pi R}{V}$ .... (ii)

$\therefore$ Average force (F) = Rate of change in momentum

$$= \frac{\Delta p}{t}$$

$$= \frac{2mv}{\pi R/v} \quad \text{[From Eqs. (i) and (ii)]}$$

$$F = \frac{2mv^2}{\pi R} \Rightarrow ma = \frac{2mv^2}{\pi R}[F = ma]$$

$$a = \frac{2v^2}{\pi R}$$

Question71

A mass is whirled in a circular path with constant angular velocity and its linear velocity is v. If the string is now halved keeping the angular momentum same, the linear velocity is

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Options:

A. $2v$

B. $\frac{v}{2}$

C. v

D. $v\sqrt{2}$

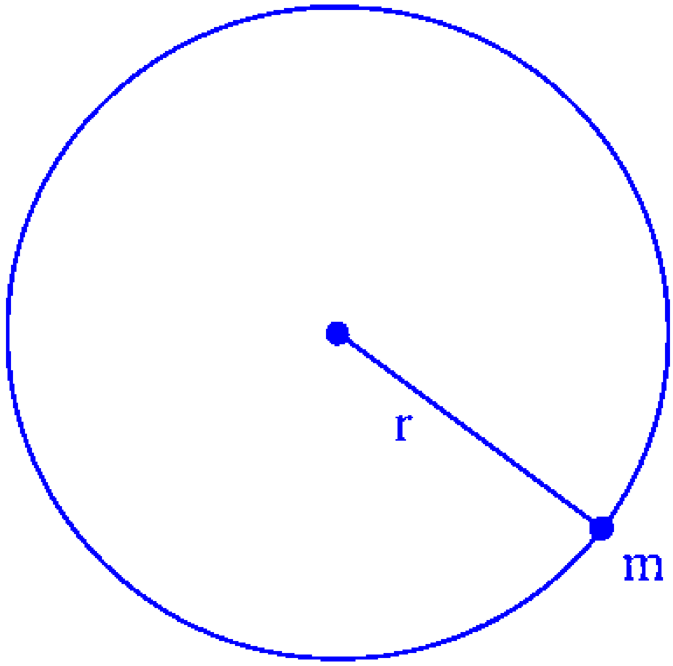
Answer: A

Solution:

Angular velocity $= \omega$

Linear velocity $= v$

Length of string = Radius $= r$



If string is halved, $r' = \frac{r}{2}$

Angular momentum, $L = \mathbf{r} \times \mathbf{p}$

where, $\mathbf{r} =$ radius vector and $\mathbf{p} =$ linear momentum.

$$= r \times mv \quad [\because \theta = 90^\circ]$$
$$= mvr$$

As L remain constant,

$mvr =$ constant

$\Rightarrow$ If $r' \rightarrow \frac{r}{2}, v' = 2v$ such that

$$mv'r' = m2v \times \frac{r}{2}$$
$$= mvr$$

Hence, linear velocity will be $2v$.

Question72

A body of mass m is performing a UCM in a circle of radius r with speed v. The work done by the centripetal force in moving it through $\left(\frac{2}{3}\right)$rd of the circular path is

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Options:

A. zero

B. $mv^2\pi r$

C. $\frac{2\pi mv^2 r}{3}$

D. $\frac{2mv^2\pi}{3}$

Answer: A

Solution:

When a body perform uniform circular motion, then centripetal force acts always in perpendicular direction to its velocity, hence work done by centripetal force is always zero.Hence, work done by centripetal force is zero, when it through $\left(\frac{2}{3}\right)$ rd of the circular path.

Question73

In U.C.M., when time interval $\delta t \rightarrow 0$, the angle between change in velocity (δv) and linear velocity $(\boldsymbol{v})$ will be

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Options:

A. 0°

B. 90°

C. 180°

D. 45°

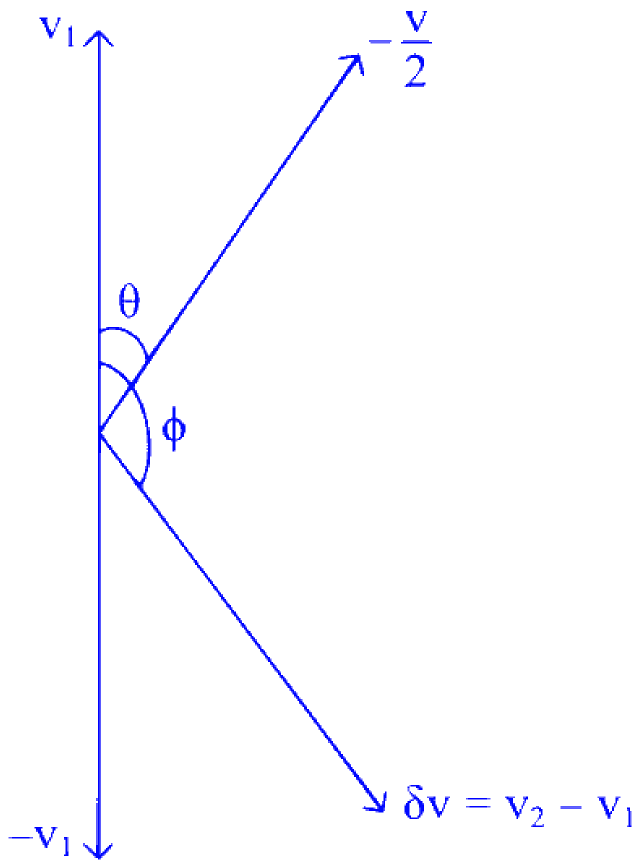
Answer: B

Solution:

The direction of change in velocity ($\delta \mathbf{v}$) is given by

$\phi=\frac{180^{\circ}-\theta}{2}=90^{\circ}-\frac{\theta}{2}$ .... (i)

This can be shown graphically as



For small time interval, i.e., $\delta t \rightarrow 0$, then angle between v_1 and v_2 is very small i.e., $\theta \approx 0^{\circ}$.

So, from Eq. (i), we get

$\phi=90^{\circ}$

Question74

A particle is performing U.C.M. along the circumference of a circle of diameter 50 cm with frequency 2 Hz . The acceleration of the particle in $\mathrm{m} / \mathrm{s}^2$ is

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Options:

A. $2\pi^2$

B. $8\pi^2$

C. π^2

D. $4\pi^2$

Answer: D

Solution:

Given, diameter of circle, $d = 50$ cm

$= 50 \times 10^{-2}$ m

and frequency, $f = 2$ Hz

The acceleration of particle in a uniform circular motion can be given as

$a = \omega^2 x$

where, $\omega =$ angular frequency $= 2\pi f$

$$x = \text{ distance from centre } = \frac{d}{2}$$

$$\Rightarrow \quad a = 4\pi^2 f^2 \times \frac{d}{2} \quad \text{... (i)}$$

Substituting given values in Eq. (i), we get

$a = 4\pi^2 \times 4 \times \frac{50 \times 10^{-2}}{2} = 4\pi^2$

Question75

A stone of mass 1 kg is tied to a string 2 m long and it's rotated at constant speed of 40 ms^{-1} in a vertical circle. The ratio of the tension at the top and the bottom is [Take $g = 10 \text{ ms}^{-2}$]

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Options:

A. $\frac{81}{79}$

B. $\frac{79}{81}$

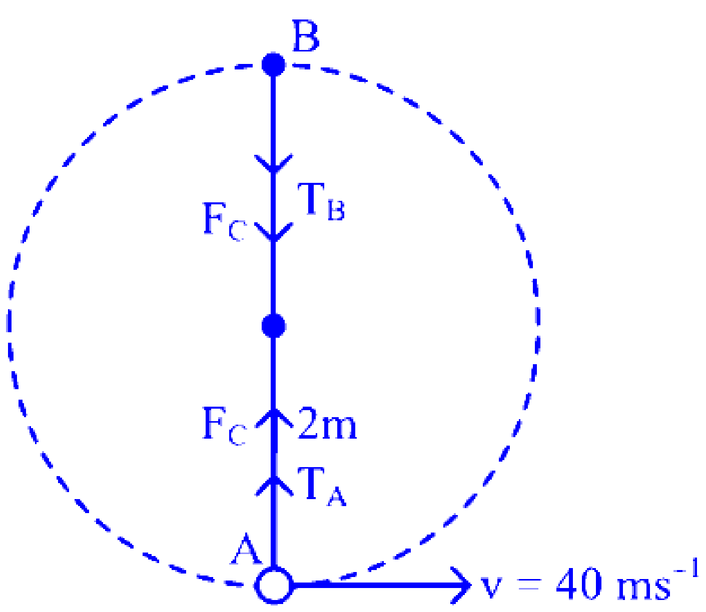
C. $\frac{19}{12}$

D. $\frac{12}{19}$

Answer: B

Solution:

Free body diagram (FBD) of a stone moving in a vertical circular path, which has tension force at point A and B as represented by T_A and T_B respectively as given below in the figure,



Given, mass of stone $(m) = 1$ kg,

length of the string $(R) = 2$ m

and rotating linear speed $(v) = 40\ \text{ms}^{-1}$

As, we know that the tension at position A,

$$T_A = \frac{mv^2}{R} + mg \quad \left(\therefore F_c = \frac{mv^2}{R}\right)$$

$$\Rightarrow \quad T_A = \frac{1 \times (40)^2}{2} + 1 \times 10 = 810\ \text{N}$$

Similarly, tension at position B,

$\Rightarrow \quad T_B = \frac{mv^2}{R} - mg = \frac{1 \times (40)^2}{2} - 1 \times 10 = 790 \text{ N}$

So, the ratio of T_B and T_A i.e.,

$\frac{T_B}{T_A} = \frac{790}{810} = \frac{79}{81}$

Hence, the ratio of tension at position B and tension at position A is $79 : 81$.

Question76

The real force ' F ' acting on a particle of mass m ' performing circular motion acts along the radius of circle ' r ' and is directed towards the centre of circle. The square root of magnitude of such force is ($T =$ periodic time)

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Options:

A. $\frac{2\pi}{T}\sqrt{mr}$

B. $\frac{Tmr}{4\pi}$

C. $\frac{2\pi T}{\sqrt{mr}}$

D. $\frac{T^2mr}{4\pi}$

Answer: A

Solution:

In circular motion, the force acting towards the center of the circle is known as the centripetal force (F). The formula for centripetal force is given by:

$F = \frac{mv^2}{r}$

where:

m is the mass of the particle,

v is the velocity of the particle,

r is the radius of the circular path.

The velocity v of an object in circular motion with a period T is given by:

$v = \frac{2\pi r}{T}$

Substitute the expression for v into the centripetal force formula:

$F = \frac{m\left(\frac{2\pi r}{T}\right)^2}{r} = \frac{m \cdot 4\pi^2 r^2}{T^2 \cdot r} = \frac{4\pi^2 mr}{T^2}$

We are interested in finding the square root of the magnitude of this force:

$\sqrt{F} = \sqrt{\frac{4\pi^2 mr}{T^2}}$

This can be simplified as follows:

$\sqrt{F} = \frac{2\pi}{T}\sqrt{mr}$

Thus, the correct option is **Option A**:

$\frac{2\pi}{T}\sqrt{mr}$
