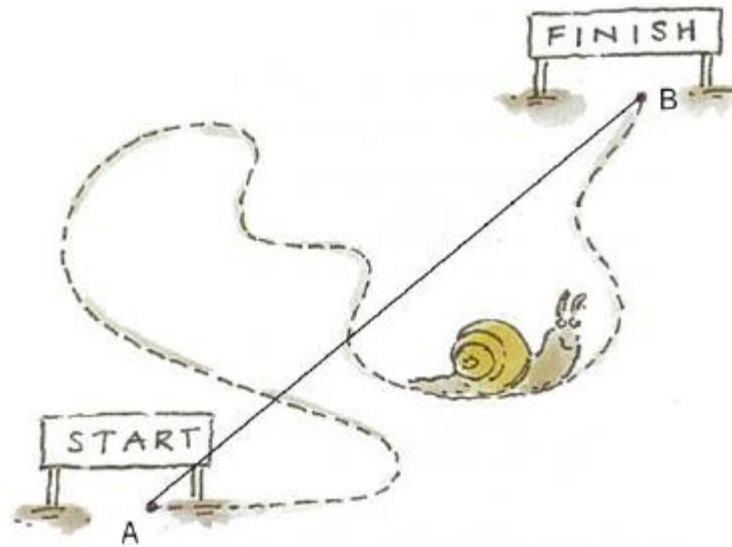


Describing Motion

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:

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

Velocity measures the rate of change of *displacement*:

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

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:

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

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

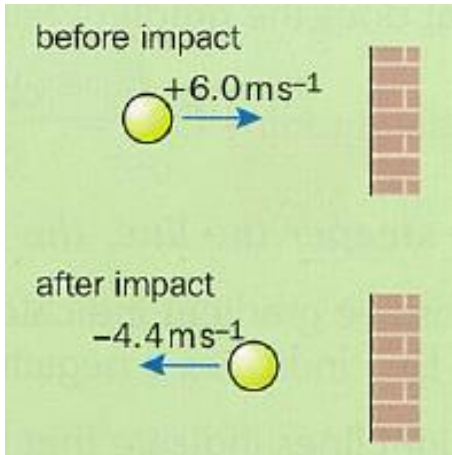
motion in a straight line (*linear motion*)

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:

$$\text{change in velocity} = \text{new velocity} - \text{old velocity}$$

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

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

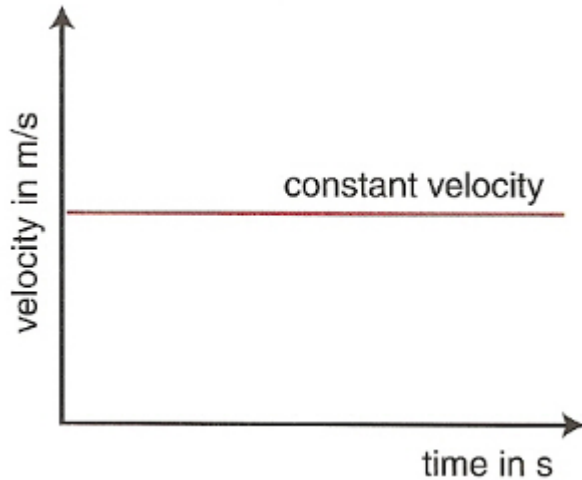
$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

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

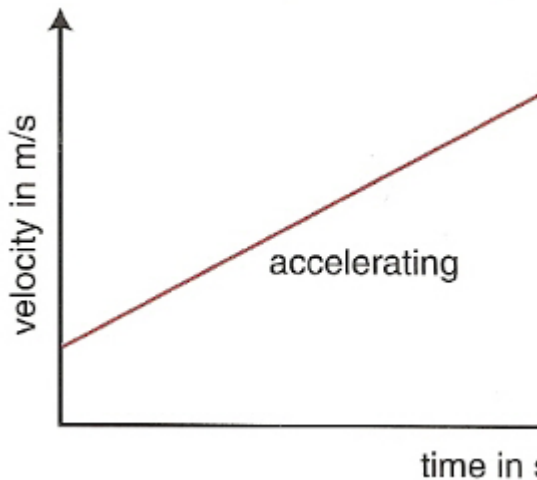
$$= \underline{-260 \text{ m s}^{-2}}$$

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

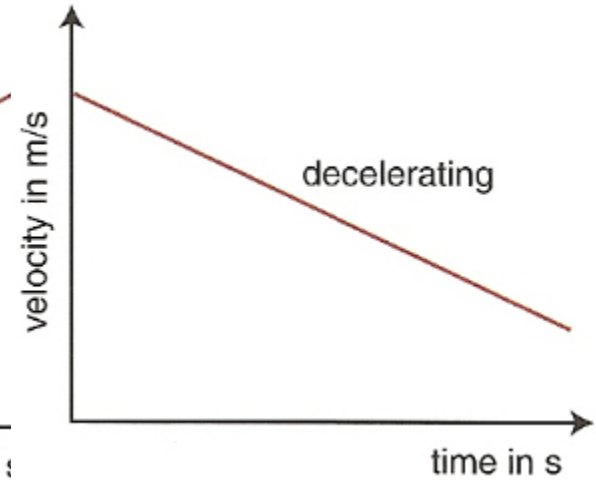
Velocity Time Graphs



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

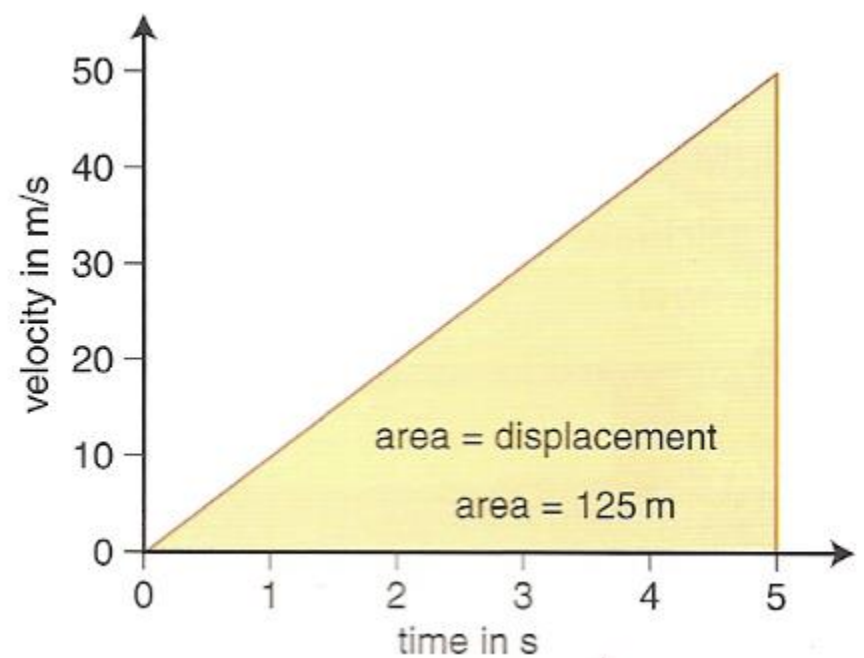
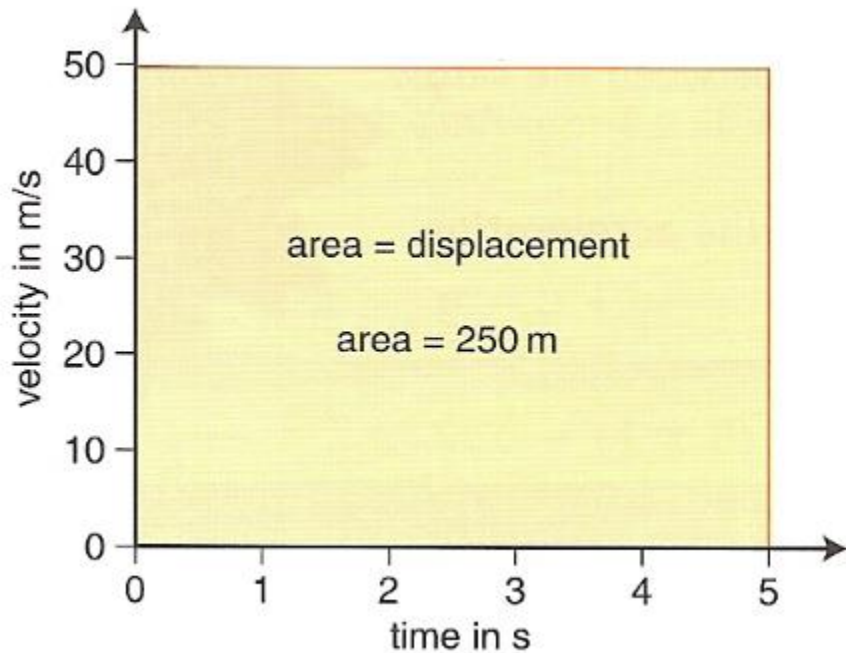


Straight line sloping upwards: constantly increasing velocity or **constant acceleration**.



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

Calculating displacement from a velocity–time graph

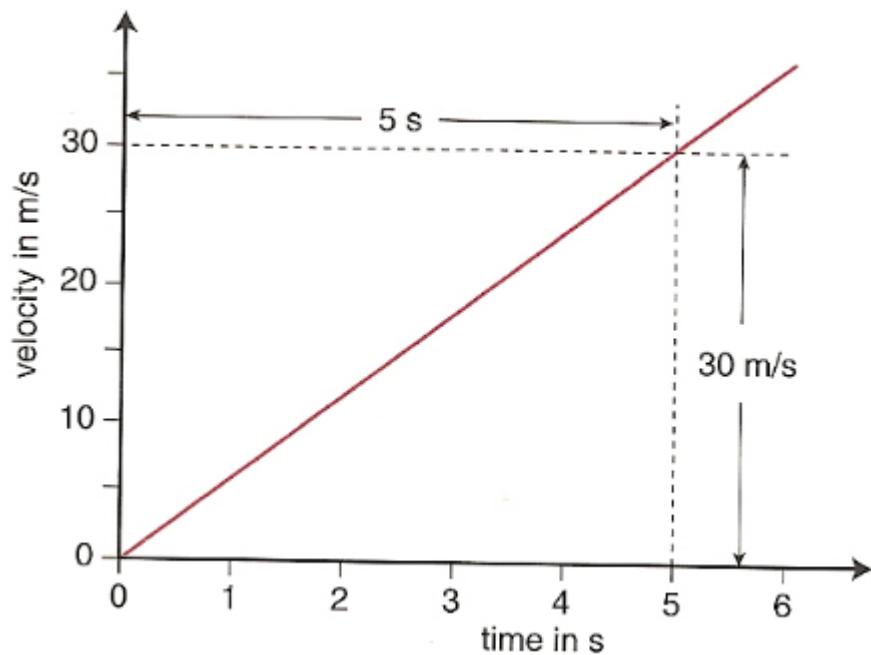


The **area** under a velocity–time graph gives the **displacement, s** , of an object.

$$s = \text{area under a } v/t \text{ graph}$$

Calculating acceleration from a velocity–time graph

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

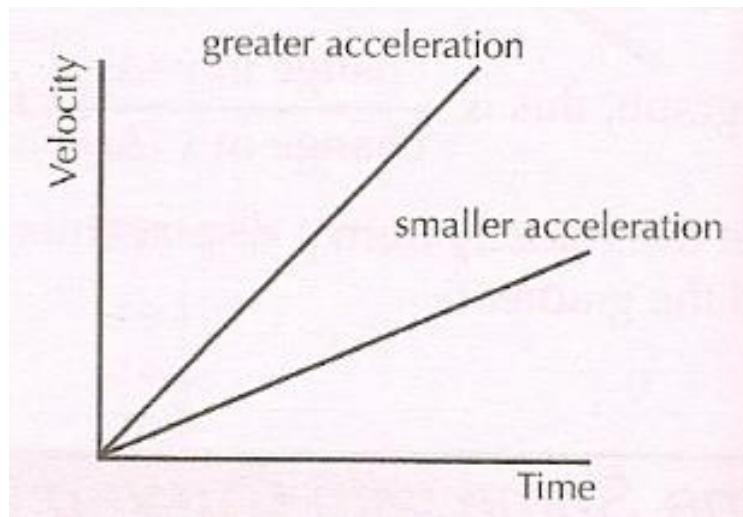


$$\frac{30 \text{ m/s}}{5 \text{ s}} = 6 \text{ m/s}^2.$$

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**.

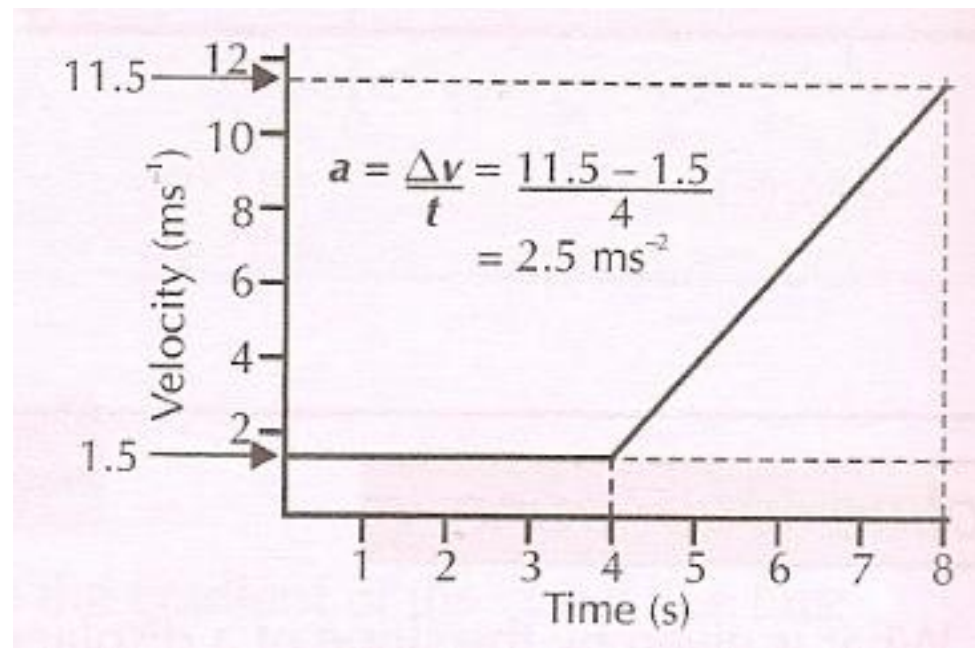
The **steeper** the **gradient**, the **greater** the **acceleration**.

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....

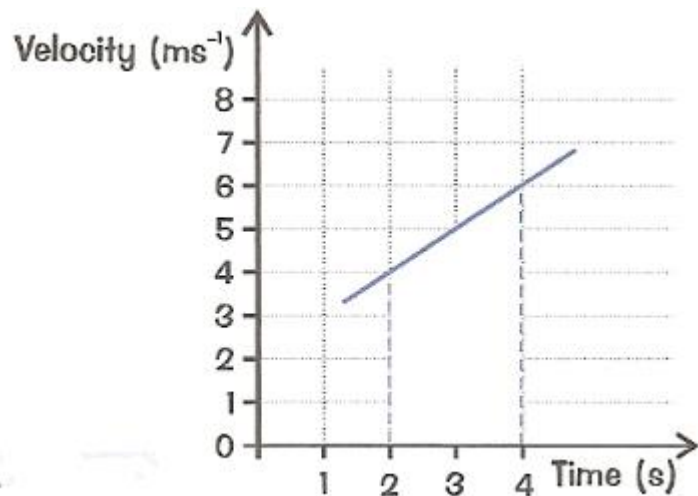
You can use a velocity-time graph to calculate two things:

- 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.

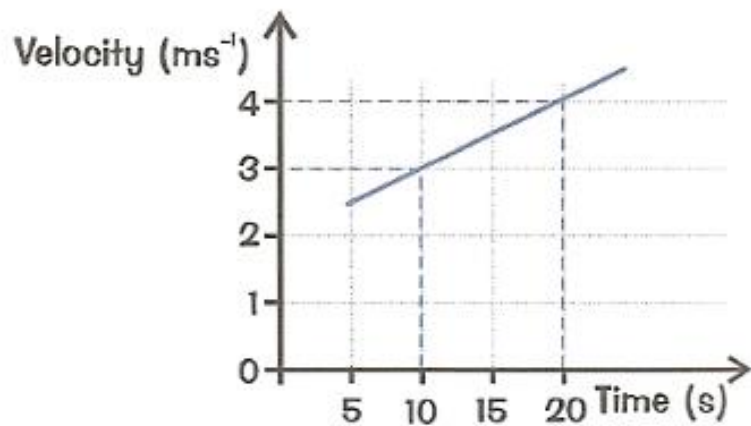
The shape is a trapezium, so the area = $\frac{1}{2}(a + b) \times h = \frac{1}{2}(4 + 6) \times 2 = 5 \text{ ms}^{-1} \times 2 \text{ s} = 10 \text{ m}$.

Calculating the Acceleration

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

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

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



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