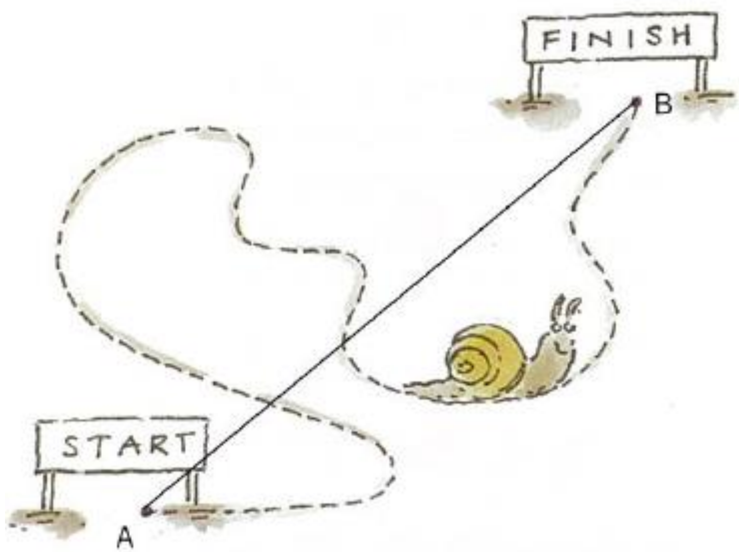
Describing Motion

Physics Year 11 Week 2

Distance & Displacement



Speed and velocity

The speed of an object tells you the distance moved per second, or the ***'rate of change of'*** distance:

$$\textbf{average speed} = \frac{\textbf{distance travelled (m)}}{\textbf{time taken (s)}}$$

Velocity measures the rate of change of ***displacement:***

$$\textbf{average velocity} = \frac{\textbf{total displacement (m)}}{\textbf{time taken (s)}}$$

Benchmarks of Speed

Military jet
450 m s^{-1}

Racing car
60 m s^{-1}

Cheetah
27 m s^{-1}

Sprinter
10 m s^{-1}

Tortoise
0.060 m s^{-1}

Acceleration

Acceleration is the rate of change of velocity:

$$\textbf{acceleration} = \frac{\textbf{change in velocity (m s}^{-1}\textbf{)}}{\textbf{time taken (s)}}$$

It is a vector quantity, acting in a particular direction.

The change in velocity may be a change in ***speed***, or ***direction*** or both.

Indicating direction

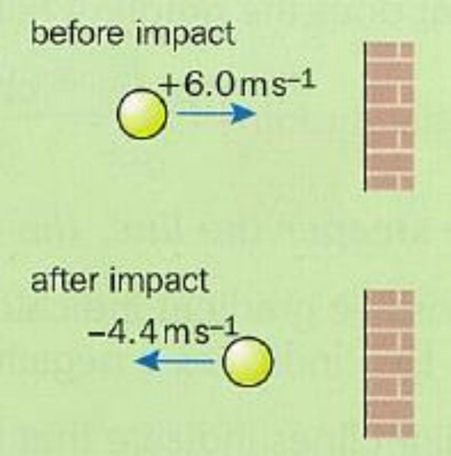
motion in a straight line (***linear motion***)

For example, with horizontal motion if you take motion to the ***right*** as ***positive*** then:

-3 m	means a displacement of 3 m to the left
$+8$ m s^{-1}	means a velocity of 8 m s^{-1} to the right
-4 m s^{-2}	means an acceleration of 4 m s^{-2} to the left
	(***or*** a deceleration of an object moving towards the right)

Acceleration Example

A ball hits a wall horizontally at 6.0 m s^{-1}. It rebounds horizontally at 4.4 m s^{-1}. The ball is in contact with the wall for 0.040 s. What is the acceleration of the ball?



Taking motion ***towards*** the wall as positive:

change in velocity = new velocity − old velocity

$$= (-4.4 \text{ m s}^{-1}) - (+6.0 \text{ m s}^{-1})$$

$$= -10.4 \text{ m s}^{-1}$$

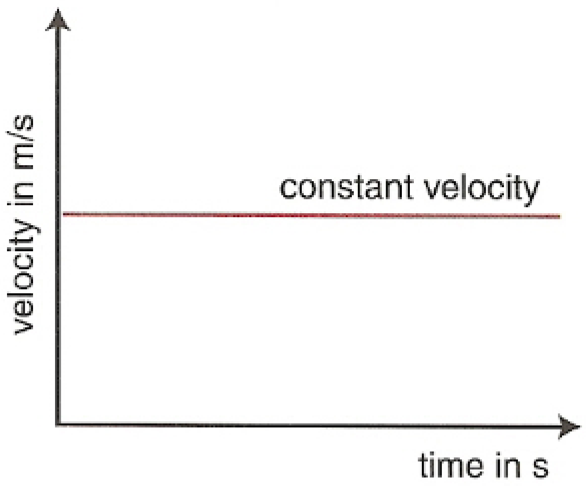
$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

$$= \frac{-10.4 \text{ m s}^{-1}}{0.040 \text{ s}}$$

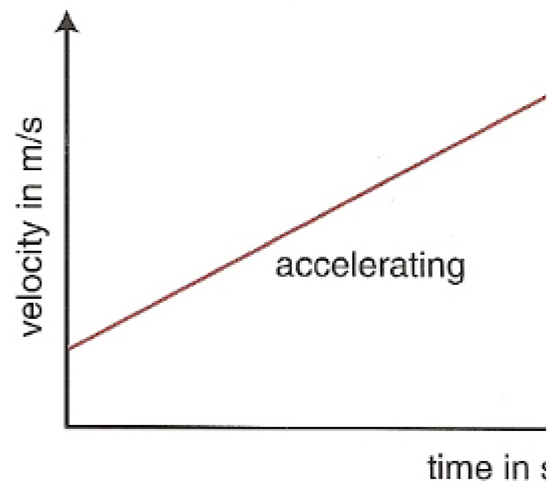
$$= \underline{-260 \text{ m s}^{-2}}$$

Negative, therefore in a direction ***away from*** the wall.

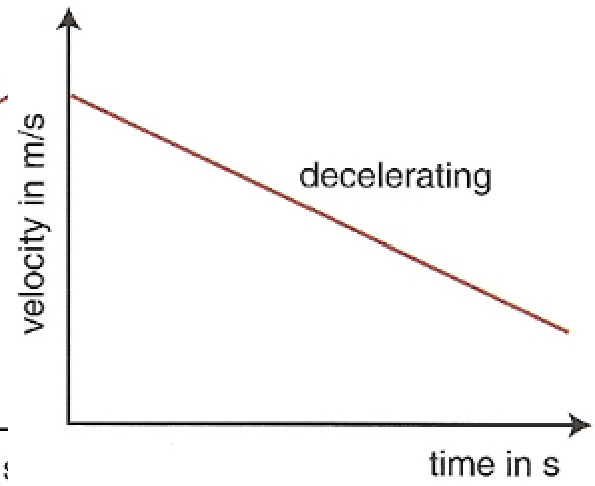
Velocity Time Graphs



Horizontal line: object moving at **constant velocity**.



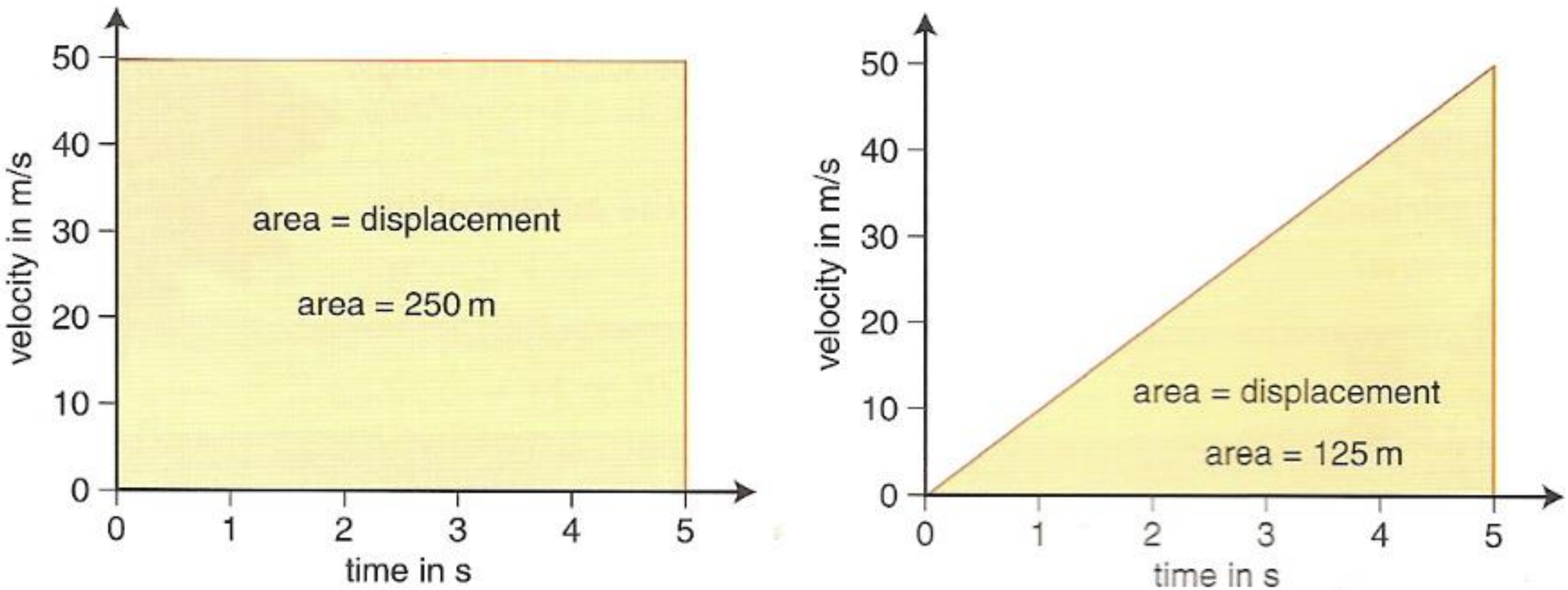
Straight line sloping upwards: constantly increasing velocity or **constant acceleration**.



Straight line sloping downwards: constantly decreasing velocity or **constant deceleration**.

The gradient of a velocity-time graph is acceleration

Calculating displacement from a velocity–time graph

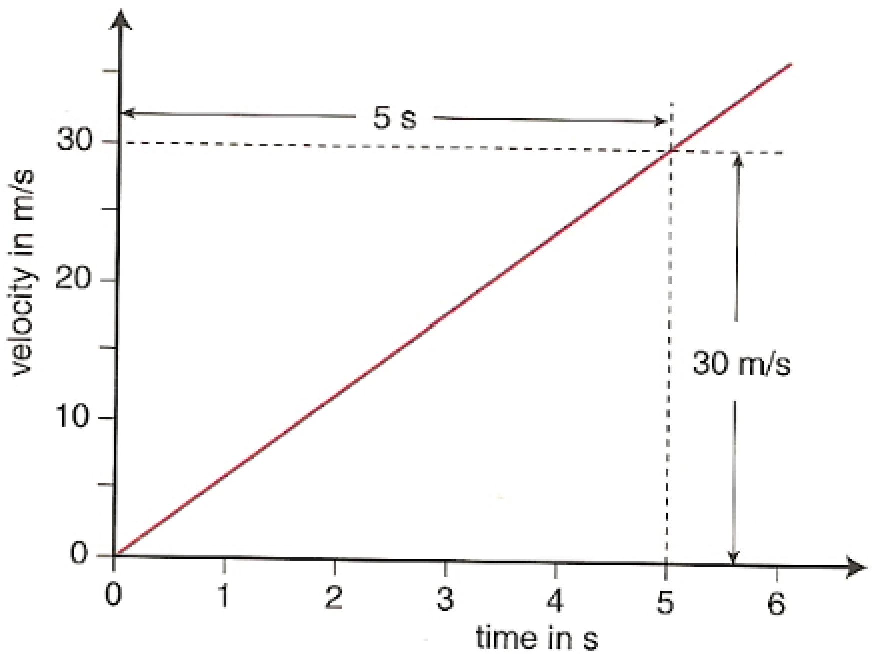


The **area** under a velocity–time graph gives the **displacement**, **s**, of an object.

s = area under a v/t graph

Calculating acceleration from a velocity–time graph

We can find the **acceleration** of an object by calculating the gradient of a velocity–time graph.

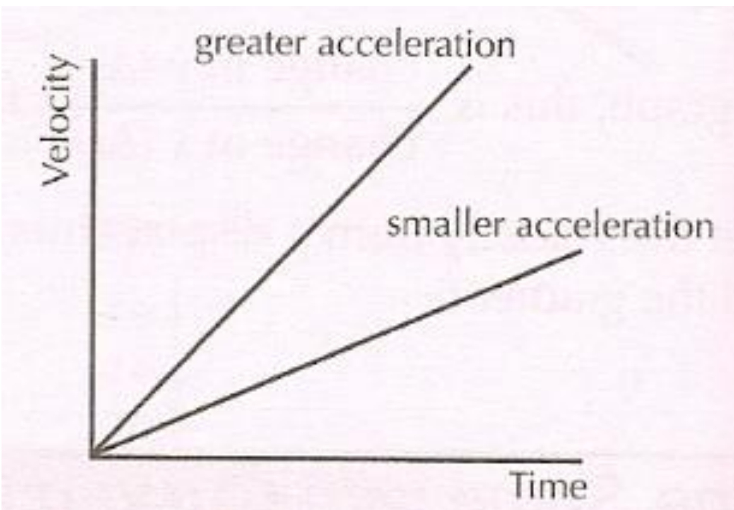


$$\frac{30\,\text{m/s}}{5\,\text{s}} = 6\,\text{m/s}^2.$$

The **Gradient** of a **Velocity-Time Graph** tells you the **Acceleration**

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

likewise for a speed-time graph



So the acceleration is just the **gradient** of a **velocity-time graph**.

Uniform acceleration is always a **straight line**.

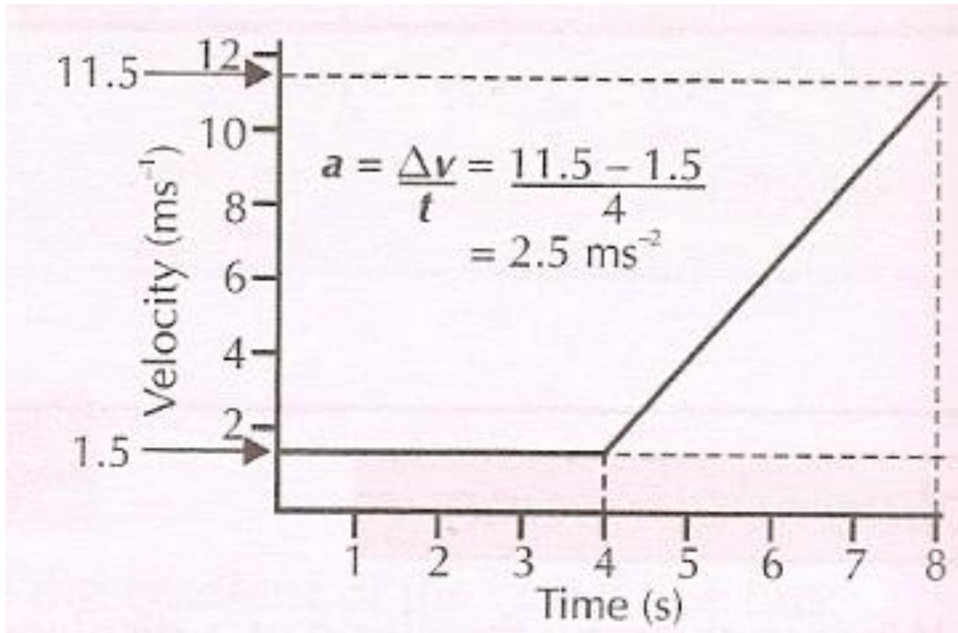
The **steeper** the **gradient**, the **greater** the **acceleration**.

Example of a VT graph

A lion strolls along at 1.5 ms^{-1} for 4 s and then accelerates uniformly at a rate of 2.5 ms^{-2} for 4 s. Plot this information on a velocity-time graph.

t (s)	v (ms^{-1})
0 – 4	**1.5**
5	**4.0**
6	**6.5**
7	**9.0**
8	**11.5**

So, for the first four seconds, the velocity is 1.5 ms^{-1}, then it increases by **2.5 ms^{-1} every second**:



You can see that the **gradient of the line** is **constant** between 4 s and 8 s and has a value of 2.5 ms^{-2}, representing the **acceleration of the lion**.

In Short You Can....

You can use a velocity-time graph to calculate two things:

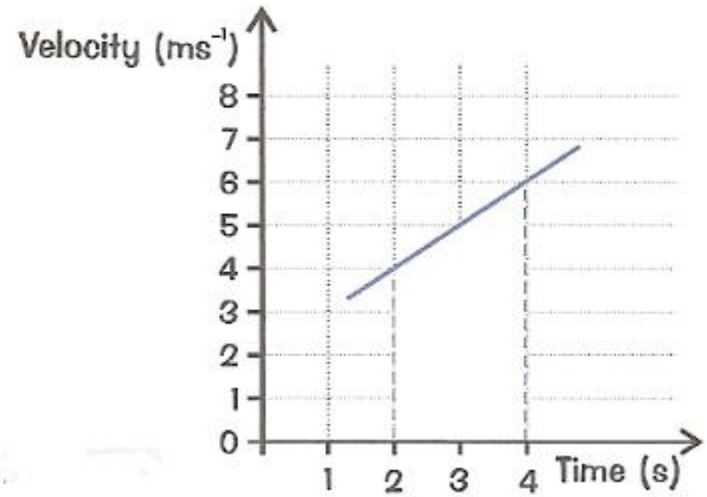
1) The distance the object has moved.

2) The acceleration.

Calculating the Distance Travelled

To find the distance an object travels between two times:

1) Draw vertical lines up from the horizontal axis at the two times, as shown.



2) Work out the area of the shape formed by these lines.
3) When you work out the area, you're multiplying time (the horizontal length) by average speed (the average vertical length), so the result is a distance.

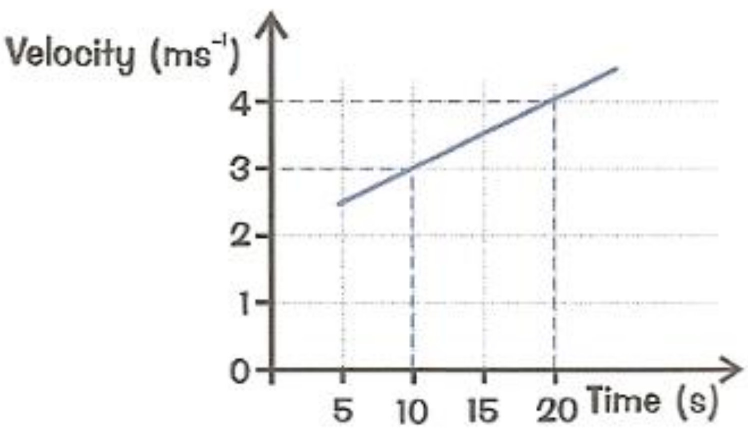
The shape is a trapezium, so the area = $\frac{1}{2}(a + b) \times h = \frac{1}{2}(4 + 6) \times 2 = 5\ ms^{-1} \times 2\ s = 10\ m$.

Calculating the Acceleration

$$\text{Acceleration } (ms^{-2}) = \frac{\text{change in velocity } (ms^{-1})}{\text{time taken } (s)}$$

This is just the gradient of the velocity-time graph.

E.g. What is the acceleration between 10 and 20 seconds?



Acceleration = $(4\ ms^{-1} - 3\ ms^{-1}) / (20\ s - 10\ s)$
$= 1\ ms^{-1} / 10\ s = 0.1\ ms^{-2}$