LAKSHYA

MHTCET 2025

Physics | Lecture - 02

Rotational Dynamics

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Topics *to be covered*

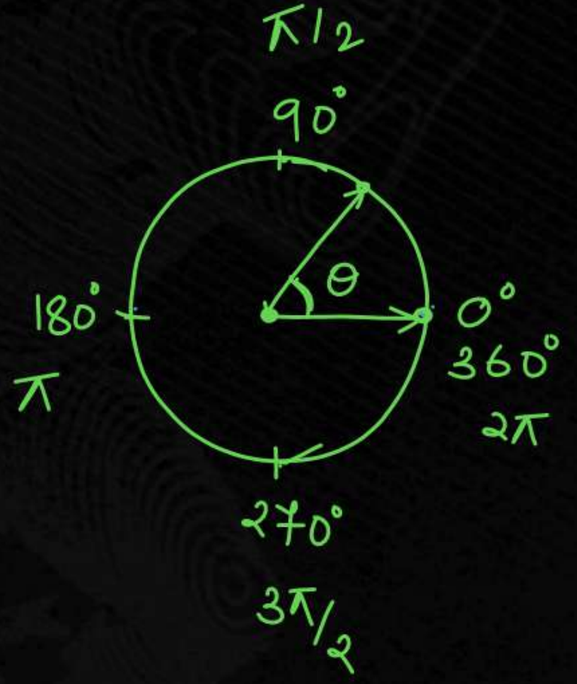
1. Centripetal and Tangential Acceleration ✓
2. Centripetal Force ✓
3. Centrifugal Force ✓

Revision :

1) Angular Displacement :

Angle traced by Radius Vector.

$\vec{ds} = \vec{d\theta} \times \vec{r}$



2) Angular Velocity :

$\omega = \theta/t \qquad \vec{V} = \vec{\omega} \times \vec{r}$

3) Angular Accl^n :

$$\alpha = \frac{\omega_2 - \omega_1}{t}$$

Centripetal And Tangential Acceleration

a_c - Centripetal Accl^n

a_t - tangential Accl^n

$\vec{a} = \vec{a_t} + \vec{a_r}$

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

$\vec{a_t} = \vec{\alpha} \times \vec{r}$

$\vec{a_r} = \vec{\omega} \times \vec{v}$

$\vec{a} = \vec{\alpha} \times \vec{r} + \vec{\omega} \times \vec{v}$

$F_{cp} = ma_c$

$F_{TF} = ma_t$

In UCM $a_t = 0$, $a_r \neq 0$

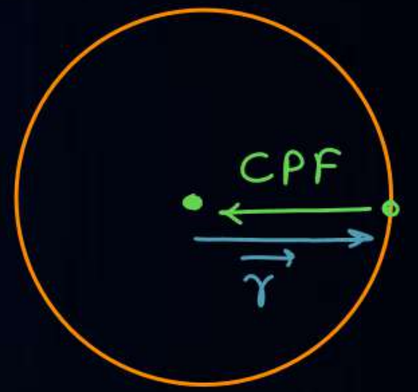
In Non UCM $a_t \neq 0$, $a_r \neq 0$

Centripetal Force

$F = ma$

Defⁿ :

The force acts on an object undergoing circular motion which is directed from object towards the center of circle.



$$\vec{F} = -\frac{mv^2}{r}\hat{r}$$

Centrifugal Force

Defⁿ :

The force which acts on object undergoing CM & directed away from the center of circle

$$\vec{F}_{CF} = \frac{mv^2}{r}\hat{r}$$

QUESTION

A body of mass 100 grams is tied to one end of a string and revolved along a circular path in the horizontal plane. The radius of the circle is 50 cm. If the body revolves with a constant angular speed of 20 rad/s, find the (i) period of revolution (ii) linear speed (iii) centripetal acceleration of the body.

$\Rightarrow$ It is UCM: $T = ?$

$m = 0.1\,kg$ $\quad v = ?$

$r = 0.5\,m$ $\quad a_r = ?$

$\omega = 20\,rad/s$

i) $\omega = \dfrac{2\pi}{T}$

$T = \dfrac{2\pi}{\omega} = \dfrac{2\pi}{20} = \dfrac{\pi}{10}$

$T = 0.314\,s.$

ii) $V = \omega r$

$V = 20 \times 0.5$

$V = 10 \text{ m/s}$.

iii) $a_r = \omega v$

$= 20 \times 10$

$= 200 \text{ m/s}^2$.

QUESTION

Calculate the angular speed of the Earth due to its spin (rotational motion).

A 7.273×10^{-5} rad/s

B 72.73×10^{-5} rad/s

C 727.3×10^{-5} rad/s

D 71.20×10^{-5} rad/s

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

$$\omega = \frac{2\pi}{24 \times 60 \times 60}$$

$$\omega = 7.273 \times 10^{-5} \text{ rad/s}$$

QUESTION

Find the angular speed of rotation of the Earth so that bodies on the equator would feel no weight. [Radius of the Earth = 6400 km, g = 9.8 m/s^2]

A 1.237×10^{-3} rad/s

B 12.37×10^{-3} rad/s

C 123.7×10^{-3} rad/s

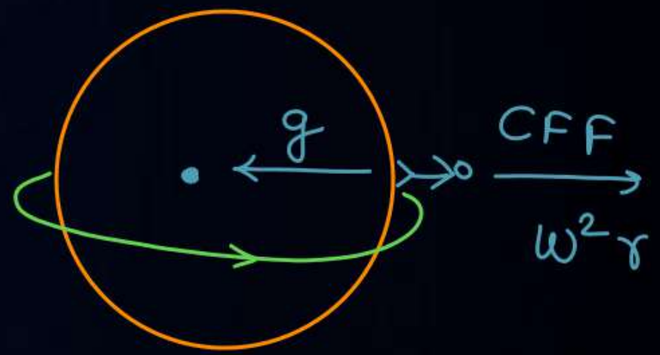
D 11.36×10^{-3} rad/s

$g = \omega^2 r$

$\omega = \sqrt{\frac{g}{r}}$

$\omega = \sqrt{\frac{9.8}{6.4 \times 10^6}}$

$\omega = 1.237 \times 10^{-3}$ rad/s.



QUESTION

To simulate the acceleration of large rockets, astronauts are seated in a chamber and revolved in a circle of radius 9.8 m. What angular speed is required to generate a centripetal acceleration 8 times the acceleration due to gravity ?
[$g = 9.8\ m/s^2$]

A 2.828 rad/s

B 3.337 rad/s

C 28.28 rad/s

D 33.37 rad/s

QUESTION

A motor part at a distance of 1.5 m from the motor's axis of rotation has a constant angular acceleration of 0.25 rad/s². Find the magnitude of its linear acceleration at the instant when its angular speed is 0.5 rad/s.

A. 0.5303 m/s²

B. 0.5404 m/s²

C. 0.54 m/s²

D. 0.5505 m/s²

$r = 1.5$ m

$\alpha = 0.25$ rad/s²

$a = ?$

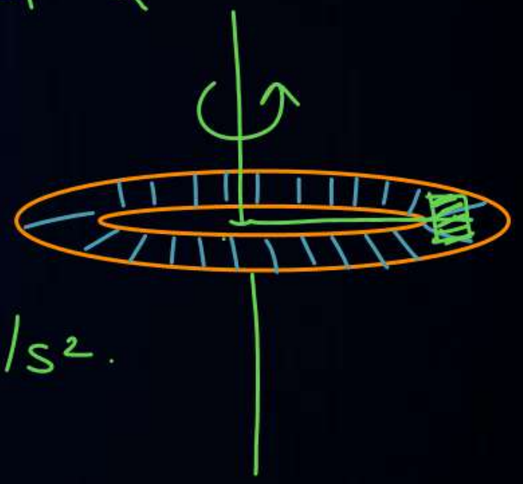
$\omega = 0.5$ rad/s.

$a_t = \alpha r$

$= 0.25 \times 1.5$

$a_t = 0.375$ m/s².

$\frac{1}{4} \times \frac{3}{2} = \frac{3}{8}$.



$a_r = r\omega^2$

$= \frac{3}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{3}{8}$ m/s².

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

$$= \sqrt{(3/8)^2 + (3/8)^2}$$

$$= \frac{3}{8} \times \sqrt{2}.$$

$$= \frac{3}{8} \times 1.414.$$

$$a = \frac{4.242}{8}$$

$$a = 0.53 \text{ m/s}^2.$$

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

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. $960\ \pi$ rad

B. $990\ \pi$ rad

C. $940\ \pi$ rad

D. $920\ \pi$ 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

1) $\vec{a}_r = \vec{\omega} \times \vec{v}$ ⟶ centripetal

$a_t = \vec{\alpha} \times \vec{r}$ ⟶ tangential

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

2) $\vec{F}_{cp} = -\frac{mv^2}{r}\hat{r}$

3) $\vec{F}_{cf} = \frac{mv^2}{r}\hat{r}$

Homework

1) Revise lecture.

2) Solve more questions on a_r & a_t.


धन्यवाद