

Ages 14–15 · Science

LESSON SLIDES

Motion

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

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Motion

SPEAKER NOTES

Ask the class: are you moving right now? Most will say no, until someone points out that the Earth is spinning and orbiting the Sun. Use this to show that whether something moves depends on what we compare it with.

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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

By the end of this lesson you can

SPEAKER NOTES

Tell students the lesson ends with calculations, so they should keep a notebook ready for the worked examples. Ask which objective they already feel confident about.

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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

Where is it? Position and reference point

SPEAKER NOTES

A passenger sitting in a moving train is at rest compared with the seat but moving compared with the platform. Ask students to describe the position of the classroom door from their own desk, with a distance and a direction. A common misconception is that rest and motion are absolute.

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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)

Distance and displacement

SPEAKER NOTES

A student who runs one full lap of a school track and stops at the start has covered a distance but has zero displacement. The size of the displacement is never more than the distance. Ask: when are they equal? Only for motion in one direction along a straight line.

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 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

Riya's trip to the shop

SPEAKER NOTES

Work out each line on the board: average speed is $400 \text{ m} \div 200 \text{ s}$ and average velocity is $200 \text{ m} \div 200 \text{ s}$. Ask why the two answers differ. The walking back cancels part of the displacement but still adds to the distance.

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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

Average speed and average velocity

SPEAKER NOTES

Show where 5/18 comes from: 1 km/h is 1000 m in 3600 s. Ask students to convert 36 km/h and 54 km/h; the answers are 10 m/s and 15 m/s. Remind them that velocity has a direction, so it can be negative.

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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

Uniform and non-uniform motion

SPEAKER NOTES

Ask students to give one example of each from their journey to school. Point out that truly uniform motion is rare in daily life; most real motion is non-uniform, which is why we talk about average speed.

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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

Acceleration: how fast velocity changes

SPEAKER NOTES

Here u is the initial velocity and v the final velocity. Braking gives negative acceleration, which is sometimes called retardation. A common misconception is that a fast object must have a large acceleration; a car cruising at a steady 100 km/h in a straight line has zero acceleration.

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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

Position-time graphs

SPEAKER NOTES

Sketch three quick graphs and ask students to act out each one by walking. Stress that a graph is not a map of the route; it shows how position changes with time. A steeper slope means a greater velocity.

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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

Velocity-time graphs

SPEAKER NOTES

Draw a line rising from 0 to 20 m/s over 20 s and ask for the acceleration (1 m/s^2) and the displacement (the triangle's area, 200 m). This graph is used on the next slides to build the kinematic equations.

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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

Kinematic equations (constant acceleration)

SPEAKER NOTES

Show how each equation comes from the velocity-time graph: the slope gives the first and the area gives the second. The third is obtained by combining them to remove t . Remind students to pick the equation that contains the three quantities they know and the one they need.

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 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 $400 = 2 \times 1 \times 200$

A metro train leaves the station

SPEAKER NOTES

The numbers are chosen for easy arithmetic, not taken from any particular metro line. Ask students to find how far the train travels in the first 10 s; the answer is 50 m, a quarter of the distance in 20 s. Checking with a second equation is a good habit.

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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

Speed and braking distance

SPEAKER NOTES

Here a is the size of the deceleration, so the minus sign has been handled. This ignores the driver's reaction time, which adds even more distance, so real stopping distances are longer. Ask students why highways have speed limits and why drivers should keep a safe gap.

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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

Uniform circular motion

SPEAKER NOTES

For the cyclist, $2 \times (22/7) \times 35 \text{ m} = 220 \text{ m}$ per lap, and $220 \text{ m} \div 22 \text{ s} = 10 \text{ m/s}$. After one full lap the displacement is zero, so the average velocity for the lap is zero. Ask: can an object have constant speed but still be accelerating? Yes, in circular motion.

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 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

Quick check

SPEAKER NOTES

Answer: C, displacement. The slope of a velocity-time graph gives acceleration, which is the most common wrong choice. Ask a student to explain the difference between slope and area in their own words.

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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

Key takeaways

SPEAKER NOTES

Ask students to write the three kinematic equations from memory and say when they apply. Then move to the five-question quiz. Homework: time a vehicle or a friend over a measured distance and calculate the average speed.