MOMENT OF INERTIA

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Physics:

1. Classical Physics
2. Modern Physics

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Classical Physics

Classical physics refers to the branch of physics that deals with the study of macroscopic objects and phenomena at speeds much slower than the speed of light, typically under conditions encountered in everyday life.

Properties of Classical Physics: Newton's Laws of Motion, Conservation Laws, Law of Gravitation, Wave-Particle Duality etc.

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Modern Physics

Modern physics refers to the branch of physics that developed in the 20th century and beyond, encompassing theories and principles that extend beyond the scope of classical physics. It includes two major pillars: quantum mechanics and relativity theory.

Properties of Modern physics: Quantum Mechanics, Theory of Relativity, Astrophysics and Cosmology etc.

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Relation In Physics:

Moment of inertia is indeed a concept within classical physics. It is a property of matter that describes how mass is distributed around an axis of rotation.

In classical mechanics, moment of inertia is analogous to mass in linear motion. It measures the resistance of an object to rotational motion and depends on both the mass and the distribution of that mass relative to the axis of rotation.

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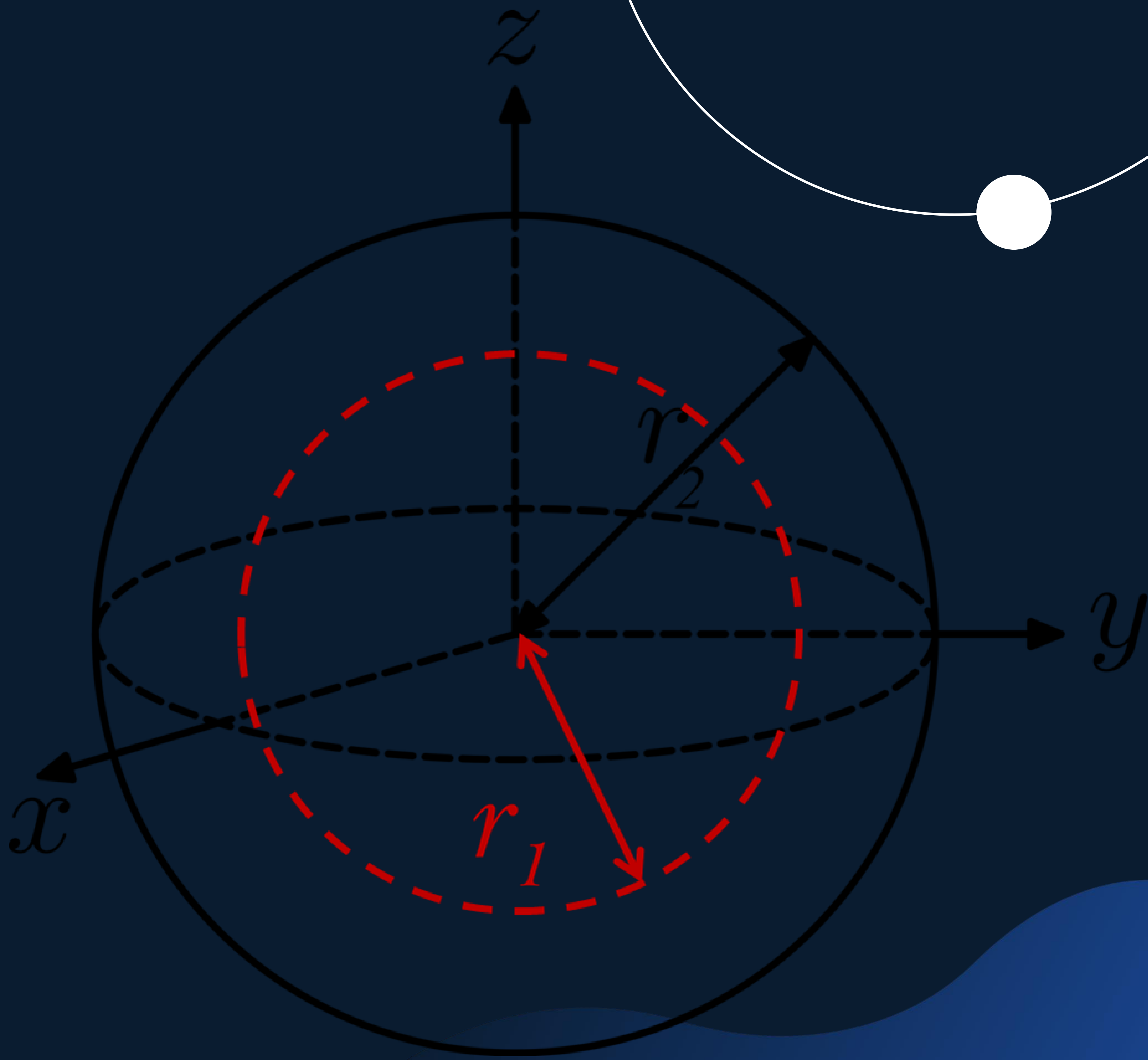
INTRODUCTION

Definition : If a rigid body rotates around an axis , then moment of inertia of that body with respect to that axis means the summation of the product of square of distance from the axis and mass of each of the particles of that body.



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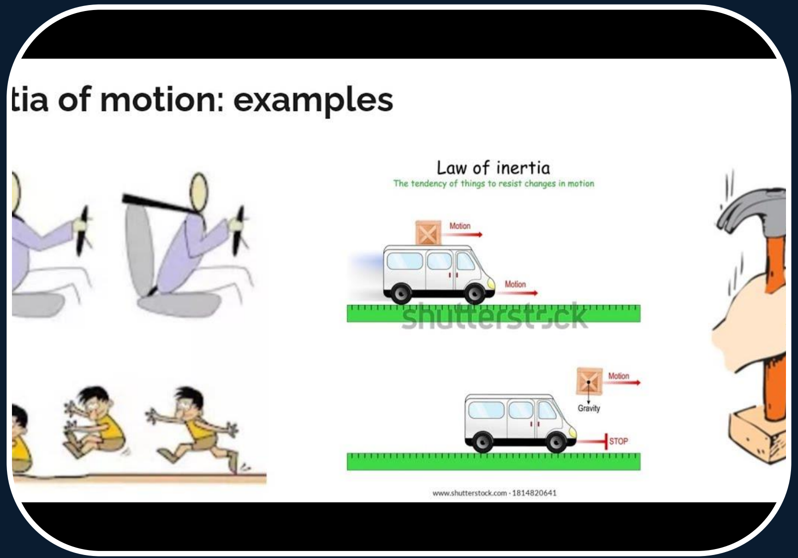
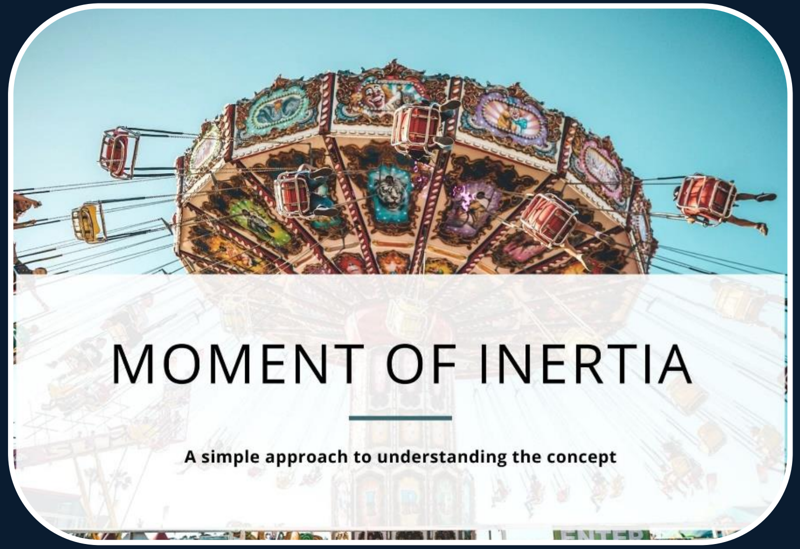
REAL LIFE USES





MOMENT OF INERTIA

HISTORY

The term moment of inertia was introduced by Leonhard Euler in his book in 1765, and it is incorporated into Euler's second law.

$$I_P = \sum_{i=1}^{N} m_i r_i^2$$

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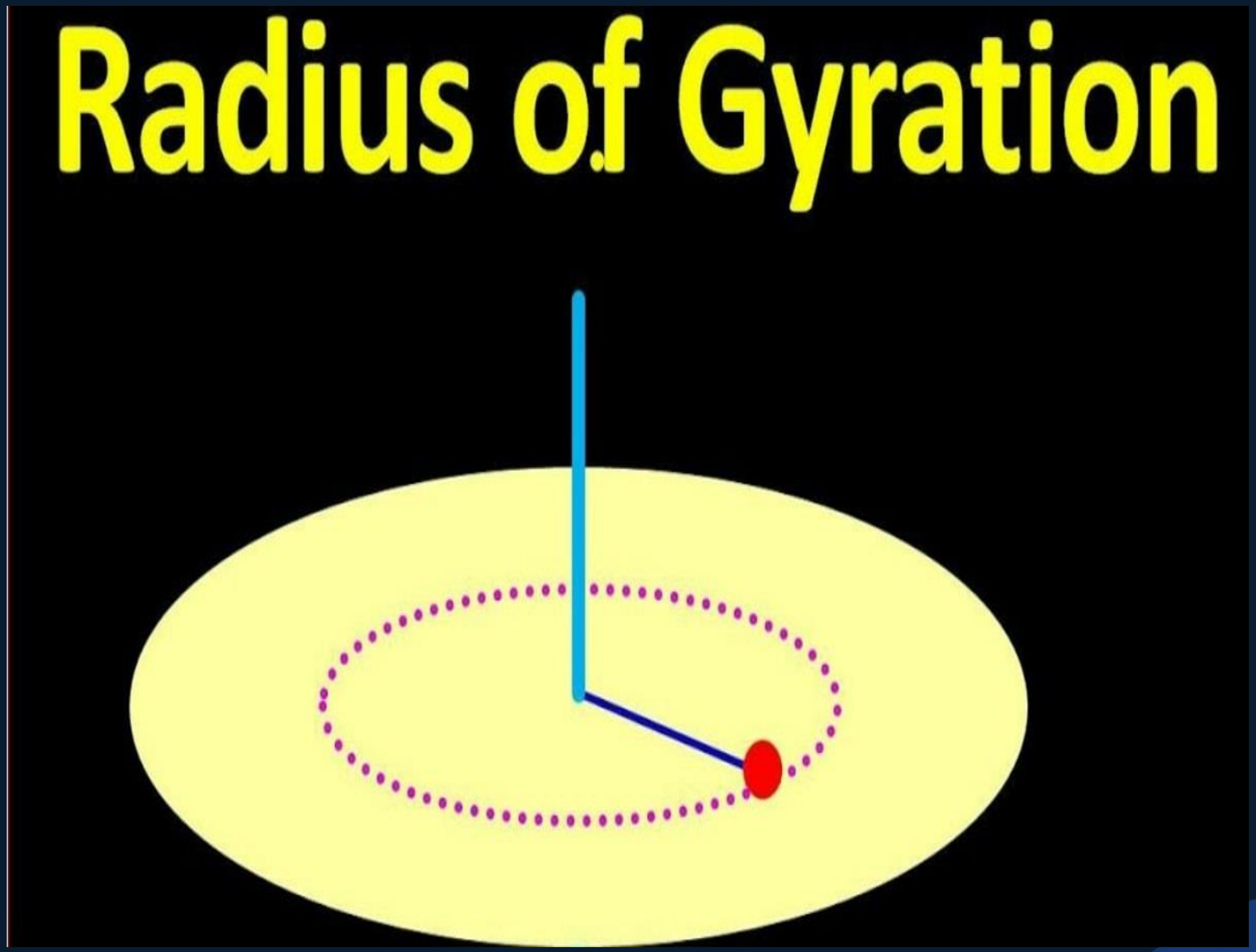
RADIOUS OF GYRATION

Definition : If the total mass of a rigid body is assumed to be concentrated at a point and if the moment of inertia of that point mass with respect to a rotational axis is equal to the moment of inertia of that whole body , then the distance of that point from the axis is called the radius of gyration . It is denoted by K.

$$R_g = \sqrt{\frac{I}{A}}$$

In structural engineering, the two-dimensional radius of gyration is used to describe the distribution of cross sectional area in a column around its centroidal axis with the mass of the body.



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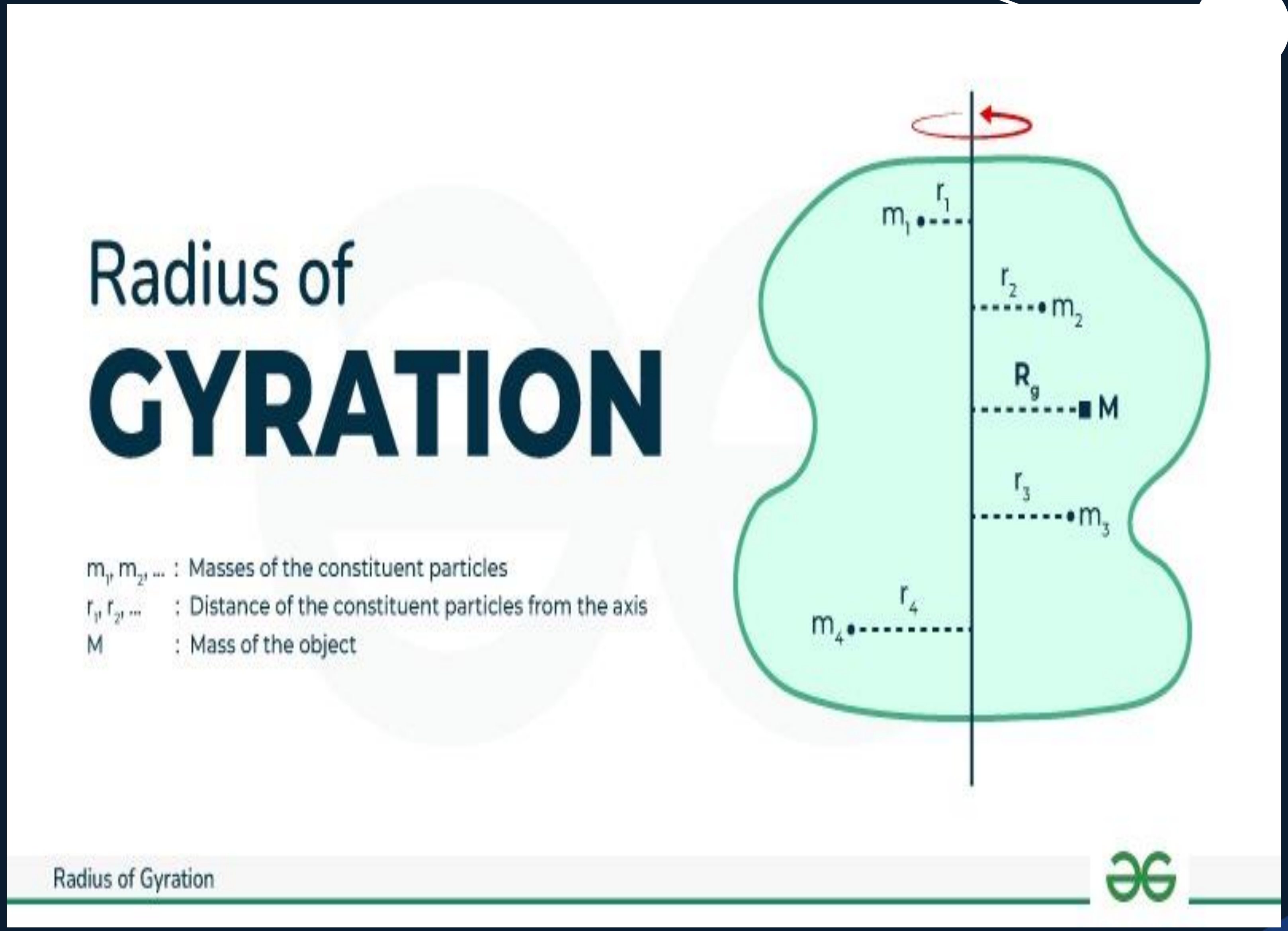
RADIOUS OF GYRATION

Radius of Gyration FormulaThe radius of gyration can be expressed numerically as the root mean square distance of particles from the axis of rotation. The Formula to calculate the radius of gyration can be derived as follows:The moment of inertia of a body with mass (m) can be given by: I = mk² ….(1)Here, k denotes the radius of gyration.So, the formula for radius of gyration can be given by:K = √I/m ….(2)



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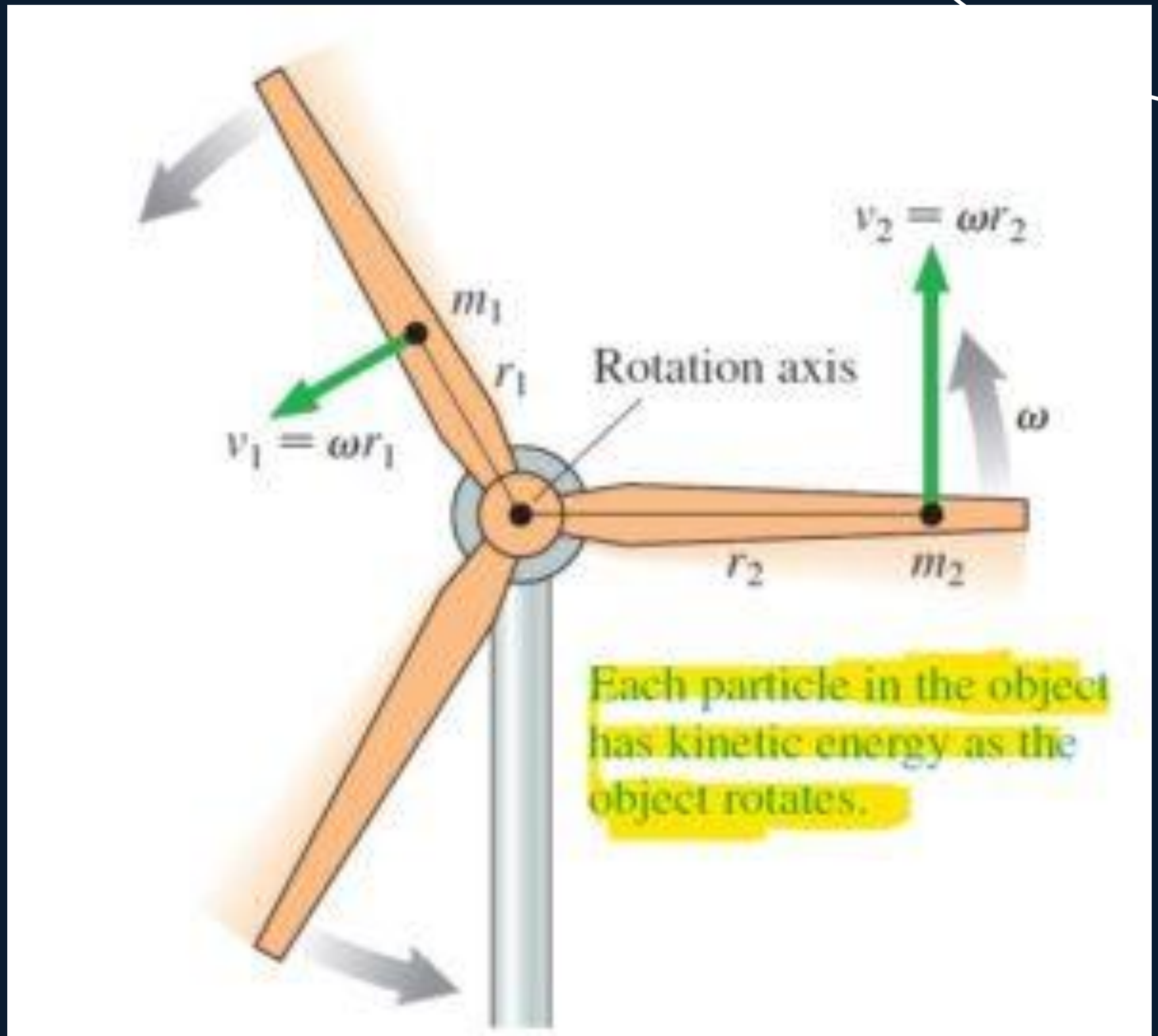
Rotational Kinetic Energy

Rotational energy or **angular kinetic energy** is kinetic energy due to the rotation of an object and is part of its total kinetic energy. Looking at rotational energy separately around an object's axis of rotation, the following dependence on the object's moment of inertia is observed:

$$E_{\text{rotational}} = \frac{1}{2} I \omega^2$$



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Rotational Kinetic Energy

Formula:

$$E_{\mathrm{rotational}} = \frac{1}{2} I \omega^2$$

Where:

- ❖ **Er is rotational kinetic energy**
- ❖ **I is moment of inertia**
- ❖ **W is the angular velocity**

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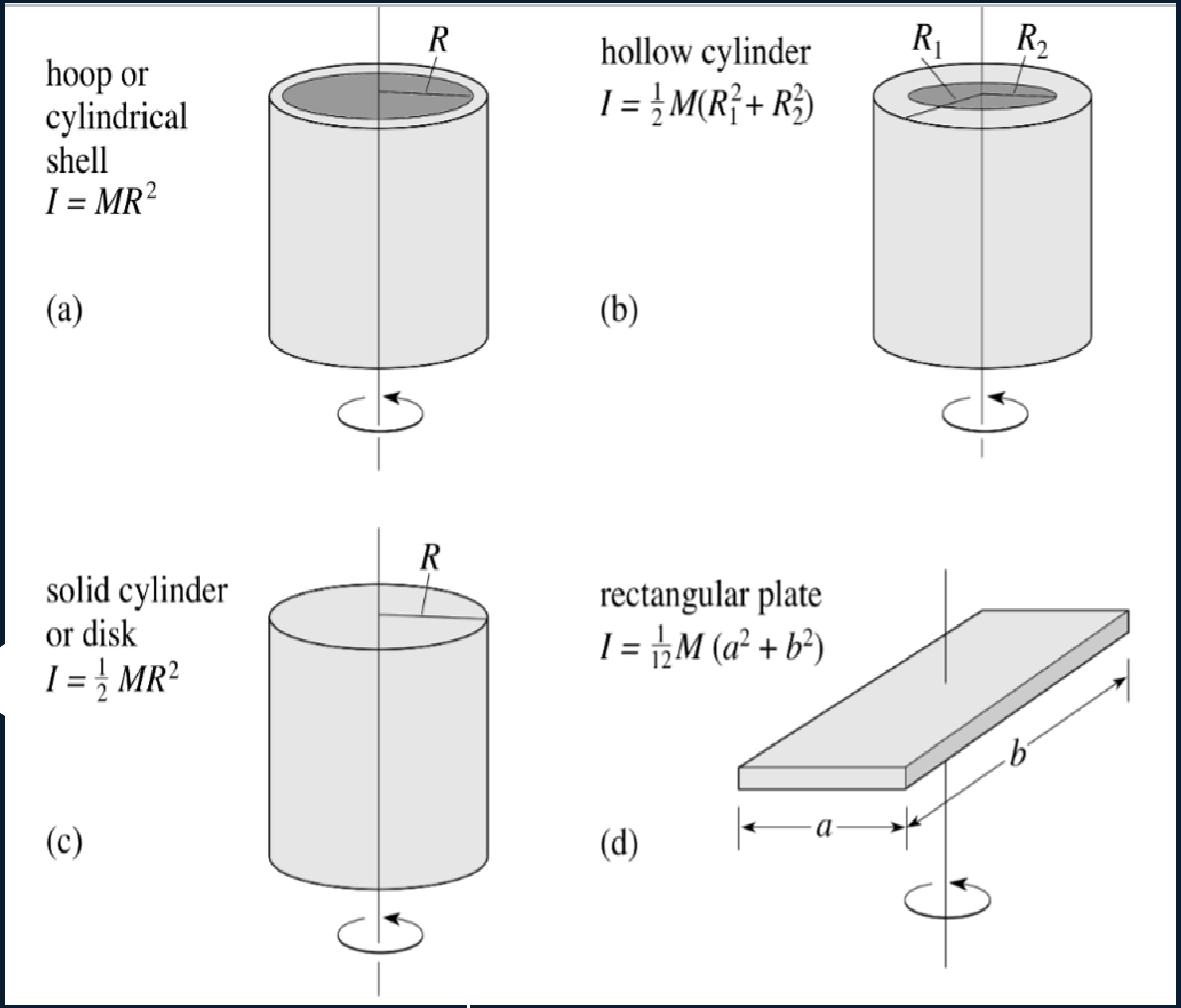
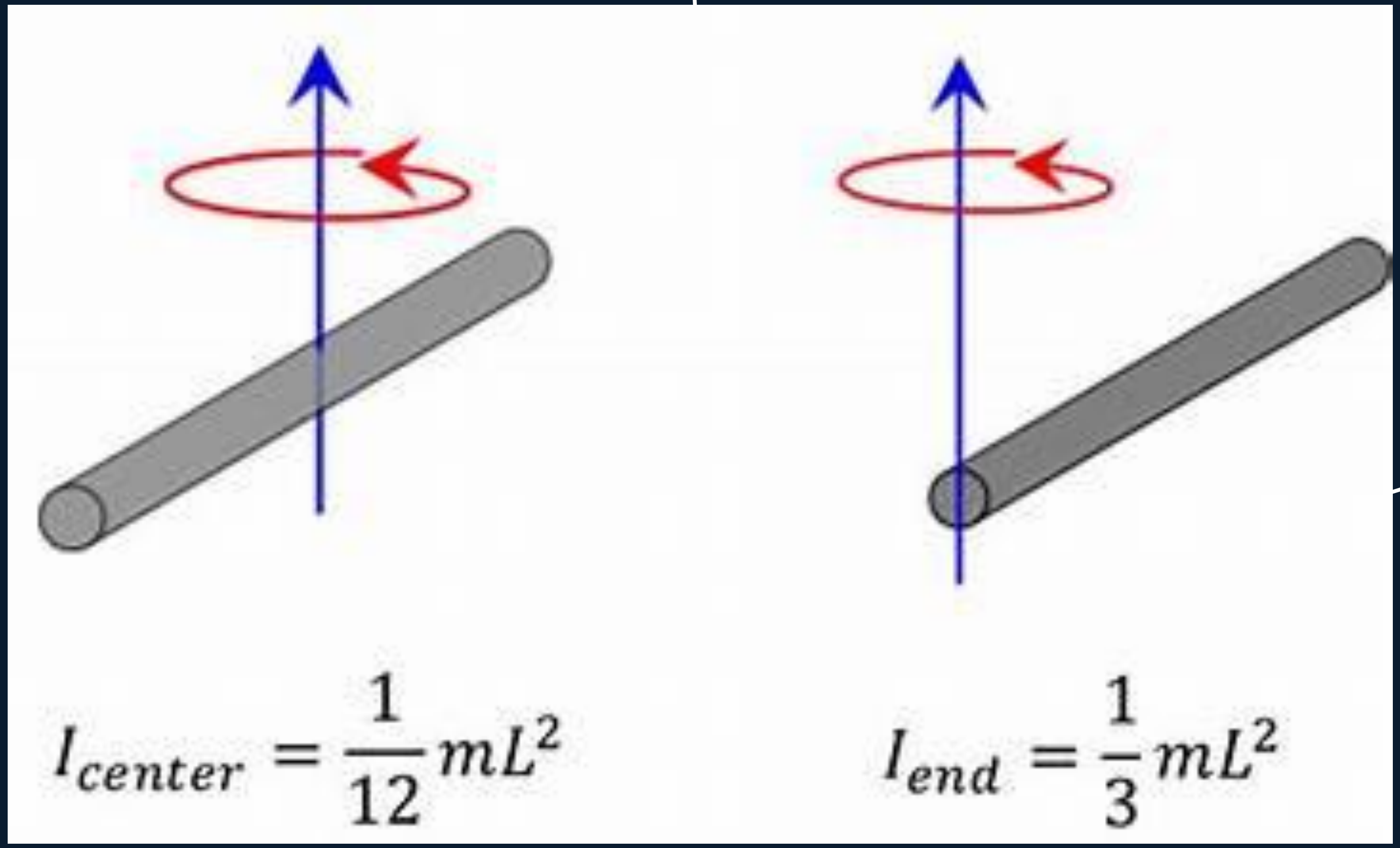
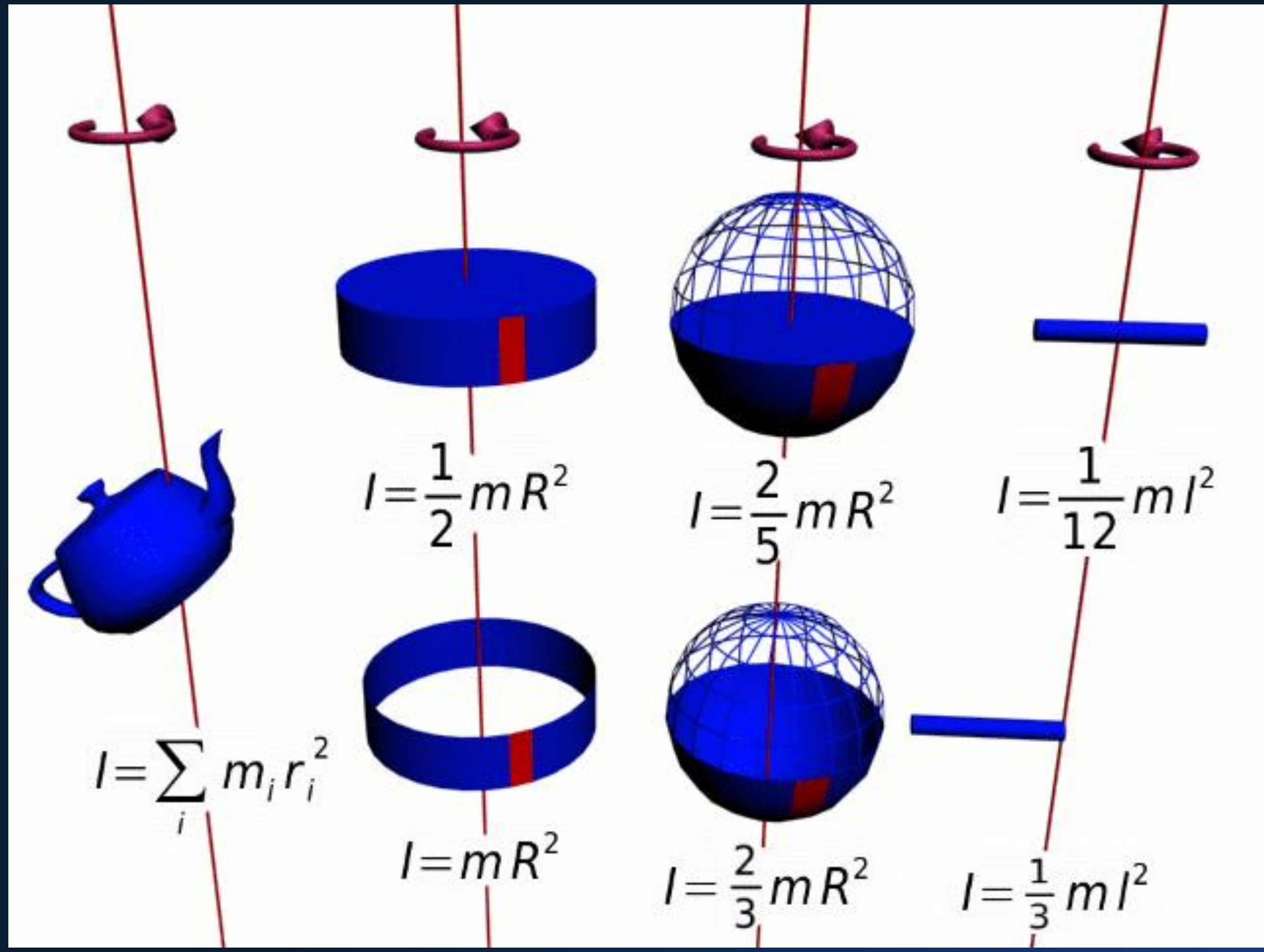
Spacial Cases







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Spacial Cases

(1) Moment of inertia and radius of gyration of a thin uniform rod about an axis through its centre and perpendicular to its length

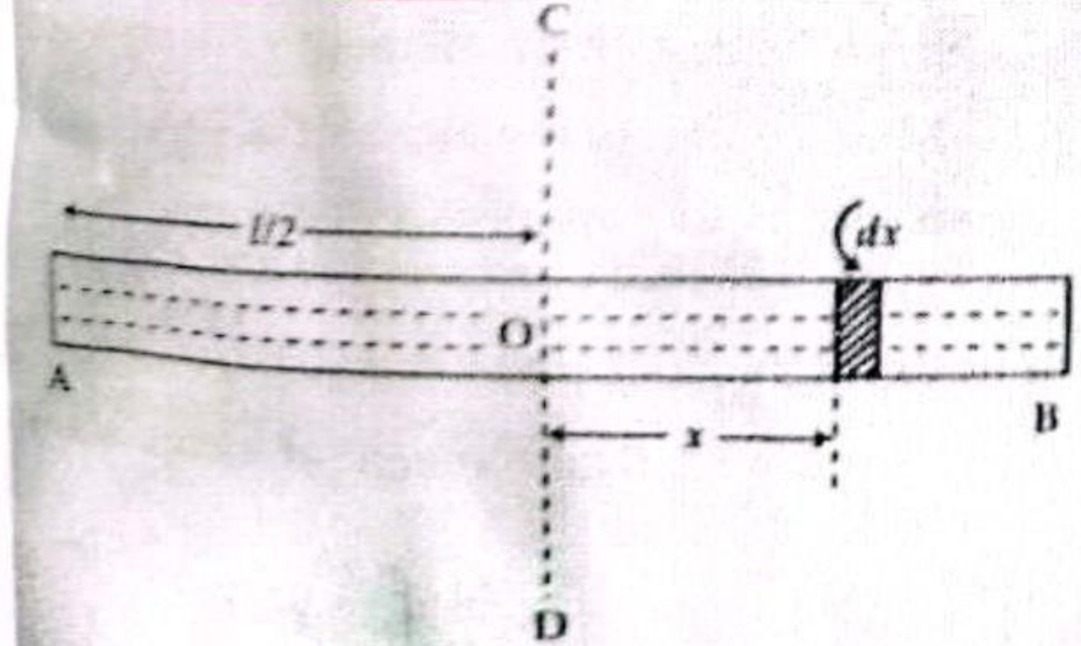


Fig. 4.33

Let AB be a thin uniform rod of length l and mass M, free to rotate about the axis CD which is passing through the centre O and perpendicular to the length of the rod [Fig. 4.33]. The moment of inertia about the axis CD and radius of gyration are to be found out.

Since the rod is uniform, the mass per unit length $= \frac{M}{l}$. So, at a distance x from the axis CD let dx be a small length whose mass is dM, then $dM = \frac{M}{l} dx$. As dx is very small, we can

$$\therefore \quad K = \sqrt{\frac{m_1r_1^2 + m_2r_2^2 + m_3r_3^2 + \ldots\ldots\ldots + m_nr_n^2}{M}}$$

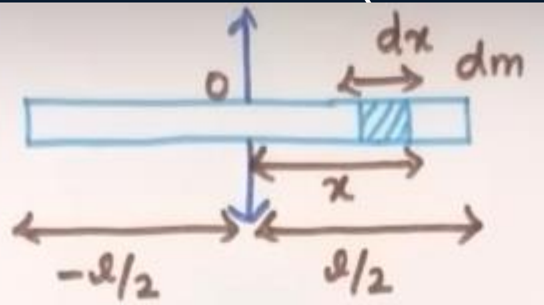
$$= \sqrt{\frac{I}{M}} \qquad \ldots \qquad \ldots \qquad \ldots \qquad (4.35)$$

Radius of gyration of a body with respect to a fixed axis is 0·2 m means that if moment of inertia is determined considering that total mass of the body is concentrated at a distance 0·2 m from that axis, then total moment of inertia is found out.

- **Example :** Moment of inertia of solid sphere with respect to diameter is, $I = \frac{2}{5}MR^2$.

So, radius of gyration with respect to the diameter is.

$$K = \sqrt{\frac{I}{M}} = \sqrt{\frac{\frac{2}{5}MR^2}{M}} = \sqrt{\frac{2}{5}}R.$$



$I = MR^2$

$dI = (dm)x^2$

$\int dI = \int dm . x^2$

$I = \int x^2 dm \rightarrow (1)$

$\lambda = \frac{M}{l}$

$\hookrightarrow$ Mass per unit length

$dm = \lambda\, dx$

$dm = \frac{M}{l} dx \rightarrow (2)$

Sub (2) in (1)

$I = \int_{-l/2}^{l/2} x^2 \left(\frac{M}{l}\right) dx$

$I = \frac{M}{l} \int_{-l/2}^{l/2} x^2 dx.$

THANK YOU!