LAKSHYA

MHTCET 2025

Physics | Lecture - 04

Rotational Dynamics

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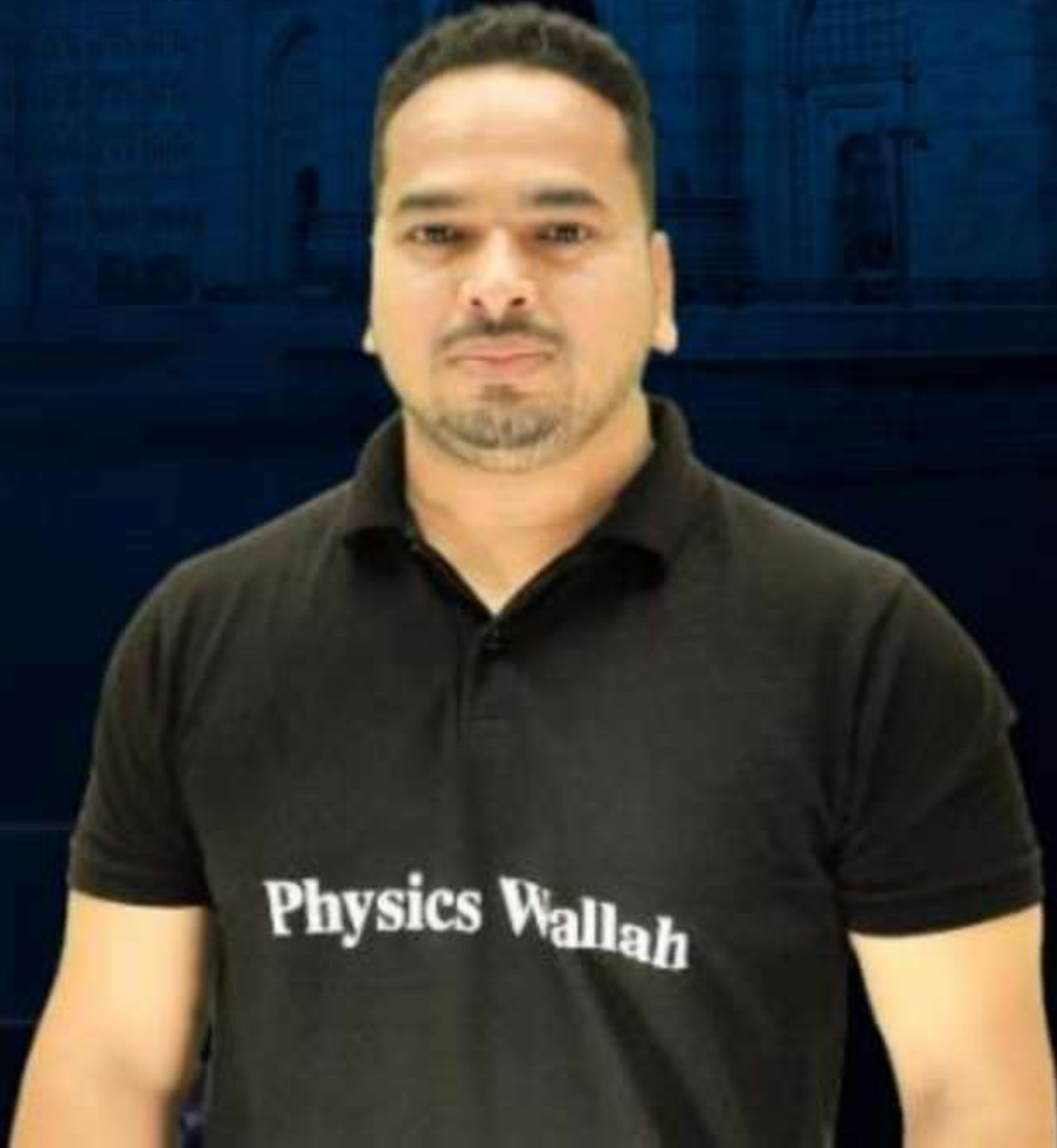
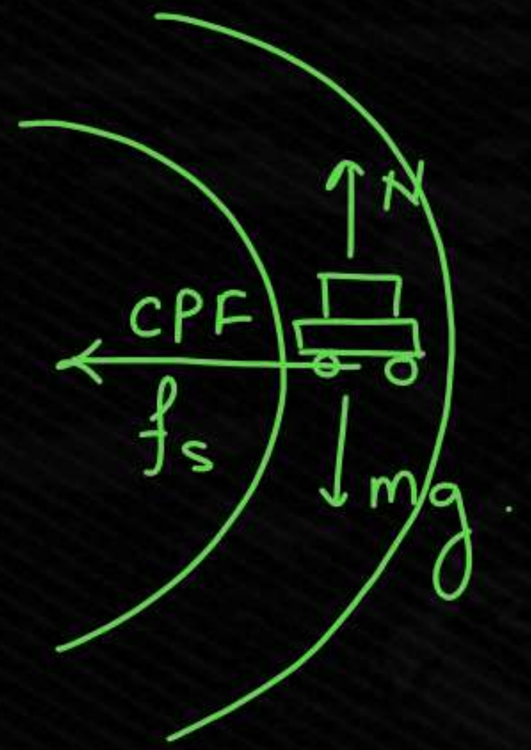


Topics *to be covered*

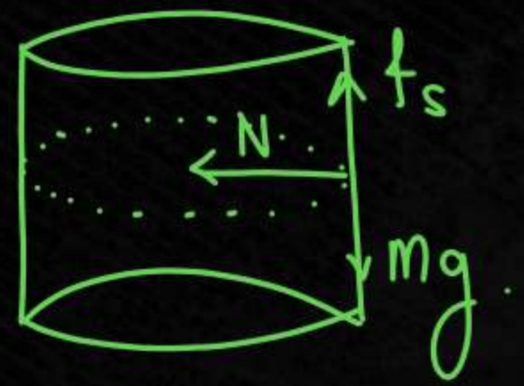
1. Vehicle on Banked Road

Revision :

- $V_{max} = \sqrt{\mu r g}$



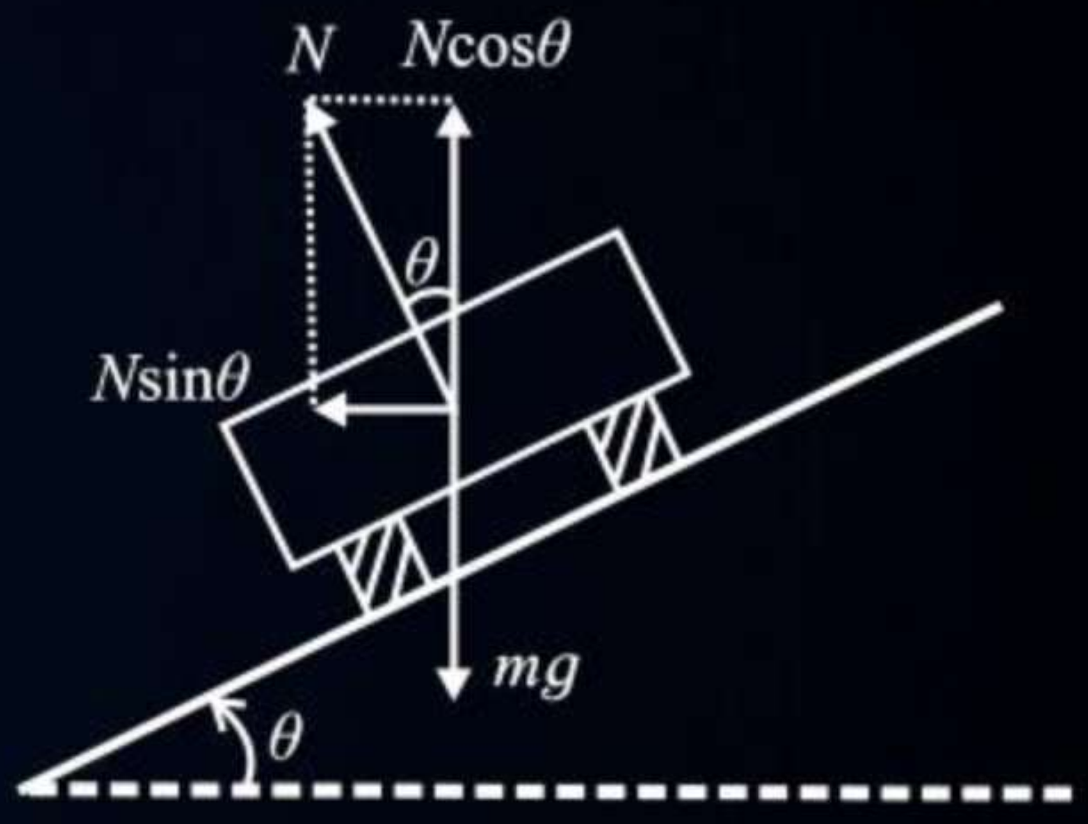
- $V_{min} = \sqrt{\frac{rg}{\mu}}$



Vehicle on a Banked Road

(*)

- Force of friction is not reliable bcoz it can be altered by rain, oil spill etc.
- The process of raising outer edge of road over inner edge is c/a B of R.



Vehicle on a banked road

$\therefore N\cos\theta = mg$

$N\sin\theta = \frac{mv^2}{r}$

$\theta = \tan^{-1}\frac{v^2}{rg}$

$\tan\theta = \frac{v^2}{rg}$

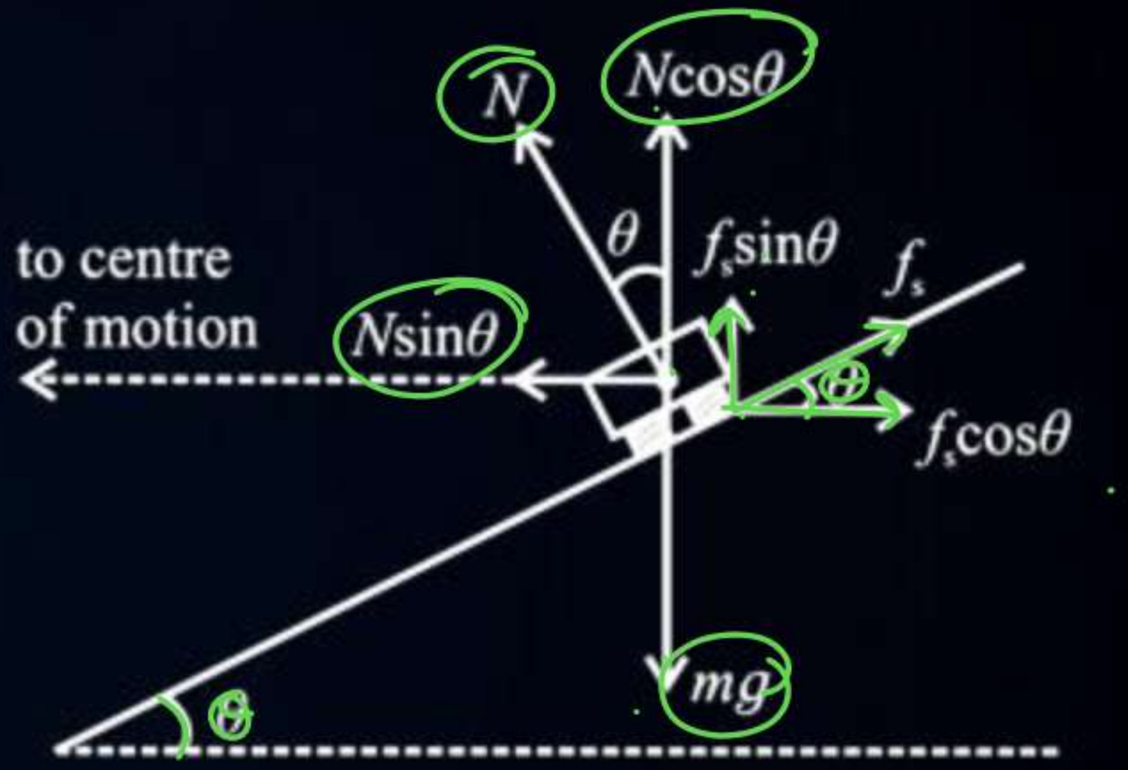
$v = \sqrt{rg\tan\theta}$.

from fig:

$$mg = N\cos\theta + f_s \sin\theta$$

$$\frac{mv^2}{r} = N\sin\theta - f_s\cos\theta$$

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



Banked road : lower speed limit.

$$\frac{V^2}{rg} = \frac{N\tan\theta - f_s}{N + f_s\tan\theta}$$

$$f_s = \mu_s N$$

$$\frac{V^2}{rg} = \frac{N\tan\theta - \mu_s N}{N + \mu_s N\tan\theta}$$

$$\frac{V^2}{rg} = \frac{\tan\theta - \mu_s}{1 + \mu_s\tan\theta}$$

$$V_{min} = \sqrt{rg\left[\frac{\tan\theta - \mu_s}{1 + \mu_s\tan\theta}\right]}$$

from fig:

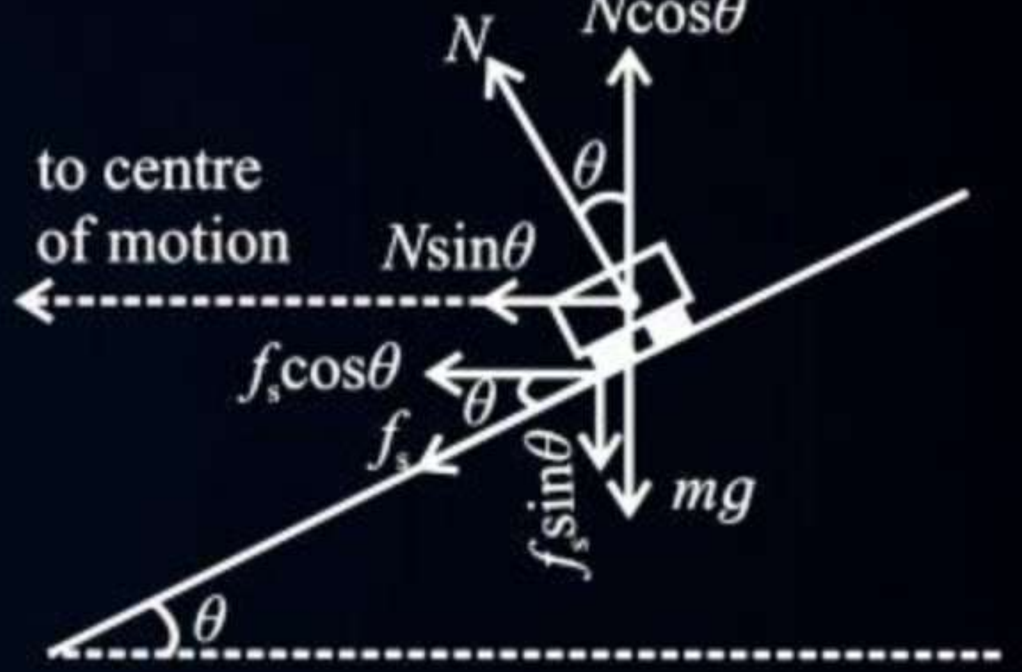
$$N\cos\theta = f_s\sin\theta + mg.$$

$$mg = N\cos\theta - f_s\sin\theta.$$

$$\frac{mv^2}{r} = N\sin\theta + f_s\cos\theta.$$

derive formula for maximum speed

(HW).



Banked road : upper speed limit.

QUESTION

On a dry day, the maximum safe speed at which a car can be driven on a curved horizontal road without skidding is 7 m/s. When the road is wet, the frictional force between the tyres and road reduces by 25%. How fast can the car safely take the turn on the wet road?

(A) 6.062 m/s

(B) 6.080 m/s

(C) 6.090 m/s

(D) 7.000 m/s

$f_s = \mu N$

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

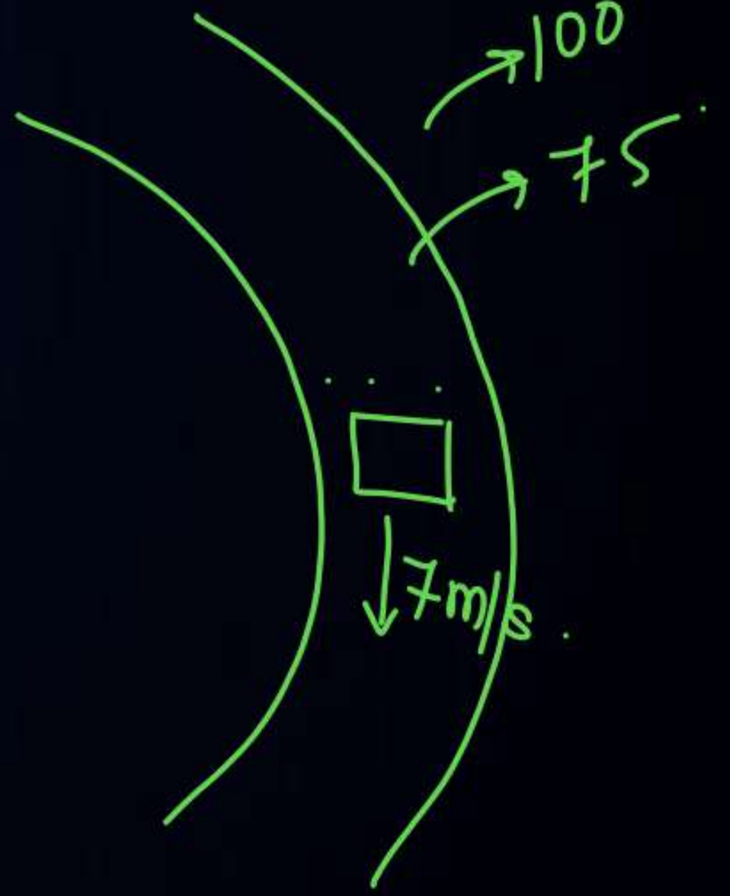
f_1, $f_2 = f_1 - 0.25 f_1$

$= 0.75 f_1$

$v = \sqrt{\mu r g}$

$v \propto \sqrt{f}$

$\frac{v_1}{v_2} = \sqrt{\frac{f_1}{f_2}}$



$$f_{dry} = f$$

$$f_w = 75\% \, f$$

$$= \frac{\cancel{75}^{3}}{\cancel{100}_{4}} f$$

$$f_w = \frac{3}{\cancel{4}} f$$

$$v = \sqrt{\mu r g}$$

$$v \propto \sqrt{f}$$

$$\frac{v_2}{v_1} = \sqrt{\frac{f_2}{f_1}}$$

$$v_2 = 7 \times \sqrt{\frac{3/4 \cancel{f}}{\cancel{f}}}$$

$$v_2 = \frac{7\sqrt{3}}{2}$$

$$v_2 = 6.062 \text{ m/s}$$

$$\frac{7}{V_2} = \sqrt{\frac{\cancel{f_1}}{\frac{3}{4}\cancel{f_1}}}$$

$$\frac{7}{V_2} = \sqrt{\frac{4}{3}}$$

$$\frac{7}{V_2} = \frac{2}{\sqrt{3}}$$

$$V_2 = \frac{7\sqrt{3}}{2}$$

$$V_2 = 3.5 \times 1.732$$

$$\boxed{V_2 = 6.062 \text{ m/s.}}$$

QUESTION

A coin kept at a distance of 5 cm from the centre of a turntable of radius 1.5 m just begins to slip when the turntable rotates at a speed of 90 rpm. Calculate the coefficient of static friction between the coin and the turntable. [$g = \pi^2$ m/s^2]

(A) 0.45

(B) 0.50

(C) 0.40

(D) 0.47

$f_s = \mu N$

$f_s = \mu mg$

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

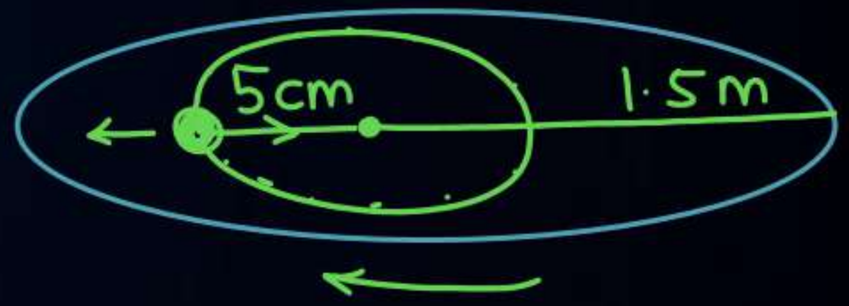
$\mu = \frac{v^2}{rg}$

$v = r\omega$

$\mu = \frac{r^2\omega^2}{rg}$

$\mu = \frac{r(2\pi f)^2}{g}$

$f = 90\,rpm$



$f = \frac{90}{60} = \frac{3}{2}\,rps.$

$$\mu = \frac{5\times10^{-2}\times \cancel{4}\times \cancel{\pi^2}}{\cancel{\pi^2}}\times\frac{9}{\cancel{4}}$$

$$\mu = 45\times10^{-2}$$

$$\boxed{\mu = 0.45}$$

QUESTION

A coin is placed on a stationary disc at a distance of 1 m from the disc's centre. At time $t = 0$ s, the disc begins to rotate with a constant angular acceleration of 2 rad/s^2 around a fixed vertical axis through its centre and perpendicular to its plane. Find the magnitude of the linear acceleration of the coin at $t = 1.5$ s. Assume the coin does not slip.

(A) 9.22 m/s^2 ✓

(B) 9.21 m/s^2

(C) 9.33 m/s^2

(D) 9.44 m/s^2

$\omega_0 = 0$ rad/s

$\alpha = 2$ rad/s²

$a = ? = \sqrt{a_t^2 + a_r^2}$

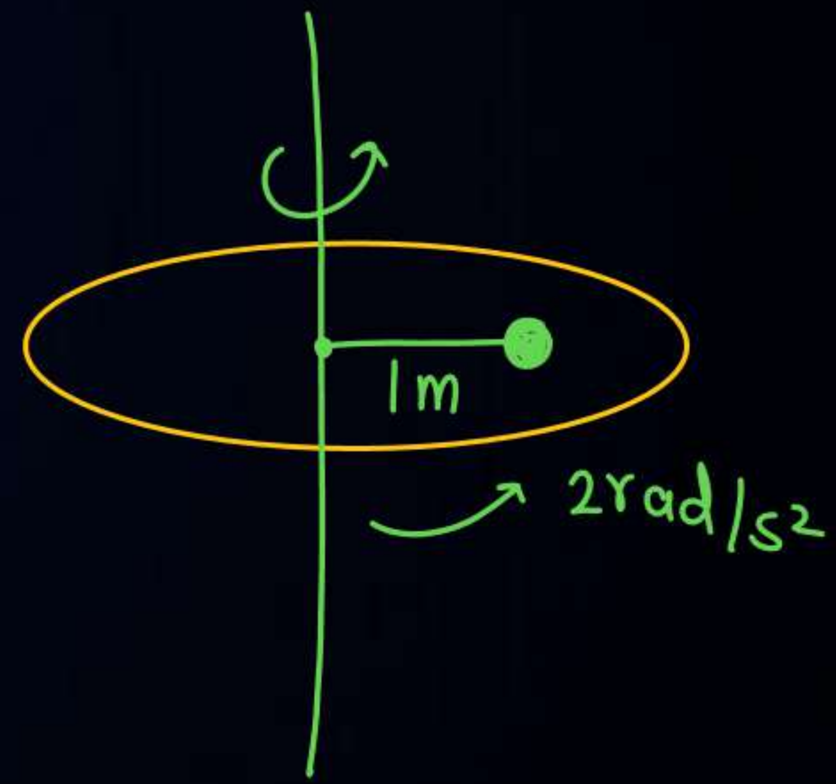
$t = 1.5$ sec

$a_r = r\omega^2$

$\omega = \omega_0 + \alpha t$

$\omega = 0 + 2 \times 3/2$

$\omega = 3$ rad/s.



$$a_r = r\omega^2$$
$$= 1 \times 3^2$$
$$a_r = 9\ m/s^2.$$

$$a_t = \alpha . r.$$
$$= 2 \times 1$$
$$a_t = 2\ m/s^2$$

$$a = \sqrt{a_t^2 + a_r^2}$$
$$= \sqrt{2^2 + 9^2}$$
$$= \sqrt{4 + 81}$$
$$a = \sqrt{85}$$
$$a = 9.22\ m/s^2.$$

QUESTION

A wheel of diameter 40 cm starts from rest and attains a speed of 240 rpm in 4 minutes. Calculate its angular displacement in this time interval.

(A) 960π rad

(B) 990π rad

(C) 940π rad

(D) 920π rad

QUESTION

A flywheel slows down uniformly from 1200 rpm to 600 rpm in 5 s. Find the number of revolutions made by the wheel in 5s.

(A) 75 revolutions

(B) 85 revolutions

(C) 89 revolutions

(D) 72 revolutions

QUESTION

An object of mass 0.5 kg is tied to a string and revolved in a horizontal circle of radius 1 m. If the breaking tension of the string is 50 N, what is the maximum speed the object can have?

(A) 10 m/s

(B) 12 m/s

(C) 9 m/s

(D) 11 m/s

QUESTION

A certain string 500 cm long breaks under a tension of 45 kg wt. An object of mass 100 g is attached to this string and whirled in a horizontal circle. Find the maximum number of revolutions that the object can make per second without breaking the string. [$g = 9.8\ m/s^2$]

(A) $f = 4.726$ Hz

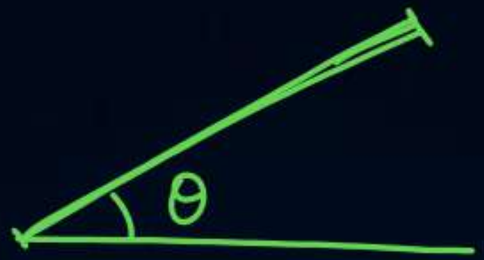
(B) $f = 4.990$ Hz

(C) $f = 5.970$ Hz

(D) $f = 5.604$ Hz

Summary

- Banking of Road



- $v = \sqrt{rg\tan\theta}$.

Homework

- Revise lecture
- Solve question on Banking of Road.

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