UNIT G481	Module 1	1.1.3	KINEMATICS

- ***Candidates should be able to :***
  - *Define **displacement, instantaneous speed, average speed, velocity** and **acceleration.***
  - *Select and use the relationships :*

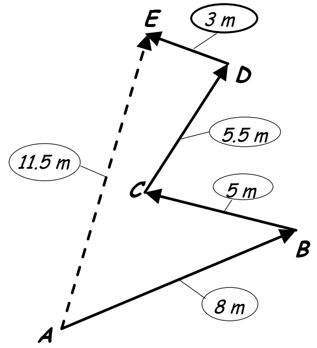
$$\text{average speed} = \frac{\text{distance}}{\text{time}}$$

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{Time}}$$

  - *Apply graphical methods to represent **displacement, speed, velocity** and **acceleration.***
  - *Determine **velocity** from the **gradient of the displacement against time graph**.*
  - *Determine **displacement** from the **area under a velocity against time graph**.*
  - *Determine **acceleration** from the **gradient of a velocity against time graph**.*

- ***DISPLACEMENT (s) / metre (m)***

- ***The distance moved by a body in a specified direction.***
- *It is a **VECTOR** quantity, so its value may be **positive** or **negative** depending on the direction from the starting point.*
- *To explain the difference between **DISTANCE MOVED** and **DISPLACEMENT** we will work out these two quantities for the ball as it is passed along the ground, from player to player during a match.*



*Distance moved = 8 m + 5 m + 5.5 m + 3 m = **21.5 m***

*Displacement = **11.5 m***

- ***SPEED (v) / metre per second (m s^{-1})***

- ***The rate of change of distance.***
- *It is a **SCALAR** quantity (i.e. it has size but no specified direction).*
- ***Instantaneous speed** is the speed at any given instant.*
- $$\text{Average speed} = \frac{\text{distance}}{\text{time}}$$

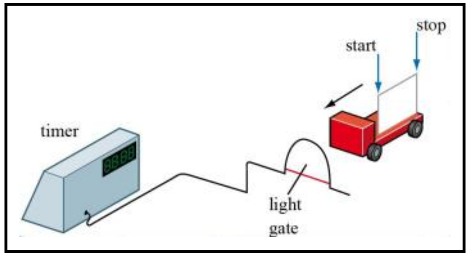
- *To explain the difference between* ***INSTANTANEOUS SPEED*** *and* ***AVERAGE SPEED****, we can consider a car journey. The instantaneous speed is continually changing and this is indicated by the speedometer reading. The average speed is calculated by dividing the distance travelled by the time taken.*

- ***Measuring Speed in the Laboratory***

  - ***Using One Light Gate***

The timer starts when the leading edge of the card breaks the light beam and it stops when the trailing edge passes through

The computer calculates the speed directly by dividing the card length by the time taken for it to go through the light gate.



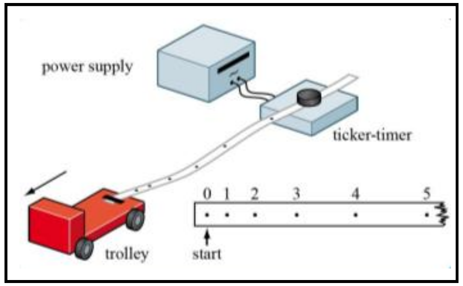
  - ***Using a Ticker-Timer***

The ticker-timer marks dots on the tape at intervals of ***1/50 s (0.02 s)*** *and the dot pattern on the tape acts as a record of the trolley's motion.*

Even dot spacing = ***constant speed.***

Increasing dot spacing = ***increasing Speed.***

Decreasing dot spacing = ***decreasing Speed.***



The ***distance moved*** *by the trolley* ***every second*** *can be obtained by measuring the distance of every* ***fifth dot*** *from the start of the tape. This gives the trolley's distance at intervals of* ***0.1 s****. A results table can then be drawn up and a* ***distance against time*** *graph can be plotted. The* ***gradient*** *of such a graph gives the* ***speed*** *of the trolley.*

- ***VELOCITY (v) / metre per second ($m\ s^{-1}$)***

- ***The rate of change of displacement of a body.***

  VELOCITY ($m\ s^{-1}$) = CHANGE IN DISPLACEMENT (m) / TIME TAKEN (s)

$$v = \frac{\Delta s}{\Delta t}$$

- *Is a* ***VECTOR*** *quantity, so its value may be* ***positive*** *or* ***negative*** *depending on the direction of motion.*

- *A body moves with* ***CONSTANT*** *(or* ***UNIFORM****) velocity if it goes through* ***equal changes in displacement*** *in* ***equal time intervals.***

  A body moving with ***non-constant*** *velocity is said to be undergoing* ***acceleration.***

- ***ACCELERATION (a) / metre per second² ($m\ s^{-2}$)***

- ***The rate of change of velocity of a body.***

  ACCELERATION ($m\ s^{-2}$) = VELOCITY CHANGE ($m\ s^{-1}$) / TIME TAKEN (s)

$$v = \frac{\Delta v}{\Delta t}$$

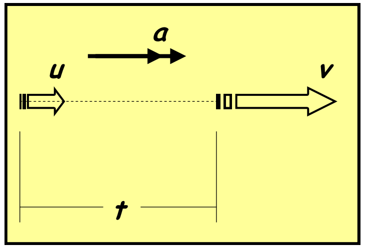
- *It is a **VECTOR** quantity so its value may be **positive** or **negative**.*

- *A body is said to be **accelerating** if :*

  - *Its **speed** changes, or*
  - *Its **direction** changes.*

  *So an object which is moving in a **circular path** at **constant speed** is **accelerating** because its **direction** is continually changing.*

- ***Acceleration Equation***



acceleration = velocity change / time

$$\text{acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{Time taken}}$$

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

- *A body moves with **CONSTANT** (or **UNIFORM**) acceleration if it goes through **equal velocity changes** in **equal time intervals.***

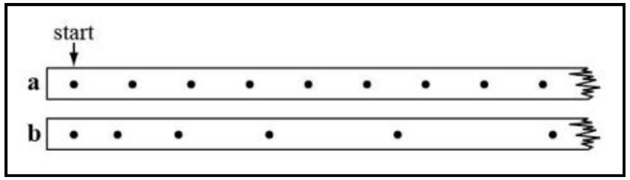
  *(e.g. a body falling under gravity in a vacuum moves with a **constant acceleration of 9.81 m s^{-2}**)*

1 (a) Calculate the ***average speed*** of an Olympic sprinter whose time for the ***100 m*** sprint is ***9.91 s.***

(b) How far will a snail crawl in ***1.5 minutes***, if its average speed is ***1.5 mm s^{-1}*** ?

(c) A trolley with a ***10 cm*** long card passed through a light gate. If the time recorded by the digital timer was ***0.5 s***, calculate the ***average speed*** of the trolley in ***m s^{-1}***.

(d)



The diagram above shows two ticker-tapes (a) and (b). Describe the motion of the trolleys which produced these tapes.

2 A fishing trawler uses echo sounding to measure the depth of water beneath its keel. If the reflected ultrasonic waves are detected ***0.65 s*** after they are transmitted, calculate the depth of the water. (speed of sound in water = ***1500 m s^{-1}***)

3 (a) The Earth completes one full revolution about its axis in ***24 hours.*** If the Earth's radius is ***6400 km***, calculate its rotational speed.

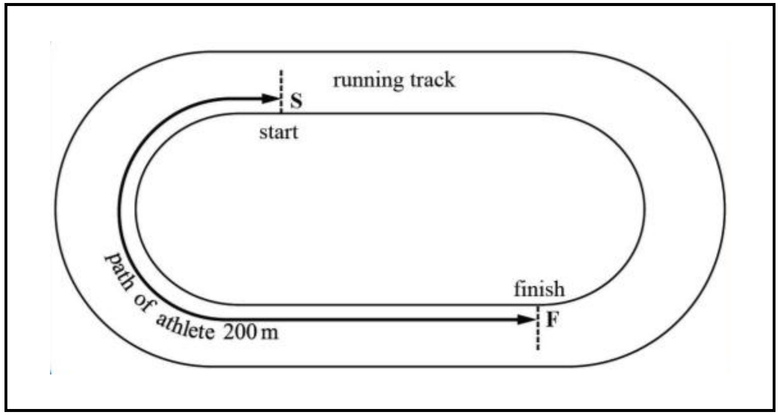
(b) The Earth takes ***365.3 days*** to make one complete orbit of the Sun. Given that the average orbital radius is ***1.5×10^{11} m***, calculate its ***average orbital speed*** in (i) ***km h^{-1}***, (ii) ***m s^{-1}***.

Explain why this is its ***average speed*** and not its ***velocity.***

4 (a) A high performance sports car accelerates from ***rest*** to reach a velocity of ***25 m s^{-1}*** in ***3.5 s***. Calculate its ***acceleration.***

(b) A bullet is fired into a large, wooden block. The bullet strikes the block with a velocity of ***250 m s^{-1}*** and slows down with a constant deceleration of ***280 m s^{-2}***. Calculate its ***velocity*** after ***0.55 s.***

5



The diagram shows the path taken by an athlete when she runs a ***200 m*** race in ***24 s*** from the start position at ***S*** to the finish at ***F.***

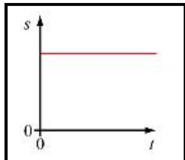
(a) Calculate the athlete's ***average speed.***

(b) Explain how the magnitude of the ***average velocity*** of the athlete would differ from her ***average speed***. A quantitative answer is not required.

(OCR Physics AS-Module 2821-June 2003)

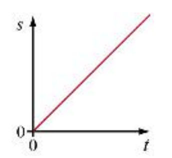
• *DISPLACEMENT-TIME (s/t) GRAPHS*

- *In this type of motion graph,* ***DISPLACEMENT (s) is plotted vertically against TIME (t) horizontally***.
- ***DISPLACEMENT*** *and* ***DISTANCE*** *can be read directly from the graph.*
- ***GRADIENT OF AN s/t GRAPH = VELOCITY***



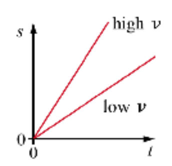
- *Gradient = 0 , so velocity = 0*

The displacement is not changing with time, so this is the s/t-graph for a ***stationary object***.

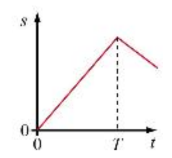


- *Gradient is* ***CONSTANT***, *so velocity is* ***CONSTANT***.

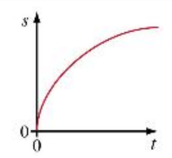
So this is the s/t-graph for an object moving at ***Constant Velocity***.



- *The* ***steeper*** *the gradient, the* ***GREATER*** *is the* ***velocity***.



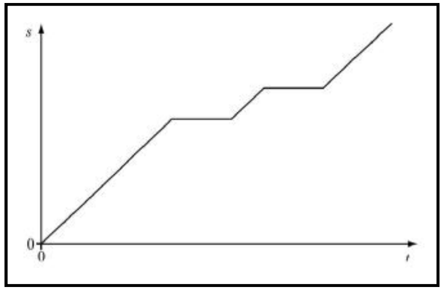
- *The gradient of this s/t-graph suddenly becomes* ***negative***. *This means that its* ***velocity is negative*** *after time = T, i.e. the object is moving back the way it came.*



- *The gradient is* ***NOT CONSTANT*** *(in fact decreasing). So this is the s/t-graph for an object whose velocity is* ***DECREASING*** *(i.e.* ***DECELERATING or having a NEGATIVE ACCELERATION).***

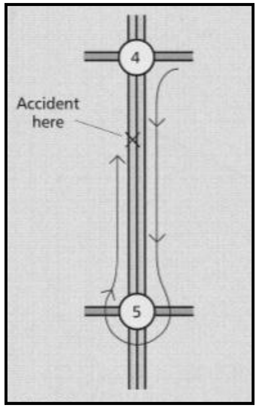
- **PRACTICE QUESTIONS (2)**

1 The displacement/time graph shown opposite represents the motion of a tram along a straight track.



Study the graph and try to describe the tram's journey as fully as you can.

2 (a) A police car joins a straight motorway at ***Junction 4*** and travels for ***8.5 km*** at constant speed for ***300 s.***



It then exits the motorway at ***Junction 5,*** rejoins on the opposite side and travels for ***6.2 km*** at constant speed for ***280 s*** to reach the scene of an accident.

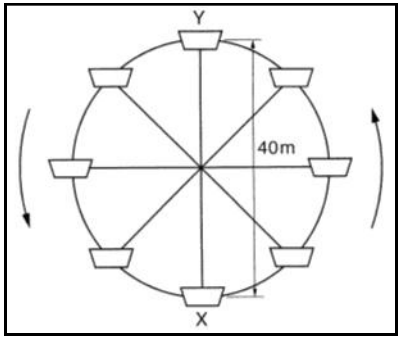
Calculate :

(i) The ***displacement*** from Junction 4 to the accident scene.

(ii) The ***velocity*** of the police car on each side of the motorway.

(b) Sketch a ***displacement/time*** graph to represent the motion of the police car.

3 The diagram opposite shows a 'Big Wheel' at a fairground. The wheel is rotating in a ***vertical plane*** and the carriages travel round a circle of diameter ***40 m*** at a constant speed, completing ***one revolution*** in ***3.5 minutes.***



(a) A carriage moves through ***half a revolution,*** from ***X to Y.***

Calculate :

(i) The ***speed*** of the carriage.

(ii) The magnitude of the ***average velocity*** of the carriage.

(b) The carriage continues to rotate and returns to point ***X.*** For the ***complete revolution,*** calculate :

(i) The ***speed*** of the carriage.

(ii) The ***average velocity*** of the carriage.

(iii) Comment on your answer.

(c) Describe how the ***instantaneous velocity*** of the carriage at ***Y*** differs from the ***average velocity*** of the carriage after travelling from ***X to Y.***

(OCR Physics AS - Module 2821 - January 2002)

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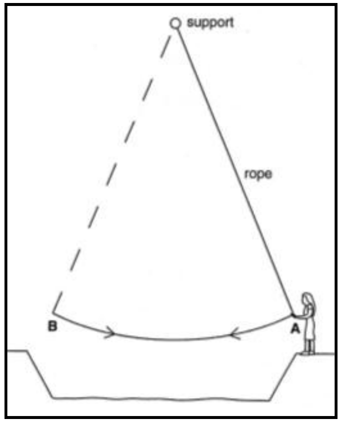


Fig. 1

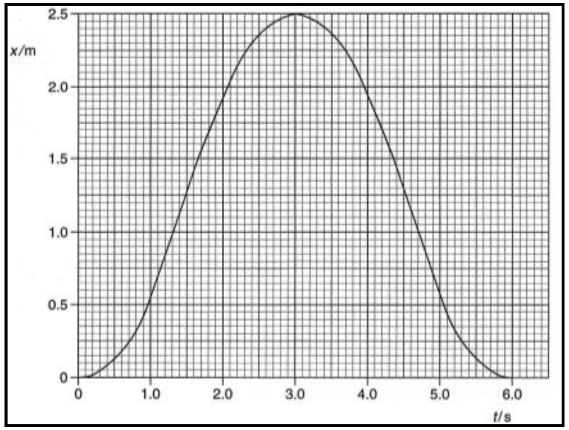


Fig. 2

Fig.1 shows a long rope tied at one end to a high support. A girl swings Backwards and forwards across a pool using the free end of the rope.

Fig. 2 shows the variation with ***time (t)*** of the ***displacement (x)*** of the girl from ***A*** to ***B*** and back to ***A.***

(a) State what the ***gradient*** of the graph represents and explain why the graph shows both ***negative*** and ***positive*** gradients.

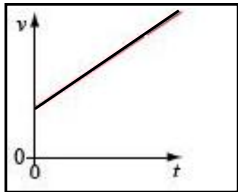
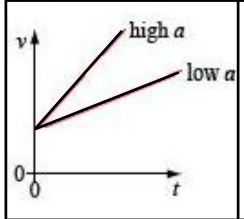
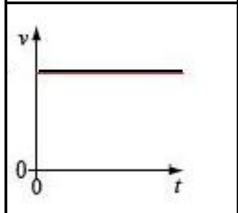
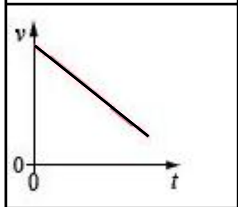
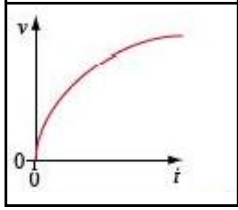
(b) Mark on Fig. 2 with a cross :

- A position where the girl's ***speed is zero*** (label ***Z***).
- A position where the girl's ***speed is a maximum*** (label ***M***).
-

(c) Use Fig. 2 to calculate the ***maximum positive speed*** of the girl. Show on Fig. 2 ***how you determined your answer.***

(OCR Physics AS - Module 2821 - January 2004)

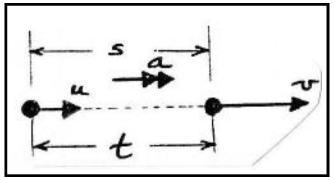
- ***VELOCITY-TIME (v/t) GRAPHS***
  In this type of motion graph, ***VELOCITY (v) is plotted vertically against TIME (t) horizontally.***
  - ***GRADIENT OF A v/t GRAPH = ACCELERATION***

	*Gradient is **CONSTANT**, so acceleration is **CONSTANT**.* *So this is the v/t graph for an object moving with **constant acceleration**.*
	*The **steeper** the gradient the **GREATER** the **acceleration**.*
	*Gradient = 0, so acceleration = 0* *The velocity is not changing with time, so this is the v/t graph for an object moving with **constant velocity**.*
	*Gradient is **CONSTANT** and **NEGATIVE.*** *This is the v/t graph for an object moving with **Constant deceleration**.*
	*The gradient is **NOT CONSTANT and decreasing**.* *So this is the v/t graph for an object moving with **decreasing acceleration**.*

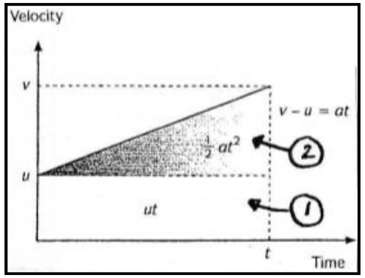
- *The **DISPLACEMENT** of a moving object can be worked out from its **VELOCITY-TIME (v/t) GRAPH**.*

AREA UNDER A VELOCITY-TIME GRAPH = DISPLACEMENT

*Consider an object moving with an **initial velocity (u)** which accelerates with a constant **acceleration (a)** to reach a **final velocity (v)** after a **time (t)**.*



*This is the **velocity-time** graph for the motion.*



displacement (s) = area under the velocity-time graph

s = area (1) + area (2)

s = ______ + ______

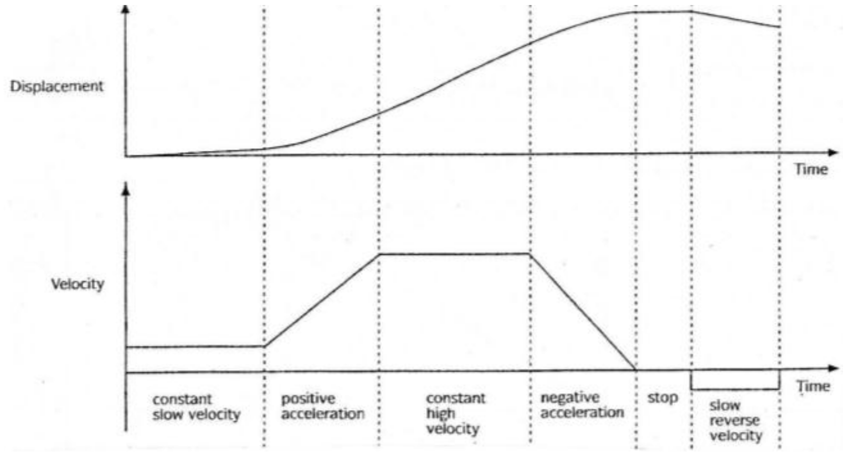
s = ______ + ______

s = ______ + ______

(But v = u + at) ***s =*** ______ + ______

s = ______ + ______

This is the equation of motion which can be used to calculate displacement s



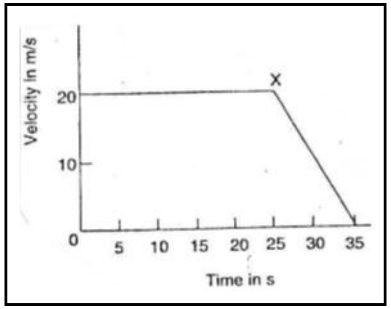
- ***QUANTITIES OBTAINABLE FROM MOTION GRAPHS***

- ***Gradient of displacement-time graph = VELOCITY***
- ***Gradient of distance-time graph = SPEED***
- ***Gradient of velocity-time graph = ACCELERATION***
- ***Area under a velocity-time graph = DISPLACEMENT***
- ***Area under a speed-time graph = DISTANCE MOVED***

UNIT G481	Module 1	1.1.3	KINEMATICS

- **PRACTICE QUESTIONS (3)**

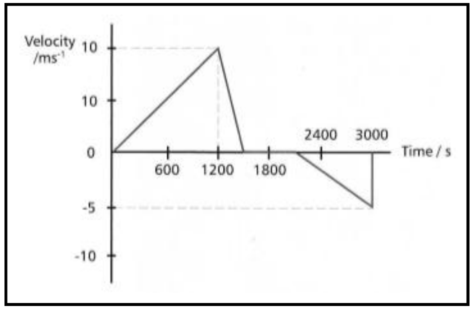
1 The v/t graph opposite shows how a car's velocity changed with time. At X, the driver started to slow down as he approached traffic lights. Use the graph to calculate :



(a) The car's **deceleration.**

(b) The **total distance** travelled by the car.

2 The graph opposite shows how the velocity of a train varied with time as it moved along a straight track over a 50 minute period after leaving the station.



(a) (i) Describe how the **displacement** of the train from the station changed with time.

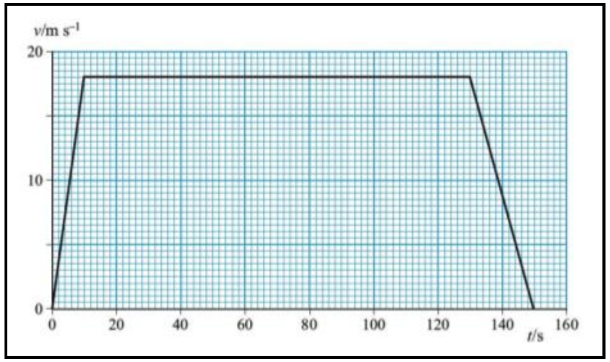
(ii) Sketch a graph to show how the displacement in part (i) varied with time.

(b) (i) Calculate how far from the station the train was after 50 min.

(ii) Calculate the **total distance** travelled by the train in this time.

3 (a) Define ***acceleration.***

(b) The graph below shows the variation of ***velocity (v),*** with ***time (t),*** of a train as it travels from one station to the next.



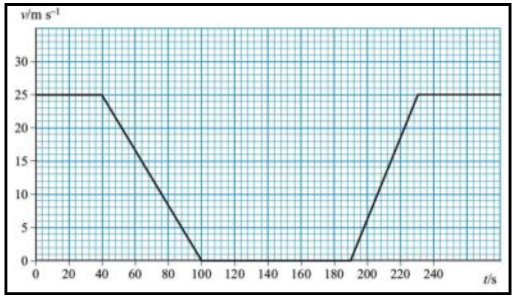
Use the graph to calculate :

(i) The ***acceleration*** of the train during the first 10.0 s,

(ii) The ***distance*** between the two stations.

(OCR Physics AS - Module 2821 - June 2001)

4 The diagram opposite shows a graph of ***velocity*** against ***time*** for a train that stops at a station.



(a) For the time interval ***t = 40 s to t = 100 s,*** calculate :

(i) The ***acceleration*** of the train,

(ii) The ***distance*** travelled by the train.

(b) Calculate the ***distance*** travelled by the train during its acceleration from rest to 25 m s^{-1}.

(c) Calculate the ***journey time*** that would be saved if the train did not stop at the station, but continued at a constant speed of 25 m s^{-1}.

(OCR Physics AS - Module 2821 - January 2001)

UNIT G481	Module 1	1.1.3	KINEMATICS

- **HOMEWORK QUESTIONS**

1 An aircraft has a landing velocity of **50 m s^{-1}** and decelerates uniformly at **10 m s^{-2}** until its velocity is reduced to **10 m s^{-1}**. Calculate :

(a) The ***time taken*** to slow down to 10 m s^{-1}.

(b) The ***distance moved*** during the deceleration.
(***Hint*** - Draw a v/t graph of the motion)

2 A sports car moves from rest with uniform acceleration to reach a velocity of ***25 m s^{-1}*** in ***4 s***. It then maintains this velocity for a further ***12 s***, after which it decelerates uniformly until it comes to ***rest 38 s*** after the start of the motion.

Sketch a ***velocity-time*** graph for the whole journey and use it to Calculate :

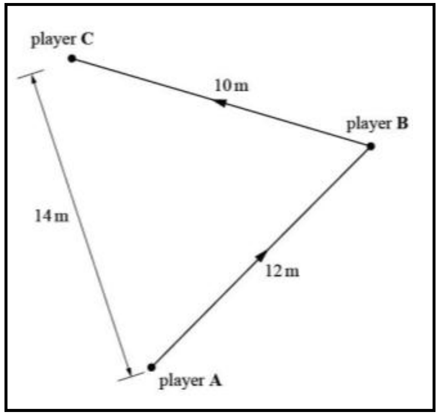
(a) The ***initial acceleration*** of the car,

(b) The ***final deceleration*** of the car,

(c) The ***total distance*** travelled,

(d) The ***average velocity*** of the car.

3 The diagram opposite shows the path of a ball as it is passed between three players. ***Player A*** passes the ball to ***player B*** who immediately passes it to ***player C***. The distances for each pass are shown in the diagram.



The ball takes ***2.4 s*** to go from ***player A*** to ***player C***.

(a) Calculate, for the ***total*** journey of the ball :

(i) The ***average speed*** of the ball,

(ii) The magnitude of the ***average velocity*** of the ball.

(b) Explain why the values of the ***average speed*** and ***average velocity*** are different.

(OCR Physics AS - Module 2821 - January 2005)

4

Velocity/m s^{-1}	0	15	30	30	20	10	0
Time/s	0	5	10	15	20	25	30

The table shows how the velocity of a saloon car changed during a speed trial along a straight track.

(a) Draw a ***velocity-time*** graph for the motion.
(b) Deduce the car's ***acceleration*** during the first 10 s ***from the data given in the table.***
(c) Calculate the car's ***acceleration*** during the first 10 s ***using the graph.***
(d) Use the graph to calculate the car's ***deceleration*** during the last 15 s.
(e) Use the graph to find the ***total distance trav-***