Chapter-7

1. Introduction Force and Motion

Force is a **push or pull** that can change the state of rest or motion of an object. This chapter focuses primarily on **gravitational force**, **free fall**, and **motion under gravity**.

2. Gravitational Force

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
- **Inversely proportional** to the square of the distance between them

Gravitational Force Formula

Formula:

$F = G\ (m_1 \square m_2)\ /\ r\square$

Where:

- **F** = Gravitational force (in newtons, N)
- **G** = Universal gravitational constant = 6.674×10^{-11} Nm²/kg²
- **m_1, m_2** = Masses of the two objects (in kilograms, kg)
- **r** = Distance between the centers of the two masses (in meters, m)

🔢 Worked Example 1

Gravitational Force Calculation.

Formula:

$F = G \square (m_1 \square m_2)\ /\ r\square$

Given:

- $m_1 = 10$ kg
- $m_2 = 20$ kg
- r = 2 m
- $G = 6.674 \times 10^{-11}$ Nm²/kg²

Solution:

$F = 6.674 \times 10^{-11} \times (10 \times 20) / 2^2$
$F = 6.674 \times 10^{-11} \times 200 / 4$
$F = 6.674 \times 10^{-11} \times 50$
$F = 3.337 \times 10^{-9}$ N

Answer: 3.34×10^{-9} N

3. Variation of Gravitational Force

A. With Mass:

- If one mass is **doubled**, force **doubles**.
- If both masses are **doubled**, force becomes **four times**.
- If both masses are **halved**, force becomes **one-fourth**.

B. With Distance:

- If distance is **doubled**, force becomes **one-fourth**.
- If distance is **halved**, force becomes **four times**.

4. Consequences of Gravitational Force

- Keeps planets in orbit
- Causes tides
- Responsible for free fall
- Keeps the atmosphere bound to Earth

5. Gravity and Acceleration Due to Gravity

Gravity

The force by which Earth attracts objects toward its center.

Difference: Gravity vs. Gravitation

Feature	Gravity	Gravitation
Scope	Between Earth and objects	Between any two masses
Nature	Earth-specific	Universal

Acceleration Due to Gravity (g)

- Symbol and Value of Gravity
- **Symbol:** g
- **Value on Earth:** 9.8 m/s^2

Weight–Mass Relationship

Weight Formula

$W = mg$

Where:

- **W** = Weight (in newtons, N)
- **m** = Mass (in kilograms, kg)
- **g** = Acceleration due to gravity (in meters per second squared, m/s^2)

📌 Weight is **proportional to mass and gravity**.

🔢 **Worked Example 2**

Weight Calculation on Earth

Formula:

`W = m □ g`

Given:

- m = 60 kg (mass of the person)
- g = 9.8 m/s² (acceleration due to gravity on Earth)

Calculation:
W = 60 × 9.8 = 588 N
Answer: `588 N`

6. Acceleration Due to Gravity is Independent of Mass

In a vacuum, all objects fall with the **same acceleration** regardless of mass.
Example: Feather and coin fall equally when air resistance is removed.

7. Mass and Weight

Feature	Mass	Weight
Definition	Quantity of matter	Force due to gravity
Unit	Kilogram (kg)	Newton (N)
Constant?	Yes	Varies with gravity
Type	Scalar	Vector

8. Variation of g on Earth

- **Highest** at poles
- **Lowest** at equator
- **Decreases** with altitude and depth

9. Free Fall

Motion of an object **only under gravity**, with **no air resistance**.
Occurs in vacuum or near-Earth free-fall environments.

10. Equations of Motion Under Gravity

Assume:

- **Initial velocity** = `u`
- **Final velocity** = `v`
- **Distance** = `s`
- **Time** = `t`
- **Acceleration due to gravity** = `g`

Equations:

1. $v = u + gt$
2. $s = ut + \frac{1}{2}gt^2$
3. $v^2 = u^2 + 2gs$

Key Equations of Motion Under Gravity

1. **Displacement:** $s = ut + (1/2)gt^2$
2. **Final Velocity:** $v = u + gt$
3. **Velocity–Displacement Relation:** $v^2 = u^2 + 2gs$

📌 **For objects falling from rest**, use $u = 0$

🔢 **Worked Example 3**

Problem: An object falls freely from rest. Find the distance it covers in 3 seconds.

Given:

- Initial velocity, $u = 0$
- Acceleration due to gravity, $g = 9.8\ m/s^2$
- Time, $t = 3s$

Formula: $s = ut + (1/2)gt^2$

Substitute values:
$s = 0 \times 3 + (1/2) \times 9.8 \times 3^2$
$s = 0 + (1/2) \times 9.8 \times 9$
$s = 4.9 \times 9 =$ **44.1 m**

Answer: 44.1 meters

🌟 Interesting Facts

- 🌙 **Moon's gravity** is approximately **1/6th** of Earth's gravity. That means objects weigh about six times less on the Moon than on Earth.
- Astronauts feel "weightless" in orbit because they are in continuous **free fall**.
- Galileo demonstrated free fall from the Leaning Tower of Pisa.

Quick Revision Summary

Gravitational Concepts & Formulas

Acceleration due to gravity on Earth: $g = 9.8\ m/s^2$
• Free fall is motion under gravity alone
• Equations of motion apply during free fall

Gravitational Force: $F = G \times (m_1 \times m_2) / r^2$

Weight: $Weight = mass \times gravity$

Common Mistakes to Avoid

• Confusing **mass** and **weight**

• Forgetting **units**: mass in kg, weight in N

Note: Do *not* use $g = 9.8\ m/s^2$ in places where it doesn't apply, such as on the Moon or other celestial bodies.

• Mixing up **gravity** and **gravitation**

• Applying motion equations to situations that are **not** free fall