- The **acceleration** of an object is determined by the **resultant force** acting on the object and the **mass** of the object.

a = F/m or F = m x a

F is the **resultant force** in **newton (N)**.
m is the **mass** in **kilogram (kg)**.
a is the **acceleration** in **metre per second squared (m/s^2)**.

- The **gradient** of a **distance-time** graph represents **speed**.

- Calculation of the **speed** of an object from the **gradient of a distance-time graph. (HT)**

- The **velocity** of an object is its **speed in a given direction**.

- The **acceleration** of an object is given by the equation:

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

a is the **acceleration** in **metre per second squared (m/s^2)**.
v is the **final velocity** in **metre per second (m/s)**.
u is the **initial velocity** in **metre per second (m/s)**.
t is the **time taken** in **second (s)**.

- The **gradient of a velocity-time graph** represents **acceleration**.

- Calculation of the **acceleration** of an object from the **gradient of a velocity-time graph. (HT)**

- Calculation of the **distance travelled** by an object from a **velocity-time graph. (HT)**

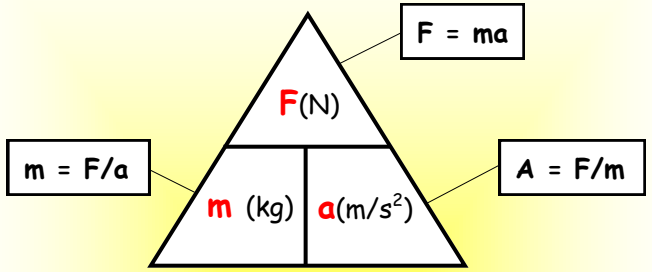
RESULTANT FORCE, MASS AND ACCELERATION

Resultant force (F), mass (m) and **acceleration (a)** are related by the equation:

resultant force = mass x acceleration

F = ma

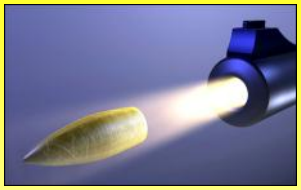
(newton, N) (kilogram, kg) (metre/second^2, m/s^2)



- The **NEWTON (N)** is the SI unit of force.

1 newton (N) is that resultant force which gives a mass of **1 kilogram (kg)** an acceleration of **1 metre per second^2 (m/s^2)**.

SPEED



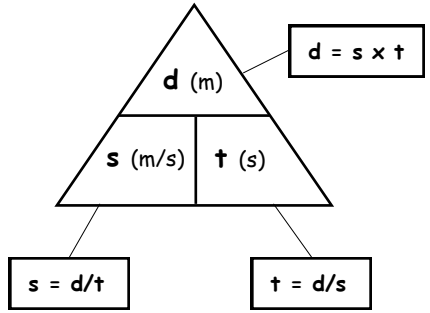
- **Speed** is the term which describes how fast a body is moving.

  For example, if a bullet travels **350 metres in each second**, its speed is said to be **350 m/s**.

- **Speed** is calculated using the following equation :

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

$$s = d/t$$



- **PRACTICE QUESTIONS (1)**

1 A car on a motorway travels **3.6 km** in **2 minutes**. Calculate :
(a) The car's **speed in m/s.**
(b) The **further distance** it would travel in **5 minutes.**

2 A bullet is fired from a rifle with a speed of **450 m/s.** How long does it take to strike a target which is **20 m** away?

3 A pulse of laser light takes **1.3 s** to travel from the Earth to the Moon. Given that light travels at **3.0×10^8 m/s** in a vacuum, calculate the **distance travelled.**

SOME SPEED EXAMPLES

- A snail at **full speed.**

- World **100m** record holder **Usain Bolt** (time = **9.58 s**).

- Cheetah moving in for the kill at **nearly full speed.**

- Earth's speed as it **rotates about its axis.**

- Earth's **orbital speed** on its yearly journey around the Sun.

- **Speed of light** in a vacuum.

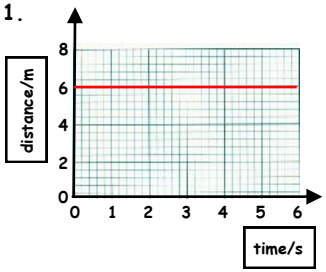
DISTANCE-TIME GRAPHS

In this type of motion graph **DISTANCE** is plotted along the **y-axis** against **TIME** along the **x-axis**.

GRADIENT of a distance-time graph = **SPEED**

Look at the **distance-time** graphs shown below and fill in the gaps.

1.

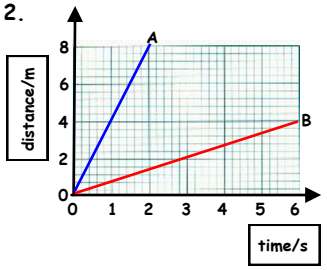


Gradient of graph = _____

Speed = _____

So this is a **distance-time** graph for a body which is at .....
i.e. .....

2.

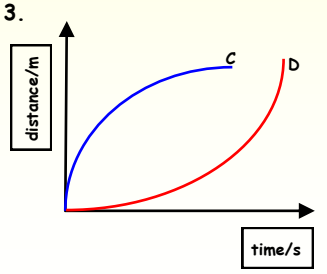


For graph **A**, the gradient is .....
and = _____ = **m/s**

For graph **B**, the gradient is .....
and = _____ = **m/s**

So **A** and **B** are **distance-time** graphs for bodies moving at **constant** (steady) speeds of ..... **m/s**

3.



For graph **C**, the slope is .....
so the speed is .....
So this is the **distance-time** graph for a body which is .....

For graph **D**, the slope is .....
so the speed is .....
So this is the **distance-time** graph for a body which is .....

• PRACTICE QUESTIONS (2)

1 **Fig 1.** opposite shows the distance-time graphs for a powerboat **A**, an ocean-going yacht **B** and a small motor boat **C** which are all travelling in the same direction.

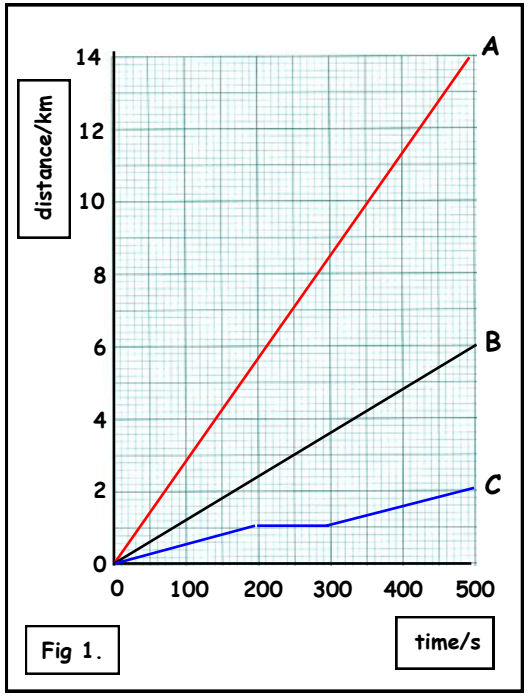


Fig 1.

(a) **How far** did each vessel travel in **500 s**?

(b) Use the graph to calculate the **speed** of :

(i) The **powerboat, A.**

(ii) The **yacht, B.**

(c) The **motor boat C** had to stop for a while.

(i) **How long** did it stop?

(ii) **How far** did it travel in the **500 s**?

(iii) What was its **average speed** for the whole journey?

2 A long distance runner is training for a race. His training method is to run at a **constant speed** for **500 m** and then **stop for 20 s.** His **first 500m** run takes **70 s** and the **second 500 m** run takes **80 s.**

(a) Sketch a **distance-time graph** to show his two runs and his rest period.

(b) Calculate his **speed** over the **first 500 m** run.

(c) Calculate his **speed** over the **second 500 m** run.

VELOCITY

- **Speed** and **velocity** are not the same.

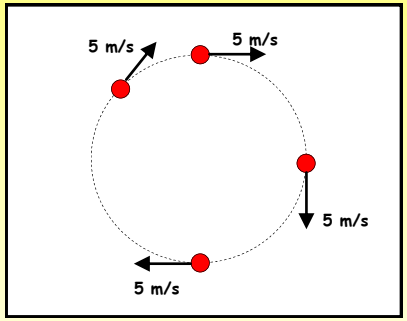
The **VELOCITY** of a moving object is its **speed in a specified direction**.

- A body is said to be moving at a **steady** or **constant** speed if it covers **equal distances in equal time intervals**.

For a body to move at **constant velocity**, it must cover **equal distances in equal time intervals** and its **direction of travel must stay the same**.

For example, an object can be moving in a circle at a **constant speed** of, say 5 m/s, and yet its **velocity is continually changing**.

This is because even though its speed stays the same, its direction motion is continually changing and velocity is speed in a given direction.



ACCELERATION

- Generally speaking, the acceleration of a body is a measure of how quickly it **speeds up** or **slows down**, but an acceleration can also be the result of a **change of direction**.

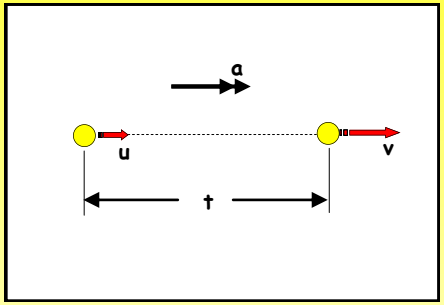
The **acceleration** of a body is the rate at which its velocity changes.

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

(m/s²) (m/s) (s)

- The **SI unit of acceleration** is : **metre per second² (m/s²)**

- Consider an object having an **initial velocity (u)**, which then accelerates with a **constant acceleration (a)** and reaches a **final velocity (v)** in a **time (t)**.



Then, the **acceleration (a)** is given by :

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

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

- **CONSTANT or UNIFORM acceleration** means that the velocity increases by the same amount every second.

- A **DECELERATION** is simply a **negative acceleration** and describes the movement of a body that is slowing down.

- **PRACTICE QUESTIONS (3)**

1 The **Bloodhound SSC** rocket car shown opposite accelerates uniformly from **rest** to reach a velocity of **80 m/s** in **4.0 s.**

It then continues to move at this velocity for a while before it decelerates uniformly for **3.0 s** and comes to **rest.**

Calculate : **(a)** The **acceleration during the first 4.0 s.**

(b) The **deceleration during the final 3.0 s.**

(c) The **average velocity during the first 4.0 s.**

(d) The **distance travelled during the first 4.0 s.**

2 **(a)** A car is being driven along a motorway at the speed limit of **31 m/s** when the driver sees that there has been a crash up ahead and slams on the brakes.

If the car decelerates uniformly at **6 m/s^2, how long will it take to come to rest?**

(b) In a crash, a car is brought to in a very short time.

Calculate the **deceleration** produced in a vehicle that crashes at **25 m/s** and is brought **to rest** in **0.01 s.**

VELOCITY-TIME GRAPHS

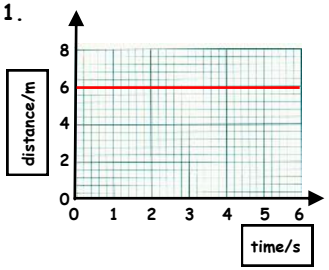
- In this type of motion graph **VELOCITY** is plotted along the **y-axis** against **TIME** along the **x-axis.**

GRADIENT of a velocity-time graph = **ACCELERATION**

AREA ENCLOSED by a velocity-time graph = **DISTANCE TRAVELLED**

- Look at the **VELOCITY-TIME** graphs shown below and fill in the gaps.

1.

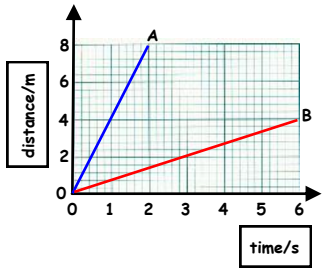


Gradient of graph = ☐

Acceleration = ☐

So this is a **velocity-time** graph for an object which is moving with a ..... velocity of.....

2.

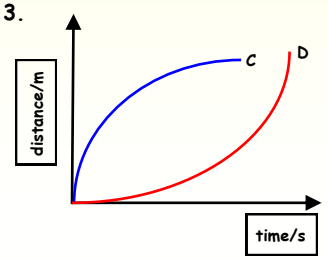


For graph **A**, the **gradient** is ..... and = ☐

For graph **B**, the **gradient** is ..... and = ☐

So **A** and **B** are **velocity-time** graphs for objects moving with **constant accelerations** of ..... **m/s^2** and ..... **m/s^2.**

3.

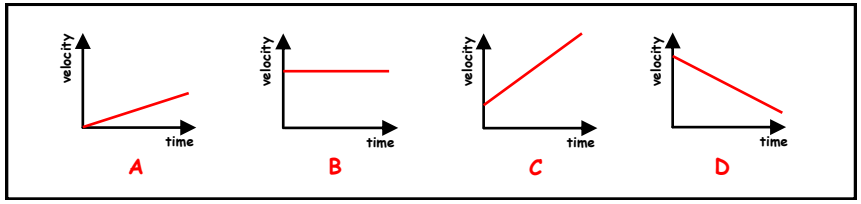


Graph **C** is the velocity-time graph for an object whose acceleration is .....

Graph **D** is the velocity-time graph for an object whose acceleration is .....

- **PRACTICE QUESTIONS (4)**

1 Look at the **velocity-time** graphs of moving objects shown below :
In which graph is the object :



(a) **Not accelerating?**
(b) **Accelerating from rest?**
(c) **Decelerating?**
(d) **Accelerating at the greatest rate?**

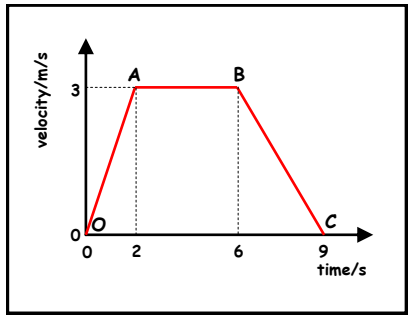
2 Sketch **velocity-time** graphs for :

(a) An object moving with a **constant velocity of 20 m/s.**

(b) An object **accelerating uniformly at 5 m/s^2 for 10 s.**

(c) An object **decelerating uniformly at 2 m/s^2 for 6 s.**

3 The **velocity-time** graph shown opposite is an approximate representation of the motion of an elevator in an office block.



(a) Briefly **describe** the motion represented by sections :
(i) **OA**, **(ii)** **AB** and **(iii)** **BC** of the graph.

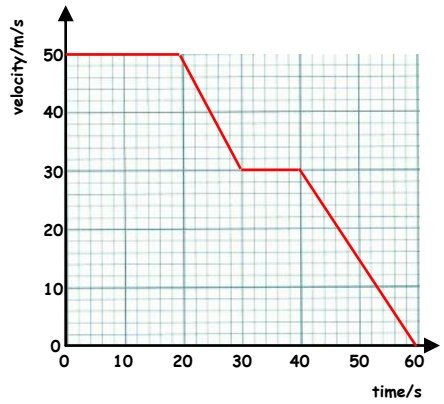
(b) **Use the graph** to calculate :

(i) The elevator's **initial acceleration**.

(ii) The **total distance travelled** by the elevator.

(iii) The elevator's **average speed** over the whole motion.

4 The velocity-time graph shown opposite represents the motion of a formula-1 racing car over a **60 second** period.



(a) **How far** does the car travel during the **first 20 s**?

(b) Between the times of **20** and **30 s**, what is the **deceleration** of the car?

(c) **How far** does the car travel during the deceleration period described in **(b)**?

(d) **How far** does the car travel between the **30th** and **40th second** of its motion?

(e) What is the **total distance** travelled by the car over the whole **60 s period**?

(f) Calculate the car's **average velocity** over the whole motion?