🌌 Chapter 6 – Gravitation

🌠 1. Introduction

Every object attracts every other object — that's gravitation.
Though weakest, it rules stars, planets, and galaxies.

Newton discovered this universal attraction, explaining both the fall of an apple and the orbit of the Moon with one equation.

🧮 2. Newton's Law of Gravitation

F=Gm1m2r2F = G \frac{m_1 m_2}{r^2}F=Gr2m1m2

Where:

- **G = 6.67×10^{-11} N·m²/kg²**
- **F ∝ m_1m_2 (directly), F ∝ $1/r^2$ (inversely).**

It's universal — same for all masses and distances.

🌍 3. Gravitational Field and Potential

Field:

Force per unit mass at a point:

$\vec{g}=\frac{F}{m}=-G\frac{M}{r^2}$

Potential:

Work done per unit mass in bringing body from ∞ to that point:

V=−GMrV = -G \frac{M}{r}V=−GrM

Unit: J/kg.
Gravitational field = −gradient of potential.

🚀 4. Acceleration Due to Gravity

At Earth's surface:

g=GMR2g = \frac{GM}{R^2}g=R2GM

M = 5.97×10^{24} kg, R = 6.37×10^{6} m → g ≈ 9.8 m/s².

Variation of g:

- **Height: g′=g(1−2hR)g' = g(1 - \frac{2h}{R})g′=g(1−R2h)**
- **Depth: g′=g(1−dR)g' = g(1 - \frac{d}{R})g′=g(1−Rd)**
- **Latitude: decreases from poles to equator (due to rotation).**

🛰️ 5. Gravitational Potential Energy

U=−GMmrU = -G \frac{M m}{r}U=−GrMm

Zero at infinity; negative for bound systems.

Work done by gravity = decrease in potential energy.

🌌 6. Escape Velocity

Minimum velocity to leave Earth's gravity:

ve=2gR=11.2 km/s (Earth)v_e = \sqrt{2 g R} = 11.2 \text{ km/s (Earth)}ve=2gR =11.2 km/s (Earth)

For Moon ≈ 2.4 km/s, for Jupiter ≈ 60 km/s.

🪐 7. Satellite Motion

For circular orbit:

GMmr2=mv2r⇒v=GMr\frac{GMm}{r^2} = \frac{mv^2}{r} \Rightarrow v = \sqrt{\frac{GM}{r}}r2GMm=rmv2⇒v=rGM

- **Orbital velocity: 7.9 km/s for low Earth orbit.**
- **Time period: T=2πr3GMT = 2π\sqrt{\frac{r^3}{GM}}T=2πGMr3 (Kepler's third law).**

🔭 8. Kepler's Laws

1. **Elliptical Law: Planets move in ellipses with Sun at one focus.**
2. **Area Law: Line joining planet to Sun sweeps equal areas in equal times.**
3. **Time–Period Law: T2∝r3T^2 ∝ r^3T2∝r3**

These laws are consequences of Newton's gravitation.

🧩 9. Geostationary Satellite

- **Period = 24 h, orbit radius ≈ 42,000 km.**
- **Appears stationary above equator.**
- **Used for communication, weather forecasting.**

📜 10. Summary

1. **Gravitational force ∝ product of masses / distance².**
2. **g decreases with height & depth.**
3. **Escape velocity on Earth = 11.2 km/s.**
4. **Satellites revolve due to gravitational pull.**
5. **Kepler's laws describe planetary motion.**