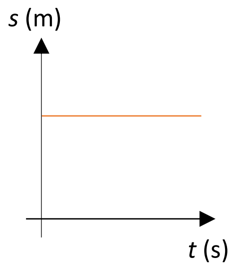
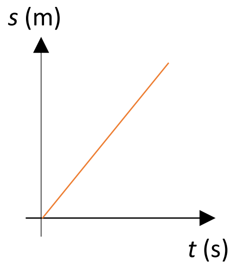
Constant acceleration

Displacement-time graphs

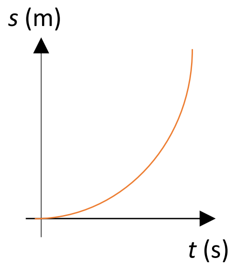
- Displacement is always plotted on the vertical axis and time on the horizontal axis.
- In these graphs *s* represents the displacement of an object from a given point in metres and *t* represents the time taken in seconds.



- *No change in displacement over time*
- *Object is stationary*



- *Displacement increases at a constant rate over time*
- *Object is moving with constant velocity*



- *Displacement is increasing at greater rate as time increases*
- *Velocity is increasing and object is accelerating*

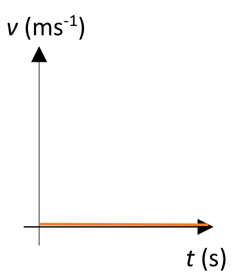
Velocity is the rate of change of displacement. Gradients of displacement-time graphs represent velocity.

Average velocity = $\frac{\text{displacement from starting point}}{\text{time taken}}$

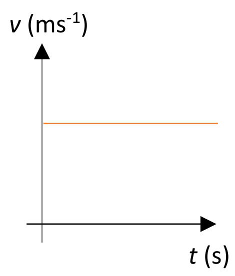
Average speed = $\frac{\text{total distance travelled}}{\text{time taken}}$

Velocity-time graphs

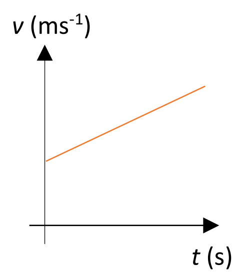
- Velocity is always plotted on the vertical axis and time on the horizontal axis.
- In these graphs *v* represents the velocity of an object in metres per second and *t* represents the time taken in seconds.



Object is stationary



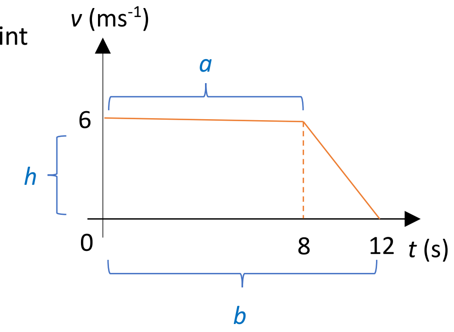
Object moves with constant velocity



Object moves with increasing velocity at a constant rate (ie. constant acceleration)

Acceleration is the rate of change of velocity, represented by gradients of velocity-time graphs. The area under the graph of velocity time graph represents distance travelled.

Example 1 : The figure shows a velocity-time graph illustrating the motion of a cyclist for a period of 12 seconds. She moves at a constant speed of 6 ms^{-1} for the first 8 secs. She then decelerates at a constant rate, stopping after a further 4 secs.



a. Find the displacement from the starting point of the cyclist after this 12 secs period.

Displacement = area under the graph

$s = \frac{1}{2}(a+b)h$

$= \frac{1}{2}(8+12)6$

$= 10 \times 6 = 60$ m

b. Work out the rate at which the cyclist decelerates.

Acceleration is the gradient of the slope. Find the deceleration between 8*s* to 12*s*.

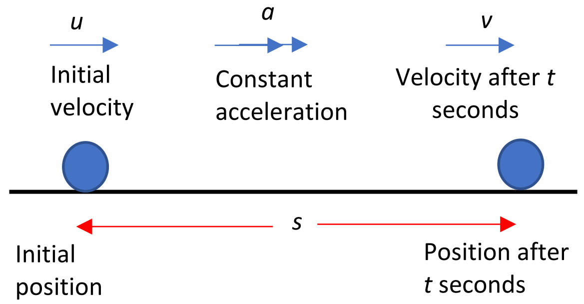
$a = \frac{0-6}{12-8}$

$= \frac{-6}{4} = -1.5$ ms^{-2}

Constant acceleration formulae 1

A standard set of letters is used for the motion of an object moving in a straight line with constant acceleration.

- *s* is the displacement
- *u* is the initial velocity
- *v* is the final velocity
- *a* is the acceleration
- *t* is the time

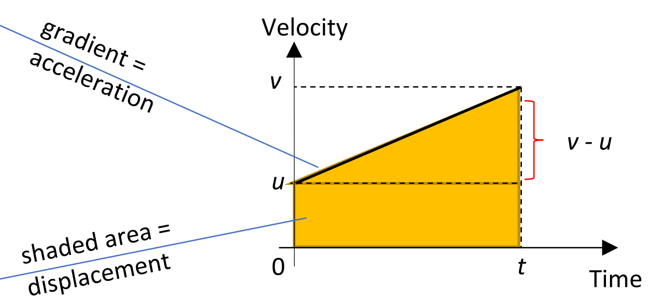


- $a = \frac{v-u}{t}$

Rearrangement of the equation above gives us :

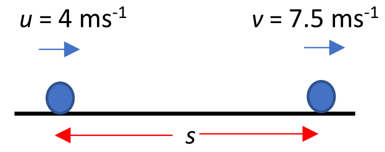
- $\boldsymbol{v = u + at}$

$\boldsymbol{s = \left(\frac{u+v}{2}\right)t}$



The formulae in the red box are often used to solve any questions. Choosing the appropriate formulae depends on which information is given by the question.

Example 2: A cyclist is travelling along a straight road. She accelerates at a constant rate from a velocity of 4 ms^{-1} to velocity of 7.5 ms^{-1} in 40 seconds. Find:



a. The distance she travels in these 40 seconds

$s = \left(\frac{u+v}{2}\right)t$

$= \left(\frac{4+7.5}{2}\right) \times 40 \quad = 230$ m

b. Her acceleration in these 40 seconds

$v = u + at$

$7.5 = 4 + a\,(40)$

$a = \frac{7.5-4}{40} = 0.0875$ ms^{-2}

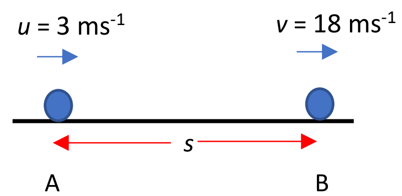
Constant acceleration formulae 2

You can derive another 3 formulae from the previous formulae $v = u + at$ and $s = \left(\frac{u+v}{2}\right)t$. This will give you another 3 formulae which are:

- $v^2 = u^2 + 2as$
- $s = ut + \frac{1}{2}at^2$
- $s = vt - \frac{1}{2}at^2$

You need to know how these formulae are derived

Example 3: A particle is moving from A to B with constant acceleration 5 ms^{-2}. The velocity of the particle at A is 3 ms^{-1} in the direction of A to B. The velocity of the particle at B is 18 ms^{-1} in the same direction. Find the distance from A to B.



$v^2 = u^2 + 2as$

$18^2 = 3^2 + 2\,(5) \times s$

$324 = 9 + 10s$

$s = \frac{324-9}{10}$

$s = 31.5$ m

Vertical motion under gravity

When an object is free falling (moves down vertically under gravity) towards the earth, the acceleration is constant, independent of the weight/mass of the object. Ignoring the air resistance, any object which falls under gravity or in vacuum will have an acceleration due to gravity which is often represented as g= 9.8 ms^{-2}. A downward vertical motion has a positive g value while an upward motion caused by gravity (eg. an object bouncing upward) will have g= - 9.8 ms^{-2}. The negative value indicates that the object is moving an opposite direction (upwards) from the gravity.