

## Lesson 1 – Gravitation (Concept Notes)

### □ 1. Introduction

- Gravitation is a **universal force** that acts between all objects having mass.
  - First explained by **Sir Isaac Newton**, who discovered that the Earth attracts all objects towards its centre.
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### □ 2. Newton's Universal Law of Gravitation

Every object in the universe attracts every other object with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

$$[ F = G \frac{m_1 m_2}{r^2} ]$$

Where:

- **F** = Gravitational Force
  - **G** = Universal Gravitational Constant =  $6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$
  - **m<sub>1</sub>, m<sub>2</sub>** = Masses of two bodies
  - **r** = Distance between them
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### 3. Kepler's Laws of Planetary Motion

1. **Law of Orbits** – Planets move around the Sun in **elliptical orbits** with the Sun at one focus.
2. **Law of Areas** – The line joining the planet and the Sun sweeps **equal areas in equal intervals of time**.
3. **Law of Periods** – The square of the planet's time period of revolution ( $T^2$ ) is directly proportional to the cube of its average distance ( $r^3$ ) from the Sun.

$$[ T^2 \propto r^3 ]$$

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#### ⚙️ 4. Centripetal Force

- Force acting towards the **centre** of a circular path is called **Centripetal Force**.
- Required to keep an object moving in a circular motion.

$$F = \frac{mv^2}{r}$$

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#### 🌍 5. Acceleration due to Gravity (g)

- The acceleration produced in a body due to Earth's gravitational pull.

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

Where M = Mass of Earth, R = Radius of Earth.

- Average value: **9.8 m/s<sup>2</sup>**
- **g decreases** with:
  - Increase in height
  - Increase in depth
  - From poles to equator

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#### ⚖️ 6. Difference between Mass and Weight

Quantity	Symbol	Unit	Constant?	Remarks
Mass	m	kg	Constant	Measure of matter/inertia
Weight	W = mg	N	Changes with g	Force due to gravity

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#### 🌐 7. Variation in g

- **With altitude:** g decreases with height.
- **With depth:** g decreases as we go inside the Earth.
- **With latitude:** g is maximum at poles, minimum at equator.
- **At centre of Earth:** g = 0

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#### 🚀 8. Escape Velocity

- Minimum velocity required by an object to escape from Earth's gravitational field.  
[  
 $v_{\text{esc}} = \sqrt{\frac{2GM}{R}} = 11.2 \text{ km/s (for Earth)}$   
]

## 🌀 9. Weightlessness

- In space or a freely falling lift, everything is in **free fall**.
- As all objects fall with the same acceleration, they appear **weightless** relative to each other.

## 🌊 10. Gravitational Waves

- Predicted by **Albert Einstein (1916)**.
- These are ripples in **space-time fabric** produced by massive moving bodies.
- First detected by **LIGO (2016)**.
- Used to study distant cosmic events like black hole mergers.

## 📐 11. Important Formulas

Concept	Formula	Units
Gravitational Force	$F = G \frac{m_1 m_2}{r^2}$	N
Weight	$W = mg$	N
Acceleration due to Gravity	$g = \frac{GM}{R^2}$	$\text{m/s}^2$
Centripetal Force	$F = \frac{mv^2}{r}$	N
Escape Velocity	$v_e = \sqrt{2GM/R}$	$\text{m/s}$
Potential Energy near Earth	$U = mgh$	J

## ☐ 12. Key Points Summary

- Gravitation is an attractive force acting between any two masses.
- $g = 9.8 \text{ m/s}^2$  on Earth (varies with position).
- At Earth's centre,  $g = 0$ .
- Escape velocity for Earth = 11.2 km/s, for Moon = 2.37 km/s.
- Satellites remain in orbit due to balance between **centripetal force** and **gravitational force**.
- Weightlessness is due to free fall condition.

