SCALAR and VECTOR QUANTITIES

The following are some of the **quantities** you will meet in the Intermediate 2 Physics course:

DISTANCE, DISPLACEMENT, SPEED, VELOCITY, TIME, FORCE.

Quantities can be divided into 2 groups:

SCALARS

These are specified by stating their **magnitude** (**size**) only, with the correct unit.

VECTORS

These are specified by stating their **magnitude** (**size**), with the correct unit, and a **direction**.

Some **scalar** quantities have a corresponding **vector** quantity.
Other **scalar** and **vector** quantities are independent. For example:

corresponding scalar quantity	corresponding vector quantity
distance (e.g., 25 m)	displacement (e.g., 25 m North)
speed (e.g., 10 m/s)	velocity (e.g., 10 m/s East)
time (e.g., 12 s)	NONE
NONE	force (e.g., 10 N to the right)

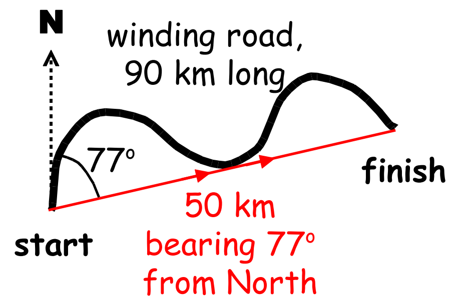
DISTANCE and DISPLACEMENT

● **Distance** (a **scalar** quantity) is **the total length of path travelled**.
[A **unit** must always be stated].

● **Displacement** (a **vector** quantity) is
the length and direction of a straight line drawn from the starting point to the finishing point.
[A **unit** and **direction** must always be stated,
unless the **displacement is zero**, in which case there is **no direction**].

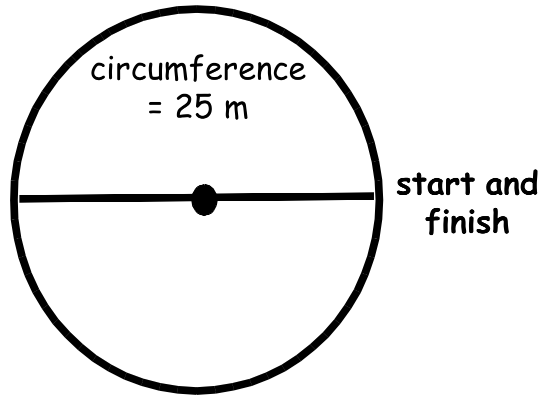
For example:

1) Mr. Hood drives 90 km along a winding road.



- Distance travelled = 90 km
- Displacement = 50 km bearing 77° from North

2) Mr. Robb jogs once around the centre circle of a football pitch.



- Distance travelled = 25 m
- Displacement = 0 m. (He is back where he started, so the length of a straight line drawn from his starting point to his finishing point is 0 m).

SPEED and VELOCITY

● **Speed** (a **scalar** quantity) is **the distance travelled every second**.

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

[A **unit** must always be stated].

● **Velocity** (a **vector** quantity) is
the change of displacement every second.

$$\text{velocity} = \frac{\text{displacement}}{\text{time}}$$

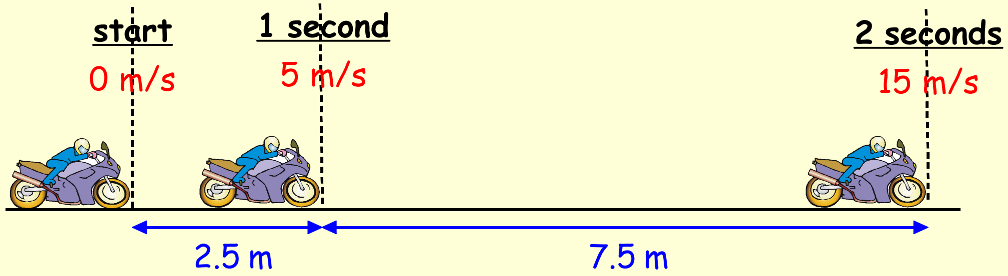
[A **unit** and **direction** must always be stated, unless the **velocity is zero**, in which case there is **no direction**].

Acceleration (and Deceleration)

This diagram shows a motorbike **accelerating** from a **stationary start** (**rest, 0 m/s**).

After each second:

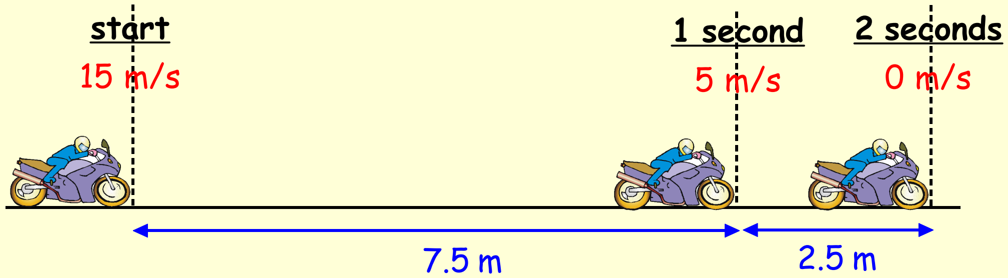
- Its **velocity** has **increased**.
- It has travelled **further** than it travelled the second before.



This diagram shows a motorbike **decelerating** from a **velocity** of **15 m/s** to **rest** (**0 m/s**).

After each second:

- Its **velocity** has **decreased**.
- It has travelled **less far** than it travelled the second before.



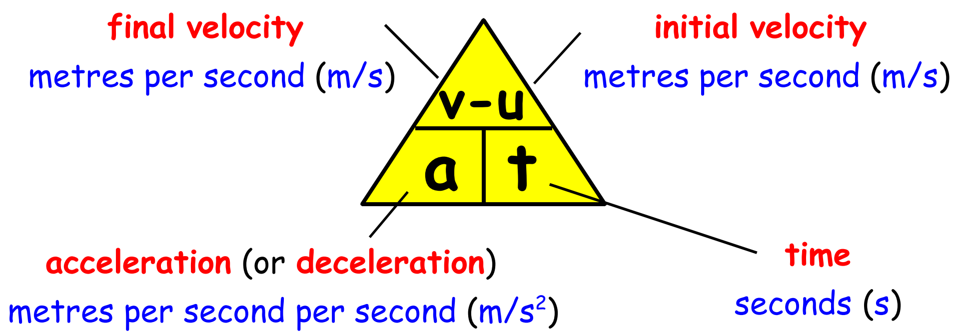
- When an object's **velocity** **increases** with time, the object is **a** _ _ _ _ _ _ _ _ _ _ _.
- When an object's **velocity** **decreases** with time, the object is **d** _ _ _ _ _ _ _ _ _ _ _.

The **acceleration** (**a**) or **deceleration** of an object is its **change in velocity** over a **given time**.

Acceleration (or **deceleration**) is a **vector** quantity.

$$\text{acceleration (or deceleration)} = \frac{\text{change in velocity}}{\text{time taken}}$$

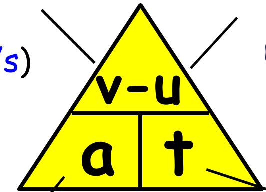
$$a = \frac{v - u}{t}$$



Acceleration Calculations

final velocity
metres per second (m/s)

initial velocity
metres per second (m/s)



acceleration (or deceleration)
metres per second per second (m/s^2)

time
seconds (s)

Sample Calculations

Acceleration

Calculate the **acceleration** of a walker who speeds up from **1 m/s** to **3 m/s** in a time of **4 s**.

- v = 3 m/s
- u = 1 m/s
- t = 4 s
- a = ?

$$a = \frac{v - u}{t} = \frac{3 - 1}{4}$$

$$= \frac{2}{4}$$

$$= \underline{0.5\ m/s^2}$$

Deceleration

Calculate the **deceleration** of a cyclist who slows down from **7 m/s** to **1 m/s** in a time of **3 s**.

- v = 1 m/s
- u = 7 m/s
- t = 2 s
- a = ?

$$a = \frac{v - u}{t} = \frac{1 - 7}{3}$$

$$= \frac{-6}{3}$$

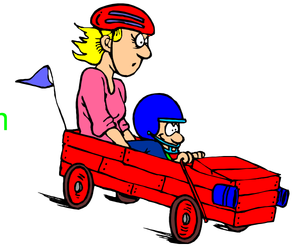
$$= \underline{-2\ m/s^2}$$

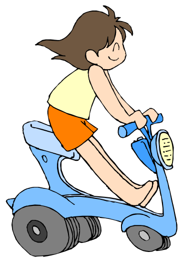
The - sign indicates "<u>deceleration</u>"

In each case, calculate the **acceleration** of the vehicle:

(a) Farmer Jones' tractor starts from rest and speeds up to 8 m/s in 10 s.

(b) In their go-kart, Jill and her Mum speed up from rest to 6 m/s in 12 s.





(c) On her motor scooter, Dominique takes 5 s to speed up from 3 m/s to 13 m/s.

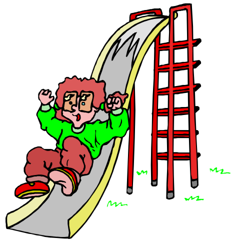
(d) Mike's motorbike takes 5 s to speed up from 10 m/s to 30 m/s.

In each case: (a) Calculate the **acceleration** or **deceleration** over the stated time interval. (b) Tick the correct **acceleration** or **deceleration** box.

- initial speed (u) = 0 m/s
- final speed (v) = 6 m/s
- time = 12 s

acceleration ☐ **deceleration** ☐

- initial speed (u) = 0 m/s
- final speed (v) = 3 m/s
- time = 2 s



acceleration ☐ **deceleration** ☐

- initial speed (u) = 4.5 m/s
- final speed (v) = 0 m/s
- time = 2.5 s

acceleration ☐ **deceleration** ☐

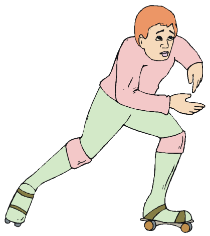
- initial speed (u) = 3.6 m/s
- final speed (v) = 0 m/s
- time = 6 s

acceleration ☐ **deceleration** ☐

- initial speed (u) = 1.5 m/s
- final speed (v) = 7.5 m/s
- time = 2 s

acceleration ☐ **deceleration** ☐

- initial speed (u) = 7.8 m/s
- final speed (v) = 2.3 m/s
- time = 2.5 s



acceleration ☐ **deceleration** ☐

- initial speed (u) = 5.5 m/s
- final speed (v) = 2.3 m/s
- time = 8 s

acceleration ☐ **deceleration** ☐

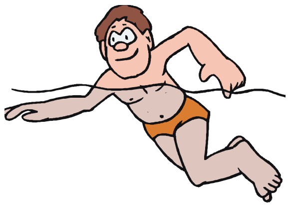
- initial speed (u) = 0.6 m/s
- final speed (v) = 6.8 m/s
- time = 4.1 s

acceleration ☐ **deceleration** ☐

- initial speed (u) = 12.3 m/s
- final speed (v) = 1.5 m/s
- time = 9 s

acceleration ☐ **deceleration** ☐

- initial speed (u) = 0.5 m/s
- final speed (v) = 2.5 m/s
- time = 20 s



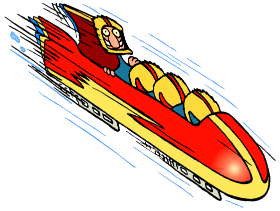
acceleration ☐ **deceleration** ☐

- initial speed (u) = 0.9 m/s
- final speed (v) = 2.1 m/s
- time = 6 s

acceleration ☐ **deceleration** ☐

- initial speed (u) = 6.7 m/s
- final speed (v) = 2.3 m/s
- time = 5.5 s

acceleration ☐ **deceleration** ☐



As a bobsleigh reaches a steep part of track, its speed increases from 24 m/s to 36 m/s. This happens in 0.4 s.

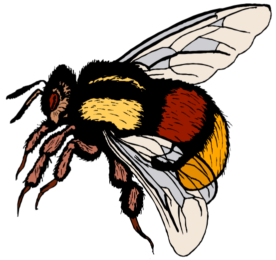
Calculate the acceleration of the bobsleigh during this time.

An arrow hits a stationary target at 50 m/s and comes to rest in 0.1 s.

Calculate the deceleration of the arrow once it hits the target.

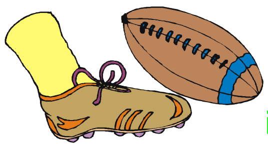
Starting from rest, a fireman slides down a pole with an acceleration of 1.2 m/s^2. His speed at the bottom of the pole is 3.6 m/s.

Calculate the time taken to slide down the pole.



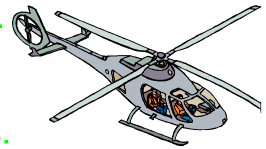
A bee, decelerating at 0.7 m/s^2, slows down from 6.7 m/s to 2.5 m/s.

What time does this take?



When a stationary rugby ball is kicked, it is in contact with a player's boot for 0.05 s. During this short time, the ball accelerates at 600 m/s^2.

Calculate the speed at which the ball leaves the player's boot.

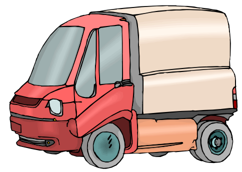


A helicopter is flying at 35 m/s. It then decelerates at 2.5 m/s^2 for 12 s.

Calculate the speed of the helicopter after the 12 s.

A speed of a conveyor belt is increased to 2.8 m/s by accelerating it at 0.3 m/s^2 for 4 s.

Calculate the initial speed of the conveyor belt.



A van decelerates at 1.4 m/s^2 for 5 s. This reduces its speed to 24 m/s.

Calculate the van's initial speed.

Velocity-Time Graphs

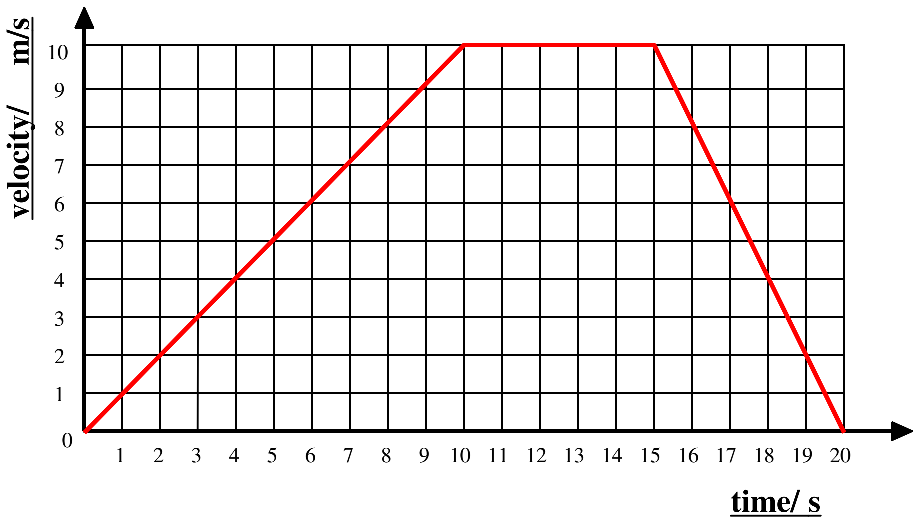
The motion of any object can be represented by a **line** drawn on a **velocity-time graph**:

constant/steady velocity
(zero acceleration)

increasing velocity
(constant/uniform acceleration)

decreasing velocity
(constant/uniform deceleration)

Describe the motion represented by the **line** on each **velocity-time graph**:



0 - 10 seconds: ____________ ____________ from ____ m/s to ____ m/s.
(Constant/uniform ________________).

10 - 15 seconds: ___________ __________ of ____ m/s.

15 - 20 seconds: ____________ ______________ from ____ m/s to ____ m/s.
(Constant/uniform __________________).

0 - 8 seconds: ____________ ____________ from ____ m/s to ____ m/s.
(Constant/uniform ________________).

8 - 11 seconds: ___________ __________ of ____ m/s.

11 - 18 seconds: ____________ _____________ from ____ m/s to ____ m/s.
(Constant/uniform __________________).

0 - 10 seconds: ____________ ____________ from ____ m/s to ____ m/s.
(Constant/uniform __________________).

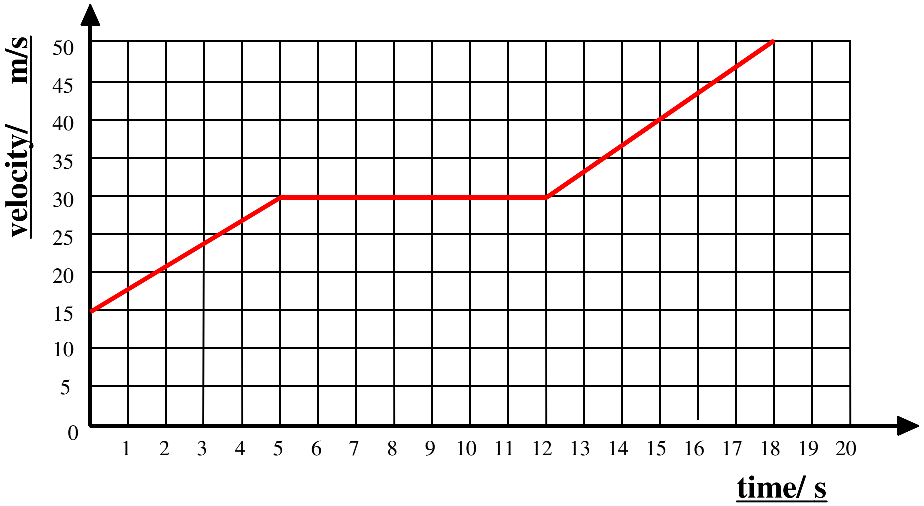
10 - 14 seconds: ____________ ___________ of ____ m/s.

14 - 20 seconds: _____________ ______________ from ____ m/s to ____ m/s.
(Constant/uniform ____________________).

0 - 30 seconds: _____________ ______________ from ____ m/s to ____ m/s.
(Constant/uniform ____________________).

30 - 75 seconds: ____________ ___________ of ____ m/s.

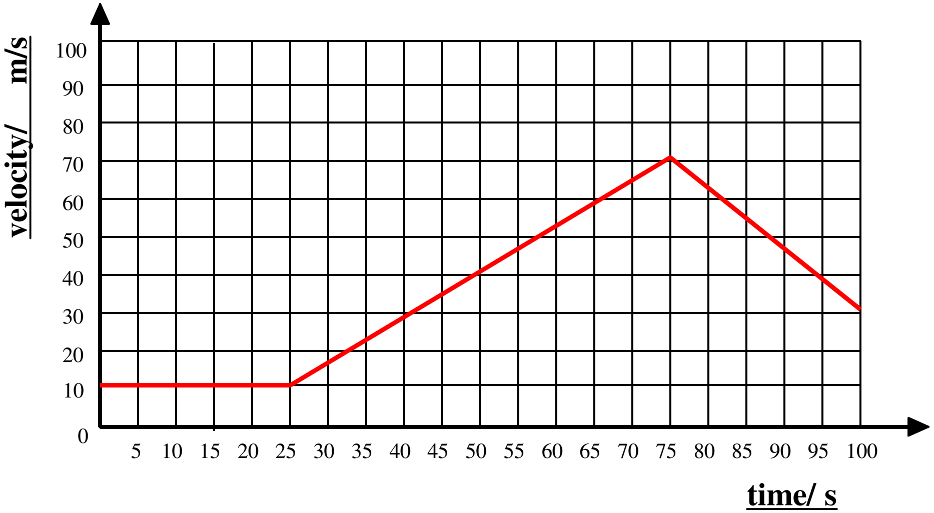
75 - 100 seconds: _____________ _____________ from ____ m/s to ____ m/s.
(Constant/uniform ____________________).



0 - 5 seconds: _____________ ______________ from ____ m/s to ____ m/s.
(Constant/uniform __________________).

5 - 12 seconds: ____________ ___________ of ____ m/s.

12 - 17 seconds: _____________ _____________ from ____ m/s to ____ m/s.
(Constant/uniform __________________).



0 - 25 seconds: ____________ ___________ of ____ m/s.

25 - 75 seconds: _____________ ______________ from ____ m/s to ____ m/s.
(Constant/uniform ________________).

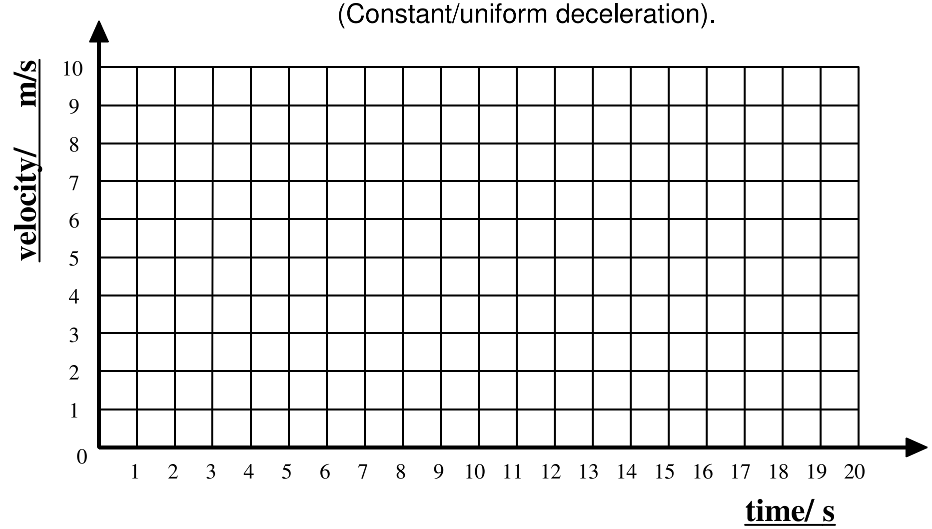
75 - 100 seconds: _____________ ______________ from ____ m/s to ____ m/s.
(Constant/uniform ____________________).

Draw the **line** on each **velocity-time graph** to represent the motion described:

0 - 5 seconds: Increasing velocity from rest (0 m/s) to 10 m/s. (Constant/uniform acceleration).

5 - 15 seconds: Constant velocity of 10 m/s.

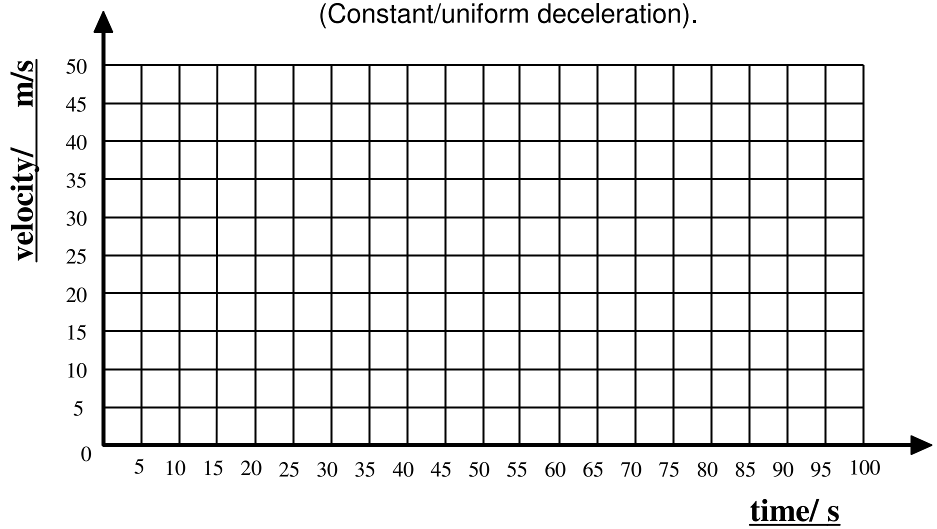
15 - 20 seconds: Decreasing velocity from 10 m/s to rest (0 m/s). (Constant/uniform deceleration).



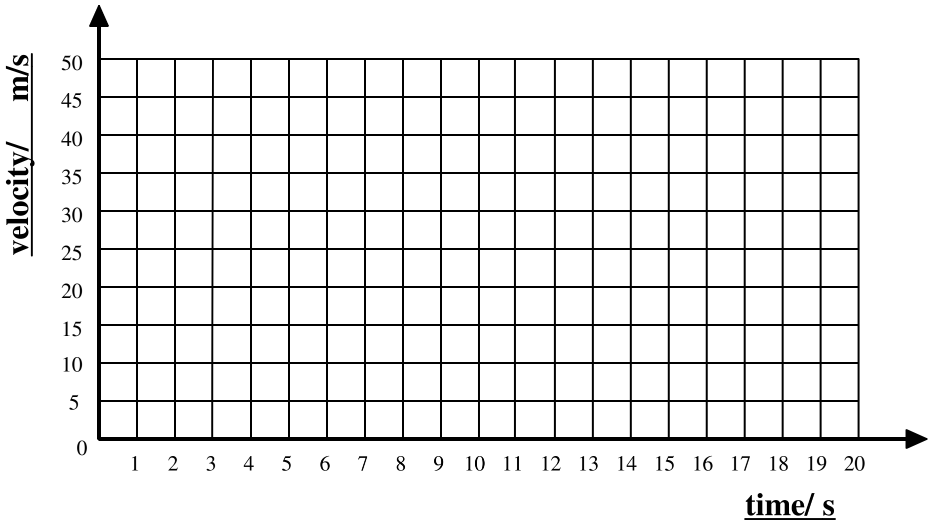
0 - 30 seconds: Increasing velocity from 25 m/s to 40 m/s. (Constant/uniform acceleration).

30 - 60 seconds: Constant velocity of 40 m/s.

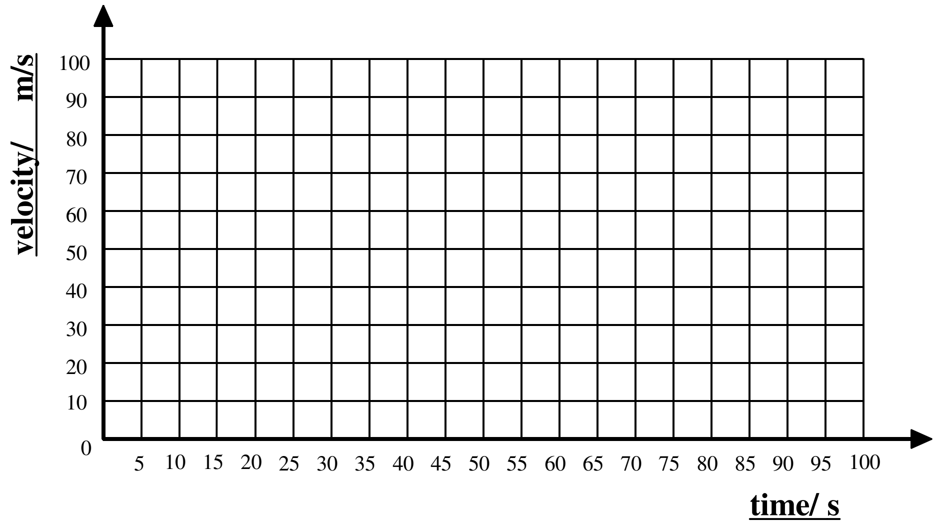
60 - 90 seconds: Decreasing velocity from 40 m/s to rest (0 m/s). (Constant/uniform deceleration).



With uniform/constant acceleration, a motorcycle takes 8 s to increase its velocity from rest to 20 m/s. The motorcycle continues to travel at this steady velocity for 4 s. It then increases its velocity to 45 m/s (constant/uniform acceleration) in 7 s.



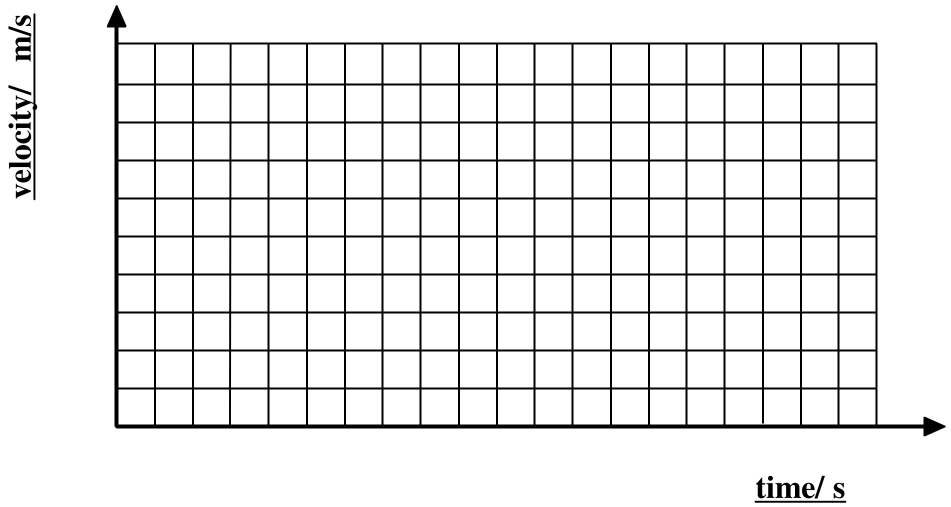
A helicopter, initially travelling at 80 m/s, decelerates constantly/uniformly to a velocity of 60 m/s in 25 s. For the next 50 s, it continues to travel at this steady velocity before decelerating constantly/uniformly to rest in a further 25 s.



Put numbers on each axis.

Maximum velocity = 9 m/s. Total time = 18 s.

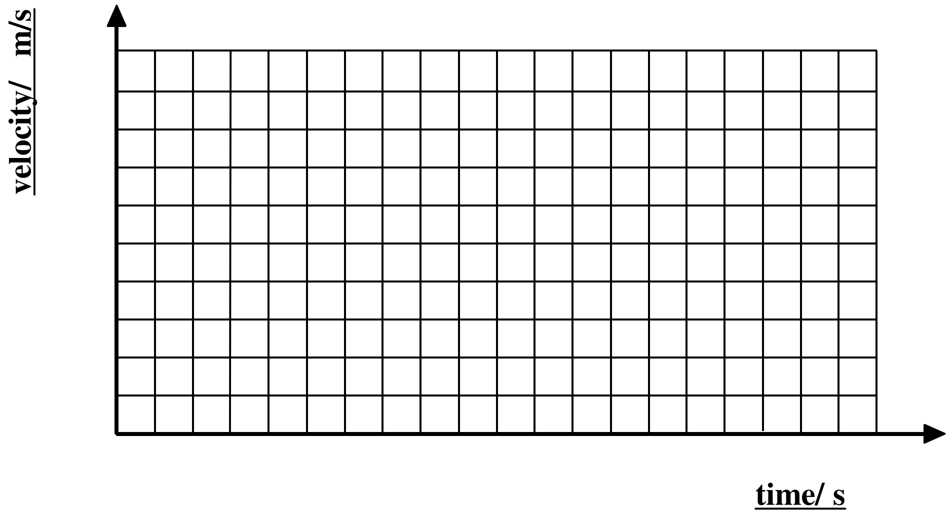
A cyclist travels at a steady velocity of 9 m/s for 6 s before decelerating constantly/uniformly to a velocity of 2 m/s in 7 s. She then travels at this steady velocity for a further 5 s.



Put numbers on each axis.

Maximum velocity = 90 m/s. Total time = 20 s.

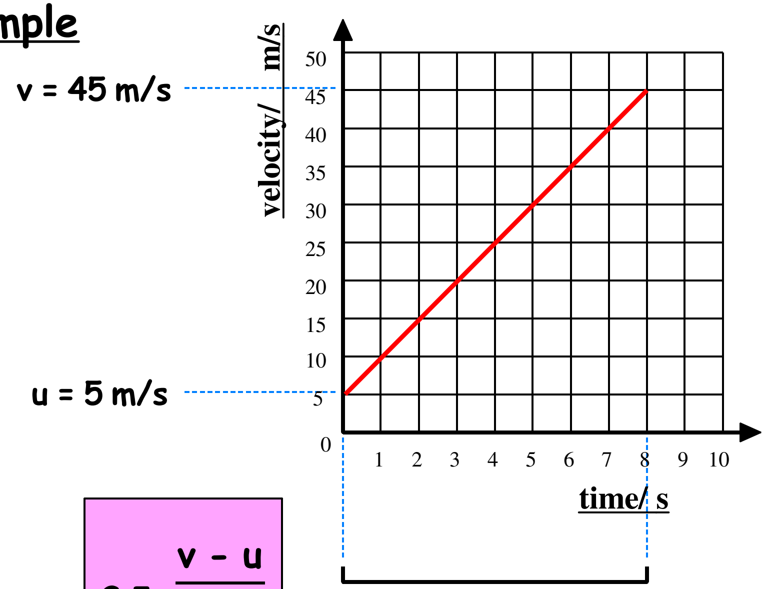
A racing car travels at a constant velocity of 10 m/s for 2 s before accelerating constantly/uniformly for 12 s to a velocity of 90 m/s. The car then immediately decelerates constantly/uniformly for 6 s to a velocity of 70 m/s.

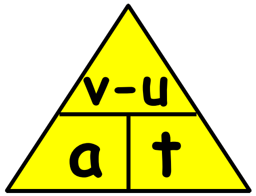


• Calculating Acceleration (or Deceleration) From a Velocity-Time Graph

By taking **velocity** and **time** values from a **velocity-time graph**, we can calculate the **acceleration** or **deceleration** of the object which the graph represents.

For Example





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

time (t) = 8 - 0

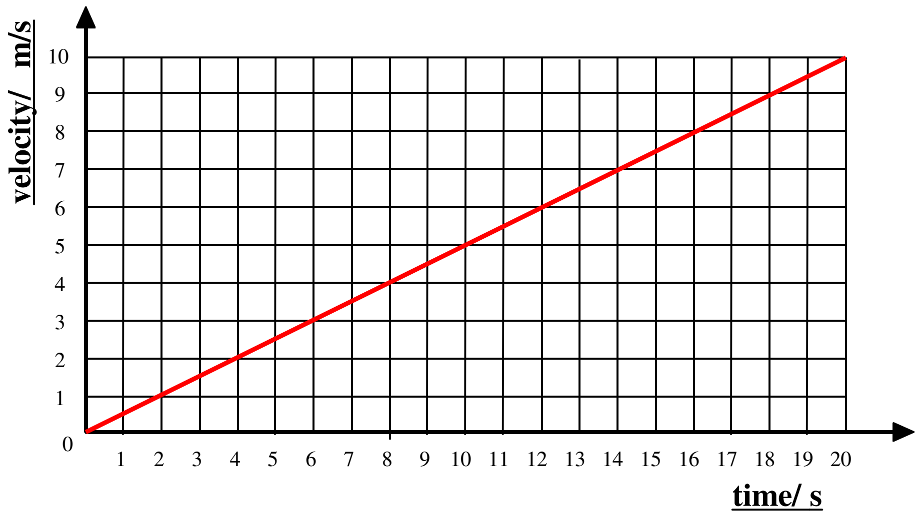
= 8 s

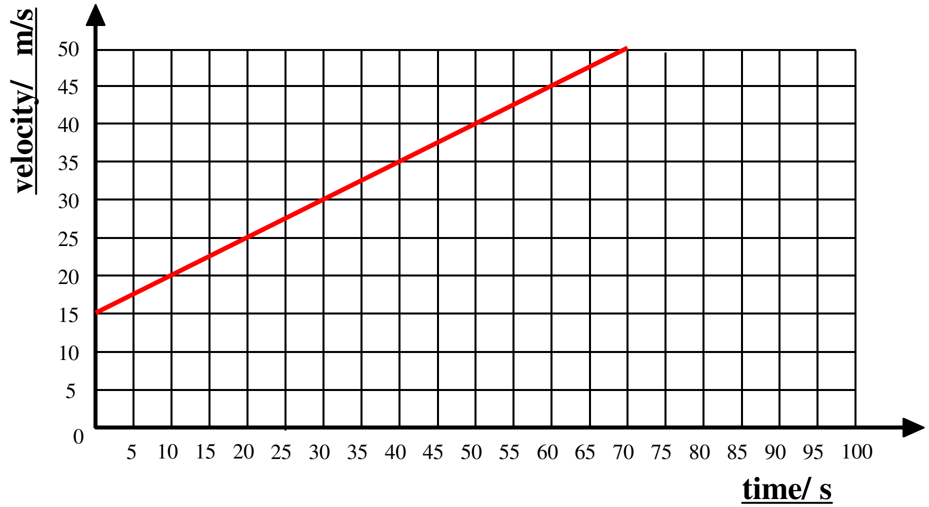
$$\text{acceleration (a)} = \frac{v - u}{t}$$

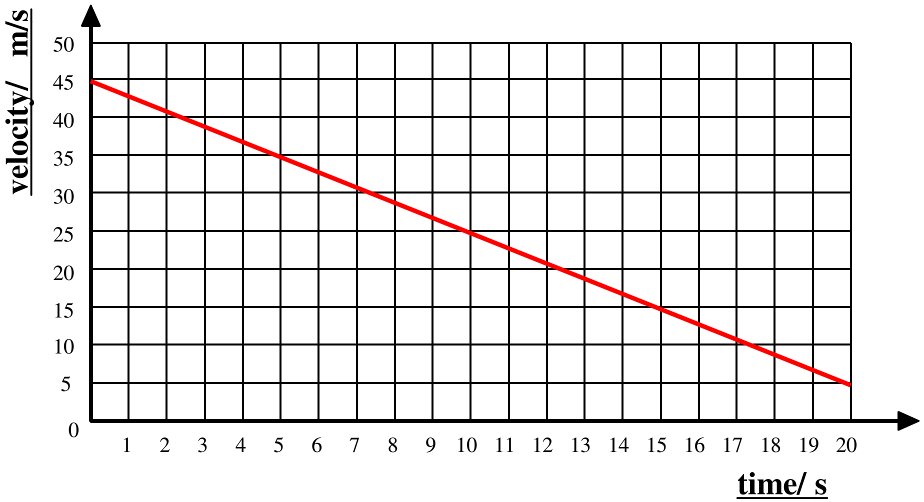
$$= \frac{45 - 5}{8}$$

$$= 5\ m/s^2$$

Calculate the **acceleration** or **deceleration** represented by the **line** on each **velocity-time graph**.







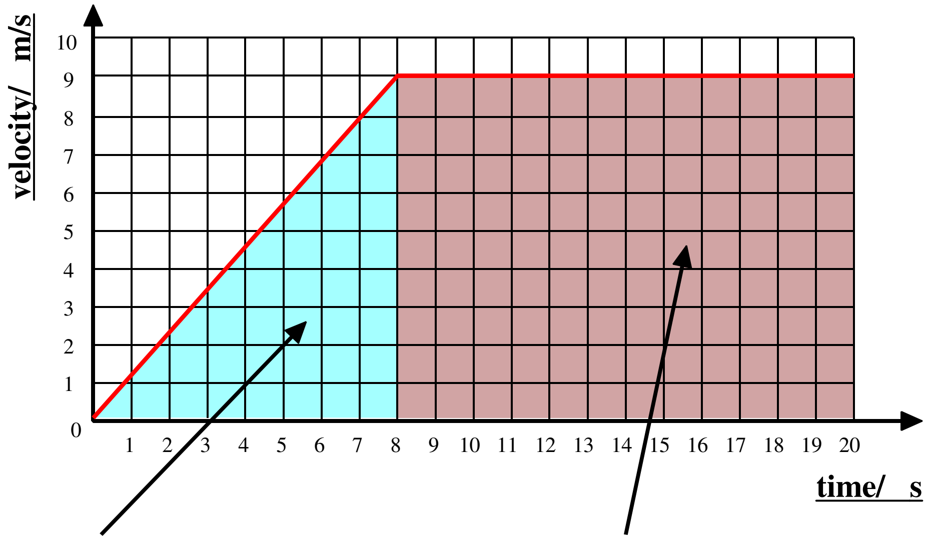
• Calculating Displacement From a Velocity-Time Graph

The **area** under a **velocity-time graph** representing the motion of an object gives the **displacement** of the object.

For Example

This **velocity-time graph** represents the motion of a go-kart for the first 20 s of its journey.

Determine the **displacement** of the go-kart during these 20 s.



Area of triangle = 1/2 x base x height
= 1/2 x 8 x 9
= 36

Area of rectangle = base x height
= 12 x 9
= 108

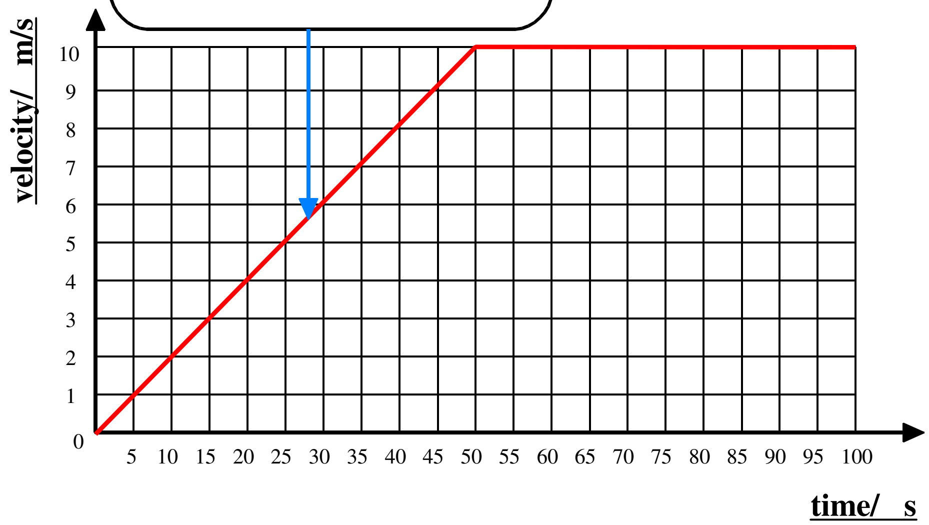
Displacement = Area under velocity-time graph
= 36 + 108
= 144 m

Displacement and Acceleration Calculations

Each of the following **velocity-time graphs** represent the motion of a vehicle.

For each graph, calculate any **accelerations** and **decelerations** of the vehicle, plus the vehicle's **displacement**:

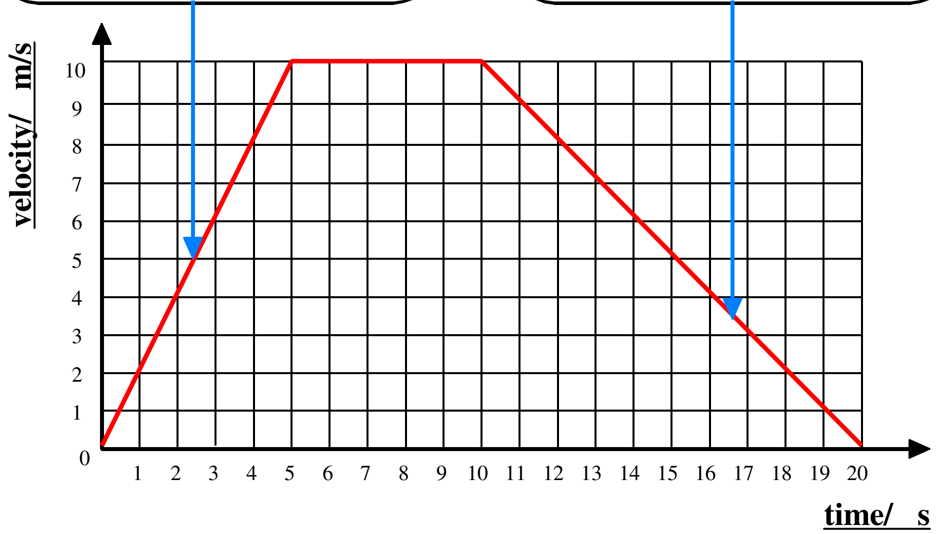
Acceleration Calculation



Displacement Calculation

Acceleration Calculation

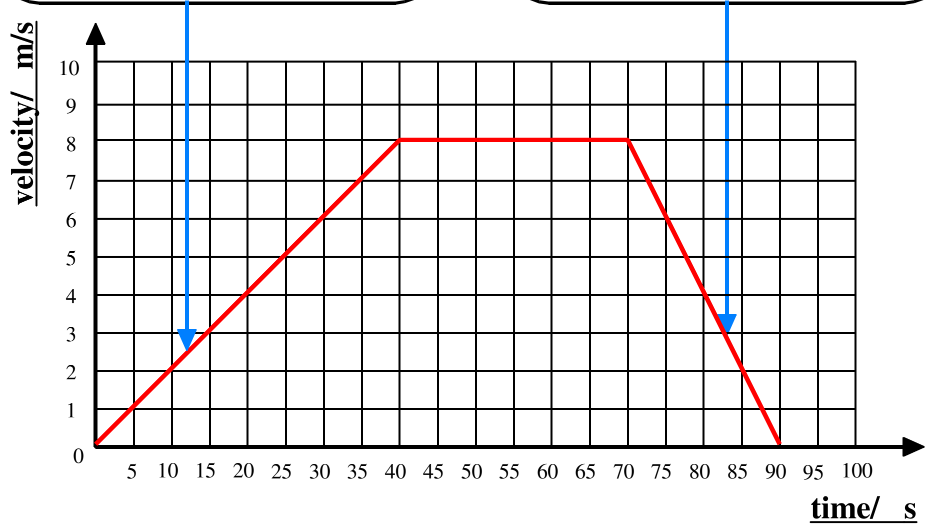
Deceleration Calculation



Displacement Calculation

Acceleration Calculation

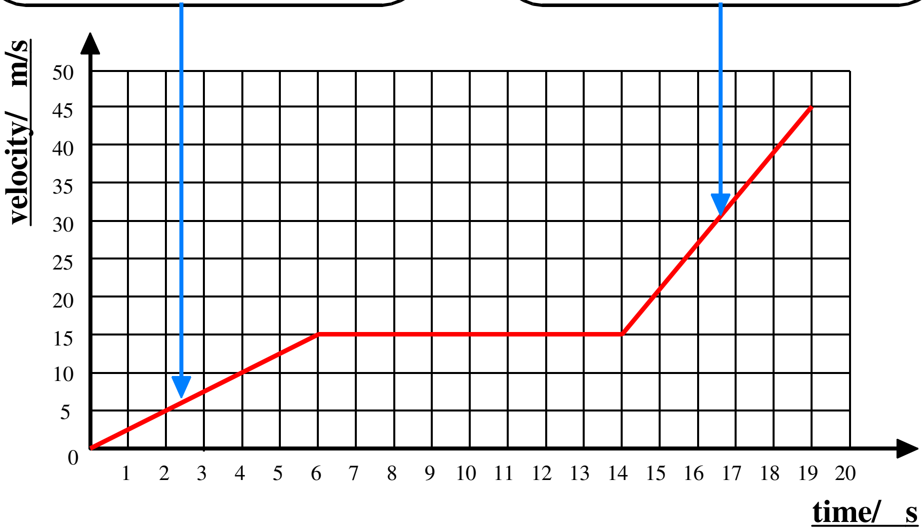
Deceleration Calculation



Displacement Calculation

Acceleration Calculation

Acceleration Calculation



Displacement Calculation

Deceleration Calculation

Deceleration Calculation

Displacement Calculation