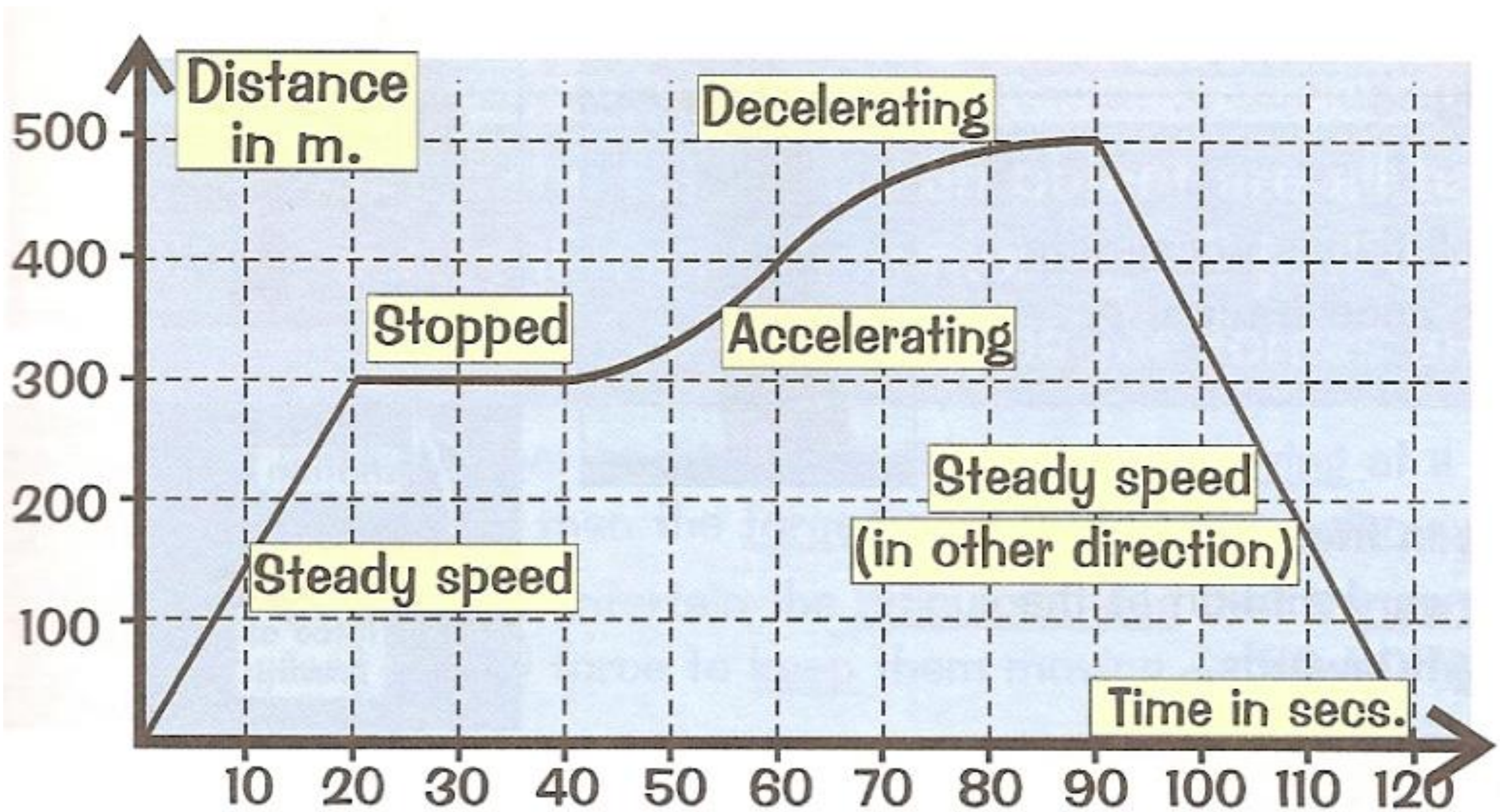
Year 11 Physics

Describing Motion Part 2

Week 3

Displacement Time Graph



Displacement Time Graph

Gradient = speed.

Flat sections are where it's stopped.

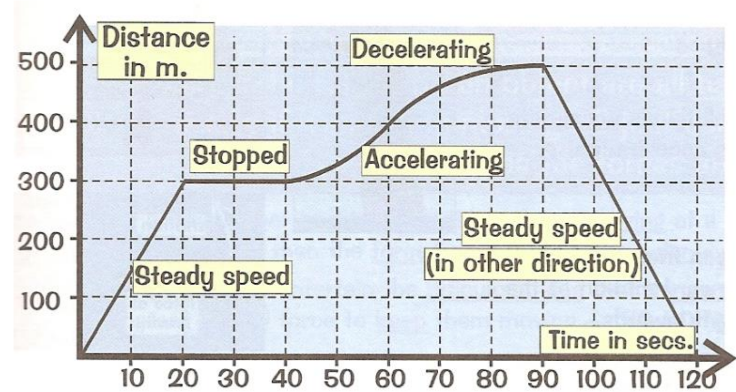
The steeper the graph, the faster it's going.

Downhill sections mean it's going back toward its starting point.

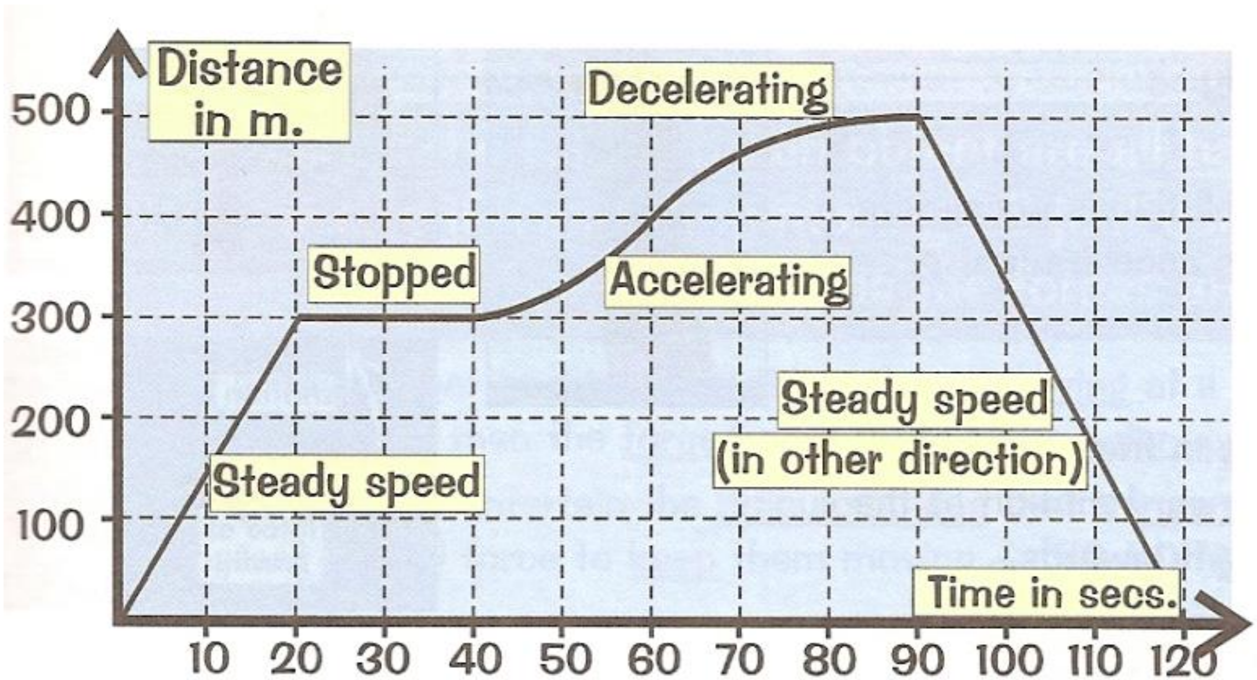
Curves represent acceleration or deceleration.

A steepening curve means it's speeding up (increasing gradient).

A levelling off curve means it's slowing down (decreasing gradient).



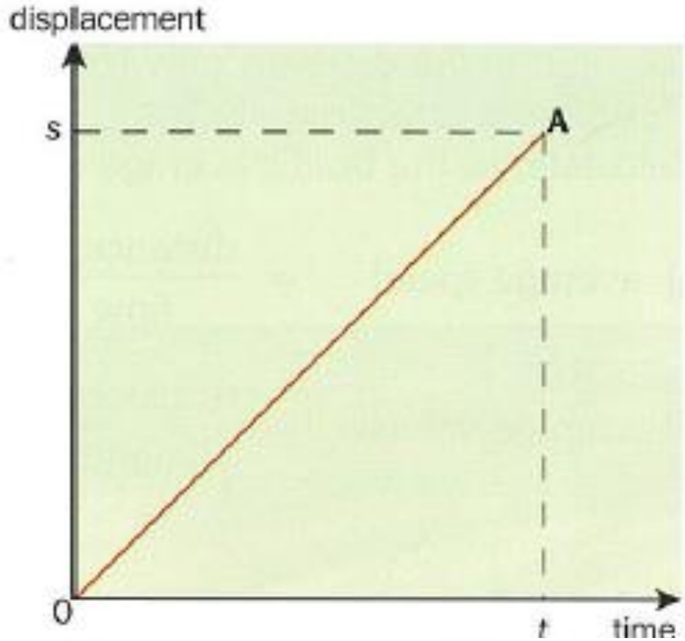
Calculating the Speed from a DT Graph



For example the speed of the return section of the graph is:

$$\text{Speed} = \text{gradient} = \frac{\text{vertical}}{\text{horizontal}} = \frac{500}{30} = 16.7 \text{ m/s}$$

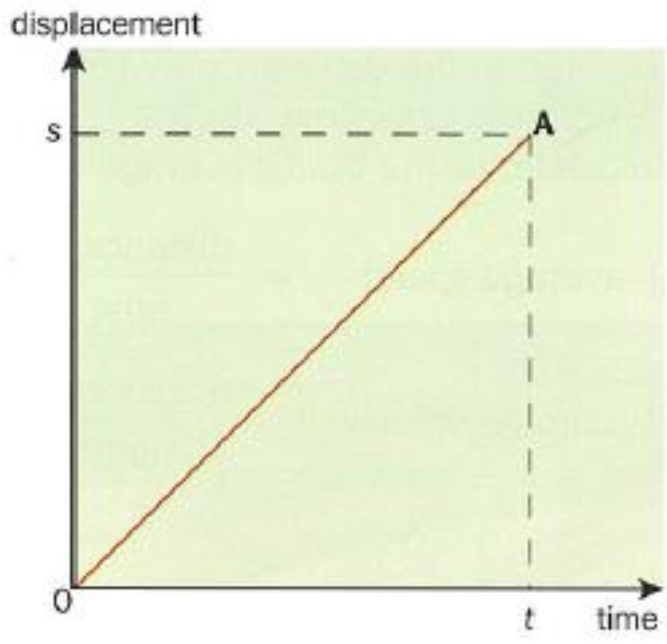
Displacement–time graphs



The diagram shows a graph of displacement against time, for a car:

The displacement increases by equal amounts in equal times. So the object is moving at **constant velocity**.

Calculating the Velocity



$$\text{Velocity from O to A} = \frac{\text{displacement}}{\text{time taken}}$$

$$= \text{gradient of line OA}$$

The steeper the gradient, the greater the velocity.

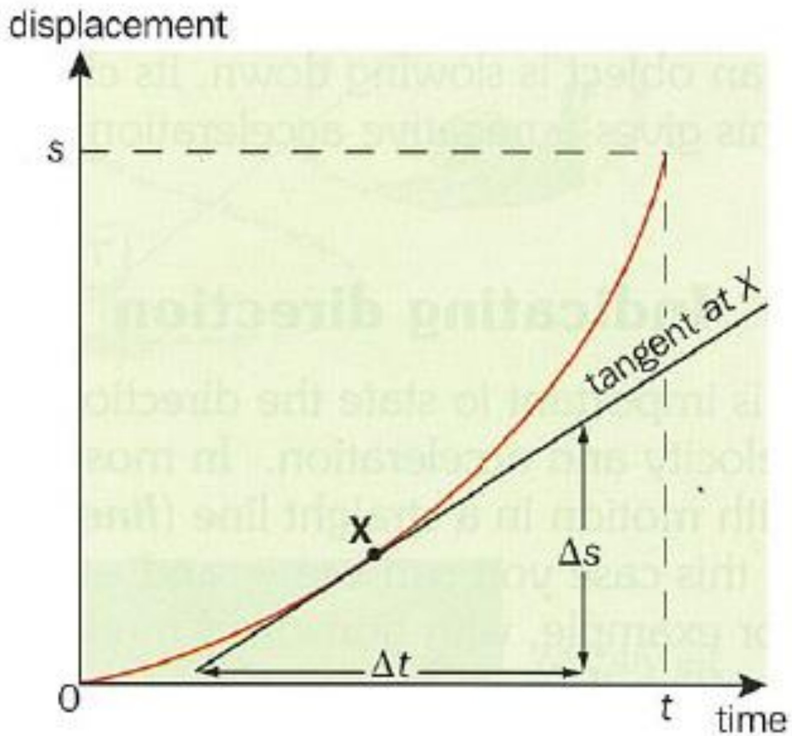
Velocity is a Vector So…..

Positive gradients (sloping upwards) indicate velocity in one direction.

Negative gradients (sloping downwards) indicate velocity in the opposite direction.

The gradient of a displacement-time graph is velocity

A Curve



The gradient of the graph is gradually increasing. This shows that the velocity is increasing. So the object is **accelerating**.

Equations Of Motion

These are 4 equations that you can use whenever an object moves with **constant, uniform acceleration** in a straight line.

s = displacement (m)
u = initial velocity ($m\ s^{-1}$)
v = final velocity ($m\ s^{-1}$)
a = constant acceleration ($m\ s^{-2}$)
t = time interval (s)

They are derived from our basic definitions of acceleration and velocity.

The Equations

$$v = u + at$$

$$s = \frac{1}{2}(u + v)\,t$$

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

$$s = ut + \frac{1}{2}at^2$$

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

You can use these equations only if the acceleration is ***constant***.

Notice that each equation contains only 4 of our five '*s u v a t*' variables.
So if we know any 3 of the variables we can use these equations to find the other two.

Which EoM?

Write down which three things you already know.

Write down which of the other things you want to find out.

Choose the equation that involves all the things you've written down.

Stick in your numbers, and do the maths.

EoM Worked Example 1

A cheetah starts from rest and accelerates at 2.0 m s^{-2} due east for 10 s.
Calculate a) the cheetah's final velocity,
b) the distance the cheetah covers in this 10 s.

s = ?
u = 0 (= 'from rest')
v = ?
a = 2.0 m s^{-2}
t = 10 s

Using equation (1): $\boldsymbol{v = u + at}$

$v = 0 + (2.0\ \text{m s}^{-2} \times 10\ \text{s}) = \underline{20\ \text{m s}^{-1}\ \text{due east}}$

Using equation (2): $\boldsymbol{s = \frac{1}{2}(u + v)t}$

$s = \frac{1}{2}(0 + 20\ \text{m s}^{-1}) \times 10\ \text{s} = \underline{100\ \text{m}\ \text{due east}}$

EoM Worked Example 2

An athlete accelerates out of her blocks at 5.0 m s^{-2}.
a) How long does it take her to run the first 10 m?
b) What is her velocity at this point?

s	=	10 m
u	=	0
v	=	?
a	=	5.0 m s^{-2}
t	=	?

Using equation (3): $\boldsymbol{s = ut + \frac{1}{2}at^2}$

$\therefore 10\text{ m} = 0 + (\frac{1}{2} \times 5.0\text{ m s}^{-2} \times t^2)$

So $t^2 = \dfrac{10\text{ m}}{2.5\text{ m s}^{-2}} = 4.0\text{ s}^2$ $\quad \therefore t = \underline{2.0\text{ s}}$

Using equation (1): $\boldsymbol{v = u + at}$

$v = 0 + (5.0\text{ m s}^{-2} \times 2.0\text{ s}) = \underline{10\text{ m s}^{-1}}$ (2 s.f.)

EoM Worked Example 3

A bicycle's brakes can produce a deceleration of $2.5\ \text{m s}^{-2}$. How far will the bicycle travel before stopping, if it is moving at $10\ \text{m s}^{-1}$ when the brakes are applied?

$s =$?

$u = 10\ \text{m s}^{-1}$

$v = 0$

$a = -2.5\ \text{m s}^{-2}$ (negative, because *decelerating*)

$$\boldsymbol{v^2 = u^2 + 2as}$$

$$0 = (10\ \text{m s}^{-1})^2 + (2 \times -2.5\ \text{m s}^{-2} \times s)$$

$$0 = 100\ \text{m}^2\ \text{s}^{-2} - (5.0\ \text{m s}^{-2} \times s)$$

So $s = \dfrac{100\ \text{m}^2\ \text{s}^{-2}}{5.0\ \text{m s}^{-2}} = \underline{20\ \text{m}}$ (2 s.f.)

EoM Worked Example 4

A car going at 10 m/s accelerates at 2 m/s² for 8 s.
How far does the car go while accelerating?

You know u (= 10 m/s), a (= 2 m/s²) and t (= 8 s).

You want to find out the distance, s.

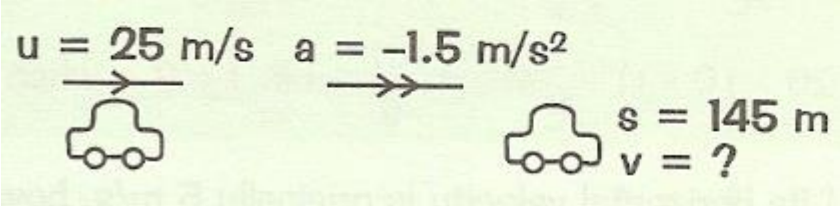
So you need the equation with all these in: u, a, t and s.

$$s = ut + \frac{1}{2}at^2$$

Put the numbers in: $s = (10 \times 8) + \frac{1}{2}(2 \times 8^2) = 80 + 64 = 144\ \text{m}$

EoM Worked Example 5

A car going at 25 m/s decelerates at 1.5 m/s^2 as it heads towards a built-up area 145 m away. What will its velocity be when it reaches the built-up area?



You know u (= 25 m/s), a (= –1.5 m/s^2 ...don't forget it's –ve!) and s (= 145 m).

You want to find out the final velocity, v.

So you need the equation with all these in: u, a, s and v

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

Put the numbers in: $v^2 = 25^2 + 2(-1.5)(145) = 190$ so $v = \sqrt{190} = 13.8$ m/s

EoM Notes

The equations only apply to constant acceleration.

The equations only apply to motion in a straight line.

The equations are vector equations; apart from time all the quantities are vectors and the direction of the motion must be taken into account.

The usual convention is to take the initial direction of the object's motion as positive and relate all other vector quantities to this direction.

Falling Bodies

- Falling air conditioning unit falls under the influence of gravity
- Accelerates at 9.8 m/s/s
- Velocity will increase by 9.8 m/s every second
- EoM can be applied to such bodies

EoM Worked Example 6

A rock is dropped from the edge of a cliff and it hits the river below 4.0 s later. Ignoring any effects from air resistance determine:

(a) its final velocity prior to hitting the water
(b) its average velocity during its fall
(c) the distance travelled by the rock.

$u = 0$
$v = ?$
$v_{av} = ?$
$s = ?$
$a = 9.8\ ms^{-2}$
$t = 4.0\ s$

(a) $v = u + at = 0 + (9.8)(4.0)$

$\therefore$ final velocity = $39.2\ ms^{-1}$ downwards

(b) $v_{av} = \frac{u + v}{2} = \frac{0 + 39.2}{2}$

$\therefore$ average velocity = $19.6\ ms^{-1}$ downwards

(c) $v_{av} = \frac{s}{t} \quad \therefore s = (v_{av})(t) = (19.6)(4) = 78.4\ m$

We could have also found s using $s = ut + \frac{1}{2} at^2$
$= 0 + (\frac{1}{2})(9.8)(4)^2 = 78.4\ m$

First 4 Seconds of Free Fall