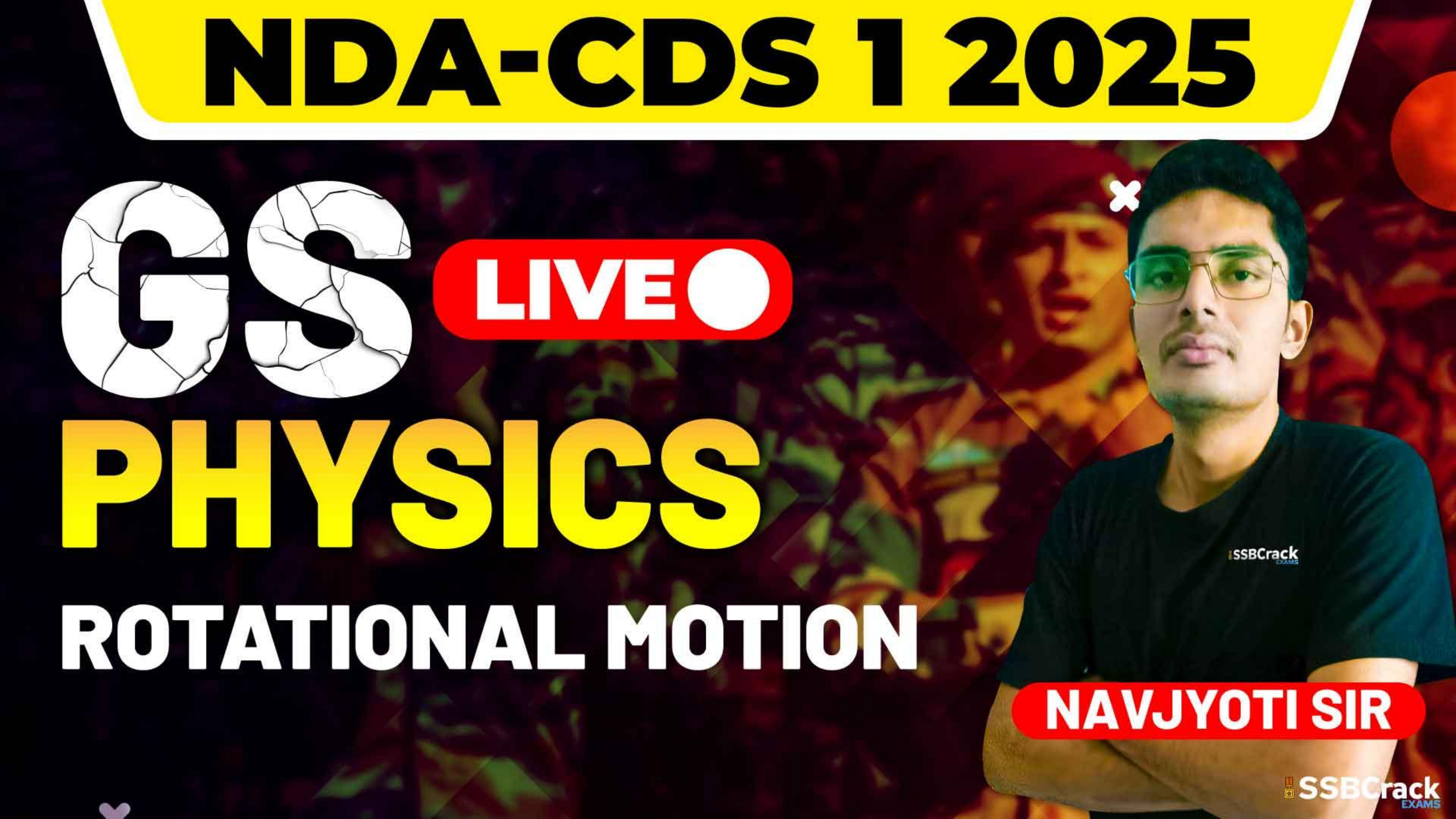

NDA-CDS 1 2025
GS
LIVE
PHYSICS
ROTATIONAL MOTION
SSBCrack EXAMS
NAVJYOTI SIR
SSBCrack EXAMS

19 Dec 2024 Live Classes Schedule

9:00AM	19 DEC 2024 DAILY DEFENCE UPDATES	DIVYANSHU SIR

SSB INTERVIEW LIVE CLASSES

9:30AM	COMPLETE SCREENING TESTS	ANURADHA MA'AM

NDA 1 2025 LIVE CLASSES

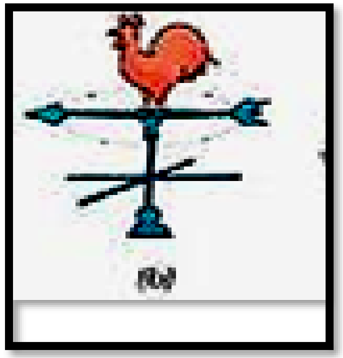
1:00PM	PHYSICS - ROTATIONAL MOTION	NAVJYOTI SIR
4:30PM	ENGLISH - SENTENCE IMPROVEMENT - CLASS 1	ANURADHA MA'AM
5:30PM	MATHS - INTEGRATION - CLASS 3	NAVJYOTI SIR

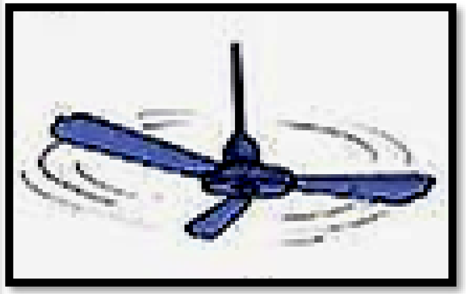
CDS 1 2025 LIVE CLASSES

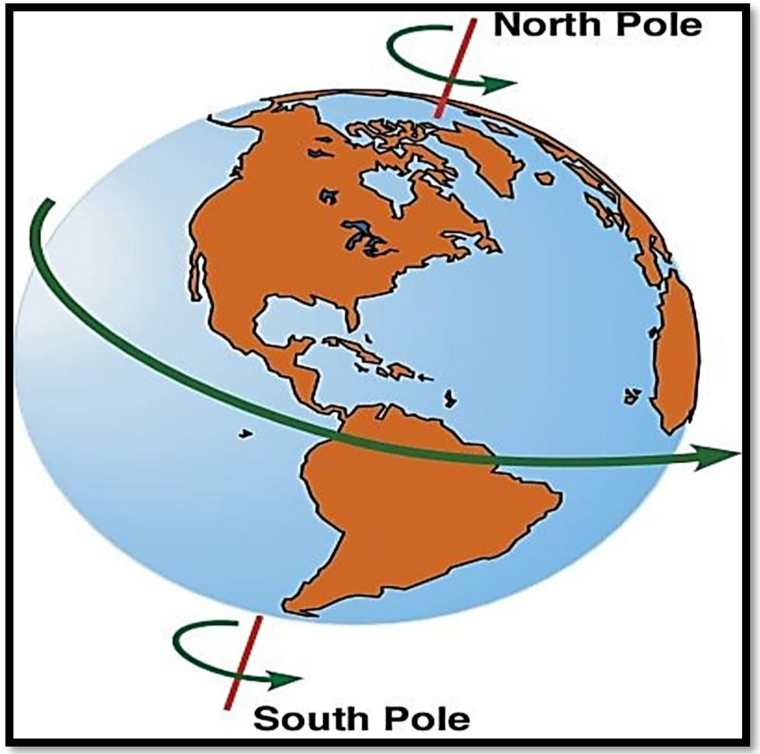
1:00PM	PHYSICS - ROTATIONAL MOTION	NAVJYOTI SIR
4:30PM	ENGLISH - SENTENCE IMPROVEMENT - CLASS 1	ANURADHA MA'AM
7:00PM	MATHS - SET THEORY	NAVJYOTI SIR

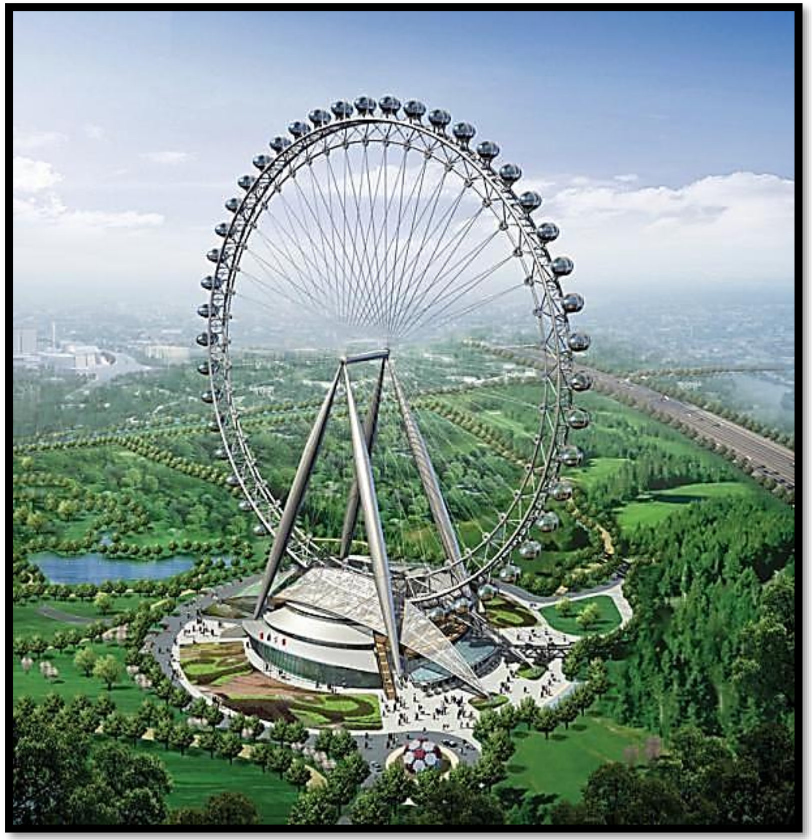
SSBCrack EXAMS

SYSTEM OF PARTICLES AND ROTATIONAL MOTION









SSBCrack EXAMS

WHAT WILL WE STUDY ?

- Centre of Mass
- Translational and Rotational Motion
- Moment of Inertia
- Parallel Axes Theorem
- Moment of Inertia of some Homogeneous Rigid Bodies
- Torque and Angular Momentum
- Rotational Kinetic Energy
- Rolling Motion

Centre of Mass

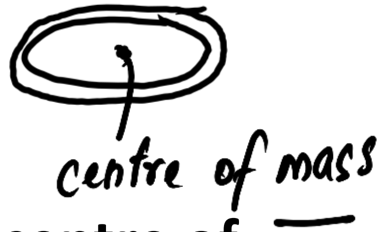
- Centre of mass of a system is the point that behaves as whole mass of the system is concentrated on it and all external forces are acting on it.

- It is a hypothetical point where the entire mass of an object may be assumed to be concentrated to visualise its motion. The center of mass is the particle equivalent of a given object for application of Newton's laws of motion.

Centre of Mass

- The position of centre of mass depends upon the shape, size and distribution of the mass of the body.

- The centre of mass of an object need not to lie with in the object.



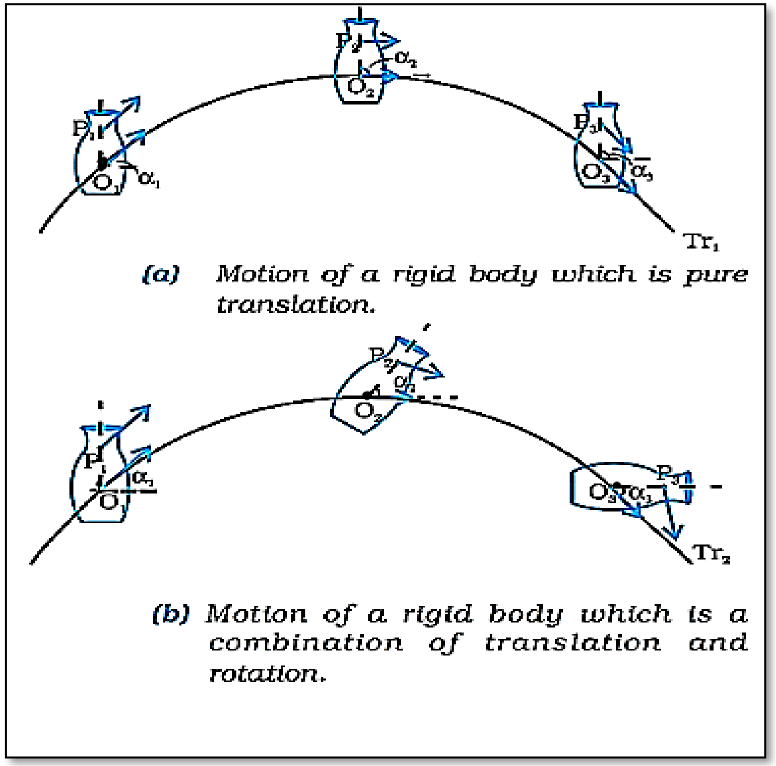
- In symmetrical bodies having homogeneous distribution of mass the centre of mass coincides with the geometrical centre of the body.

- The position of centre of mass of an object changes in translatory motion but remains unchanged in rotatory motion.

SSBCrack EXAMS

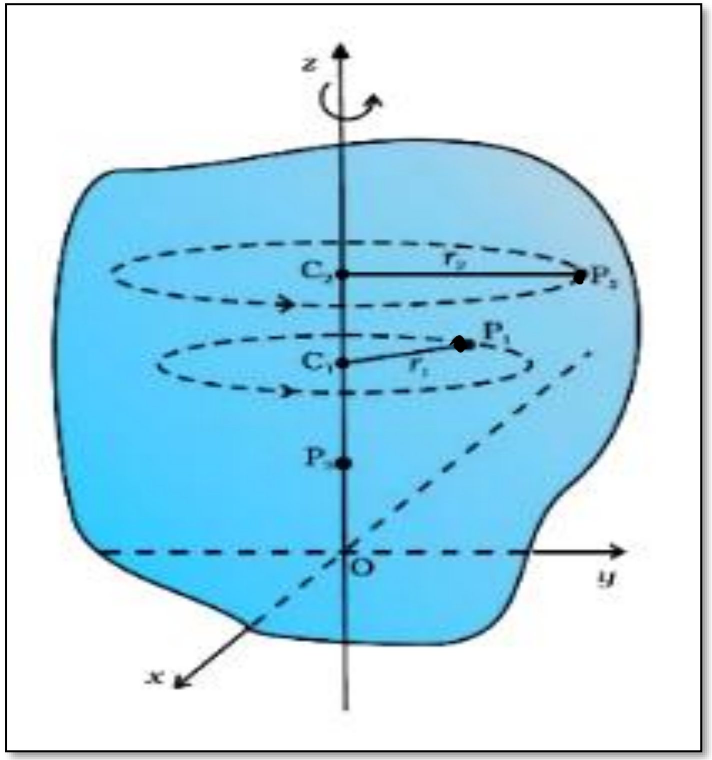
Translational and Rotational Motion

- A rigid body performs a pure translational motion, if each particle of the body undergoes the same displacement in the same direction in a given interval of time.
- A rigid body performs a pure rotational motion, if each particle of the body moves in a circle, and the centre of all the circles lie on a straight line called the axes of rotation.



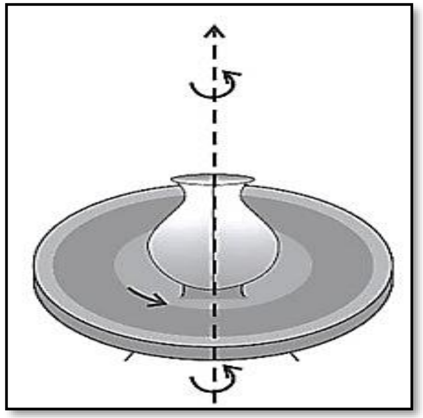
(a) Motion of a rigid body which is pure translation.

(b) Motion of a rigid body which is a combination of translation and rotation.



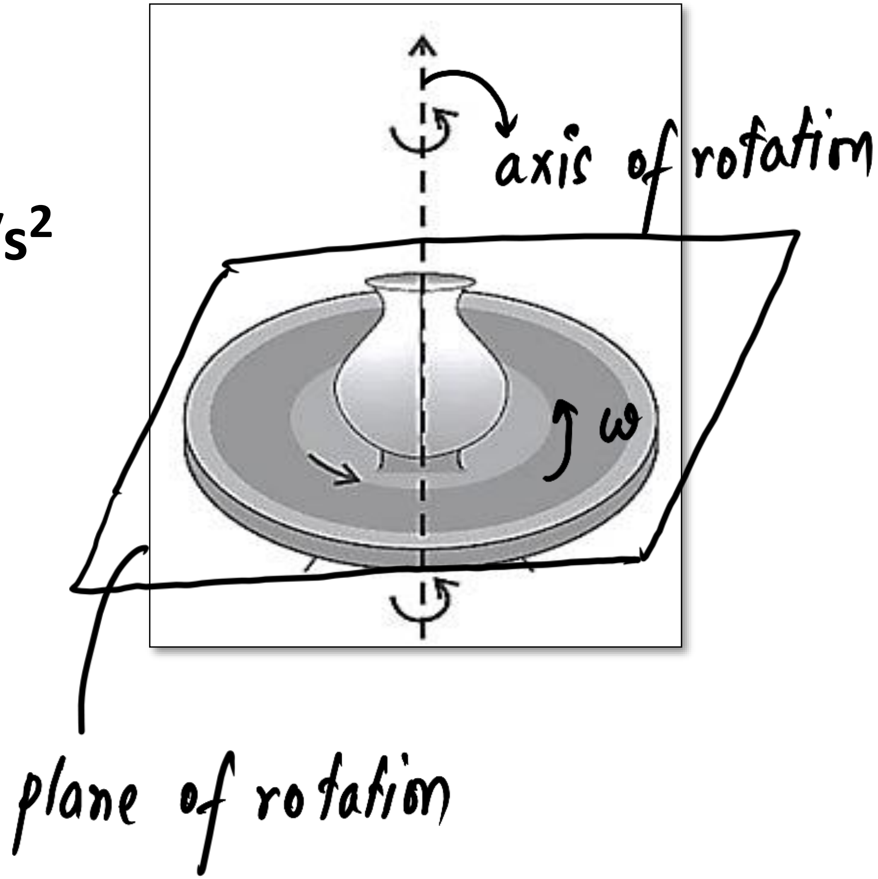
TERMS ASSOCIATED WITH ROTATIONAL MOTION

- **Axis of Rotation** : An imaginary line drawn perpendicular to the plane of motion of different points of the body and passing through the stationary point is called the axis of rotation.
- **Angle of Rotation (θ)** : When the object rotates, its configuration changes, the angle by which any line drawn on the object rotates during the change in angle of rotation. While the body rotates, every point of the body moves in a circle, whose centre lies on axis of rotation, and every point experience the same angular displacement during a particular time interval.



TERMS ASSOCIATED WITH ROTATIONAL MOTION

- **Angular Velocity (ω) :** $\omega = \frac{d\theta}{dt}$ The unit is rad/s.
- **Angular Acceleration :** $\alpha = \frac{d\omega}{dt}$ The unit is rad/s^2
(α)



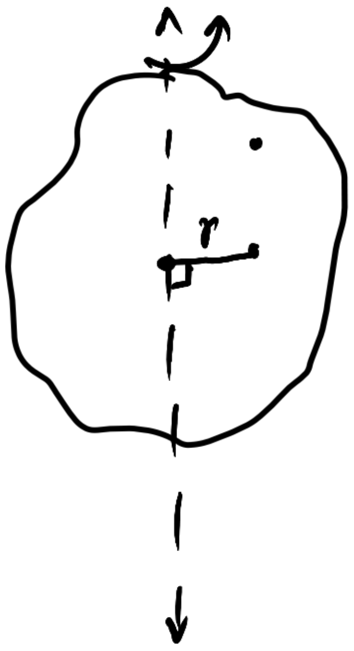
MOMENT OF INERTIA

- **The tendency to resist rotational motion.**
- **The moment of inertia of a body about a given axis is equal to the sum of the products of the masses of its constituent particles and the square of their respective distances from the axis of rotation.**
- Moment of inertia of a body,

$$I = m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 + \ldots = \sum_{i=1}^{n} m_i r_i^2$$

$I = MR^2$

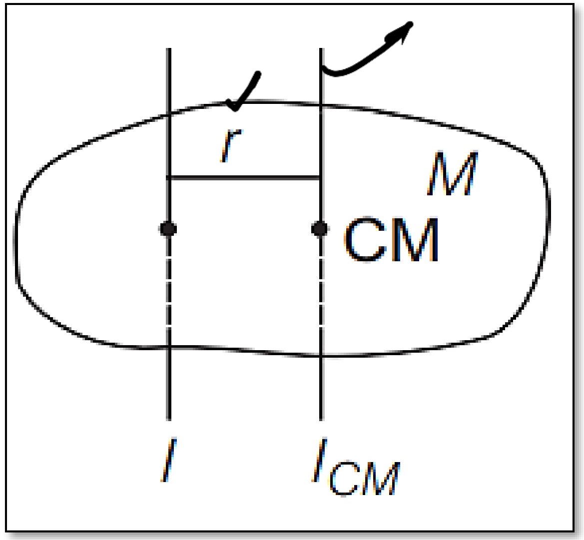
Mass of body — Radius



- **Its unit is kgm^2 .**

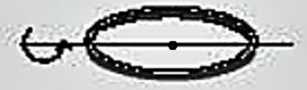
PARALLEL AXES THEOREM

- **The moment of inertia of any object about any arbitrary axis is equal to the sum of moment of inertia about a parallel axis passing through the centre of mass and the product of mass of the body and the square of the perpendicular distance between the two axes.**



$$I = I_{CM} + Mr^2$$

MOMENT OF INERTIA OF SOME HOMOGENEOUS RIGID BODIES

Body	Axis	Figure	I
Thin circular ring, radius R	Perpendicular to plane, at centre		MR^2
Thin circular ring, radius R	Diameter		$MR^2/2$
Thin rod, length L	Perpendicular to rod, at mid point		$ML^2/12$
Circular disc, radius R	Perpendicular to disc at centre		$MR^2/2$
Circular disc, radius R	Diameter		$MR^2/4$

MOMENT OF INERTIA OF SOME HOMOGENEOUS RIGID BODIES

Hollow cylinder, radius R	Axis of cylinder		MR^2 ✓
Solid cylinder, radius R	Axis of cylinder		$MR^2/2$ ✓
# Solid sphere, radius R	Diameter		$2MR^2/5$ ✓

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

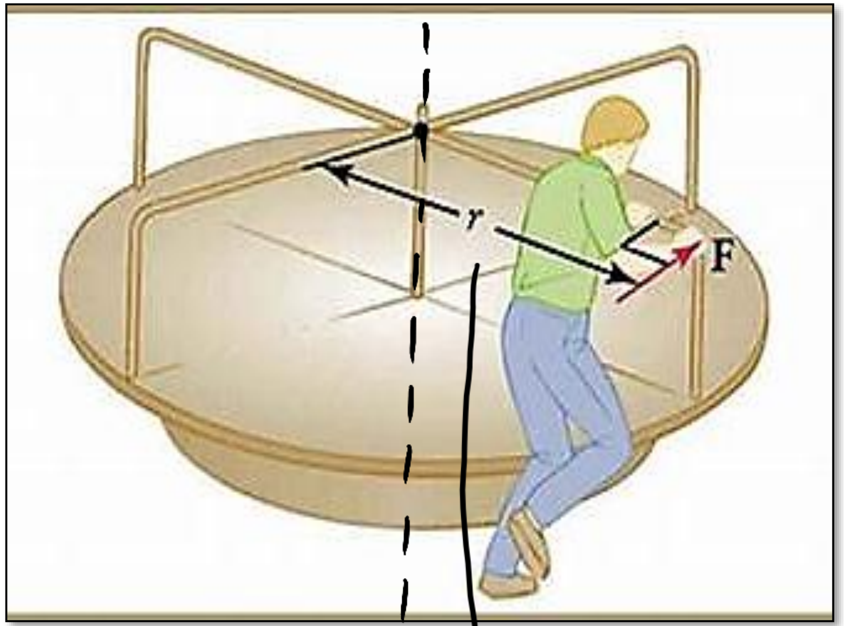
SSBCrack EXAMS

DYNAMICS OF ROTATIONAL MOTION ABOUT A FIXED AXIS

	Linear Motion	Rotational Motion about a Fixed Axis
1	Displacement x	Angular displacement θ
2	Velocity $v = dx/dt$	Angular velocity $\omega = d\theta/dt$
3	Acceleration $a = dv/dt$	Angular acceleration $\alpha = d\omega/dt$
4	Mass M	Moment of inertia I
5	Force $F = Ma$	Torque $\tau = I\alpha$
6	Work $dW = F\,ds$	Work $W = \tau d\theta$
7	Kinetic energy $K = Mv^2/2$	Kinetic energy $K = I\omega^2/2$
8	Power $P = Fv$	Power $P = \tau\omega$
9	Linear momentum $p = Mv$	Angular momentum $L = I\omega$

TORQUE

- The tendency of a force to rotate the body.



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

$= rF\sin\theta$

$\tau = 0$

$(\theta = 0°)$

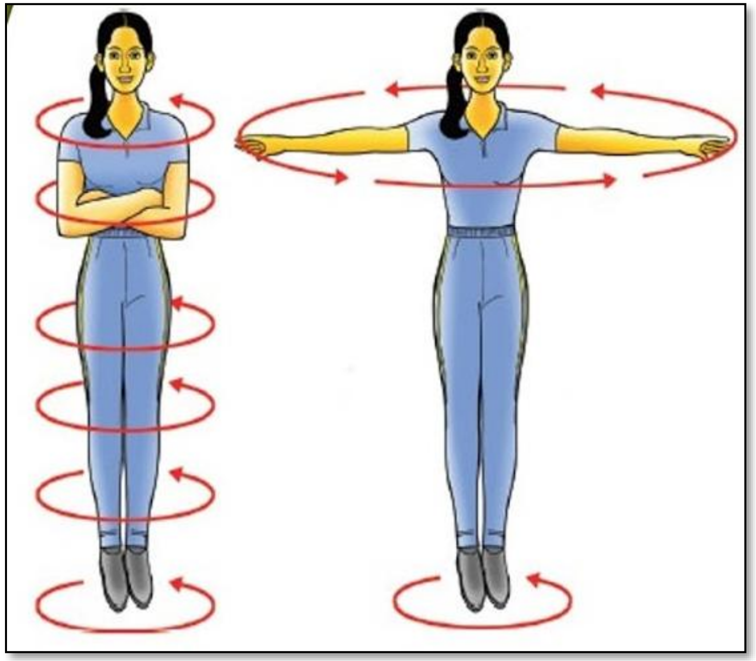
or

$(\theta = 180°)$

distance b/w axis of rotation and point of application of force.

CONSERVATION OF ANGULAR MOMENTUM (L)

- **If the external torque acting on a system is zero, then its angular momentum remains conserved.**



$$\text{If } \tau_{ext} = 0, \text{ then } L = I\omega = \text{constant} \Rightarrow I_1\omega_1 = I_2\omega_2$$

$I = Mr^2 \longrightarrow I \propto r^2$

$r\downarrow \rightarrow I\downarrow \quad \omega\uparrow \qquad$ as $\quad I \cdot \omega = \text{constant}$

$r\uparrow \rightarrow I\uparrow \quad \omega\downarrow$

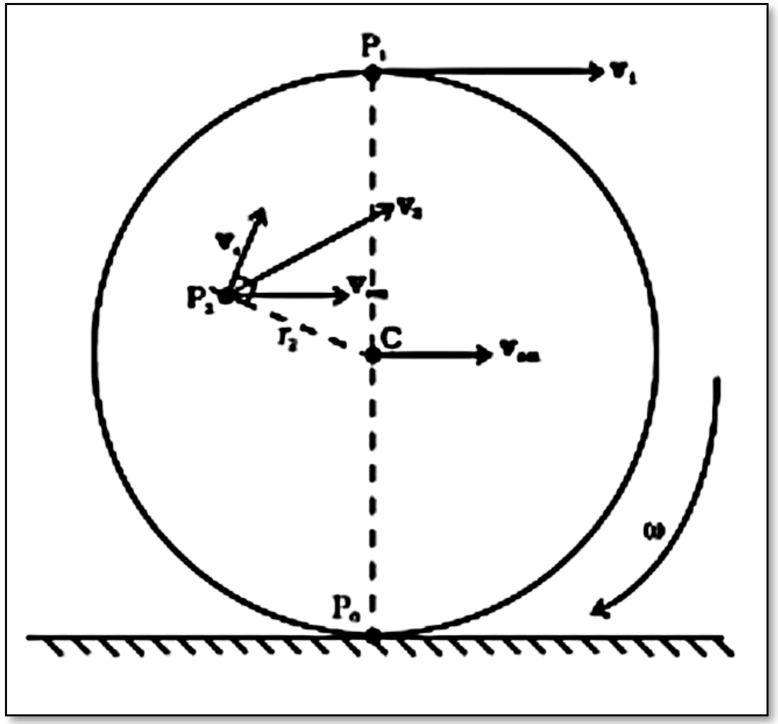
Rotational Kinetic Energy

Linear $\longrightarrow$ $K = \frac{1}{2} m v^2$

for rotation, $K_{rot} = \frac{1}{2} I \omega^2$

Rolling Motion

- When a body is set in rolling motion, every particle of body has two velocities - one due to its Rotational motion and the other due to its Translational motion, and the resulting effect is the vector sum of both velocities at all particles.



$$K = KE_R + KE_T$$

$$K = \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2$$

SUMMARY

- Centre of Mass
- Translational and Rotational Motion
- Moment of Inertia
- Parallel Axes Theorem
- Moment of Inertia of some Homogeneous Rigid Bodies
- Torque and Angular Momentum
- Rotational Kinetic Energy
- Rolling Motion

A solid disc and a solid sphere have the same mass and same radius. Which one has the higher moment of inertia about its centre of mass ?

(a) The disc

(b) The sphere

(c) Both have the same moment of inertia

(d) The information provided is not sufficient to answer the question

disc: $\frac{MR^2}{2}$

sphere: $\frac{2}{5}MR^2$

(M – Mass ; R – Radius)

$0.5MR^2 > 0.4MR^2$

A solid disc and a solid sphere have the same mass and same radius. Which one has the higher moment of inertia about its centre of mass ?

(a) The disc

(b) The sphere

(c) Both have the same moment of inertia

(d) The information provided is not sufficient to answer the question

Answer : A

A thin disc and a thin ring, both have mass M and radius R. Both rotate about axes through their center of mass and are perpendicular to their surfaces at the same angular velocity. Which of the following is true ?

(a) The ring has higher kinetic energy ✓

(b) The disc has higher kinetic energy

(c) The ring and the disc have the same kinetic energy

(d) Kinetic energies of both the bodies are zero since they are not in linear motion

$$K_{rot} = \frac{1}{2} I \omega^2$$

$K_{rot} \uparrow$ if $I \uparrow$

	ring		disc
I	MR^2	$>$	$\frac{1}{2}MR^2$

A thin disc and a thin ring, both have mass M and radius R. Both rotate about axes through their center of mass and are perpendicular to their surfaces at the same angular velocity. Which of the following is true ?

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(c) The ring and the disc have the same kinetic energy

(d) Kinetic energies of both the bodies are zero since they are not in linear motion

Answer : A

For which of the following does the centre of mass lie outside the body ?

(a) A pencil

(b) A shotput

(c) A dice

(d) A bangle

For which of the following does the centre of mass lie outside the body ?

(a) A pencil

(b) A shotput

(c) A dice

(d) A bangle

When a torque acting on a system is zero, then which of the following should not change?

(A) linear velocity

(b) angular momentum — conservation law

(c) angular displacement

(d) force acting on the body

When a torque acting on a system is zero, then which of the following should not change?

(A) linear velocity

(b) angular momentum

(c) angular displacement

(d) force acting on the body

Two rings have their moments of inertia in the ratio 2 : 1 and their diameters are in the ratio 2 : 1. The ratio of their masses will be

(a) 2 : 1

(b) 1 : 2

(c) 1 : 4

(d) 1 : 1

$$\frac{I_1}{I_2} = \frac{2}{1}$$

$$\frac{2R_1}{2R_2} = \frac{2}{1}$$

$$\frac{R_1}{R_2} = \frac{2}{1}$$

$$\frac{m_1 R_1^2}{m_2 R_2^2} = \frac{2}{1}$$

$$\frac{m_1}{m_2} = \frac{2}{1}\left(\frac{R_2}{R_1}\right)^2 = 2\left(\frac{1}{2}\right)^2 = 2 \times \frac{1}{4} = \frac{1}{2} = 1:2$$

Two rings have their moments of inertia in the ratio 2 : 1 and their diameters are in the ratio 2 : 1. The ratio of their masses will be

(a) 2 : 1

(b) 1 : 2

(c) 1 : 4

(d) 1 : 1

Angular acceleration is produced in a body when a ……………… acts on it.

A. Moment of Inertia

B. Velocity

C. Torque

D. None of the Above

SSBCrack EXAMS

Angular acceleration is produced in a body when a ……………… acts on it.

A. Moment of Inertia

B. Velocity

C. Torque

D. None of the Above

The rotational energy of a body with a given angular speed depends on its

(a) mass only

(b) material only

(c) size only

(d) mass as well as the distribution of its mass about the axis of rotation

$I = MR^2$

$K_{rot} = \frac{1}{2} I \omega^2 \Rightarrow K_{rot} \propto I$

mass

The rotational energy of a body with a given angular speed depends on its

(a) mass only

(b) material only

(c) size only

(d) mass as well as the distribution of its mass about the axis of rotation

The combination of rotational motion and the translational motion of a rigid body is known as ___________________.

A. Frictional motion

B. Axis motion

C. Angular motion

D. Rolling motion

The combination of rotational motion and the translational motion of a rigid body is known as ___________________.

A. Frictional motion

B. Axis motion

C. Angular motion

D. Rolling motion

A body in rotational motion possesses rotational kinetic energy given by

__________________.

a. $KE = \frac{1}{2} I^2 \omega$

b. $KE = \frac{1}{2} I \omega^2$

c. $KE = 2 I^2 \omega$

d. $KE = I \omega$

A body in rotational motion possesses rotational kinetic energy given by

_________________.

a. $KE = \frac{1}{2} I^2 \omega$

b. $KE = \frac{1}{2} I \omega^2$

c. $KE = 2I^2 \omega$

d. $KE = I\omega$

Answer: (B)

Moment of inertia, of a spinning body about an axis, doesn't depend on which of the following factors?

a) Distribution of mass around axis ✓

b) Orientation of axis

c) Mass

d) Angular velocity ✓

$I = MR^2$

Moment of inertia, of a spinning body about an axis, doesn't depend on which of the following factors?

a) Distribution of mass around axis

b) Orientation of axis

c) Mass

d) Angular velocity

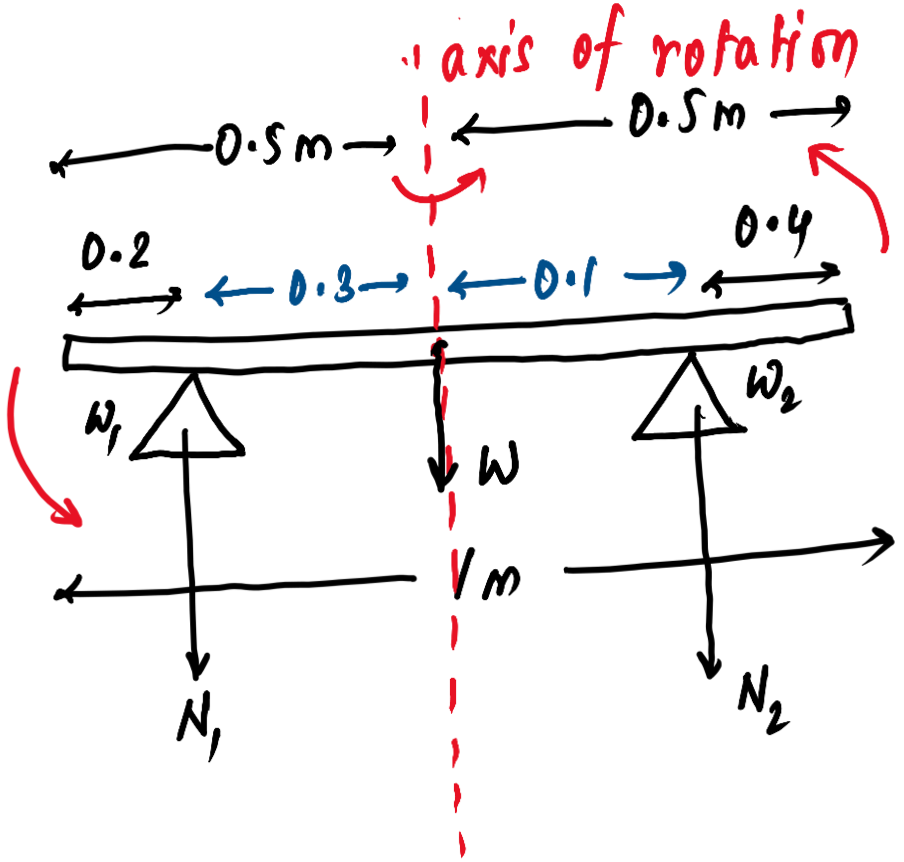
A uniform meter scale of mass 0·24 kg is made of steel. It is kept on two wedges, W_1 and W_2, in a horizontal position. W_1 is at a distance of 0·2 m from one of its ends, while W_2 is at distance of 0·4 m from the other end. If the force on the scale is N_1 due to W_1 and N_2 due to W_2, then : (take $g = 10{\cdot}0 \text{ m s}^{-2}$)

(a) $N_1 = 1{\cdot}6$ N and $N_2 = 0{\cdot}8$ N ✗

(b) $N_1 = 0{\cdot}8$ N and $N_2 = 1{\cdot}6$ N ✗

(c) $N_1 = 0{\cdot}6$ N and $N_2 = 1{\cdot}8$ N ✓

(d) $N_1 = 1{\cdot}8$ N and $N_2 = 0{\cdot}6$ N ✗



uniform → COM – at centre

Weight W (mg) $= N_1 + N_2$

$0.24 \times 10 = N_1 + N_2$

$2.4 = N_1 + N_2$

Torque due to W_1 − Torque due to W_2 = 0

$\tau_{W_1} = \tau_{W_2}$

$N_1 \times 0.3 = N_2 \times 0.1 \Rightarrow 3N_1 = N_2$

A uniform meter scale of mass 0·24 kg is made of steel. It is kept on two wedges, W_1 and W_2, in a horizontal position. W_1 is at a distance of 0·2 m from one of its ends, while W_2 is at distance of 0·4 m from the other end. If the force on the scale is N_1 due to W_1 and N_2 due to W_2, then : (take $g = 10{\cdot}0 \text{ m s}^{-2}$)

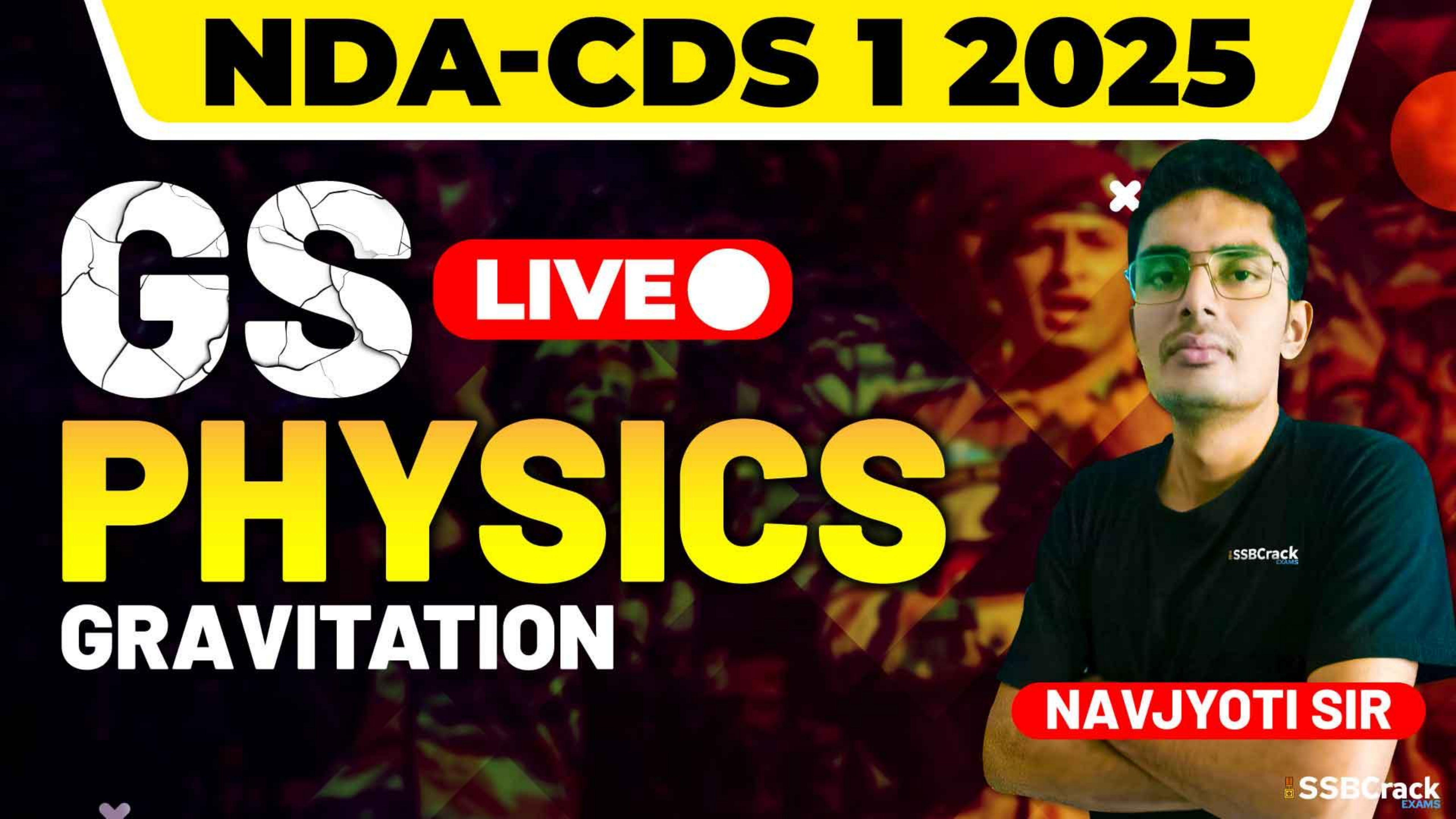
(a) $N_1 = 1{\cdot}6$ N and $N_2 = 0{\cdot}8$ N

(b) $N_1 = 0{\cdot}8$ N and $N_2 = 1{\cdot}6$ N

(c) $N_1 = 0{\cdot}6$ N and $N_2 = 1{\cdot}8$ N

(d) $N_1 = 1{\cdot}8$ N and $N_2 = 0{\cdot}6$ N

Answer: (C)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