# CHAPTER 3: DYNAMICS I

## 1. INTRODUCTION TO DYNAMICS

- **Dynamics** is the branch of mechanics that deals with **motion of objects along with the causes of motion**.
- Earlier, in **kinematics**, motion was described without considering its causes.
- In dynamics, we answer questions like:
  - Why does an object start moving?
  - Why does it stop?
  - Why does its speed or direction change?
- The answer to all such questions is **force**

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## 2. FORCE

### 2.1 Definition of Force

- **Force** is a **vector quantity**.
- It can:
  - Start or stop motion
  - Change speed (accelerate or decelerate)
  - Change direction of motion
- Unit of force is **newton (N)**

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## 3. CLASSIFICATION OF FORCES

Forces are broadly divided into **contact forces** and **non-contact forces**.

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### 3.1 Contact Forces

These forces act **only when objects are in physical contact**.

#### *(a) Normal Force*

- Acts **perpendicular** to the surface of contact.
- Prevents objects from passing through each other.
- Example: A book resting on a table

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#### *(b) Thrust*

- Force that pushes an object **in the direction of motion**.
- Produced by engines, rockets, jet planes, etc.

#### *(c) Friction*

- Opposes the **relative motion** between surfaces in contact.
- Acts **opposite to motion or attempted motion**.
- Air resistance is a type of friction (drag force).

#### *(d) Tension*

- Force transmitted through **string, rope, cable, or wire**.
- Acts along the length of the string.
- Exists only when the string is stretched.

#### *(e) Elastic Force*

- Force produced when an object resists deformation.
- Example: stretched spring or rubber band.
- Tension is elastic only during **extension**, not compression.

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### 3.2 Non-Contact Forces

These forces act **without physical contact** (action at a distance).

#### *(a) Gravitational Force*

- Attractive force between any two masses.
- Responsible for weight and planetary motion.

#### *(b) Electrostatic Force*

- Force between electric charges.
- Can be attractive or repulsive.

#### *(c) Magnetic Force*

- Force between magnetic poles.
- Like poles repel, unlike poles attract

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## 4. FUNDAMENTAL FORCES OF NATURE

All forces in nature can be classified into **four fundamental forces**:

### 1. Strong Nuclear Force

- Strongest force.
- Holds protons and neutrons together in the nucleus.
- Very short range.

### 2. Electromagnetic Force

- Acts between electric charges.
- Responsible for normal force, friction, tension.
- Infinite range.
- Mediated by **photons**.

### 3. Gravitational Force

- Weakest force.

- Acts between all masses.
- Infinite range.
- Mediated by **gravitons** (not yet detected).

### 4. Weak Nuclear Force

- Responsible for radioactive decay.
- Very short range.
- Mediated by **$W^+$, $W^-$ and $Z^0$ bosons**

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## 5. FORCE DIAGRAMS

### 5.1 System Diagram (SD)

- Shows all objects involved in interaction.

### 5.2 Free Body Diagram (FBD)

- Shows **only one object** under consideration.
- All forces acting on it are drawn as arrows.
- Length of arrow ∝ magnitude of force.
- Forces are labelled (Fg, FN, Ff, T, etc.).

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## 6. NET FORCE (RESULTANT FORCE)

- **Net force** is the **vector sum of all forces** acting on an object.
- If **net force = 0**, forces are **balanced** → no change in motion.
- If **net force ≠ 0**, forces are **unbalanced** → object accelerates.
- Like parallel forces are added.
- Unlike parallel forces are subtracted.
- Forces at angles are added using **vector addition**

 

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## 7. NEWTON'S LAWS OF MOTION

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### 7.1 Newton's First Law (Law of Inertia)

*An object remains at rest or continues to move with uniform velocity unless acted upon by an external net force.*

- Explains **inertia** (resistance to change in motion).
- Mass is a measure of inertia.
- Larger mass → greater inertia.
- Explains:
  - Jerks in buses
  - Coins falling into glass experiment
  - Dust flying off carpets

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### 7.2 Newton's Second Law

- Acceleration is:
  - Directly proportional to net force
  - Inversely proportional to mass
- Acceleration occurs in the **direction of net force**.
- Defines **SI unit of force (newton)**.
- Used to calculate acceleration, force, and mass

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## 7.3 Newton's Third Law

*For every action, there is an equal and opposite reaction.*

- Action and reaction:
  - Are equal in magnitude
  - Act on different bodies
- Examples:
  - Walking
  - Rocket propulsion
  - Recoil of gun
  - Jumping from ground

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## 7.4 Limitations of Newton's Laws

- Not applicable at:
  - Atomic and subatomic scales (quantum mechanics)
  - Very high speeds close to speed of light (relativity)
- Still extremely accurate for everyday motion

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# 8. MASS AND WEIGHT

## Mass

- Amount of matter in an object.
- Measure of inertia.

 

- Constant everywhere.

### Weight

- Gravitational force acting on mass.
- Depends on gravitational field strength.
- Varies from place to place.

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## 9. MEASURING FORCE AND MASS

- **Spring balance** measures force.
- **Force sensor** measures force electronically.
- Weighing machines measure **weight** but display **mass** using g

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## 10. GRAVITATIONAL FIELD

- Region around a mass where gravitational force acts.
- **Gravitational field strength (g)**:
  - Force per unit mass
  - Vector quantity
  - Directed toward center of Earth
- Value of g varies on different planets

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## 11. MOMENTUM

- Momentum = product of mass and velocity.
- Vector quantity.



 

- Larger momentum → harder to stop.

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## 12. FORCE AND CHANGE IN MOMENTUM

- Force equals **rate of change of momentum**.
- Larger stopping time → smaller force.
- Explains safety features like airbags and catching balls by moving hands backward.

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## 13. IMPULSE

- Impulse = force × time.
- Equal to change in momentum.
- Graphically equal to **area under force-time graph**.

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## 14. ISOLATED SYSTEM

- A system with **no external force** acting.
- Internal forces cancel out.

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## 15. LAW OF CONSERVATION OF MOMENTUM

*Total momentum of an isolated system remains constant.*

- Explains:
    - Gun recoil
    - Rocket motion
    - Explosions
- Momentum before interaction = momentum after interaction

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# ALL FORMULAE (COLLECTED AT END)

1. **Newton's First Law**

$$F_{net} = 0 \Rightarrow a = 0$$

2. **Newton's Second Law**

$$F_{net} = ma$$

3. **SI Unit of Force**

$$1N = 1kg \cdot m/s^2$$

4. **Weight**

$$W = mg$$

5. **Mass**

$$m = \frac{W}{g}$$

6. **Gravitational Field Strength**

$$g = \frac{F}{m}$$

7. **Momentum**

$$p = mv$$

8. **Force and Momentum**

$$F = \frac{\Delta p}{\Delta t}$$

9. **Impulse**

$$J = F\Delta t = \Delta p$$

10. **Conservation of Momentum**

$$m_1 v_1 + m_2 v_2 = m_1 v_1' + m_2 v_2'$$



 