

LESSON SLIDES

Motion

Physics · Describing motion in a straight line and in a circle

By the end of this lesson you can

- 🎯 Describe position from a reference point
- 🎯 Tell distance apart from displacement
- 🎯 Calculate speed, velocity and acceleration
- 🎯 Read position-time and velocity-time graphs
- 🎯 Use the kinematic equations

Where is it? Position and reference point

- Position needs a fixed reference point, called the origin
- Give both distance and direction from the origin
- An object moves if its position changes with time
- Motion depends on the observer's reference point

Distance and displacement

Distance

- Total length of the path travelled
- Has size only
- Never decreases as the object moves
- Unit: metre (m)

Displacement

- Change in position: final minus initial
- Has size and direction
- Can be zero, even after a long trip
- Unit: metre (m)

 Example

Riya's trip to the shop

- 1 Riya walks 300 m east, then 100 m back west
- 2 Distance = $300 + 100 = 400$ m
- 3 Displacement = 200 m east of home
- 4 The trip takes 200 s
- 5 Average speed = 2 m/s; average velocity = 1 m/s east

Average speed and average velocity

- Average speed = total distance $\div$ time taken
- Average velocity = displacement $\div$ time taken
- SI unit of both: metre per second (m/s)
- To convert km/h to m/s, multiply by $5/18$
- Example: 72 km/h (about 45 mph) = 20 m/s

Uniform and non-uniform motion

- Uniform: equal distances in equal time intervals
- Non-uniform: unequal distances in equal time intervals
- A train cruising at steady speed on a straight track
- A bus in city traffic, stopping and starting

Acceleration: how fast velocity changes

- Average acceleration = change in velocity $\div$ time
- $a = (v - u) \div t$
- SI unit: metre per second squared (m/s^2)
- Negative when velocity is decreasing in the positive direction
- A change of direction is also a change in velocity

Position-time graphs

- Time on the x-axis, position on the y-axis
- Straight sloping line: constant velocity
- Slope of the line gives the velocity
- Flat line: the object is at rest
- Curved line: velocity is changing

Velocity-time graphs

- Time on the x-axis, velocity on the y-axis
- Flat line: constant velocity, zero acceleration
- Slope of the line gives the acceleration
- Area under the graph gives the displacement

Kinematic equations (constant acceleration)

- $v = u + at$
- $s = ut + \frac{1}{2}at^2$
- $v^2 = u^2 + 2as$
- u initial velocity, v final velocity, a acceleration
- s displacement, t time; valid only if a is constant

 Example

A metro train leaves the station

- 1 Starts from rest: $u = 0$
- 2 Speeds up at $a = 1 \text{ m/s}^2$ for $t = 20 \text{ s}$
- 3 $v = u + at = 20 \text{ m/s}$ (72 km/h)
- 4 $s = ut + \frac{1}{2}at^2 = \frac{1}{2} \times 1 \times 20^2 = 200 \text{ m}$
- 5 Check: $v^2 = u^2 + 2as$ gives $400 = 2 \times 1 \times 200$

Speed and braking distance

- When stopping, $v = 0$, so braking distance $s = u^2 \div 2a$
- At 20 m/s with 5 m/s² braking: $s = 40$ m
- At 40 m/s with the same brakes: $s = 160$ m
- Double the speed means four times the braking distance

Uniform circular motion

- Motion along a circle at constant speed
- Direction of motion changes at every point
- So velocity changes: this is accelerated motion
- Speed = circumference $\div$ time for one round = $2\pi r \div T$
- Cyclist: 35 m radius, one lap in 22 s, about 10 m/s

 Quick check

On a velocity-time graph, what does the area under the line give?

A Acceleration

B Speed at the end

C Displacement

D Time taken

Key takeaways

- ✓ Position is measured from a chosen reference point
- ✓ Displacement has direction; distance does not
- ✓ Acceleration is the rate of change of velocity
- ✓ Slopes and areas of graphs describe motion
- ✓ Three equations link u , v , a , s and t