# NDA-CDS 1 2025

# GS

LIVE

# PHYSICS

## GRAVITATION

NAVJYOTI SIR

# 20 Dec 2024 Live Classes Schedule

| | | |
|---|---|---|
| 8:00AM | 20 DEC 2024 DAILY CURRENT AFFAIRS | RUBY MA'AM |
| 9:00AM | 20 DEC 2024 DAILY DEFENCE UPDATES | DIVYANSHU SIR |

## SSB INTERVIEW LIVE CLASSES

| | | |
|---|---|---|
| 9:30AM | SSB 'LECTURETTE TEST' | ANURADHA MA'AM |

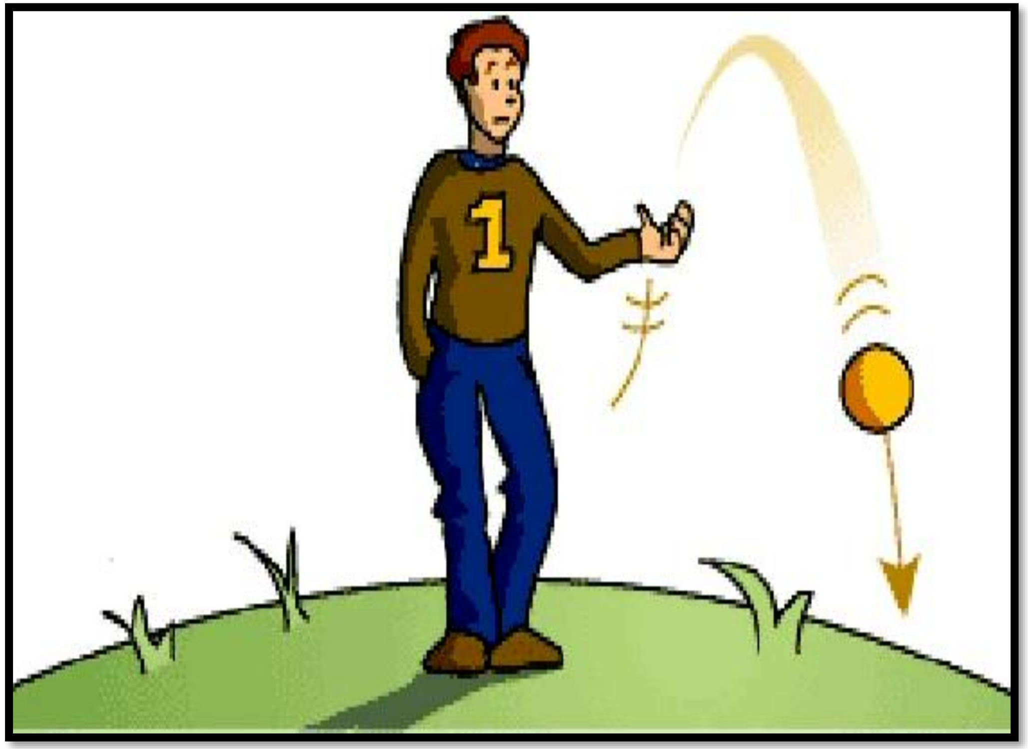
## NDA 1 2025 LIVE CLASSES

| | | |
|---|---|---|
| 1:00PM | PHYSICS - GRAVITATION | NAVJYOTI SIR |
| 4:30PM | ENGLISH - SENTENCE IMPROVEMENT - CLASS 2 | ANURADHA MA'AM |
| 5:30PM | MATHS - INTEGRATION - CLASS 4 | NAVJYOTI SIR |

## CDS 1 2025 LIVE CLASSES

| | | |
|---|---|---|
| 1:00PM | PHYSICS - GRAVITATION | NAVJYOTI SIR |
| 4:30PM | ENGLISH - SENTENCE IMPROVEMENT - CLASS 2 | ANURADHA MA'AM |

# GRAVITATION

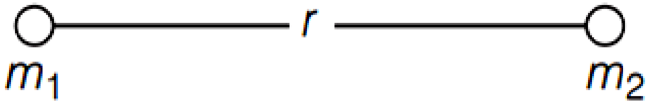


# WHAT WILL WE STUDY ?

- Newton’s Law of Gravitation
- Acceleration due to Gravity
- Kepler’s Laws
- Time period of a Pendulum
- Satellite
- Escape Speed

# NEWTON's LAW OF GRAVITATION

- **Gravitational force is a attractive force between two masses $m_1$ and $m_2$ separated by a distance r .**




Gravitational force, $F = \dfrac{Gm_1m_2}{r^2}$

where, $G$ is universal gravitational constant.

The value of $G$ is $6.67 \times 10^{-11}$ N-m$^2$ kg$^{-2}$ and is same throughout the universe.

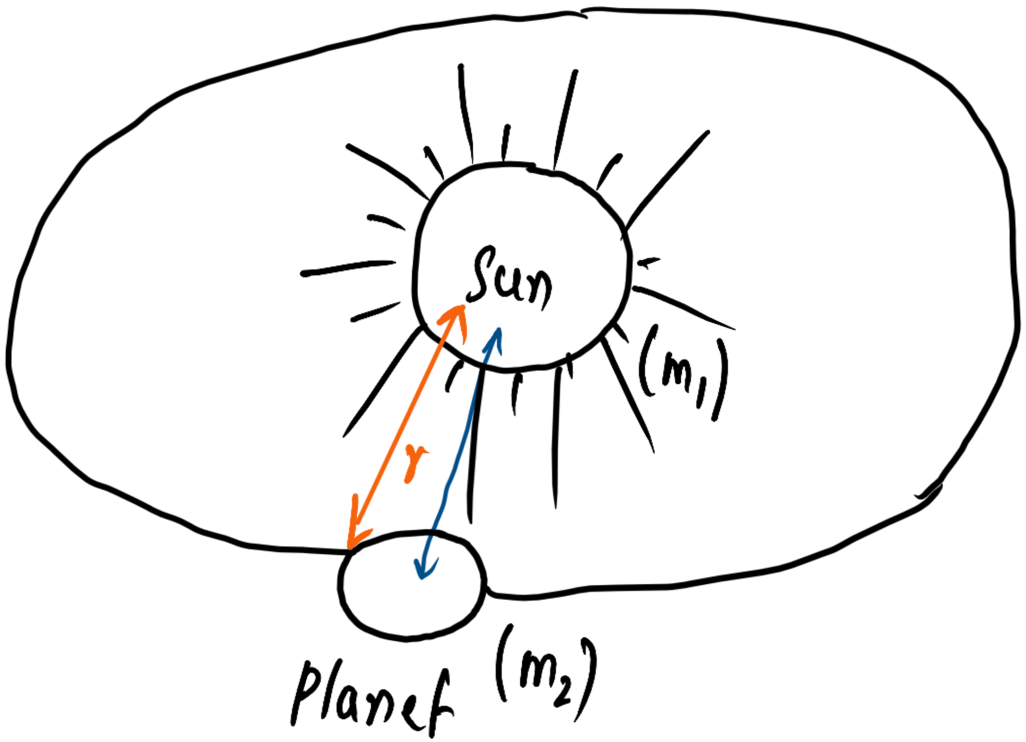
# GRAVITATIONAL FORCE

- **Gravitational force is a central as well as conservative force.**

- **The law of gravitation is applicable for all bodies, irrespective of their size, shape and position.**

# GRAVITATIONAL FORCE

- **Gravitational force acting between sun and planet provide it centripetal force for orbital motion.**



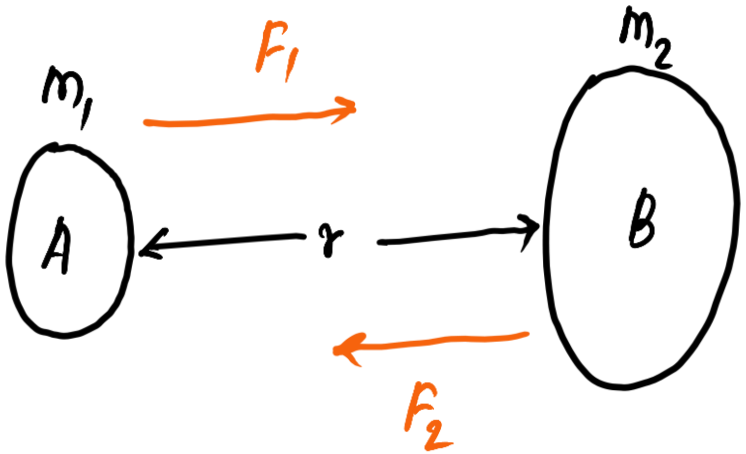

$$\frac{G m_1 m_2}{r^2} = \frac{m_2 v^2}{r}$$

Gravitational force

Centripetal force

# GRAVITATIONAL FORCE

- Newton's third law of motion holds good for the force of gravitation. It means the gravitational forces between two bodies are action-reaction pairs.




($F_1$) force on B by A $= \dfrac{G m_1 m_2}{r^2}$

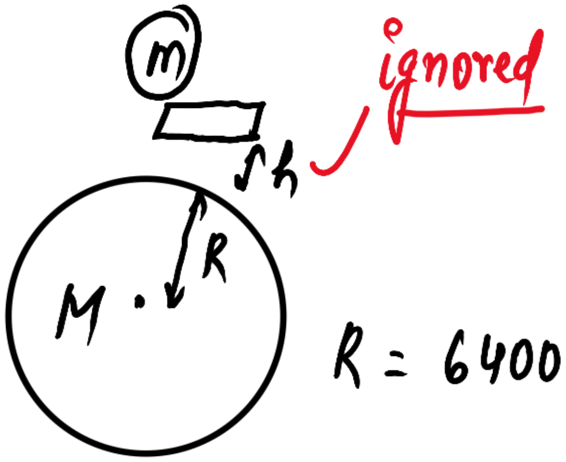
($F_2$) force on A by B $= \dfrac{G m_1 m_2}{r^2}$

So, magnitude of forces are the same, but directions are opposite.

# Acceleration Due to Gravity (g)

- The uniform acceleration produced in a freely falling object due to the gravitational pull of the earth is known as acceleration due to gravity.

- It is a vector quantity and its direction is towards the centre of the earth.




$R = 6400$ km

$\frac{GMm}{R^2}$ = weight of object of mass m

$$\frac{GMm}{R^2} = mg \Rightarrow g = \frac{GM}{R^2}$$

$$g = \frac{GM}{R^2}$$

For any object of mass 'm', 'g' will not depend on it.

R can slightly change because of change in R.

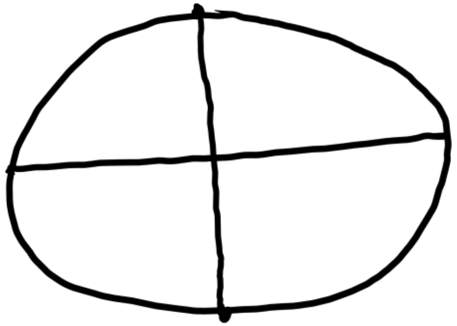
# Acceleration Due to Gravity (g)

- **The value of g is independent of the mass of the object which is falling freely under gravity.**

# Acceleration Due to Gravity (g)

- The value of g changes slightly from place to place.

$$g = \frac{GM}{R^2} \Rightarrow g \propto \frac{1}{R^2}$$



- The value of g is taken to be 9.8 $m/s^2$ for all practical purposes.

approximately = 10 $m/s^2$

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# Acceleration Due to Gravity (g)

- The value of acceleration due to gravity on the moon is about one sixth of that on the earth and on the sun is about 27 times of that on the earth.

$$g_{earth} = 6\,g_{moon}$$

$$g_{sun} = 27\,g_{earth}$$

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# FACTORS AFFECTING 'g'

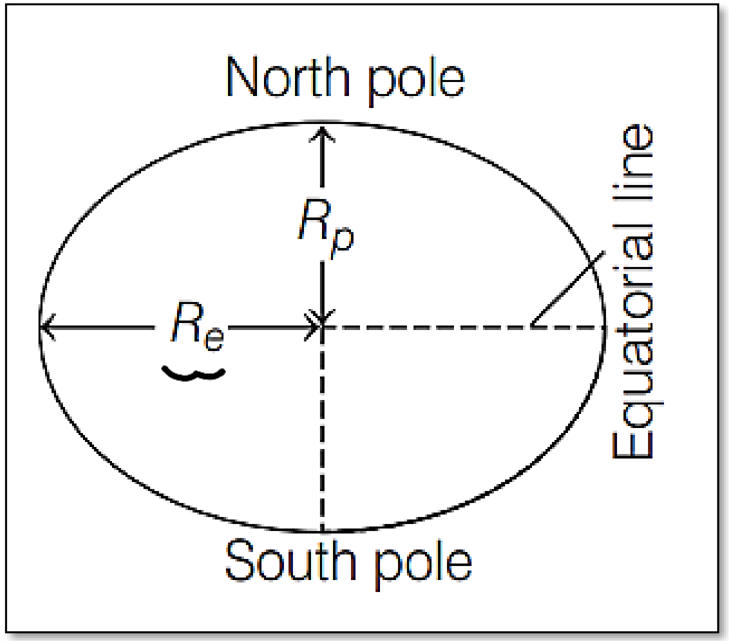
## 1. SHAPE OF EARTH :

$R_e$ is max.

$R_p$ is min.

$g \propto \frac{1}{R^2}$ ⇒ g is min. at equator

⇒ g is max. at poles,

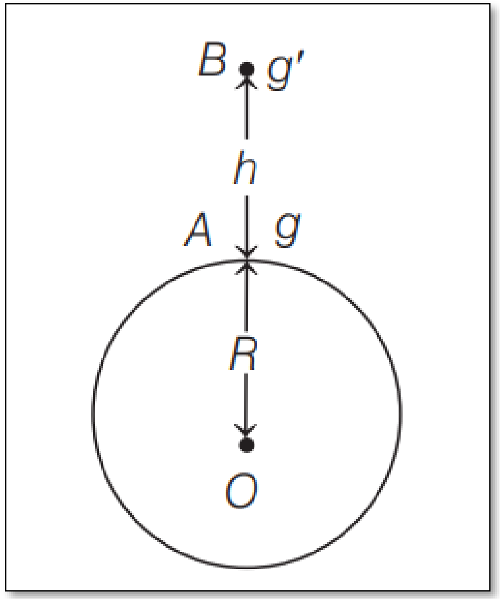



- g is minimum at equator and maximum at poles.

# FACTORS AFFECTING 'g'

## 2. ALTITUDE :

Acceleration due to earth's gravity decreases going up from the surface




$$g' = g\left(1 - \frac{2h}{R}\right)$$

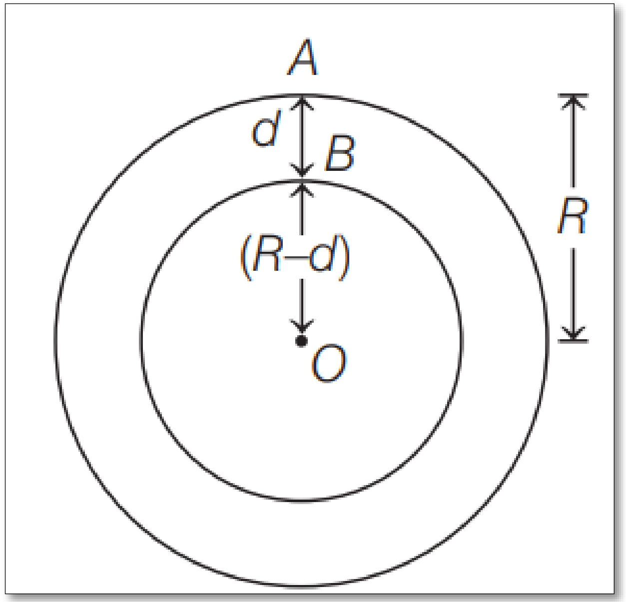
$$= g - \frac{2h}{R}(g)$$

subtracting from g,

# FACTORS AFFECTING 'g'

## 3. DEPTH :

Acceleration due to earth's gravity is maximum on its surface decreasing whether you go up or down.



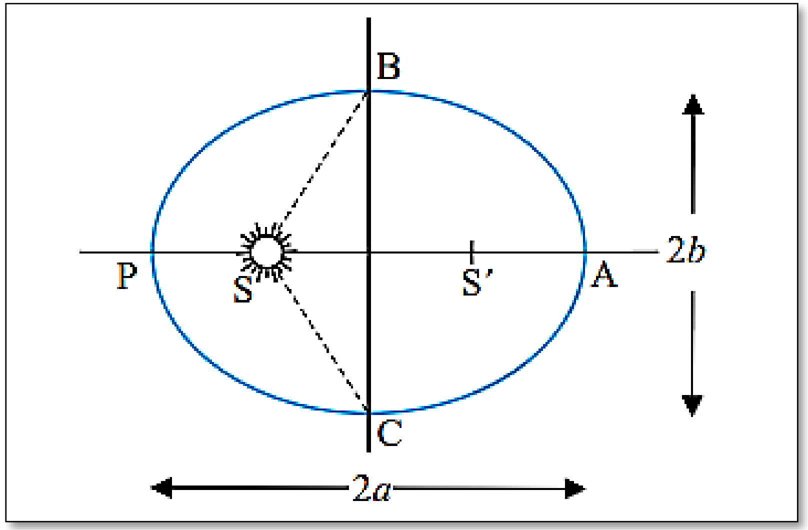

$$g' = g\left(1 - \frac{d}{R}\right)$$

$$= g - \frac{gd}{R}$$

# KEPLER's LAWS

## 1. Law of orbits :

All planets move in elliptical orbits with the Sun situated at one of the foci.



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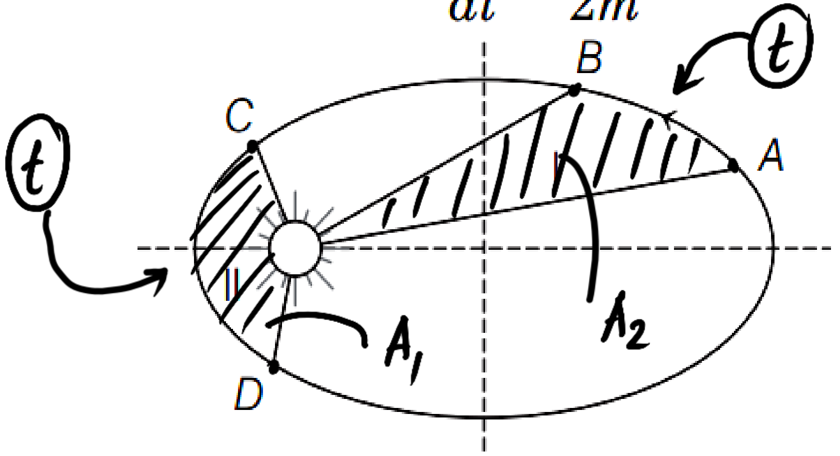
# KEPLER's LAWS

## 2. Law of areas :

**The line that joins any planet to the sun sweeps equal areas in equal intervals of time.**

Areal velocity of a planet $\frac{dA}{dt} = \frac{\mathbf{L}}{2m} = \text{constant}$




where, $L$ = angular momentum and $m$ = mass of the planet.

For same time t,

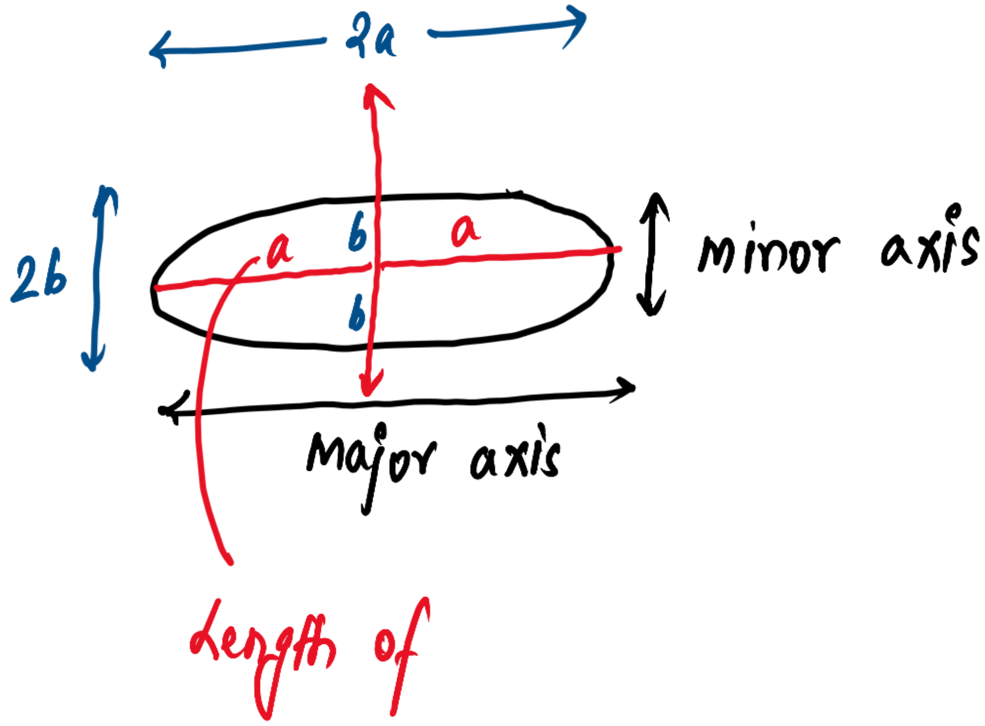
$A_1 = A_2$

# KEPLER's LAWS

## 3. Law of period :

The square of the time period of revolution of a planet around the sun is directly proportional to the cube of semi-major axis of its elliptical orbit.

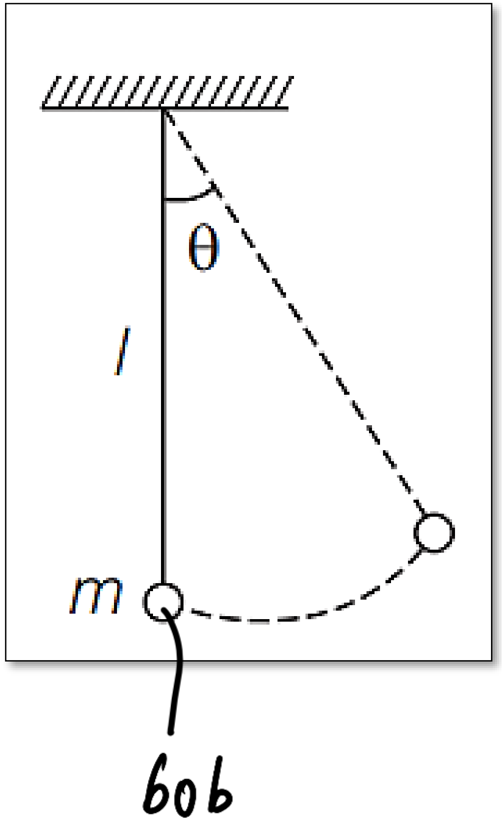
$$T^2 \propto a^3 \quad \text{or} \quad \left(\frac{T_1}{T_2}\right)^2 = \left(\frac{a_1}{a_2}\right)^3$$




$T^2 \propto R^3$ (if radius R of orbit is given)

# TIME PERIOD OF A PENDULUM

- A simple pendulum consists of a heavy point mass suspended from a rigid support by means of an elastic inextensible string.




For small amplitudes, (θ is small)

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$T \propto \sqrt{l}$

$T \propto \frac{1}{\sqrt{g}}$

T does not depend on mass of bob (m).

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$= \frac{2\pi}{\sqrt{g}} \times \sqrt{l}$$

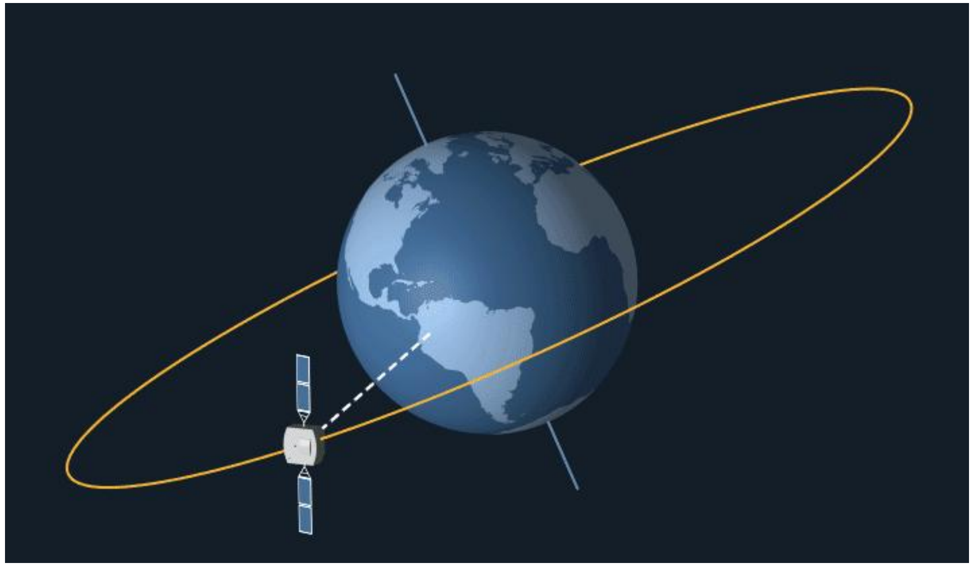
$$T \approx 2\sqrt{l}$$

$g = 9.8$ m/s

$\sqrt{g} \approx 3.1 = \pi$

# SATELLITES

**A satellite is a body which is revolving continuously in an orbit around a comparatively much larger body.**

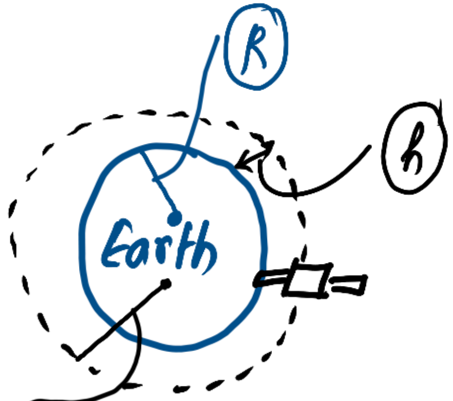


# TYPES OF SATELLITES

- Natural
  - (Moon)
- Artificial — (man - made)
  - (Sputnik - 1, Aryabhatta)

# ORBITAL VELOCITY

velocity at which satellite is run, so that it orbits the planet.




$R + h$ = radius of orbit of satellite.

$$v_o = \sqrt{\frac{GM}{R+h}} = R\sqrt{\frac{g}{R+h}}$$

$$g = \frac{GM}{R^2}$$

$$GM = gR^2$$

# ORBITAL VELOCITY CLOSE TO EARTH

$$v_o = R\sqrt{\frac{g}{R+h}}$$

$h = 0$ ; $v_0 = R\sqrt{\frac{g}{R}} = \sqrt{gR}$

$$v_0 = \sqrt{gR}$$

$g = 9.8\ m/s^2$ ; $R = 6.4 \times 10^6\ m$

# ORBITAL VELOCITY - CLOSE TO EARTH SURFACE

$$v_o = \sqrt{9.8 \times 6.4 \times 10^6} = 7.92 \times 10^3 \text{ m/s}$$

$$= 7.92 \text{ km/s} \approx 8 \text{ km/s}$$

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# TIME PERIOD

$$T = 2\pi\sqrt{\frac{(R+h)^3}{GM}} = 2\pi\sqrt{\frac{(R+h)^3}{gR^2}}$$

✓

Time taken by satellite to go one revolution.

$$\text{Time period} = \frac{\text{circumference of orbit}}{\text{orbital speed}} = \frac{2\pi(R+h)}{\sqrt{\frac{GM}{R+h}}} = 2\pi\sqrt{\frac{(R+h)^3}{gR^2}}$$

# TIME PERIOD - CLOSE TO EARTH SURFACE

$$T = 2\pi\sqrt{\frac{(R+h)^3}{gR^2}}$$

$h = 0$ ; $T = 2\pi\sqrt{\frac{R^3}{gR^2}} = 2\pi\sqrt{\frac{R}{g}}$

$R = 6.4 \times 10^6$ m ; $g = 9.8$ m/s$^2$

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# TIME PERIOD - CLOSE TO EARTH SURFACE

$$T = 2\pi\sqrt{\frac{6.4\times10^{6}}{9.8}} = 5078\ \text{s} = 84.6\ \text{min}$$

(just less than $1\frac{1}{2}$ hour)

# TOTAL ENERGY OF SATELLITE

$$E = -\frac{GMm}{2r}$$

M → Mass of earth

m → mass of satellite,

r → radius of orbit

E → kinetic energy + potential energy

Energy required to take satellite out of its orbit ; (Binding Energy)

$$+\frac{GMm}{2r} = \frac{GMm}{2r}$$

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# ESCAPE SPEED

The minimum speed with which a body must be projected vertically upwards in order that it may just escape from the gravitational pull of the earth.

$$v_e = \sqrt{2gR}$$

For earth, escape speed = 11.2 km/s

$$v_o = \sqrt{gR}$$

$$\left( v_e = \sqrt{2}\, v_o \right)$$

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# SUMMARY

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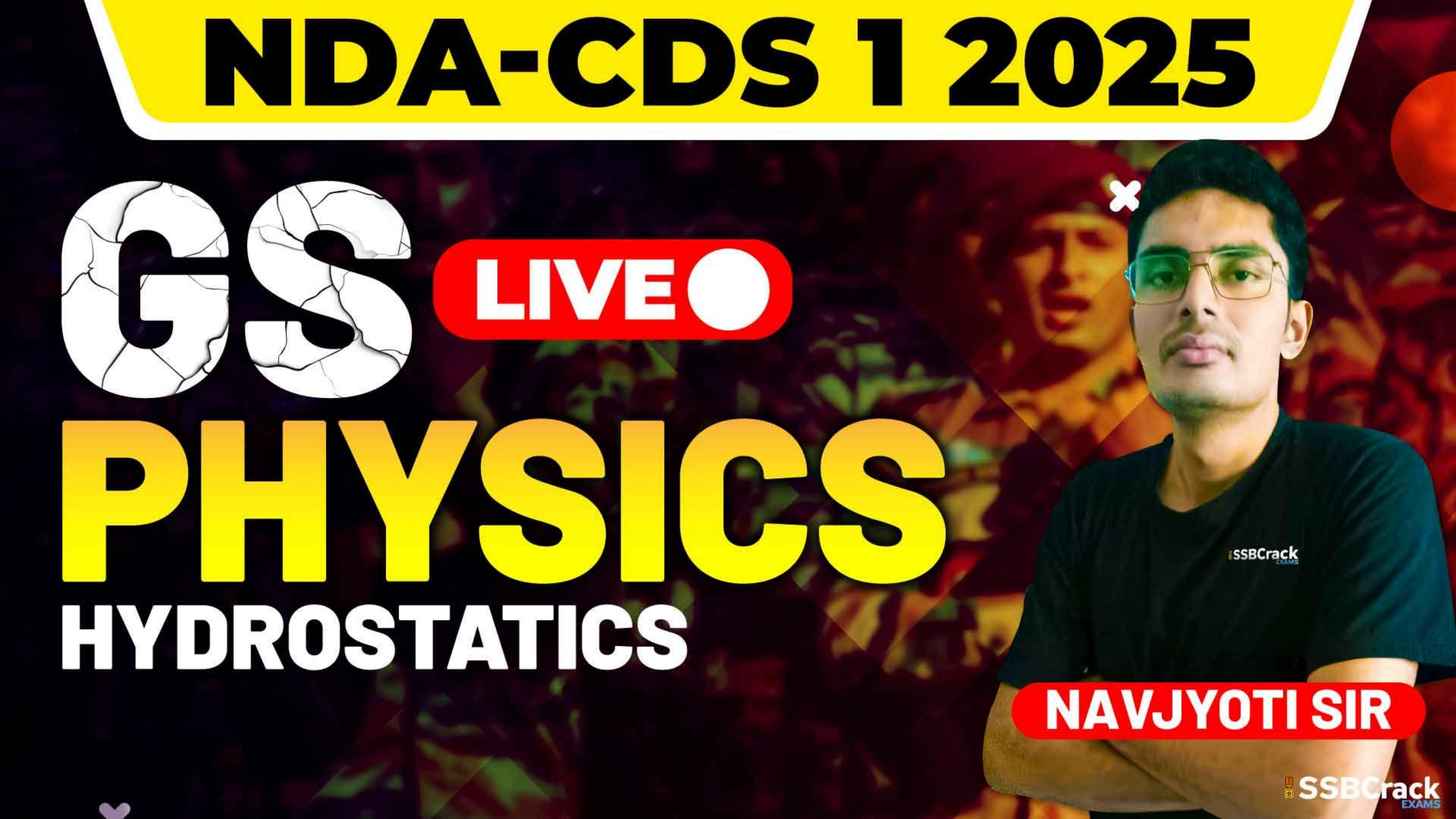
- Acceleration due to Gravity
- Kepler's Laws
- Time period of a Pendulum
- Satellites
- Escape Speed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