AS Level Physics

Chapter 2 – Mechanics

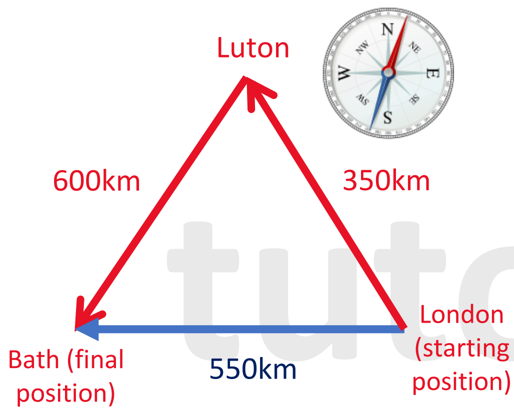
2.2.1 Kinematics

Notes

Distance and Displacement

- **Distance** is the complete path travelled by an object during its motion (a scalar quantity). It doesn't include a direction.
- **Displacement** (a vector quantity) is the distance moved in a stated direction.

Lets consider a car that sets off from London and stops at Luton before going to Bath.



To determine the fuel the car needs for the journey you would need to know the total distance.

If the driver just wanted to know his final position relative to the starting position, then the displacement is required.

Distance travelled by the car: 600 km + 350 km = **950 km.**

Displacement: **550 km due East (90°).**

As you can see ***distance only has a magnitude***, but the ***displacement has both size and direction***.

Speed VS Velocity

- **Speed** is the ***distance*** travelled divided by **time** (a scalar quantity).
- **Velocity** is the ***displacement*** divided by **time** (a vector quantity).

Lets say that the cars journey from London, to Luton, to Bath lasted 10 hours, then the speed would be:

$$Speed = \frac{distance}{time} = \frac{950\ km}{10\ h} = 95\ kmh^{-1}$$

However the velocity would be:

$$Velocity = \frac{displacement}{time} = \frac{550\ km}{10\ h} = 55\ kmh^{-1} due\ East\ (90°)$$

As you can see, both speed and velocity have the same units but ***speed*** only has a ***magnitude (size)*** whereas the ***velocity*** has both ***size and direction***.

SPEED, DISTANCE, TIME AND INSTANTANEOUS SPEED

- **Speed** is the ***distance*** travelled per unit time (a scalar quantity).

OR

The rate of change of distance.

OR

$$Average\ speed(ms^{-1}) = \frac{distance\ travelled\ (m)}{time\ taken\ (s)}$$

Average speed is determined by measuring the distance travelled by an object in a given time.

The formula above can only tell us an objects speed, but doesn't tell us if the object is speeding up or slowing down.

- **Instantaneous Speed** – the speed at any given instant.

Difference between Instantaneous Speed and Average Speed

To understand the difference between instantaneous speed and average speed can be understood, by a common example of a person driving a car.

The **instantaneous speed** is one that **changes constantly** and is represented by the **speedometer** of the car. So at one instant the car can be travelling at 60mph and at another instant the car can be travelling at 20mph and this is shown on the speedometer reading.

The **average speed** of that same journey is taking all of the instantaneous speeds and finding the average. For example 60mph + 20 mph = 80mph /2 = 40mph. So the average speed is 40mph. That **value doesn't change**. The other way for calculating average speed is **dividing** the **total distance travelled by the time taken**.

SPEED, DISTANCE, TIME AND INSTANTANEOUS SPEED

Example:

A car travels 550 metres in 60 seconds, then 1550 metres in 90 seconds. Calculate the cars average speed for the whole journey.

s in a-level physics means distance or displacement and not speed.

Step 1: Calculate the total distance first (s):

$$550m + 1550m = 2100m$$

Step 2: Calculate the total time taken (t):

$$60\ s + 90\ s = 150\ s$$

The find the speed:

$$speed = \frac{distance}{time} = \frac{s}{t} = \frac{2100\ m}{150\ s} = 14\ m/s$$

$$Speed = 14\ ms^{-1}$$

VELOCITY, DISPLACEMENT AND TIME

- **Velocity** is the **displacement** per unit time (a vector quantity).

OR

The rate of change of displacement.

$$Velocity = \frac{change\ in\ displacement}{time\ taken}$$

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

$Where:$

- $velocity\ (v)\ measured\ in\ metres\ per\ second\ (ms^{-1})$
- $displacement\ (s)\ meaured\ in\ metres\ (m)$
- $time\ (t)\ measured\ in\ seconds\ (s)$

s in a-level physics means distance or displacement and not speed.

Velocity is a vector quantity so that means the value can be either positive or negative depending on the direction of motion.

For example, positive velocity can mean that the object is moving to the right and therefore negative velocity means the object is moving to the left, and vice versa.

In exam questions you will come across a term called constant (uniform) velocity.

This means the object is moving with a steady (constant) speed that doesn't change and therefore isn't accelerating.

If an object is moving with a non-constant (uniform) velocity then the object has a non-constant speed and the object is either accelerating on decelerating.

VELOCITY, DISPLACEMENT AND TIME

Example:

What is the average velocity of a car that has moved 45 km East and 85 km West in 2 hours?

Step 1: Determine that anything to the East is positive

Step 2: Calculate the total displacement:

$$45\ km - 85\ km = -40\ km$$

Displacement is a vector quantity so it needs to have a magnitude as well a direction. So if anything East is positive everything to the West is negative. So we get a displacement of -85 km. This just means 85 m West.

Step 3: Calculate the velocity:

s in a-level physics means distance or displacement and not speed.

$$v = \frac{\Delta s}{\Delta t} = \frac{45\ km\ - 85\ km}{2\ hours} = \frac{-40\ km}{2\ hours} = \frac{-40000\ m}{7200\ seconds} = -5.6\ m/s$$

You need to convert the quantities to its SI units form.

Velocity = 5.6 m/s West

ACCELERATION

- Acceleration – the rate of change of velocity

$$Acceleration = \frac{change\ in\ velocity}{time\ taken} = \frac{\Delta v}{\Delta t}$$

Taking the above formula you get:

$$Acceleration = \frac{final\ velocity\ - initial\ velocity}{time} = \frac{v-u}{t}$$

Therefore:

$$a = \frac{v-u}{t}$$

$where$:

- $Acceleration\ (a)\ measured\ in\ metres\ per\ second\ squared\ (ms^{-2})$
- $Final\ velocity\ (v)\ measured\ in\ metres\ per\ second\ (ms^{-1})$
- $Initial\ velocity\ (u)\ measured\ in\ metres\ per\ second\ (ms^{-1})$
- $Time\ (t)\ measured\ in\ seconds\ (s)$

Acceleration is a vector quantity so that means the value can either be positive or negative.

- Positive acceleration = an object is speeding up = accelerating
- Negative acceleration = an object is slowing down = decelerating
- Constant acceleration = constant velocity = not speeding up or slowing down

ACCELERATION

Example:

A car accelerates from 12 m/s to 16 m/s in 7 seconds. What is its acceleration?

Step 1: Write down what you know:

$$Initial\ velocity\ (u)\ =\ 12\ m/s$$
$$Final\ velocity\ (v)\ =\ 16\ m/s$$
$$Time\ (t)\ = 7\ s$$
$$Acceleration\ (a)\ = ?$$

Step 2: Write down the equation, substitute and solve:

$$a = \frac{v-u}{t} = \frac{16m\ - 12m}{7s} = \frac{4m}{7s} = 0.57\ ms^{-2}$$

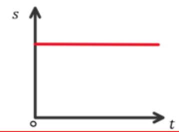
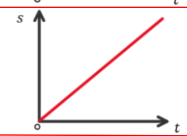
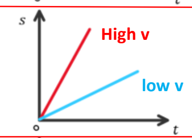
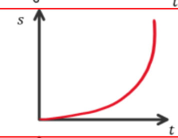
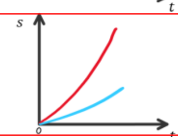
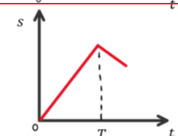
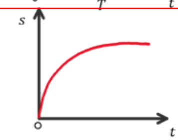
$$a = 0.57\ ms^{-1}\ (2\ d.p.)$$

GRAPHICAL REPRESENTATION

Displacement Vs. Time Graphs

You can plot displacement (s) against the y-axis and time (t) against the x-axis.

$$\boldsymbol{Gradient} = \frac{change\ in\ displacement}{change\ in\ time} = \frac{\Delta s}{\Delta t} = \boldsymbol{velocity}\ (\boldsymbol{v})$$

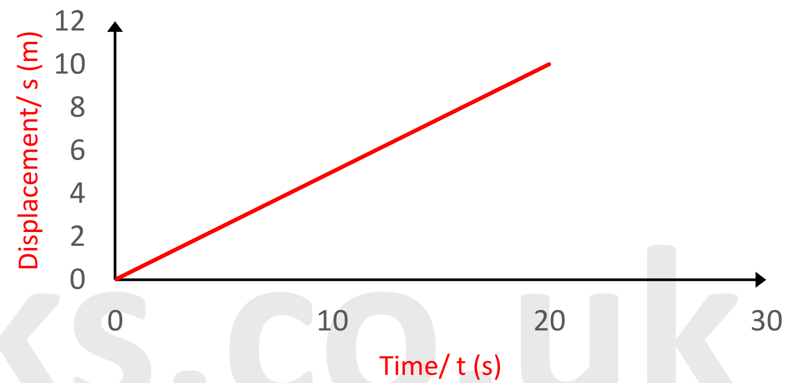
	The displacement is constant therefore the displacement isn't changing. This means that the object is not moving or is stationary or at rest. Therefore gradient = 0 , so velocity = 0
	A straight line sloping upwards shows an object moving away at a steady speed or moving with a constant velocity. This graph represents positive velocity. Therefore gradient is constant, and velocity = positive = constant
	The steeper the gradient of the displacement time graph the greater the velocity. A steeper gradient means you are travelling faster and therefore a greater area is covered which means a greater velocity.
	A curved graph shows that the gradient isn't constant. This graph shows that the object is speeding up (or accelerating); the velocity is positive and increasing.
	The steeper the gradient of the displacement time graph the bigger the acceleration. So the red curve has a bigger acceleration than the blue curve.
	A straight line sloping downwards (after time T) shows that the object is coming back to its starting position at a steady speed. This graph represents a negative displacement which means the object is moving in the opposite direction. In simple terms it just means coming back the way it came.
	A curved graph shows that the gradient isn't constant. This graph shows that the object is slowing down (or decelerating); the velocity is positive and is decreasing.

GRAPHICAL REPRESENTATION

Displacement Vs. Time Graph

Example:

Find the velocity after 20 s of the object whose displacement-time graph is shown in the diagram below:



Calculating the gradient of the line will give you the velocity:

$$Gradient = \frac{10\ m\ - 0\ m}{20\ s\ - 0\ s} = \frac{10\ m}{20\ s} = 0.5\ ms^{-1}$$

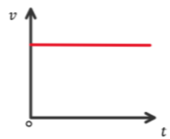
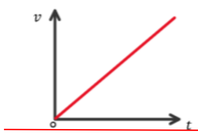
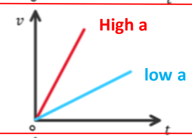
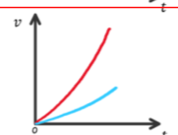
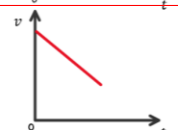
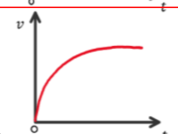
$$\therefore Velocity = 0.5\ ms^{-1}$$

GRAPHICAL REPRESENTATION

Velocity Vs. Time Graphs

You can plot velocity (v) against the y-axis and time (t) against the x-axis.

$$Gradient = \frac{change\ in\ velocity}{change\ in\ time} = \frac{\Delta v}{\Delta t} = acceleration\ (a)$$

	The velocity is constant therefore the velocity isn't changing with time. This means that the object is moving with a constant velocity. Therefore gradient = 0 , so velocity = 0, and acceleration = 0
	A straight line sloping upwards shows an object steadily increasing speed. This graph represents uniform positive acceleration. Therefore gradient is constant, and velocity = positive, acceleration = constant
	The steeper the gradient of the velocity time graph the greater the acceleration.
	A curved graph shows that the gradient isn't constant. This graph shows an object moving with an increasing acceleration.
	The steeper the gradient of the velocity time graph the greater the increase in the acceleration. So the red curve has a greater increase in the acceleration than the blue curve.
	A straight line sloping downwards shows that the object is steadily decreasing speed. This graph represents negative acceleration or deceleration.
	A curved graph shows that the gradient isn't constant. This graph shows an object moving with a decreasing acceleration.

GRAPHICAL REPRESENTATION

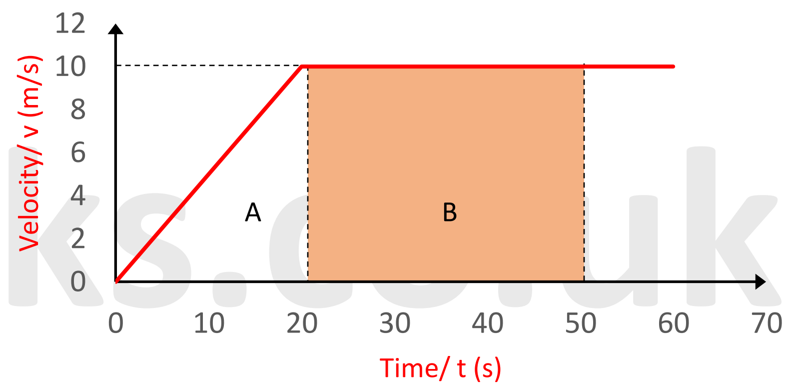
Velocity Vs. Time Graphs

Gradient of a velocity time graph = acceleration

Area under the velocity time graph = displacement

Example:

Find the displacement after 50 s of the object whose velocity-time graph is shown in the diagram below:



Split the graph into sections A (triangle) and B (rectangle).

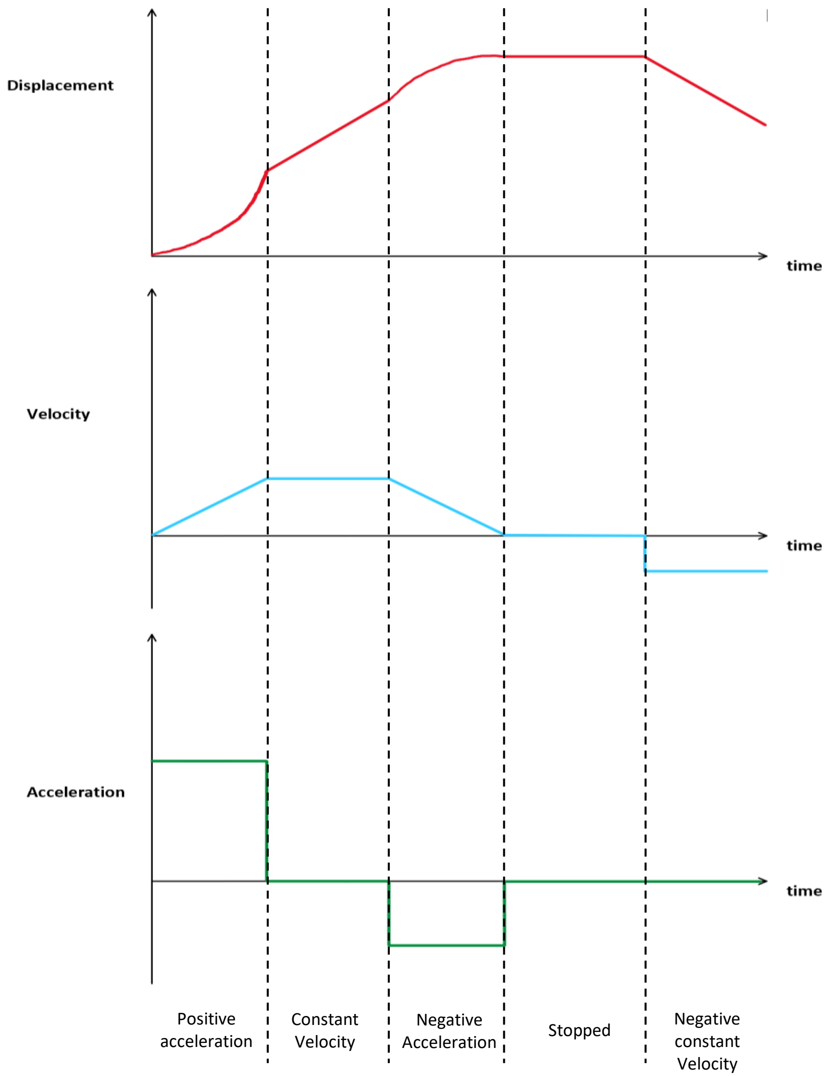
Calculate the area of each section and add the two results together.

A: $Area = \frac{1}{2} \times base \times height = \frac{1}{2} \times 20s \times 10\ m/s = 100m$

B: $Area = 30s\ \times 10\ m/s = 300m$

Total displacement = 100m + 300m = 400m.

GRAPHICAL REPRESENTATION



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ANALYSING MOTION

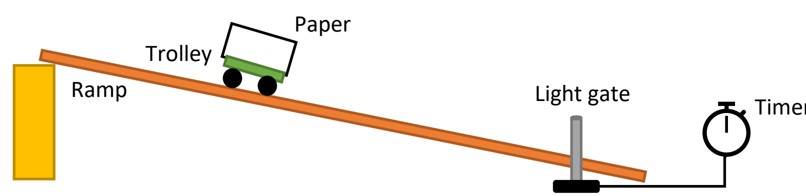
To calculate the speed of an object two measurements need to be recorded:

- The distance (how far the object travels)
- The time taken to travel that distance

Those measurements can be taken using a ruler (to measure the distance) and a stopwatch (to measure the time).

Or you can use light gates. The light gate connects to a timer, which gives a reading. A piece of card can be placed on a small toy trolley and you measure the distance (size) of the card using a ruler. When the leading end of the card breaks the light beam, the timer starts and when the trailing end passes through the light beam, the timer stops. This way you have the distance and the time travelled.

You can also use a camera and take a video of a moving object where the distance moved can be observed on a ruler in the video. The time is also known from the length of the video.



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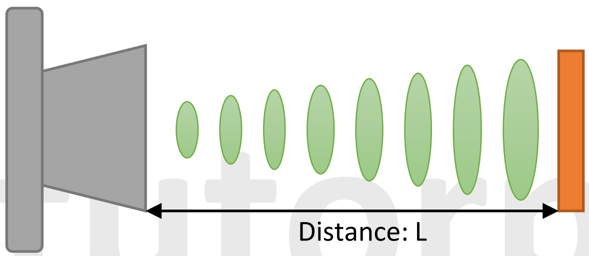
ANALYSING MOTION

You can also use an ultrasound position sensor. The ultrasound position sensor transmit a short bursts of ultrasound towards a target and receives the wave reflected back from the target. The sensor determines the distance to the target by measuring the time between the transmission and reception. If you attach one of those sensors to a data-logger, you can get real-time displacement and velocity time graphs.



Data-loggers are more accurate, can display real time graphs and can take a lot of readings per second.

Please see the '2.2.2 Kinematics Worked Examples' pack for exam style questions.

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For more revision notes, tutorials, worked examples and more help visit www.tutorpacks.co.uk

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