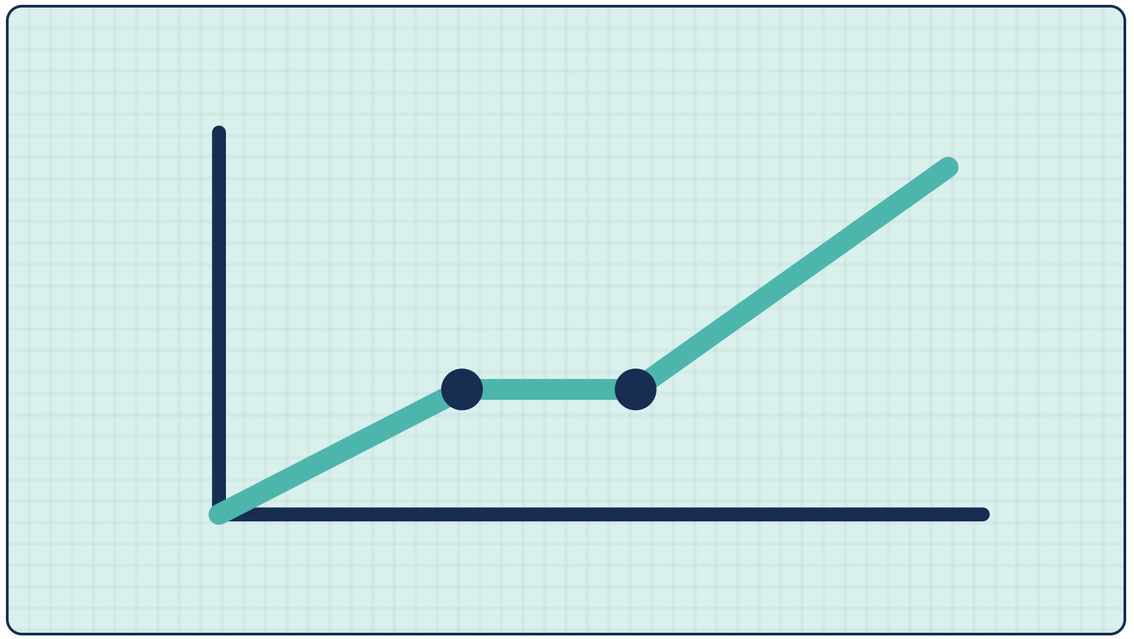
Physics · Describing motion in a straight line and in a circle

Motion



Goals

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)

Worked example

Riya's trip to the shop

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

Average speed and average velocity

- Average speed = total distance ÷ time taken
- Average velocity = displacement ÷ 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 ÷ 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

Worked example

A metro train leaves the station

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

Summary

Key takeaways

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