Chapter 9: Gravitation — Detailed Premium Notes

1. Introduction to Gravitation

◇ *What is Gravitation?*

Gravitation is a natural force of attraction that acts between any two objects having mass.
It is a universal force, which means it acts everywhere in the universe — whether it's between the Earth and the Sun, the Earth and the Moon, or even two small stones placed near each other.

Simple Example:
When you throw a ball up, it eventually comes down. This happens because the Earth pulls the ball towards itself due to the force of gravitation.

◆ *Discovery of Gravitation*

The concept of gravitation became clear when Sir Isaac Newton made a brilliant observation.
According to a popular story, Newton saw an apple fall from a tree and wondered,

"Why did it fall straight down and not sideways or upward?"

This question led him to the idea that the Earth attracts every object towards its center — a force we now call gravity.

Difference Between Gravity and Gravitation

Basis	*Gravitation*	*Gravity*
Definition	*It is the universal force of attraction acting between any two objects in the universe.*	*It is the force by which the Earth (or any celestial body) attracts objects towards its center.*
Scope	*It applies to all objects having mass, anywhere in the universe.*	*It is limited to the region around a particular celestial body like the Earth.*
Example	*Attraction between the Earth and the Moon.*	*A ball falling towards the ground.*
Nature	*Acts between any two masses, no matter how far they are.*	*Acts mainly near the surface of the Earth or other planets.*
Type	*It is a general phenomenon.*	*It is a specific case of gravitation.*

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2. Newton's Universal Law of Gravitation

Statement of the Law

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

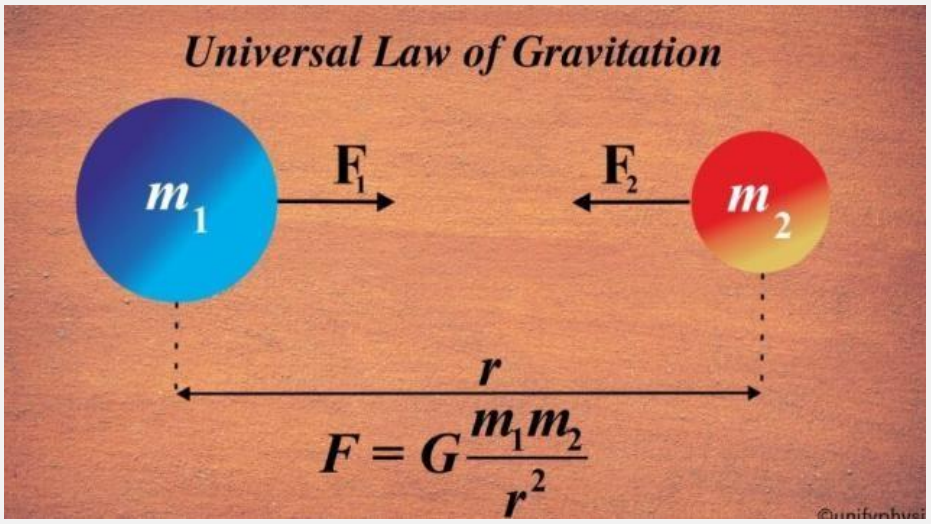
◇ ***Mathematical Expression***

$$F = G\frac{m_1 m_2}{r_2}$$

Where:

- ***F → Force of gravitation between two objects***
- ***m_1 and m_2 → Masses of the two objects***
- ***r → Distance between the centers of the two objects***
- ***G → Universal Gravitational Constant***

Value of G: 6.67×10^{-11} N·m²/kg²



◆ *Explanation of the Law*

1. ***The greater the masses of the two objects, the stronger the force between them.***
2. ***The greater the distance between the two objects, the weaker the force becomes.***
3. ***The force of gravitation always acts along the line joining the centers of the two objects.***

◇ *Importance of the Law*

- ***Explains how the Earth attracts objects towards itself (gravity).***
- ***Helps understand how the Moon revolves around the Earth and planets revolve around the Sun.***
- ***Useful in studying satellite motion and tides.***
- ***Shows that the same laws of nature apply on Earth and in the universe — proving the universe's unity.***

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3. Universal Gravitational Constant (G)

Definition: The force of attraction between two 1 kg masses placed 1 meter apart in vacuum.

Formula: $F = G \frac{m_1 m_2}{r^2}$

Value: 6.67×10^{-11} N·m²/kg²

SI Unit: N·m²/kg²

Key Point: G is constant everywhere in the universe and its value is very small.

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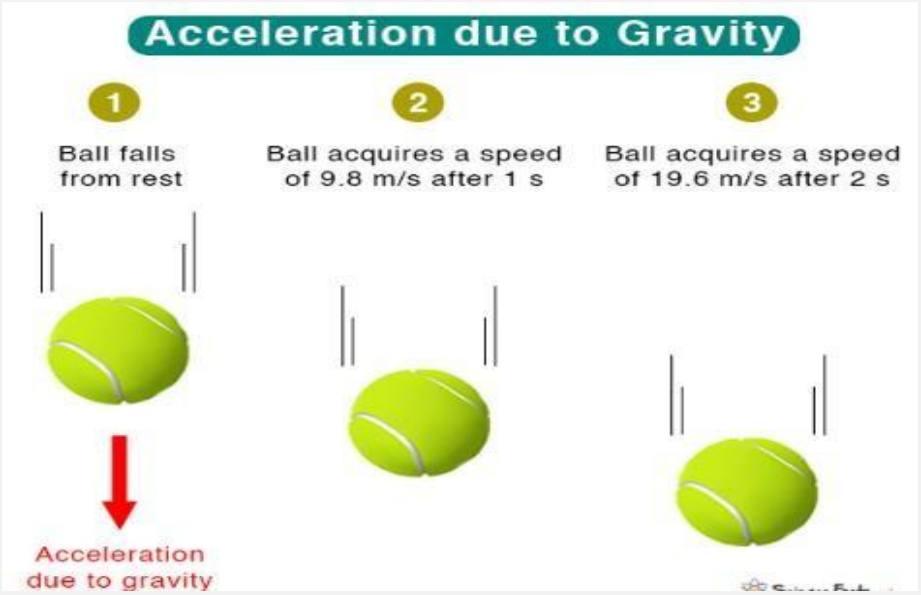
4. Gravity on Earth

- **Definition:**
  Gravity is the force with which the Earth attracts objects towards its center.
- **Cause:**
  It is due to the Earth's mass, which produces a gravitational pull on everything around it.
- **Effect:**
  - **Makes all objects fall towards the ground when dropped.**
  - **Gives objects weight.**
  - **Keeps the atmosphere and oceans bound to Earth.**
- **Acceleration due to Gravity (g):**
  Every object near the Earth's surface falls with an acceleration called g.

$$g = 9.8 \text{ m/s}^2$$

- **Direction:**
  Always acts towards the center of the Earth.



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5. Difference Between Mass and Weight

Basis	Mass	Weight
Definition	The amount of matter present in a body.	The force with which the Earth attracts a body towards its center.
Formula	—	W = m × g
Nature	Scalar quantity	Vector quantity
Unit	Kilogram (kg)	Newton (N)
Constant or Variable	Constant everywhere	Changes with the value of g
Measured by	Beam balance	Spring balance

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6. Variation of Gravity with Altitude and Depth

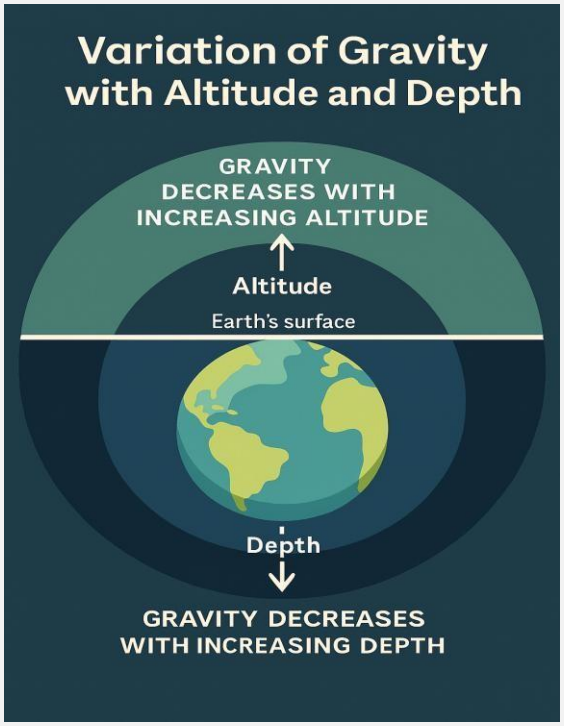
- ◇ *1. Variation with Altitude (Height)*
- *As we go higher above the Earth's surface, the value of g*

decreases.

- *This happens because the distance from the Earth's center increases, reducing the gravitational pull.*
- *Example: g is slightly less on a mountain top than at sea level.*

◇ *2. Variation with Depth*

- *When we go below the Earth's surface, the value of g also decreases.*
- *At the center of the Earth, g becomes zero because the pulls from all directions cancel out.*



◆ *In Short*

- *Higher altitude → g decreases*
- *Greater depth → g decreases*
- *Maximum g at Earth's surface*

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7. Free Fall and Acceleration due to Gravity

◇ *Free Fall*

- ***Definition: The motion of a body under the influence of gravity alone, without air resistance, is called free fall.***
- ***Example: A stone dropped from a height (ignoring air resistance).***

◇ *Acceleration due to Gravity (g)*

- ***Every object in free fall near the Earth's surface accelerates at a constant rate called g.***
- ***Value:*** $g = 9.8$ ***m/s²***
- ***Direction: Towards the center of the Earth.***

◇ *Key Points*

- ***In free fall, all bodies fall with the same acceleration regardless of their mass.***
- ***Weight of the body = mass × g***
- ***Free fall is a special case of gravitational motion.***

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8. Weightlessness and Apparent Weight

◇ *Weightlessness*

- ***Definition: The condition in which a body seems to have no weight is called weightlessness.***
- ***Cause: Occurs when there is no contact force acting on the body, such as in a freely falling elevator or a satellite orbiting the Earth.***
- ***Key Point: The body still has mass, but its weight is effectively zero.***

◇ *Apparent Weight*

- ***Definition: The weight measured by a scale or felt by a body is called apparent weight.***
- ***Difference from Actual Weight: Apparent weight changes if the body is in accelerating systems (like elevators).***
    - ***Accelerating upwards → apparent weight increases***
    - ***Accelerating downwards → apparent weight decreases***

◇ *In Short*

- ***Weightlessness: No contact force → weight seems zero.***

- ***Apparent Weight: Weight felt by a body; can be more or less than actual weight depending on motion.***

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9. Mass and Weight on Different Planets

- ***Mass remains the same everywhere.***
- ***Weight changes depending on the planet's gravity.***
- ***Weight on another planet = mass × gravity of that planet.***

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10. Buoyant Force

◇ *Definition*

The upward force exerted by a fluid (liquid or gas) on a body immersed in it is called buoyant force.

◇ *Cause*

- ***Caused by the pressure difference in the fluid: pressure at the bottom of the body is greater than at the top, pushing it upward.***

◇ *Key Points*

- ***Buoyant force opposes the weight of the object.***
- ***Determines whether an object floats, sinks, or remains suspended.***
- ***Floating: Buoyant force = weight of the object***
- ***Sinking: Weight > Buoyant force***
- ***Suspended: Weight = Buoyant force***

◇ *In Short*

Buoyant force is the upward push that fluids exert on objects, making them float or feel lighter in water.

11.Thrust and Pressure

THRUST: The Push That Starts It All

- *Thrust is just a force, but with a direction — normal (perpendicular) to the surface.*
- *Example: When you stand on the ground, your body exerts a thrust on the floor.*

◇ *Key Insight: Thrust doesn't care about area — it's all about the total force.*

PRESSURE: Force with Finesse

- *Pressure tells us how concentrated the thrust is.*
- *Smaller area → higher pressure Larger area → lower pressure* ◇ *Real-Life Analogy:*
- *A sharp knife cuts better than a blunt one because it applies more pressure on a smaller area.*

Applications That Matter:

- *School Bags: Wide straps reduce pressure on shoulders.*
- *Nails & Pins: Pointed tips = tiny area = high pressure = easy penetration.*
- *Hydraulic Systems: Use pressure to lift heavy loads with small force.*

12.Importance of Gravitation

- *Keeps planets in orbit around the Sun.*
- *Causes tides on Earth due to Moon's gravity.*
- *Responsible for formation of galaxies and stars.*

13.Sample Problems

Q: Two objects of masses 5 kg and 10 kg are 2 meters apart. Calculate the gravitational force between them.

A: Using the formula:

Force $F = G \times (m_1 \times m_2) \div d^2$

$= 6.67 \times 10^{-11} \times (5 \times 10) \div (2 \times 2)$

$= 6.67 \times 10^{-11} \times 50 \div 4$

$= 6.67 \times 10^{-11} \times 12.5$

$= 8.34 \times 10^{-10}$ Newtons

Q: A wooden block of mass 2 kg is floating in water. If the volume of the block is 0.004 m^3, calculate the buoyant force acting on it. (Take density of water = 1000 kg/m^3, g = 9.8 m/s^2)

A: Using the formula:
Buoyant Force (F) = $\rho \times V \times g$
Where:

- ***ρ = density of fluid = 1000 kg/m^3***
- ***V = volume of object submerged = 0.004 m^3***
- ***g = acceleration due to gravity = 9.8 m/s^2***

$F = 1000 \times 0.004 \times 9.8 =$
3.92 Newtons

Q: A force of 200 N is applied on a surface of area 0.25 m^2. Calculate the pressure exerted on the surface.

Solution:

Thrust (F) = 200 N

Area (A) = 0.25 m^2

Pressure (P) = F / A

= 200 / 0.25

= 800 Pascal (Pa)

Final Answer: The pressure exerted on the surface is 800 Pa.

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