VARSITY ‘Ka’ ADMISSION PROGRAM-2020

PHYSICS

Lecture : P-03

Chapter 4 : Newtonian mechanics

উদ্ভাস
একাডেমিক এন্ড এডমিশন কেয়ার

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PHYSICS 1ST Paper

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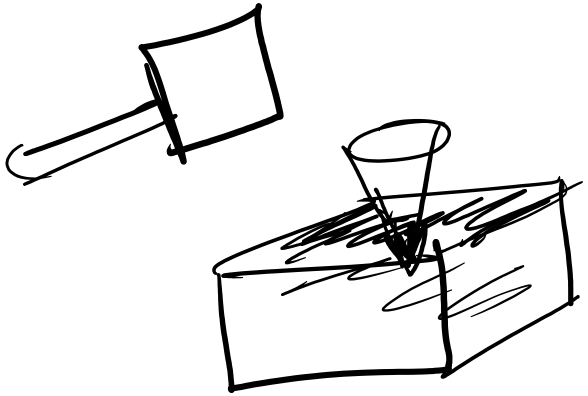
Force, Impulsive Force, Impulse of Force Related Theory

Force: (i) Static Object → Dynamic
↳ tries to be dynamic

(ii) Dynamic object → chang the value & direction of velocity
↳ tries to →

$$\Sigma F = ma = m\frac{\Delta V}{\Delta t}$$



Impulsive Force: (i) Huge amount of force
(ii) Small amount of time

Impulse of Force:

$$J = F\Delta t = ma\Delta t = m\frac{\Delta V}{\Delta t}\Delta t = m\Delta V = m(V - V_0) = mV - mV_0$$

$$J = P - P_0 = \Delta P$$

Poll Question-01

- A force of 16N acts for 2s on an object having the mass of 4kg. What is the change in velocity of the object?

(a) $16ms^{-1}$

(b) $8ms^{-1}$

(c) $10ms^{-1}$

(d) $20ms^{-1}$

$F = ma = m\frac{\Delta v}{\Delta t}$

$\Rightarrow \Delta v = \frac{F\Delta t}{m} = \frac{16\times 2}{4} = 8ms^{-1}$

Force, Impulsive Force, Impulse of Force Related mathematical problem

- A object having the mass of 3kg running in uniform-acceleration travels a distance of 0.18m and 0.30m in the fifth and eighth seconds of motion, respectively. Determine the value of the force acting on the object. **[SAU’14-15]**

Displacement at t_{th} second, $S_{th} = u + \frac{1}{2}a(2t-1)$

$0.18 = u + \frac{1}{2}a(2\times5-1)$

$\Rightarrow 0.18 = u + \frac{9a}{2} \quad \cdots (1)$

$0.30 = u + \frac{1}{2}a(2\times8-1)$

$\Rightarrow 0.30 = u + \frac{15a}{2} \quad \cdots (2)$

$(2)-(1) \Rightarrow 0.12 = 3a$

$\therefore a = 0.04\, ms^{-2}$

We know,

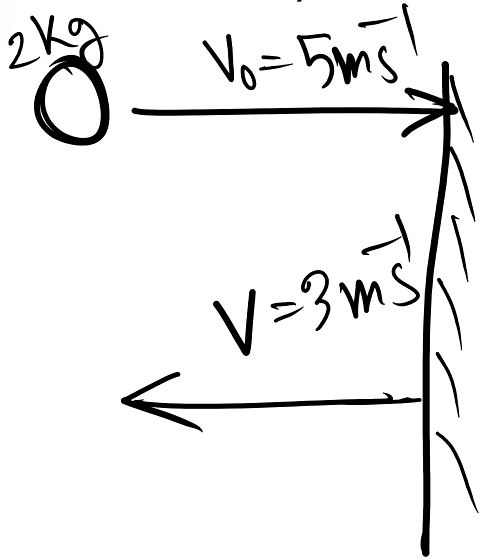
$F = ma$

$\Rightarrow F = 3\times0.04 = 0.12N$, [Ans]

Force, Impulsive Force, Impulse of Force Related mathematical problem

Vector quantity → value, Direction

An iron sphere of mass 2kg moving horizontally was pushed vertically at a speed of $5ms^{-1}$ and returned in the opposite direction at a speed of $3ms^{-1}$ .What is the impulse of the force? If the sphere is 0.01s in contact with the wall, what is the force exerted by the wall?



So, $V_0 = 5ms^{-1}$, $V = -3ms^{-1}$

$\therefore J = m(V - V_0) = 2(-3-5) = -16\ Ns$

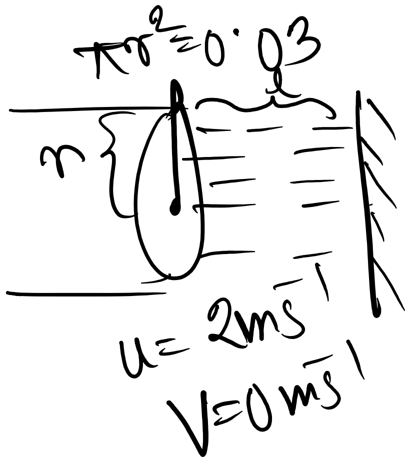
$J = Ft \Rightarrow F = \frac{J}{t} = \frac{-16}{0.01} = -1600N$

Force, Impulsive Force, Impulse of Force Related mathematical problem

Vector quantity → value, direction

$s = vt$ → $l = 2t$ (Let's)

Water comes out of a pipe at a speed of $2ms^{-1}$ and hits a wall vertically. The cross section of the tube is $0.03m^2$. Suppose the water is not rebounding. What amount of force is applied on the walls by water, (Water density $1000kgm^{-3}$) **[DU'09-10]**



Mass of water, $m = \rho V = \rho \times \pi r^2 l = 1000 \times 0.03 \times 2t = 60t$

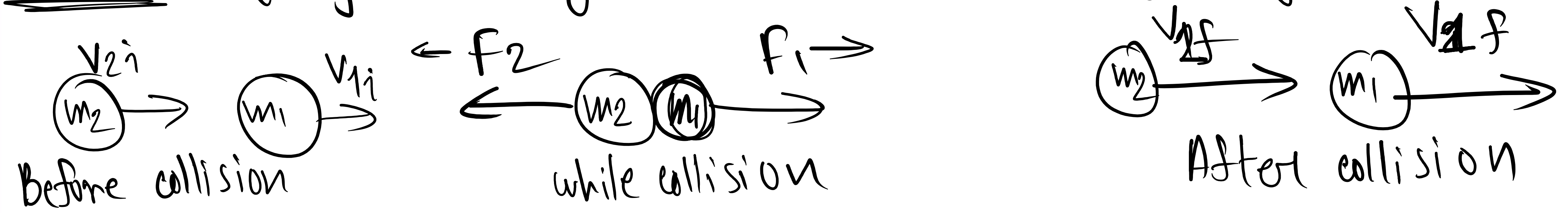
Force applied on water, $F_1 = \frac{m(v-u)}{t} = \frac{mv - mu}{t} = \frac{m\times 0 - m\times u}{t}$

$= \frac{-60t \times 2}{t} = -120N$

$\therefore$ Force applied on wall, $F_2 = -F_1 = -(-120)N = 120N$, [Newton's 3rd Law] [Ans]

Collision, Momentum, Rocket related theory

Collision: "2 Objects → Huge amount of Force → working in very small amount of time"



$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$

$v_{1i} - v_{2i} = v_{2f} - v_{1f}$

$v_{1f} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) v_{1i} + \left(\frac{2m_2}{m_1 + m_2}\right) v_{2i}$

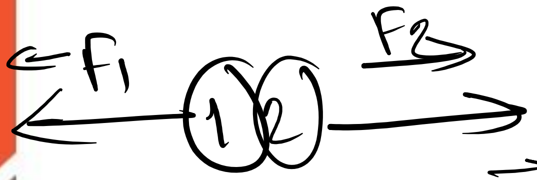
$v_{2f} = \left(\frac{2m_1}{m_1 + m_2}\right) v_{1i} + \left(\frac{m_2 - m_1}{m_1 + m_2}\right) v_{2i}$

Collision, Momentum, Rocket related theory

$P = mv$

Unit $= kgms^{-1}$

Dimension $= [MLT^{-1}]$



$\vec{F_1} = -\vec{F_2} \Rightarrow \vec{F_1} + \vec{F_2} = 0$

$\Rightarrow \frac{d\vec{P_1}}{dt} + \frac{d\vec{P_2}}{dt} = \vec{0}$

$\Rightarrow \frac{d}{dt}(\vec{P_1} + \vec{P_2}) = \vec{0}$

$\Rightarrow \frac{d\vec{P}}{dt} = 0$

$\vec{F} = \frac{d\vec{P}}{dt}$

$\vec{P} = \vec{P_1} + \vec{P_2}$ = Total momentum = constant

$\therefore \vec{P_i} = \vec{P_f}$

$\Rightarrow \vec{P_{1i}} + \vec{P_2} = \vec{P_{1f}} + \vec{P_{2f}}$

$\Rightarrow m_1V_{1i} + m_2V_{2i} = m_1V_{1f} + m_2V_{2f}$

Angular Momentum:

$L = I\omega$

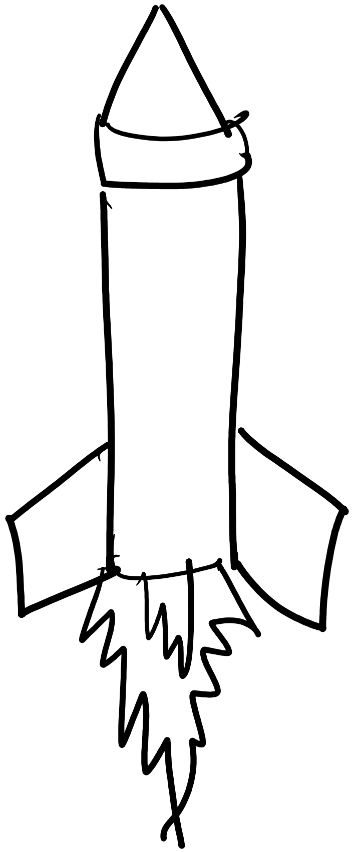
$\vec{L} = \vec{r} \times \vec{p}$

$|\vec{L}| = rp\sin\theta$

Unit $= kgm^2s^{-1}$

Dimension $= ML^2T^{-1}$

Collision, Momentum, Rocket related theory



(a) Push of the rocket (Thrust) $= V_r \frac{dm}{dt}$

V_r → speed of fuel burning

$\frac{dm}{dt}$ → rate of fuel burning

(b) Gained force during Launch $= V_r \frac{dm}{dt} - Mg$

M → Total mass of rocket along with fuel

(c) Gained force when fuel runs out $= V_r \frac{dm}{dt} - M'g$

M' → Mass of the only rocket without fuel

Poll Question-02

The unit of momentum in CGS method is: -

(a) gram / second

(b) Gram-seconds

(c) gram-centimeters / second ✓

(d) gram / centimeter-second

SI: $Kg\,m\,s^{-1}$

C.G.S: gram centimeters / second

Collision, Momentum, Rocket related mathematical problem

An object of mass 2kg collides with a stationary object in an elastic collision. After the collision, the object continued to move in the same direction with a velocity of one-fourth of the original velocity. What is the mass of a stationary object?

Given,

$m_1 = 2K$, $V_{1i} = V_{1i}$, $V_{2i} = 0$, $V_{1f} = \frac{1}{4} V_{1i}$, $m_2 = ?$

$$V_{1f} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) V_{1i} + \left(\frac{2m_2}{m_1 + m_2}\right) V_{2i}^{\nearrow 0}$$

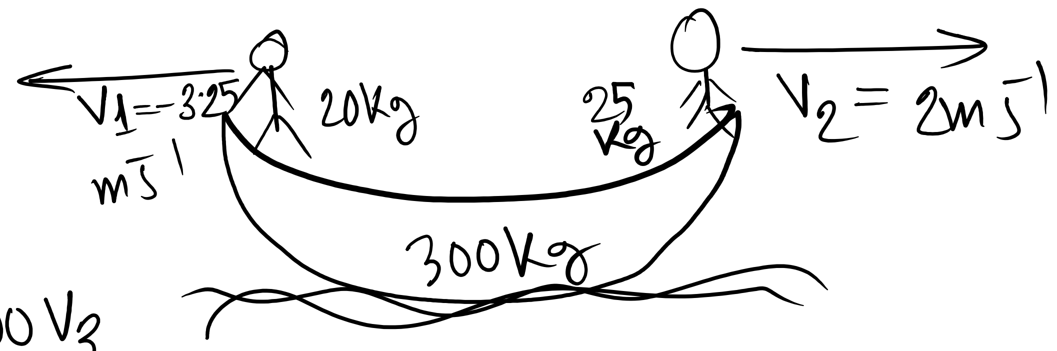
$$\Rightarrow \frac{V_{1f}}{V_{1i}} = \frac{2 - m_2}{2 + m_2} \Rightarrow \frac{1}{4} = \frac{2 - m_2}{2 + m_2} \Rightarrow 2 + m_2 = 8 - 4m_2$$

$$\Rightarrow 5 m_2 = 6 \quad \Rightarrow \quad \therefore m_2 = 1.2 \text{ Kg}, \text{ [Ans]}$$

Collision, Momentum, Rocket related mathematical problem

Vector Quantity → Value
→ Direction

Two boys having the mass of 20kg and 25kg jump from two hulls of a 300kg mass boat at 3.25ms^{-1} and 2ms^{-1} respectively. How fast will the boat go and in which direction?



Let,

Direction of 2nd boy → (+)ve

$m_1u_1 + m_2u_2 + m_3u_3 = m_1v_1 + m_2v_2 + m_3v_3$

$\Rightarrow 20\times0 + 25\times0 + 300\times0 = 20\times(-3.25) + 25\times2 + 300v_3$

$\Rightarrow 0 = -65 + 50 + 300v_3$

$\therefore v_3 = 0.05\ ms^{-1}$

∴ Direction of Boat would resemble with the 2nd boy.

Collision, Momentum, Rocket related mathematical problem

A rocket with 15,000kg of fuel weighs 20,000kg. The rocket burns fuel at a speed of 3,000ms^{-1} at a rate of 200kgs^{-1}. If the rocket is moving vertically upwards, then determine the-

(1) Push the top of the rocket

(2) Gain force applied to the rocket during launch

(3) The created applied gained force when the fuel runs out

(a) $V_r \frac{dm}{dt} = 3000 \times 200 = 6 \times 10^5 N$

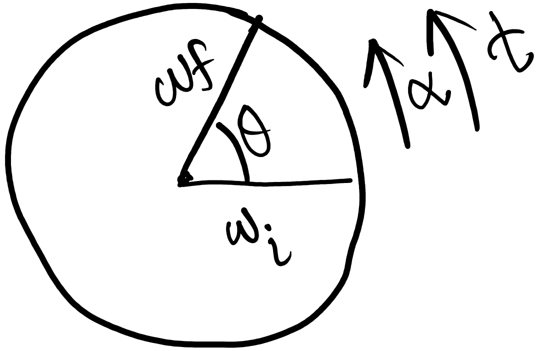
(b) $V_r \frac{dm}{dt} - Mg = 6 \times 10^5 - (20,000 \times 9.8)$

$= 4.04 \times 10^5 N$

(c) $m' = (20,000 - 15000) = 5000$

$V_r \frac{dm}{dt} - m'g = 6 \times 10^5 - (5000 \times 9.8) = 5.51 \times 10^5 N$, [Ans]

Angular Velocity and other related theories



$V = \omega r$

$a = \alpha r$

Unit of α = rad/s^2
Unit of ω = rad/s
Dimension of $\omega = [T^{-1}]$
Dimension of $\alpha = [T^{-2}]$

$\theta = \omega t$
$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$
$\omega_f = \omega_0 + \alpha t$
$\omega_f^2 = \omega_0^2 + 2\alpha\theta$
$\theta = 2\pi n$

$\vec{\tau} = \vec{r} \times \vec{F}$

$\therefore |\vec{\tau}| = rF\sin\theta$

$= rF \; [\theta = 90^\circ]$

Dimension of $\tau = ML^2T^{-2}$

Unit of τ = Nm

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Poll Question-03

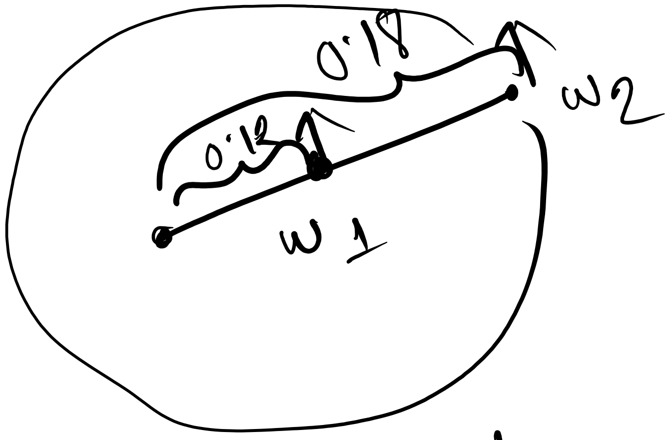
A gramophone record rotates at a uniform angular velocity. What is the ratio of the linear velocities at the points 0.12m and 0.18m away from the center on the record?

(a) 3/2

(b) 2/3

(c) 0.06

(d) 0.15



$\omega_1 = \omega_2$

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

$\Rightarrow \frac{v_1}{v_2} = \frac{r_1}{r_2} = \frac{0.12}{0.18} = \frac{2}{3}$

Angular Velocity and other related mathematical problems

A fan rotates 1200 times per minute. The fan stopped at 3 minutes after the switch was turned off. How many times will the fan turn before it stops?

$$\omega_0 = \frac{2\pi N}{t} = 2\pi \times \frac{1200}{60} = 40\pi$$

$+\alpha$, $-\alpha$

$\omega = 0$

$$\therefore \omega = \omega_0 - \alpha t \Rightarrow \alpha = \frac{\omega_0}{t} = \frac{40\pi}{(3\times 60)} = \frac{40\pi}{180}$$

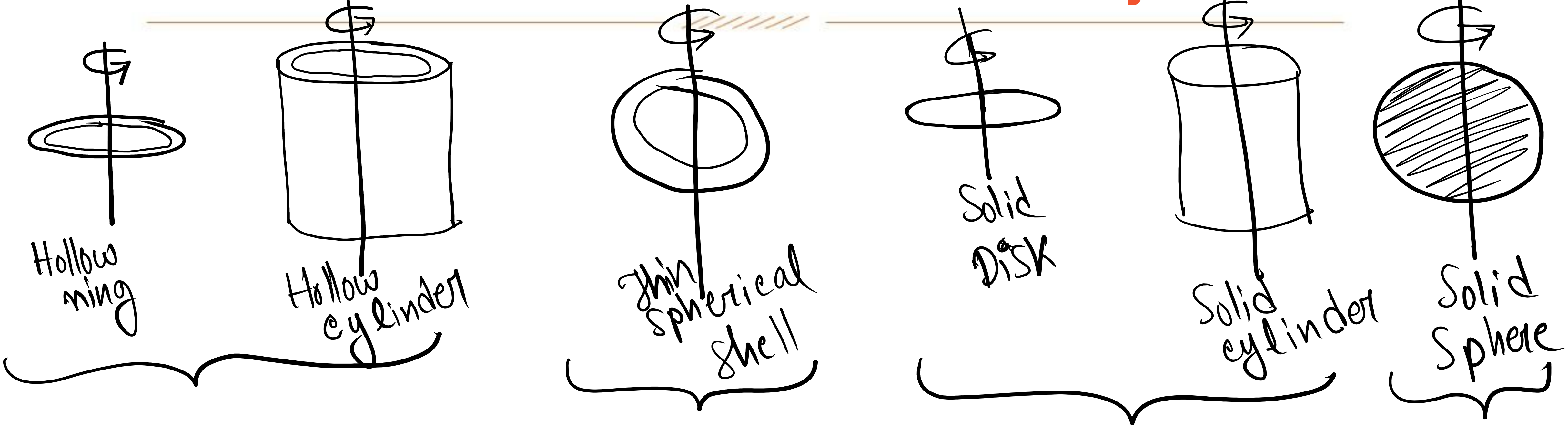
$$\theta = \omega_0 t - \frac{1}{2}\alpha t^2 = 40\pi \times (180) - \frac{1}{2}\left(\frac{40\pi}{180}\right)(180)^2$$

$$= 3600\pi$$

$$\therefore \theta = 2\pi n \Rightarrow n = \frac{\theta}{2\pi} = \frac{3600\pi}{2\pi} = 1800 \text{ turns}$$

$I = \sum mr^2$

Moment of Inertia Related Theory



Hollow ring, Hollow cylinder:

$$2MR^2 = \frac{2}{2}MR^2 = MR^2$$

Thin spherical shell:

$$2MR^2 = \frac{2}{3}MR^2$$
$$\frac{2}{3}MR^2$$

Solid Disk, Solid cylinder:

$$2MR^2 = \frac{2}{4}MR^2 = \frac{1}{2}MR^2$$

Solid Sphere:

$$2MR^2$$
$$\frac{2}{5}MR^2$$
$$= \frac{2}{5}MR^2$$

Moment of Inertia of ROD

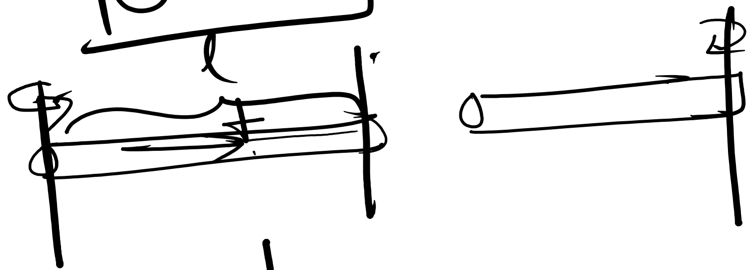
Case: I

R

= 1 2

$$M.O.I = \frac{ML^2}{12}$$

Case: 1



R

1 + 2 = 3

$$\therefore M.O.I = \frac{ML^2}{3}$$

Poll Question-04

What is the radius of gyration if the moment of inertia of the wheel is $0.25 kgm^2$ and the mass is 4kg?

(a) 4

(b) 0.25 ✓

(c) 0.50

(d) 0

$$I = MK^2$$

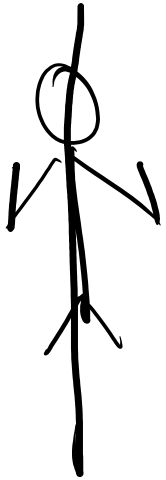
$$\Rightarrow K = \sqrt{\frac{I}{M}} = \sqrt{\frac{0.25}{4}}$$

$$= \sqrt{(0.25)^2}$$

$$= 0.25$$

Moment of Inertia Related Mathematical Theory

What is the current angular velocity of a dancer if she reduces the moment of inertia by 20% by folding her hands while rotating at an angular velocity of $20 rad s^{-1}$?



$I_1 = 100\%$

$I_2 = (100 - 20)$

$= 80\%$

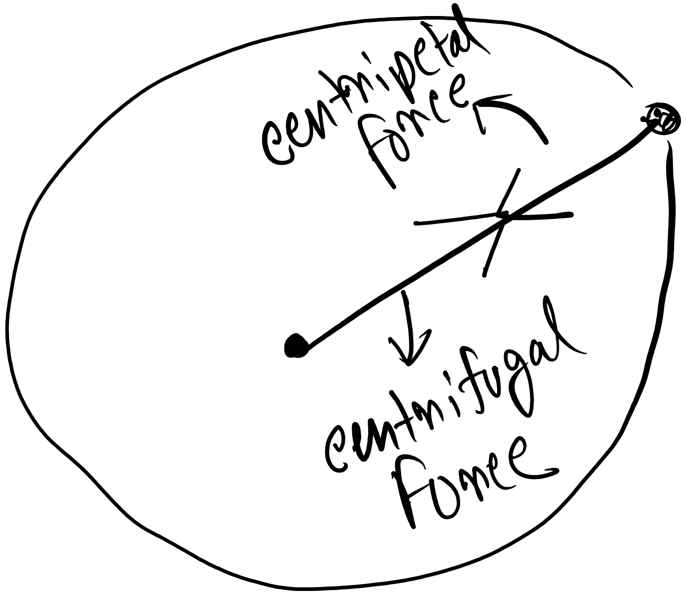
$L_1 = L_2$

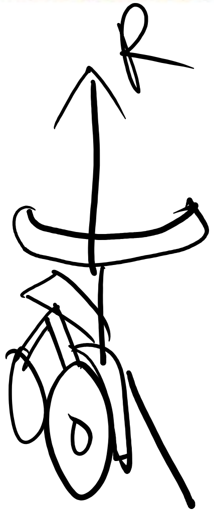
$\Rightarrow I_1 \omega_1 = I_2 \omega_2$

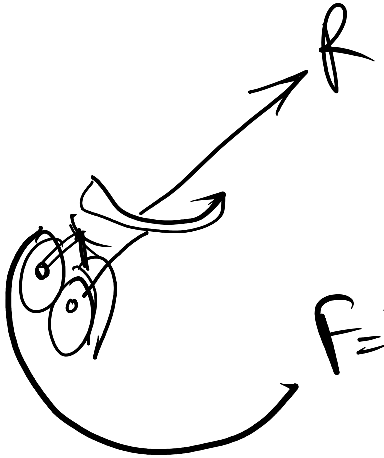
$\Rightarrow 100 \times 20 = 80 \times \omega_2$

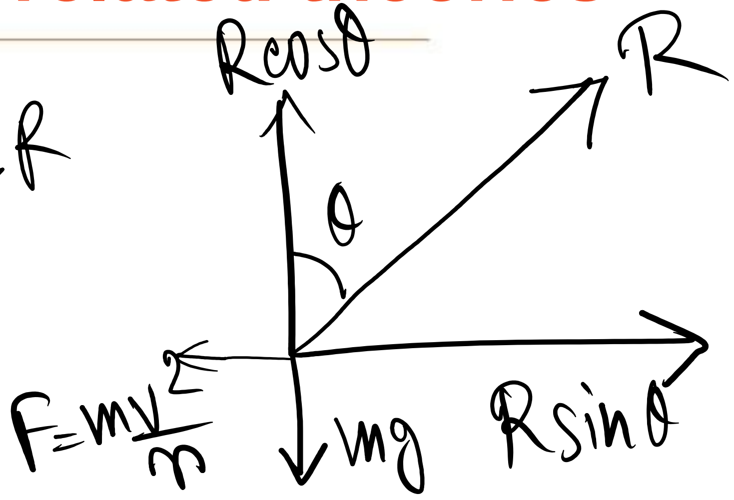
$\Rightarrow \omega_2 = \frac{2000}{80} = 25 rad s^{-1}$

Centrifugal, centripetal and banking angle related theories









$$F = ma = m \cdot \frac{v^2}{r} = \frac{mv^2}{r}$$

$$\therefore \quad R\sin\theta = \frac{mv^2}{r} \quad \ldots (1)$$

$$R\cos\theta = mg \quad \ldots (2)$$

$(1) \div (2) \Rightarrow$

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

Poll Question-05

At what speed does a rider of a motorcycle rotate in a circular path with a radius of **r** inclination at that angle $\boldsymbol{\theta}$ with the vertical plane?

(a) $rgtan\,\theta$

(b) $\sqrt{rgtan\theta}$ ✓

(c) $tan^{-1}(\theta/\text{rg})$

(d) rg $\sqrt{(tang\theta)}$

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

$\Rightarrow v^2 = rg\tan\theta$

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

Centrifugal, centripetal and banking angle related problems

For which angle will a bicycle incline along the vertical plane if it rotates in a circular path with a radius of 100m at a velocity of $20ms^{-1}$?

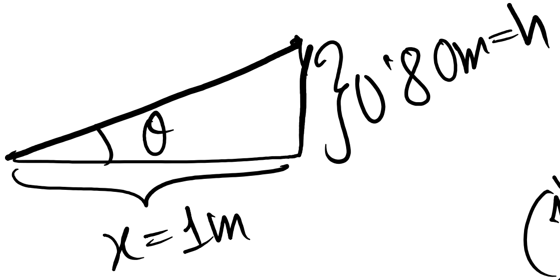
$$\tan\theta = \frac{v^2}{rg}$$

$$\Rightarrow \theta = \tan^{-1}\left(\frac{v^2}{rg}\right) = \tan^{-1}\left(\frac{20^2}{100 \times 9.8}\right)$$

$$\therefore \theta = 22.203^\circ \text{ [Ans]}$$

Centrifugal, centripetal and banking angle related problems

The center of gravity of a railway truck is 0.80m above the level of the railway line. The distance between the two railway lines is 1m. What is the maximum speed at which the truck can safely turn on a non-banking curve having 50m as the radius? [g= $10ms^{-2}$]



$$\tan\theta = \frac{h}{x} \quad \text{---} (1)$$

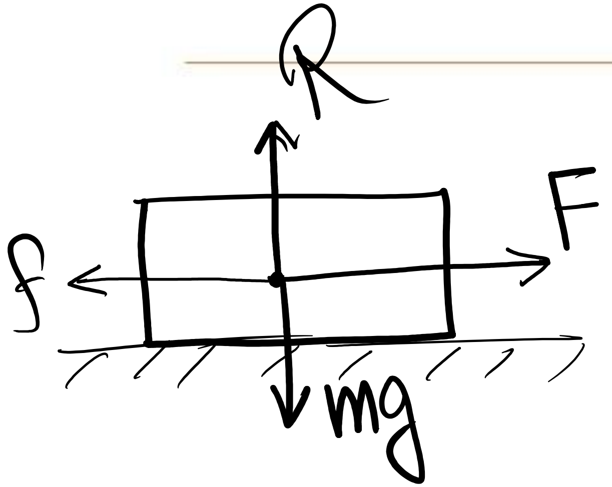
$$\tan\theta = \frac{v^2}{rg} \quad \text{---} (2)$$

(1) & (2) ⇒

$$\frac{h}{x} = \frac{v^2}{rg}$$

$$\Rightarrow v = \sqrt{\frac{hrg}{x}} = \sqrt{\frac{0.80 \times 50 \times 10}{1}} = 20ms^{-1}$$

Theory of friction



Static Friction:

$$f_s \propto R$$

$$\Rightarrow f_s = \mu_s R$$

$$\therefore \boxed{\mu_s = \frac{f_s}{R}}$$

Dynamic Friction:

$$f_k \propto R$$

$$\Rightarrow f_k = \mu_k R$$

$$\Rightarrow \boxed{\mu_k = \frac{f_k}{R}}$$

$$\boxed{\mu_s > \mu_k}$$

Object moves	Object in stable
$\Sigma F = ma$	$\Sigma F = 0$
$f_k = \mu_k R$	$f_s = \mu_s R$
opposite direction of applied force (f_k)	0. of the applied force) opposite of f_s tendmies

Poll Question-06

A marble of 10g mass rolled over the floor and stopped after 10s. The initial velocity of the marble was $10ms^{-1}$ .What is the value of the friction force?

(a) 0.01N ✓

(b) 0.1N

(c) 1

(d) 10N

Frictional Force $F = ma = m\frac{\Delta v}{\Delta t} = \frac{10}{1000} \times \frac{10}{10}$

$= 0.01N$

Friction Related Mathematical Problem

When an 8N force is applied horizontally on a rectangular object having the mass of 10kg, it starts moving. Then with the help of 4N force the object can be kept moving at a certain speed. What will be the position/static friction force and friction coefficient? **[g=10 ms^{-2}]**

For 8N Force, $a=0$

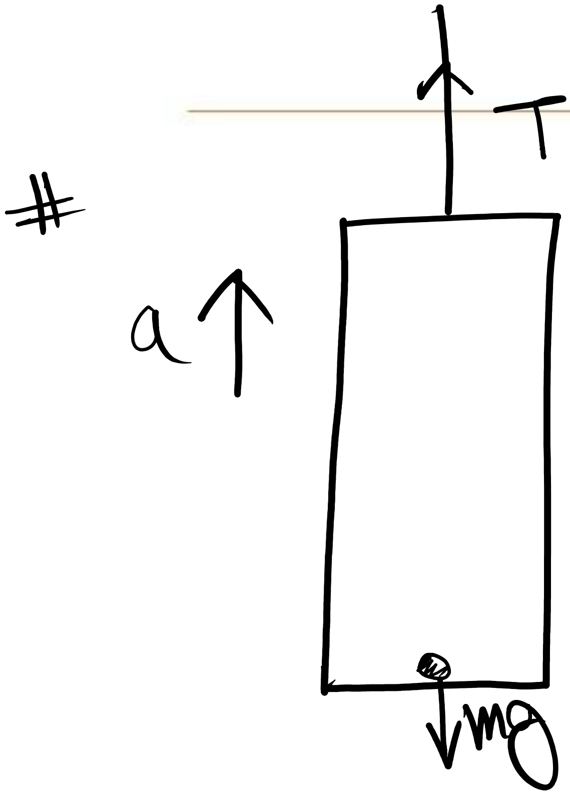
$F=8N=f_s$

$\therefore \mu_s = \frac{f_s}{R} = \frac{8N}{10\times10} = 0.08$

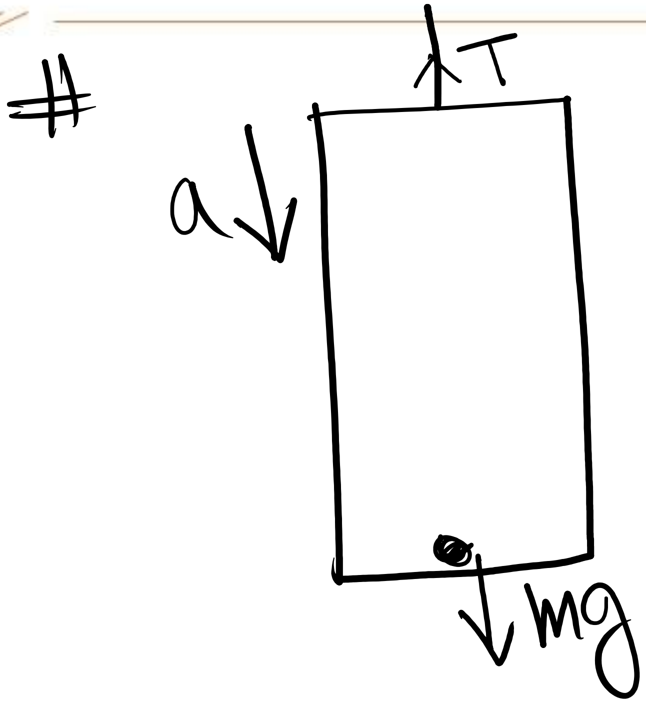
$R \rightarrow mg$

$\mu_K = \frac{f_K}{R} = \frac{4}{mg} = \frac{4}{10\times10} = 0.04$, [Ans]

Theory of LIFT



$$\sum F = ma$$
$$\Rightarrow T - mg = ma$$
$$\Rightarrow T = mg + ma$$
$$\therefore T = m(g+a)$$



$$\sum F = ma$$
$$\Rightarrow mg - T = ma$$
$$\Rightarrow T = mg - ma$$
$$\therefore T = m(g-a)$$

Poll Question-07

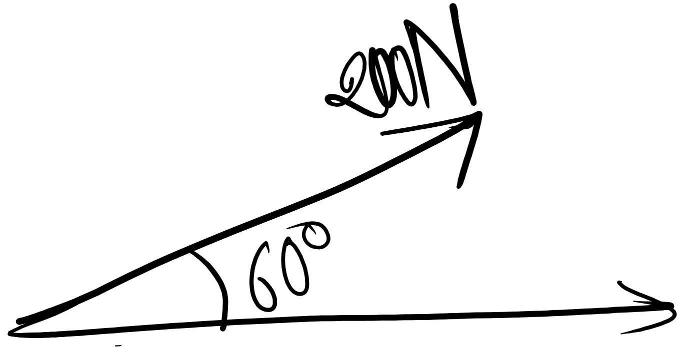
A piece of wood is being pulled by a 200N force at an angle of 60^0 with the horizontal. What is the effective force on the object horizontally?

(a) 200N

(b) 100N ✓

(c) 174N

(d) 0 N



~~200N~~

$F\cos\theta$

$= 200\cos 60^0 = 200 \times \frac{1}{2}$

$= 100$, [Ans]

LIFT related Mathematical Problems

For how much force applied to an object of mass 10kg will cause the object to move vertically (1) upwards at an acceleration of $1.2ms^{-2}$ and (2) at an acceleration of downwards $2.8\ ms^{-2}$?

(1) $F = m(g+a) = 10(9.8+1.2) = 10 \times 11 = 110\ N$

(2) $F = m(g-a) = 10(9.8-2.8) = 10 \times 7 = 70N$,

[Ans]

না বুঝে মুখস্থ করার অভ্যাস
প্রতিভাকে ধ্বংস করে।