Kinematics

" Kinematics is the study of movement only (without studying its cause, such as force) "

Distance

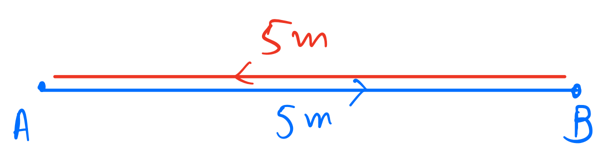
Length of path from one point to another irrespective of direction.

- Distance is scalar quantity
- SI unit is meter (m)

Displacement

Shortest / straight directed path from initial to final point.

Example



From A to B and back:

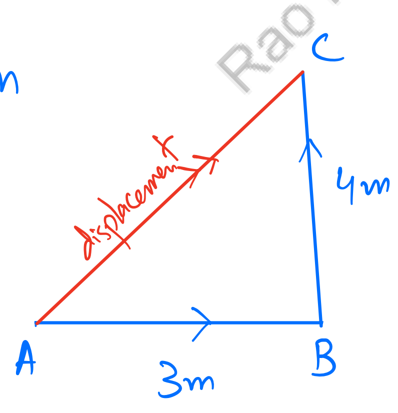
distance = 10 m (5m + 5m)

displacement = 0 m (5m + (-5m))

- Distance from A to C = 7m
- Displacement from A to C:

$$\sqrt{3^2 + 4^2}$$

$$= 5m$$



- Displacement is vector quantity (its negative if direction of object reverses)

- SI unit of displacement is meter (m)

Speed

Distance per unit time

$$\text{Speed} = \frac{\text{distance}}{\text{time}} \quad ; \quad v = \frac{s}{t}$$

- Speed is a scalar quantity
- SI unit : $m\,s^{-1}$

Velocity

Displacement per unit time

$$\text{velocity} = \frac{\text{displacement}}{\text{time}} , \quad v = \frac{s}{t}$$

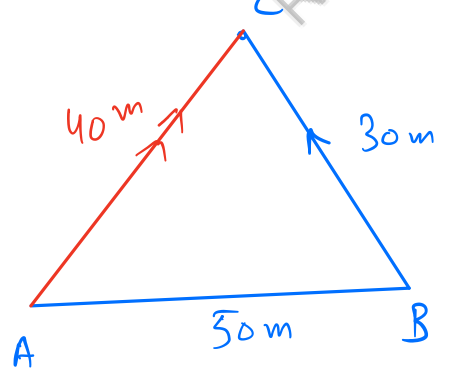
- velocity is a vector quantity
- SI unit : $m s^{-1}$

Example

A person runs from A to B and B to C as shown in diagram, find his speed and velocity (time = 70 sec)

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

$$= \frac{80}{70} \approx 1.1 \, m s^{-1}$$



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

$$= \frac{40}{70} \approx 0.57 \, m s^{-1}$$

Acceleration

Change in velocity per unit time

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

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

$v \rightarrow$ final velocity
$u \rightarrow$ initial velocity
$t \rightarrow$ time

- acceleration is vector quantity
- SI unit: ms^{-2}

Note: If velocity of an object decreases with time, it is said to be decelerating means accelerating negatively.

Example: A car increases in velocity from $10\ ms^{-1}$ to $25\ ms^{-1}$ in 12 sec, find the car's acceleration.

Sol: $v = 25\ ms^{-1}$, $u = 10\ ms^{-1}$, $t = 12$ sec

$$a = \frac{25 - 10}{12}$$

$$a = \frac{15}{12} = 1.25\ ms^{-2}$$

Example: A racing decelerates at $0.8\ ms^{-2}$ and Comes to rest in 60 Sec, find its velocity when brakes were applied.

Sol: $a = -0.8\ ms^{-2}$, $V = 0\ ms^{-1}$, $U = ?$

$t = 60\ Sec$

$$a = \frac{V-U}{t}$$

$$-0.8 = \frac{0-U}{60}$$

$$\Rightarrow U = 60 \times 0.8$$

$$U = 48\ ms^{-1}$$

Free-fall Motion:

falling motion in the absence of air resistance, such as, a steel ball dropped from rest, a heavy stone falling downwards etc

- In free fall motion, the velocity increases at the rate of approximately $9.8\ ms^{-1}$ every second. therefore, free fall acceleration is $9.8\ ms^{-2}$

$$g = 9.8\ ms^{-2} \quad \text{on Earth}$$

(for object thrown upwards: $g = -9.8\ ms^{-2}$)

* value of g on different planets is different depending upon their gravitational field strength.

* <u>Equations of Motion</u> (Compulsory for Edexcel Students)

  · equations of motion provide mathematical relationship between basic terms used in Kinematics such as :

  v: final velocity , u: initial velocity, a: acceleration

  S: displacement , t: time

* These equations apply when motion is linear and uniformly accelerated

(1) $v = u + at$

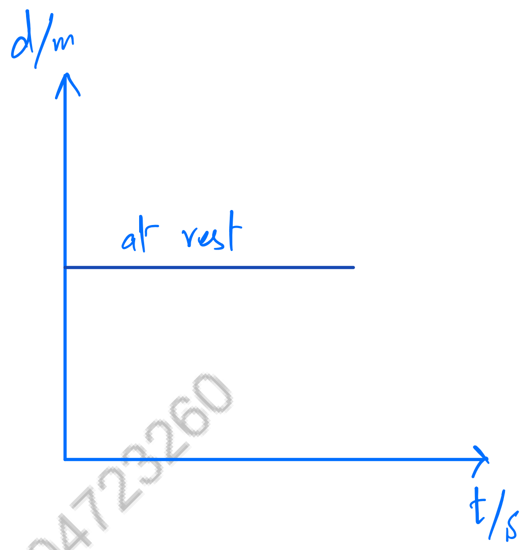
(2) $S = ut + \frac{1}{2}at^2$

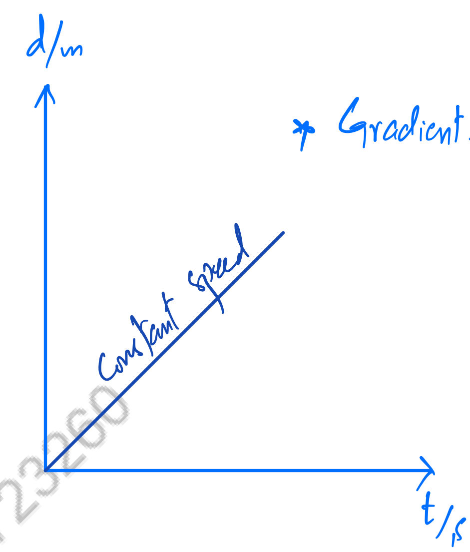
(3) $v^2 = u^2 + 2aS$

(4) $S = \left(\frac{v+u}{2}\right)t$

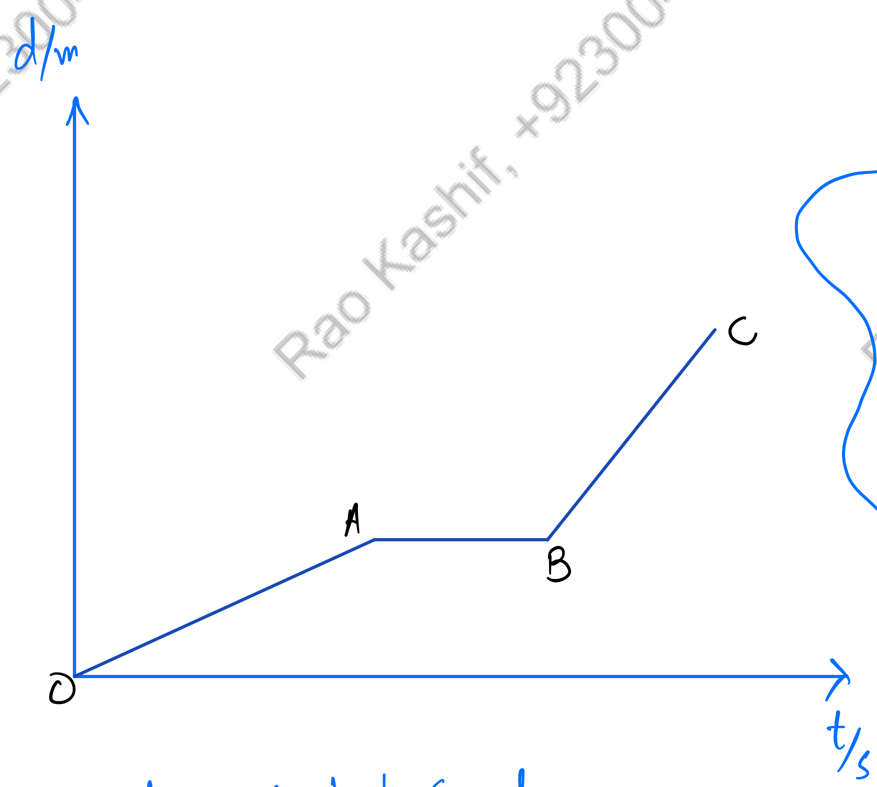
(Graphs of Motion)

• Distance - Time Graph





* Gradient = speed



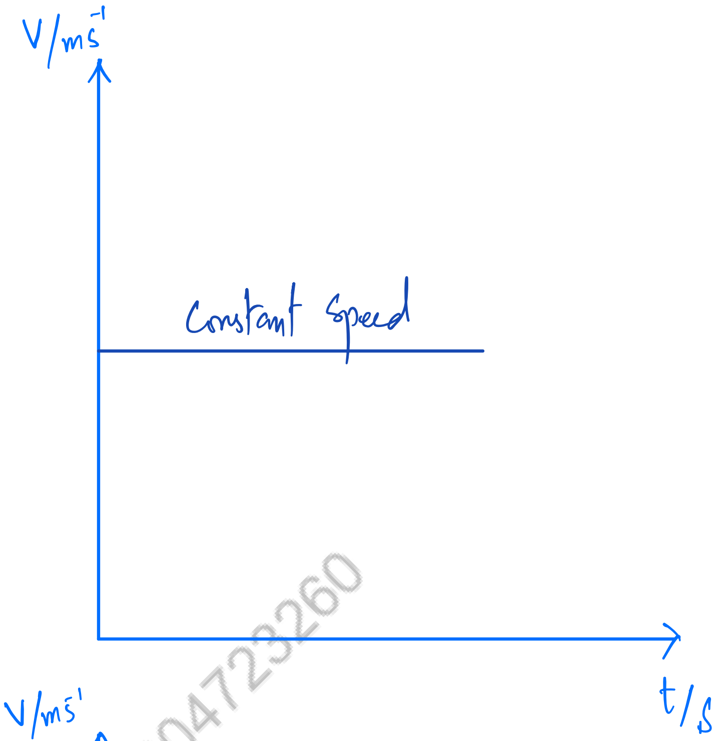
* The key difference between distance - time and displacement - time graph is that distance - time graph remains unchanged whether object reverses direction, as distance is scalar. However, displacement becomes negative in graph if object reverses direction.

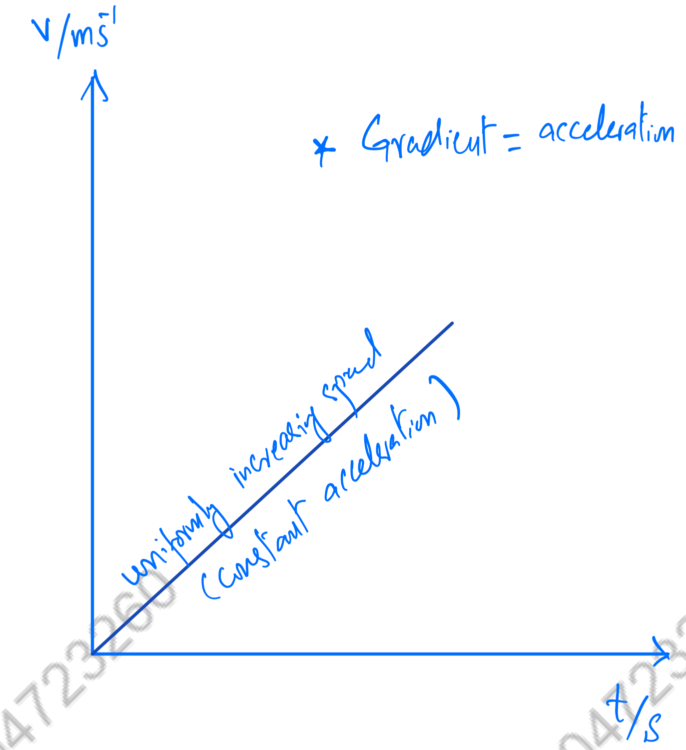
OA : Constant Speed

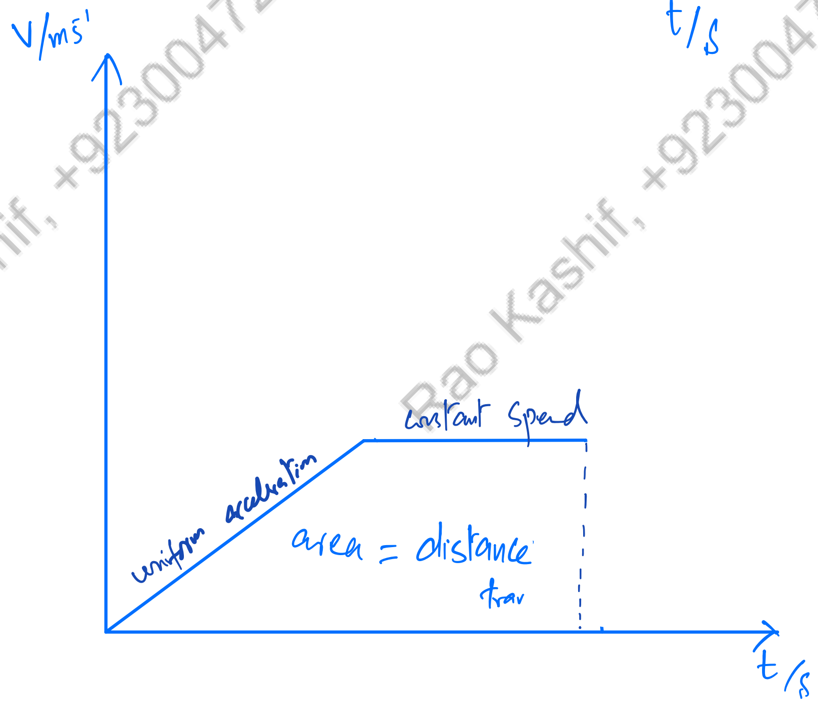
AB : object at rest

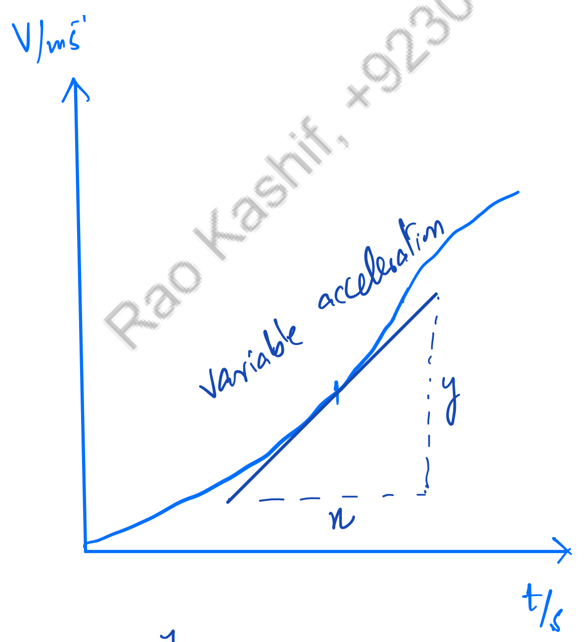
BC : Constant speed (more gradient, more speed)

Speed - Time Graph (v-t graph)





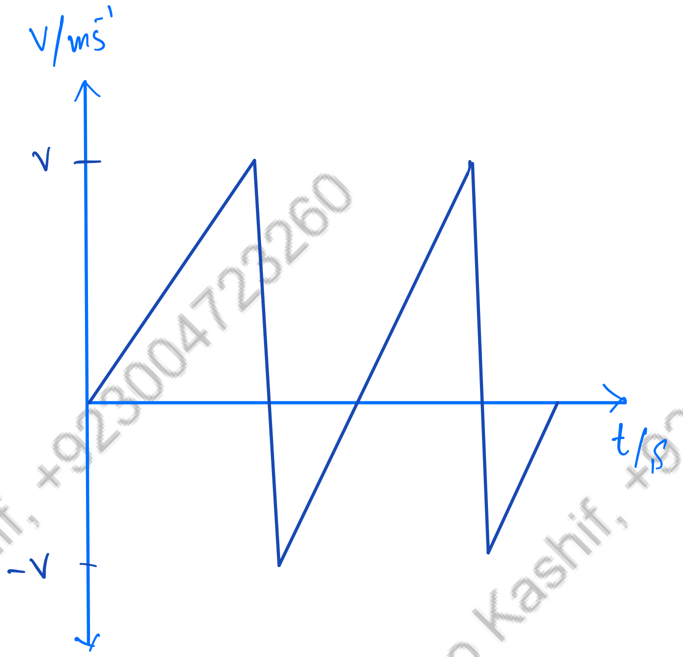


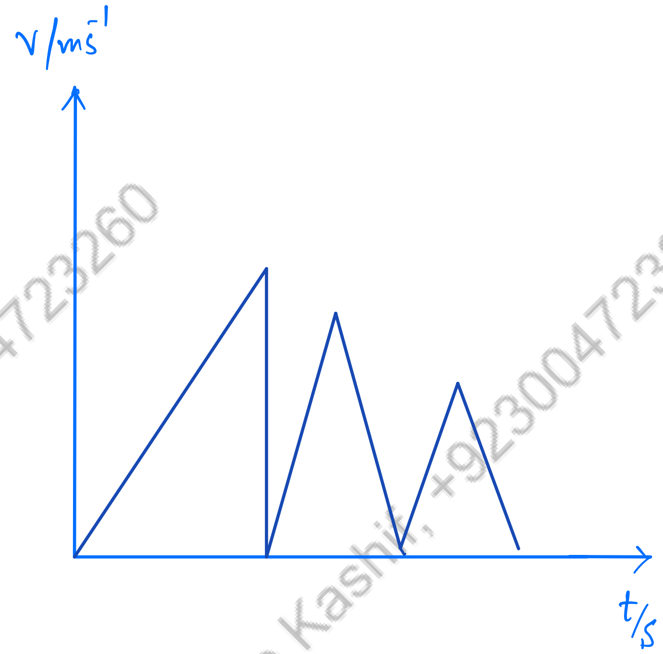


$\frac{y}{x} \rightarrow$ instantaneous acceleration

- Speed - time Vs velocity - time graph

Example : A Steel ball is dropped from rest, it hits a hard Surface and bounces several times. Draw its velocity - time and speed - time graph.





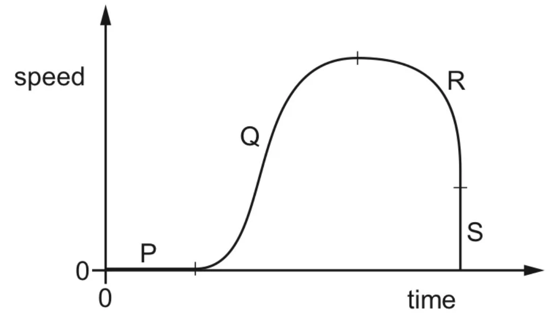
* Velocity - time graph

(Velocity is vector, it is negative when object reverses direction)

* Speed - time graph

(Speed is Scalar, it is not negative even when object reverses direction)

1 The speed–time graph for a racing car is divided into four sections, P, Q, R and S. The car starts the race but soon crashes into a wall of tyres.



Which sections of the graph show that there is an acceleration that is changing?

A P, Q, R and S

B Q, R and S only

C Q and R only

D R and S only

* There is a change of gradient at these points

2 A steel ball is dropped from the top floor of a building. Air resistance can be ignored.

Which statement describes the motion of the ball?

A The ball falls with constant acceleration.

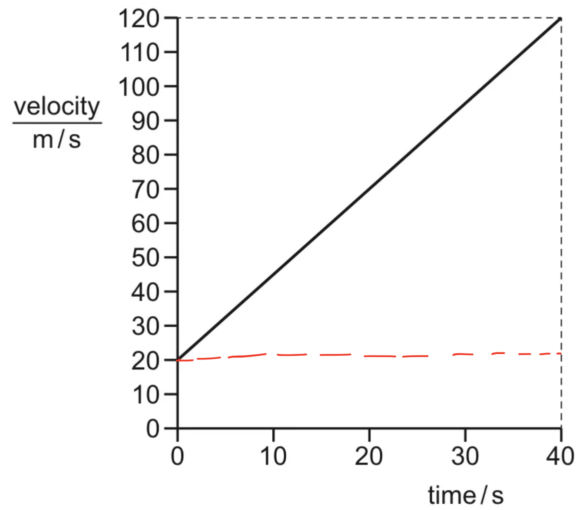
B The ball falls with constant speed.

C The ball falls with decreasing speed.

D The ball falls with increasing acceleration.

* free-fall motion, uniform acceleration of $9.8\ m s^{-2}$

3 The diagram shows a velocity–time graph for an object which is accelerating.



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

$a = \frac{120-20}{40}$

$a = 2.5\ m s^{-2}$

What is the acceleration of the object?

A $0.40\,m/s^2$ **B** $2.5\,m/s^2$ **C** $3.0\,m/s^2$ **D** $100\,m/s^2$

1 Fig. 1.1 is a speed–time graph for an ice skater.

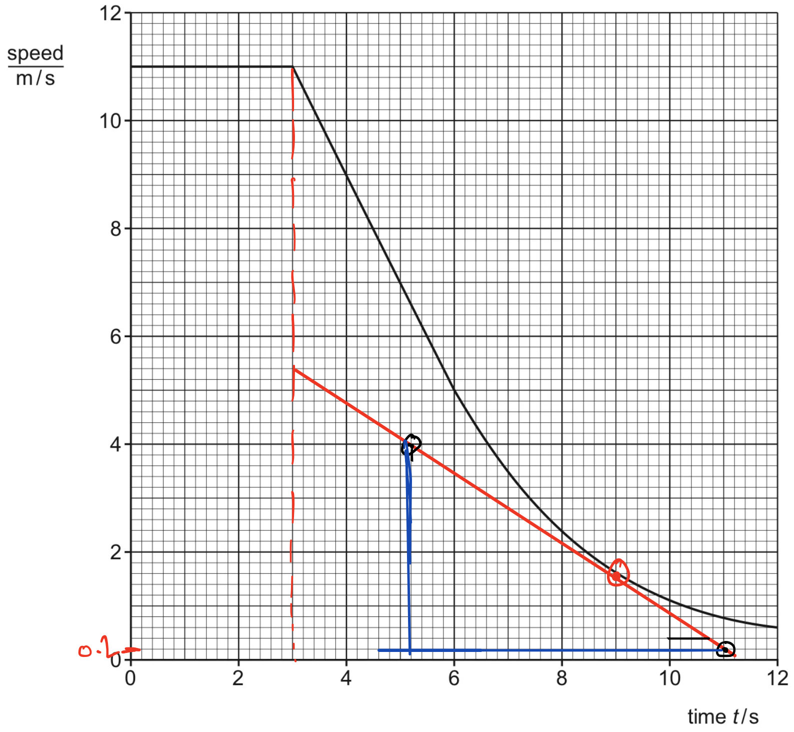


Fig. 1.1

(a) Describe the motion of the skater between $t = 0$ and $t = 3.0$ s.

Constant speed [1]

(b) Calculate the distance travelled by the skater between $t = 0$ and $t = 3.0$ s.

area of rectangle: $3 \times 11 = 33$ m

distance = 33 m [2]

(c) (i) State what is meant by deceleration.

negative acceleration (acceleration when speed decreases) [1]

(ii) Draw a tangent to the graph at $t = 9.0$ s.

Use the tangent to calculate the deceleration of the skater at $t = 9.0$ s.

$$\text{Gradient} = \frac{4 - 0.2}{11 - 5.2} = 0.65\ \text{ms}^{-2}$$

deceleration = $0.65\ \text{ms}^{-2}$ [3]

[Total: 7]