# 1. Basic Concepts

## 1.1 Displacement ($\vec{s}$)

- Vector quantity: Change in position of an object.

$$\vec{s} = \vec{x}_f - \vec{x}_i$$

Where $\vec{x}_f$: Final position, $\vec{x}_i$: Initial position.

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## 1.2 Distance

- Scalar quantity: Total length of the path traveled by an object.

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## 1.3 Speed ($v$)

- Scalar quantity: Rate of change of distance.

$$v = \frac{\text{distance}}{\text{time}}$$

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## 1.4 Velocity ($\vec{v}$)

- Vector quantity: Rate of change of displacement.

$$\vec{v} = \frac{\vec{s}}{t}$$

  - Instantaneous velocity:

$$\vec{v} = \frac{d\vec{x}}{dt}$$

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## 1.5 Acceleration ($\vec{a}$)

- Vector quantity: Rate of change of velocity.

$$\vec{a} = \frac{\Delta\vec{v}}{\Delta t} = \frac{d\vec{v}}{dt}$$

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# 2. Equations of Motion (Constant Acceleration)

For an object moving with uniform acceleration ($a$):

## 2.1 First Equation of Motion

$$v = u + at$$

Where $u$: Initial velocity, $v$: Final velocity, $t$: Time.

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## 2.2 Second Equation of Motion

$$s = ut + \frac{1}{2}at^2$$

Where $s$: Displacement.

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## 2.3 Third Equation of Motion

$$v^2 = u^2 + 2as$$

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## 2.4 Displacement in $n$-th Second

$$s_n = u + \frac{a}{2}(2n - 1)$$

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# 3. Graphical Representations

## 3.1 Displacement-Time Graph

- Slope of $x$-$t$ graph: Instantaneous velocity.

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### 3.2 Velocity-Time Graph

1. Slope of $v$-$t$ graph: Acceleration.
2. Area under $v$-$t$ graph: Displacement.

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### 3.3 Acceleration-Time Graph

- Area under $a$-$t$ graph: Change in velocity.

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## 4. Free Fall (Vertical Motion Under Gravity)

### 4.1 Acceleration Due to Gravity

- Denoted by $g$, directed downward.
  Value: $g \approx 9.8\ \text{m/s}^2$.

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### 4.2 Equations of Motion for Free Fall

1. Velocity:
$$v = u + gt$$
2. Displacement:
$$h = ut + \frac{1}{2}gt^2$$
3. Velocity-Displacement Relation:
$$v^2 = u^2 + 2gh$$

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### 4.3 Time of Flight (for objects thrown vertically)

1. **Time to reach maximum height**:
$$t_{\text{up}} = \frac{u}{g}$$
2. **Total time of flight**:

$$T = \frac{2u}{g}$$

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### 4.4 Maximum Height

- Maximum height reached by an object:

$$H = \frac{u^2}{2g}$$

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## 5. Relative Motion in 1D

### 5.1 Relative Velocity

- Relative velocity of object A with respect to object B:

$$\vec{v}_{AB} = \vec{v}_A - \vec{v}_B$$

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## 6. Key Results and Special Cases

### 6.1 Motion of Two Objects Meeting

- If two objects start at $x_1$ and $x_2$ with velocities $v_1$ and $v_2$, and accelerations $a_1$ and $a_2$, they meet when:

$$x_1 + v_1 t + \frac{1}{2} a_1 t^2 = x_2 + v_2 t + \frac{1}{2} a_2 t^2$$

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### 6.2 Uniform Motion (Zero Acceleration)

1. Velocity is constant:

$$v = \frac{s}{t}$$

2. Displacement:

$$s = vt$$

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## 6.3 Relative Acceleration

- Relative acceleration of object A with respect to object B:

$$\vec{a}_{AB} = \vec{a}_A - \vec{a}_B$$