WJEC (Wales) Physics GCSE

2.1: Distance, Speed & Acceleration

Detailed Notes

(Content in **bold** is for higher tier **only**)

Speed & Velocity

Speed is the measure of how **fast** something is travelling. It is a **scalar** quantity meaning it just has **magnitude** but **no sense of direction**, so it must have a positive value. Speed can be calculated from the distance travelled in a given time.

$$s = d / t$$

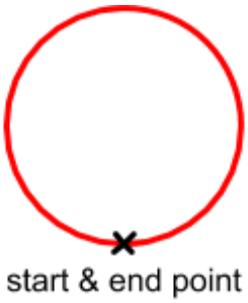
s is speed in m/s, d is distance in meters (m) and t is time in (s).
Other units may be used.

Velocity is a **vector** quantity meaning it has **magnitude and direction**. It can be positive or negative, with the sign indicating the direction. It has a similar relationship to distance and time as speed, except the distance is referred to as **displacement**, where the displacement is the distance moved **from a given point** in a specified direction (vector quantity).

$$v = d / t$$

v is velocity in m/s, d is displacement in meters (m) and t is time in (s).
Other units may be used.

If an object travels in one direction then eventually ends up back at the same point, its **displacement is zero** but distance travelled is not zero.



Distance Travelled = Circumference ***Displacement = Zero***

Acceleration

If the velocity of an object changes, it is **accelerating or decelerating**. This change in velocity is measured as the change in velocity per second (**m/s^2**).

$$a = (v - u) / t$$

a is acceleration in m/s^2, v is initial velocity in m/s, u is final velocity in m/s and t is time in s.
Other units may be used.

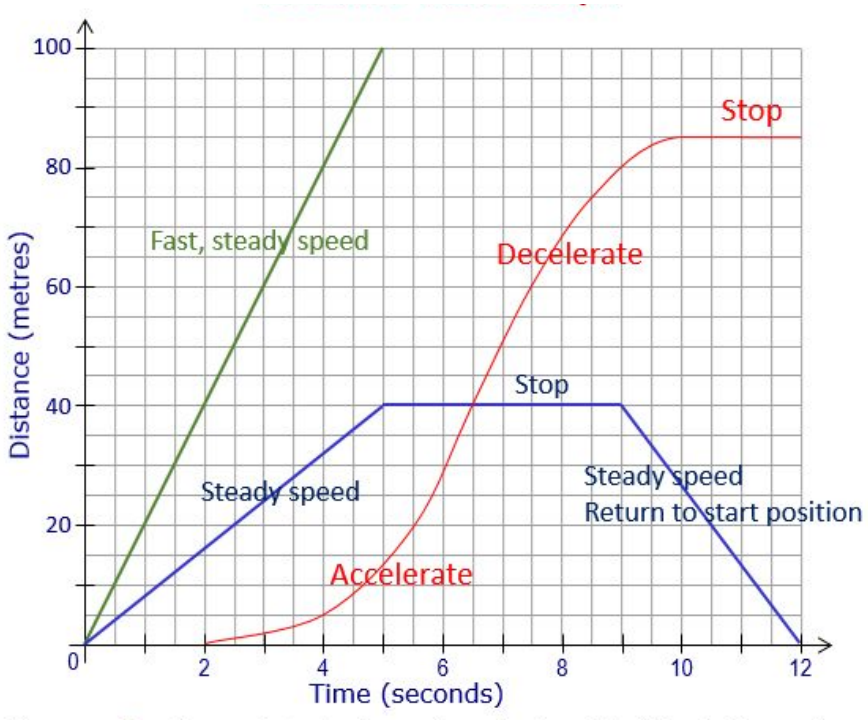
Motion Graphs

Distance-time Graphs

These graphs have time on the x-axis and distance on the y-axis meaning the **gradient shows velocity** (displacement/time).

The **steeper** the gradient, the **faster** the speed. A **negative** gradient indicates the moving object is returning back to the starting point. A **horizontal** line indicates the object is **stationary**.

If the gradient is **not constant** (a curved line) it shows the **velocity is changing** and the object is accelerating or decelerating.



Distance-time graph showing different possible motions (onlinemathlearning.com).

Confusingly the axis of this graph are incorrectly labelled in this graph since the y-axis actually represents the displacement of the object from its origin along a unidirectional line. Since the object can move in more than one direction (two directions: forwards and backwards) we should refer to it as displacement, not distance.

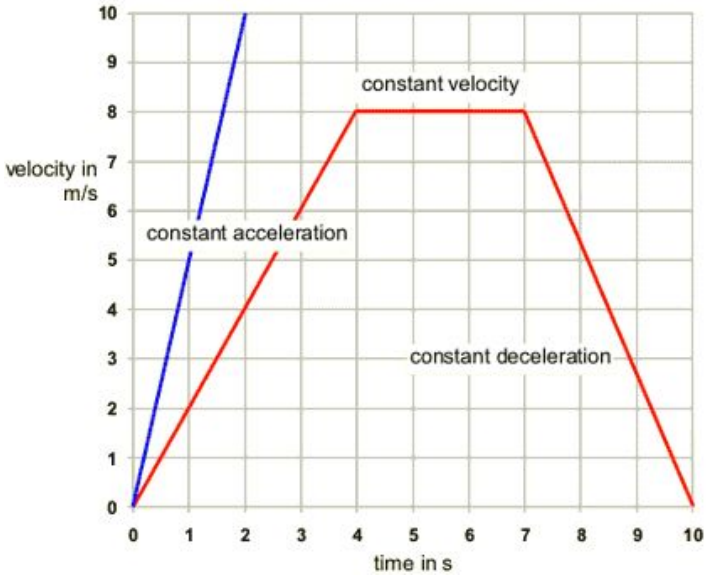
Velocity-time Graphs

These graphs have time on the x-axis and velocity on the y-axis meaning the **gradient shows acceleration** (change in velocity/time).

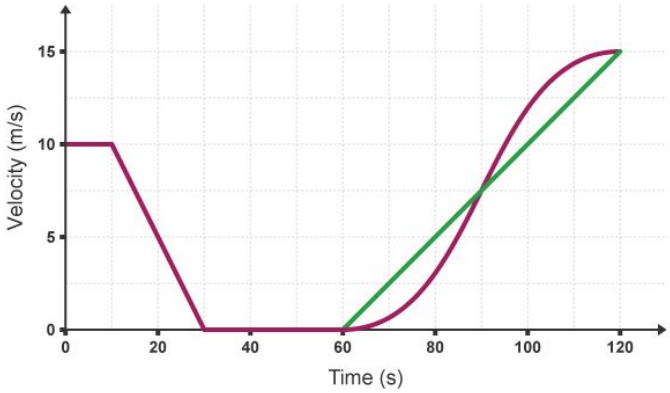
The **steeper** the gradient, the **greater** the acceleration. A **negative** gradient indicates the object is **decelerating**. A **horizontal** line indicates the object is moving at a **constant speed**.

The **average acceleration** or the **distance travelled** over a curved region of a graph may need to be calculated. Draw a straight line through the curve and find its **gradient** to calculate the average acceleration.

The distance travelled can be found by calculating the area under the curve (i.e. the distance travelled over a given time period is the area between the line and the x-axis over the time period of concern)



Velocity-time graph showing different possible motions (onlinemathlearning.com).



The green line shows the average acceleration through the curved region (bbc.co.uk).

Physics & Road Safety

Stopping Distances

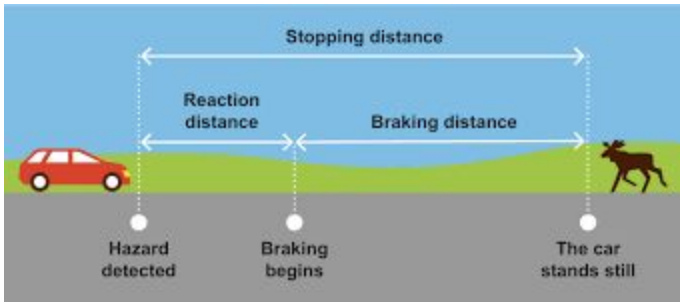
The velocity of a vehicle can affect how quickly and hence safely the vehicle can stop. Stopping distances are made up of two separate distances:

1. **Thinking distance** - the distance travelled **before** the driver reacts.
2. **Braking distance** - the distance travelled **whilst** the driver is reacting and **braking**.

The thinking distance is affected by the **speed** of the car and **reaction time**. The reaction time of the driver can be slowed by tiredness, poor concentration and/or the influence of drugs/alcohol.

The braking distance is affected by **speed** and **physical factors** such as poor road conditions, condition of the car (balding tyres, worn brake pads etc.) and weight of the car (car weight alone + weight of passengers/luggage etc.).

The overall stopping distance is the **sum** of the thinking distance and braking distance.



Vehicle stopping distances (korkortonline.se).

Vehicle Safety

When braking hard, there is a **large deceleration**. Therefore, a **large force** is exerted on the passengers and the vehicle which can be dangerous, as the force experienced can cause injuries such as whiplash. These impacts of dangerous forces can be **reduced** through several **safety measures**:

Seatbelts

Seatbelts strap you in, but also **stretch slightly** under large forces. This stretching **increases the distance** moved for passengers to stop which **decreases the magnitude of the deceleration** of the passenger, **reducing the force** experienced.
Without these, when braking hard you will keep moving and not decelerate (momentum), causing you to fly through the windshield.

Crumple Zones

Softer areas at the front of the car, which crumple upon impact absorb energy to deform and compact. This **increases the time** taken for the car to stop, **reducing the deceleration** of the car and thus the force experienced by passengers.
Without these, the car acts as a **solid metal block**, which would immediately stop during a crash, meaning the collision time would be much shorter, the deceleration would be much greater and therefore so would the force experienced by passengers.

Air Bags

Air bags inflate **automatically** upon a crash. Your head hits the bag and slows down. Therefore the time taken for the head to stop moving is **increased**, reducing the force on the neck.
Without these your head would **whip forward** during a crash, potentially causing it to hit the steering wheel resulting in potentially severe head and/or neck injuries.

Each of these features uses the principles of **Newton's 2nd Law** to **reduce the force** experienced, by **increasing the time** of the impact or distance travelled during it.

$$F = ma = \frac{m(v-u)}{t}$$

F is force in Newtons (N), m is mass in kg, v is final velocity in m/s, u is initial velocity in m/s and t is time in s. Other units may be used.