KINEMATICS

1

SPEED, VELOCITY AND ACCELERATION

GRAPHICAL ANALYSIS OF MOTION

FREE-FALL

SPEED, VELOCITY & ACCELERATION

STATE WHAT IS MEANT BY *SPEED* AND *VELOCITY*

Speed & Velocity

Aspect	Speed	Velocity
Definition	Rate of change of distance	Rate of change of displacement
Type of Quantity	Scalar	Vector
Formula	$speed = \frac{distance}{time}$	$velocity = \frac{displacement}{time}$

SPEED, VELOCITY & ACCELERATION

CALCULATE AVERAGE SPEED USING DISTANCE TRAVELLED/TIME TAKEN.

AVERAGE SPEED

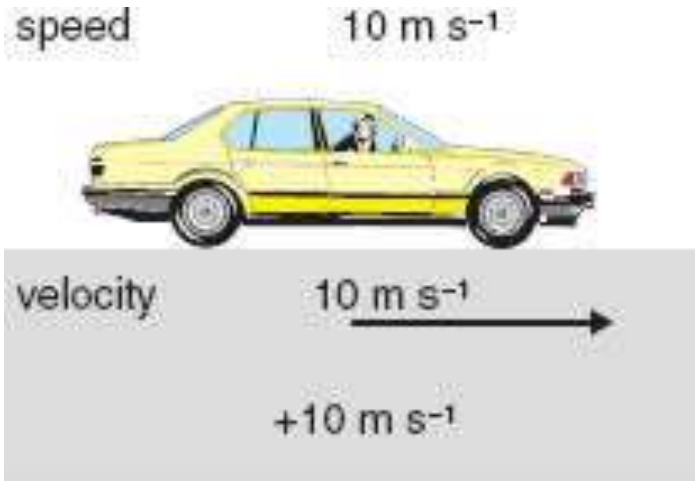
- For most journeys, speed is not constant. Normally we take the journey as a whole and calculate the **average speed**.

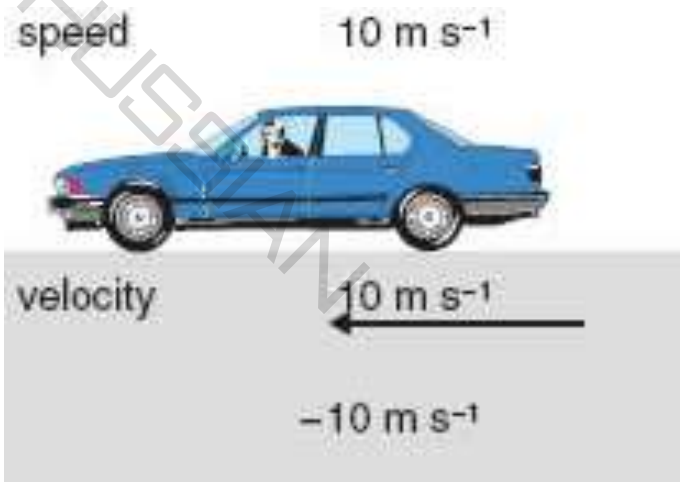
$$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$

Problem solving

1. If a car is taken from the garage, driven for 100 km before returning to the garage after 2 hours, what is it average speed?
2. A spacecraft is orbiting the Earth at a steady speed of 8 km/s. How long will it take to complete a single orbit, a distance of 40,000 km?
3. A speed-camera takes 2 photos 0.6 s apart while a car travels 12 m . What is its speed?

- **Velocity** is the distance travelled per unit time in a specified direction.
- Since it is **vector** quantity therefore the direction of travel is important.





PROBLEM SOLVING 1

- A boy run 5 km due west and then return back to travel a further distance of 4 km before resting. The whole journey takes 1 hour. Calculate
  - his total distance travelled,
  - his average speed,
  - his displacement from the starting point,
  - his average velocity.

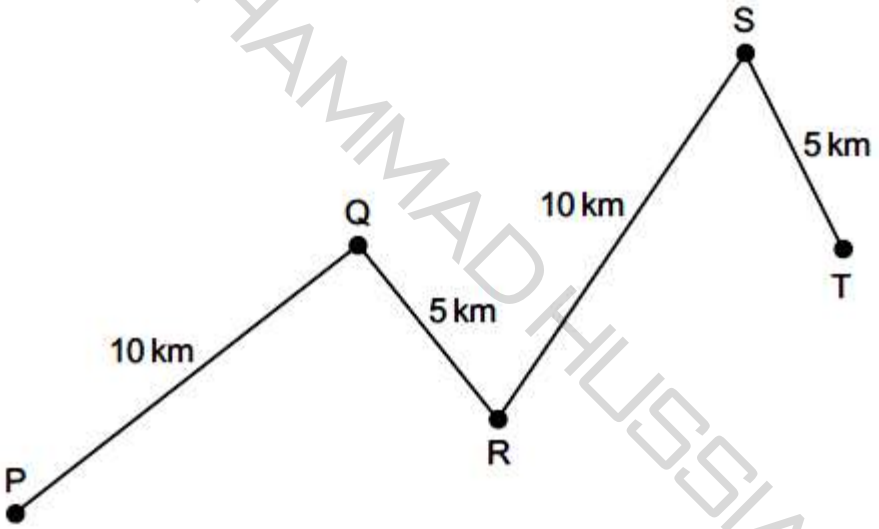
PROBLEM SOLVING 2

- A cyclist travels 6 km due east and then makes a turn to travel a further distance of 8 km due north. The whole journey takes 2 hours. Calculate
  - the distance travelled by the cyclist,
  - the average speed of the cyclist,
  - the displacement of the cyclist,
  - the average velocity of the cyclist.

Problem Solving 3

- A car starts from point O and moves to U, 50 m to the north in 60 s. The car then moves to B, 120 m to the west in 40 s. Finally, it stops. Calculate the:
  - total distance moved by the car
  - displacement of the car
  - speed of the car when it is moves to the north
  - velocity of the car
  - average speed of the car

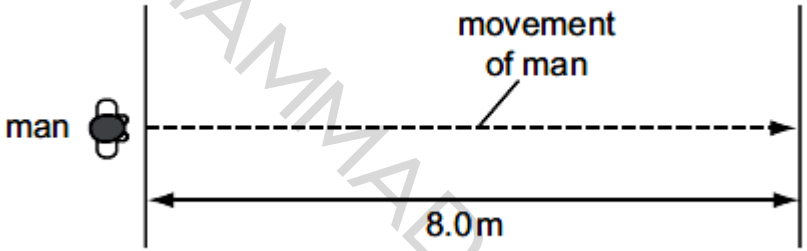
1. A car travels along the route PQRST in 30 minutes.



What is the average speed of the car?

A. 10 km/hour
B. 20 km/hour
C. 30 km/hour
D. 60 km/hour

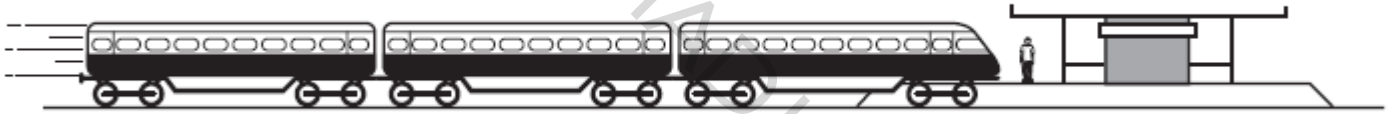
2. A man crosses a road 8.0 m wide at a speed of 2.0 m/s.



How long does the man take to cross the road?

A. 4.0 s
B. 6.0 s
C. 10 s
D. 16 s

3. A child is standing on the platform of a station, watching the trains.

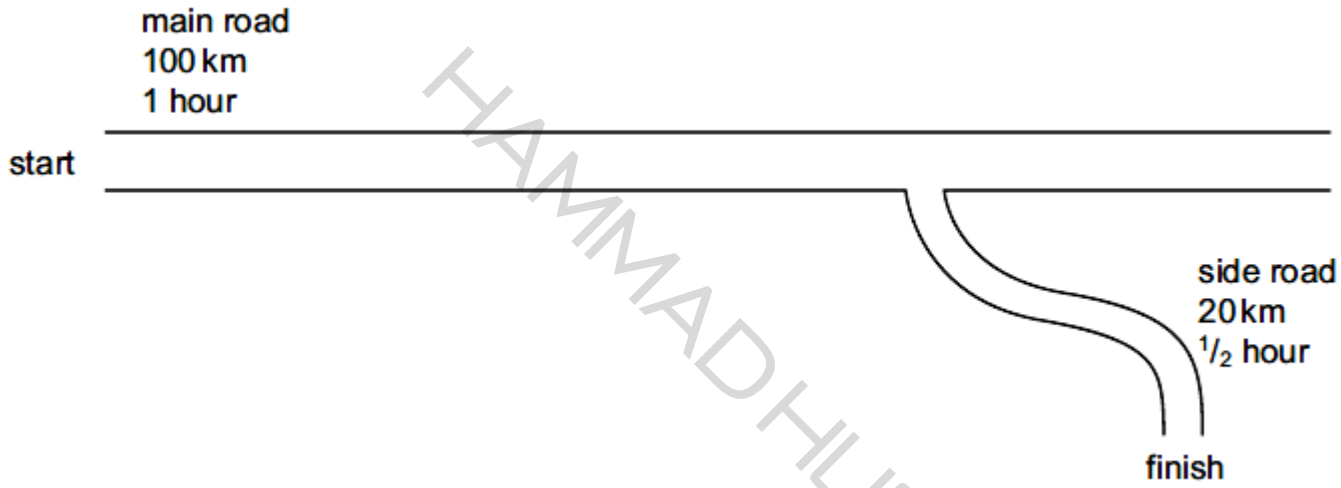


A train travelling at 30 m/s takes 3 s to pass the child.

What is the length of the train?

A. 10 m
B. 30 m
C. 90 m
D. 270 m

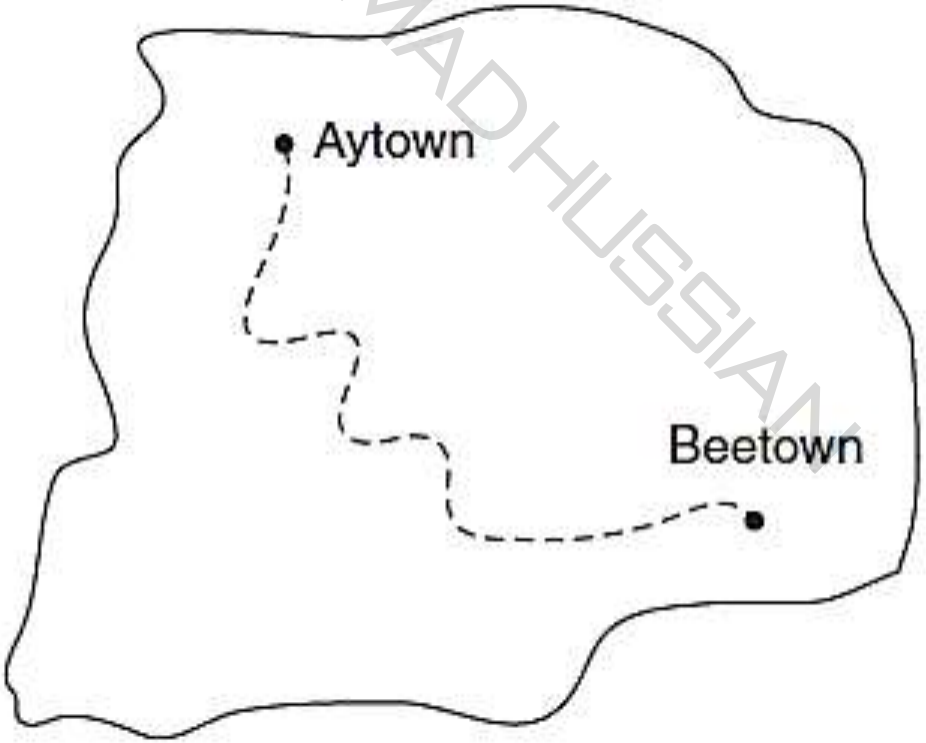
4. A car takes 1 hour to travel 100 km along a main road and then ½ hour to travel 20 km along a side road.



What is the average speed of the car for the whole journey?

A. 60 km/h
B. 70 km/h
C. 80 km/h
D. 100 km/h

5. A train travels along a track from Aytown to Beetown. The map shows the route.



The distance travelled by the train between the towns is 210 km. It moves at an average speed of 70 km/h.

How long does the journey take?

A less than $\frac{70}{210}$ hours, because the journey is not in a straight line

B exactly $\frac{70}{210}$ hours

C exactly $\frac{210}{70}$ hours

D more than $\frac{210}{70}$ hours, because the journey is not in a straight line

C

6. The circuit of a motor racing track is 3 km in length. In a race, a car goes 25 times round the circuit in 30 minutes.

   What is the average speed of the car?

   A. 75 km/hour
   B. 90 km/hour
   C. 150 km/hour
   D. 750 km/hour

7. A tunnel has a length of 50 km. A car takes 20 min to travel between the two ends of the tunnel.

   What is the average speed of the car?

   A. 2.5 km/h
   B. 16.6 km/h
   C. 150 km/h
   D. 1000 km/h

8. A car travels at various speeds during a short journey.

   The table shows the distances travelled and the time taken during each of four stages P, Q, R and S.

stage	P	Q	R	S
distance travelled / km	1.8	3.6	2.7	2.7
time taken / minutes	2	2	4	3

During which two stages is the car travelling at the same speed?

A. P and Q
B. P and S
C. Q and R
D. R and S

9. A car driver takes a total of two hours to make a journey of 75 km. She has a coffee break of half an hour and spends a quarter of an hour stationary in a traffic jam.

   At what average speed must she travel during the rest of the time if she wants to complete the journey in the two hours?

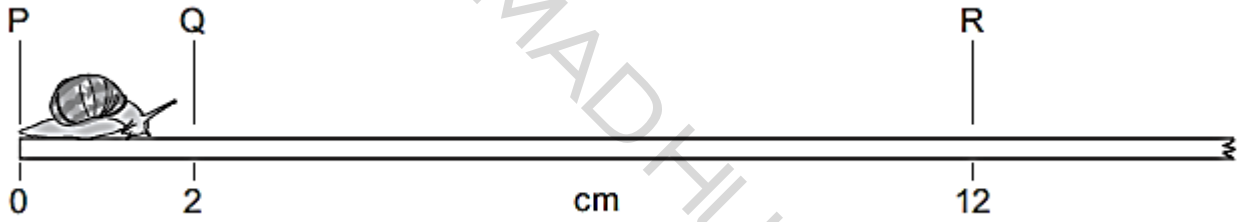
   A. 38 km/h
   B. 50 km/h
   C. 60 km/h
   D. 75 km/h

10. A car travels 100 km. The highest speed of the car is 90 km/h, and the lowest speed is 30 km/h. The journey takes two hours.

    What is the average speed for the journey?

    A. 30 km/h
    B. 50 km/h
    C. 60 km/h
    D. 90 km/h

11. A snail moves along a ruler. It takes 20 s to move from Q to R.



What is its average speed from Q to R?

A $\frac{12}{20}$ cm/s

B $\frac{12-2}{20}$ cm/s

C $\frac{20}{12}$ cm/s

D $\frac{20}{12-2}$ cm/s

B

SPEED, VELOCITY & ACCELERATION

STATE WHAT IS MEANT BY *UNIFORM ACCELERATION* AND CALCULATE THE VALUE OF AN ACCELERATION USING CHANGE IN

VELOCITY/TIME TAKEN.

ACCELERATION

- **Acceleration** is defined as the rate of change of velocity.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time taken}}$$

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

- The SI unit for acceleration is **m/s²**.
- Acceleration is a vector quantity. The direction of acceleration is the direction of change in velocity.

SPEED, VELOCITY & ACCELERATION

RECALL THAT DECELERATION IS A NEGATIVE ACCELERATION

- There is acceleration only when velocity changes.
  - If velocity is constant throughout, there is no acceleration.
  - If the velocity is increasing, the object is said to be accelerating.
  - If the velocity is decreasing, then the object is said to have negative acceleration or **deceleration** or **retardation**.

Problem Solving

1. A car accelerates from rest to 50 m/s in 10 s. Calculates the acceleration of the car.
2. A train, initially moving at 12 m/s, speeds up to 36 m/s in 120 s. What is its acceleration?
3. What is the acceleration of a car that speeds up from 12 m/s to 30 m/s in 15 seconds?

4. A car is uniformly retarded and brought to rest from a speed of 108 m/s in 15 s. Find its acceleration.
5. The driver of a car brakes when the car is travelling at 30 m/s. The velocity of the car is reduced to 10 m/s after 5 s. What is its average acceleration?
6. A sport car accelerates from rest at 4 m/s^2 for 10 seconds. Calculate the final velocity.

7. How fast does a car travel if it is going 4 m/s and accelerates at 3.5 m/s^2 for 5 seconds?
8. If a car is going at 12 m/s, how long will it take to reach a speed of 26 m/s if it accelerates at 2.2 m/s^2?
9. A car moving along a straight level road has an initial speed of 3 m/s and its acceleration is 2 m/s^2. What is the speed of the car after 5 s?
10. If a car can accelerate at 3.2 m/s^2, how long will it take to speed up from 15 m/s to 22 m/s?

SPEED, VELOCITY & ACCELERATION

DISCUSS NON-UNIFORM ACCELERATION.

Uniform Acceleration

- The acceleration is not changing or it is constant.
  - Lets say a car is moving with an uniform acceleration of 10 m/s^2 . It means its acceleration is not changing as time is passing. Although the speed is changing, the change in speed is also constant. That is each second the speed will change by 10 m/s. In short uniform acceleration means same acceleration throughout.

Non-Uniform Acceleration

- The acceleration is changing. It may increase or decrease.
  - Consider a car is accelerating with 10 m/s^2, suddenly during a turn he reduce the acceleration a bit to 8 m/s^2 and again in a straight road he increased it to 15 m/s^2. So the car is not accelerating at a same speed. It is increasing or decreasing depending on needs. In terms of speed it is definitely changing as when acceleration occurs then definitely speed changes. But the change is not constant. Lets say his speed increased by 10 m/s in the first journey , then 8 m/s and then it changed by 15 m/s the next minute.

1. What must change when a body is accelerating?
   A. the force acting on the body
   B. the mass of the body
   C. the speed of the body
   D. the velocity of the body

2. Which of the following **defines** acceleration?

A $\frac{\text{change in velocity}}{\text{time taken}}$

B $\frac{\text{change in speed}}{\text{time taken}}$

C $\frac{\text{change in distance}}{\text{time taken}}$

D $\frac{\text{change in distance in a fixed direction}}{\text{time taken}}$

A

3. Which quantity X is calculated using this equation?

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

A. acceleration
B. average velocity
C. distance travelled
D. speed

4. A car is brought to rest in 5 s from a speed of 10 m/s.

   What is the average deceleration of the car?

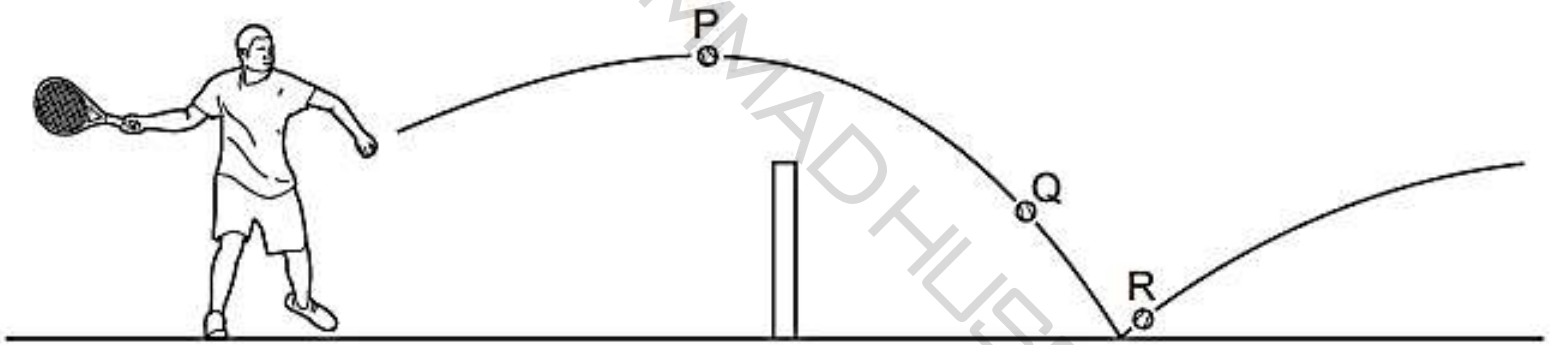
   A. 0.5 m/s^2
   B. 2 m/s^2
   C. 15 m/s^2
   D. 50 m/s^2

5. A student measures the speed of a trolley. At one instant, the speed of the trolley is 1.0 m/s and two seconds later the speed is 4.0 m/s.

   What is the acceleration of the trolley?

   A. 1.5 m/s^2
   B. 2.0 m/s^2
   C. 2.5 m/s^2
   D. 5.0 m/s^2

5. A tennis player hits a ball over the net.



In which position is the ball accelerating?

A. P and Q only
B. P and R only
C. Q and R only
D. P, Q and R

GRAPHICAL ANALYSIS OF MOTION

PLOT AND INTERPRET SPEED-TIME AND DISTANCE-TIME GRAPHS.

GRAPHICAL ANALYSIS OF MOTION

RECOGNISE FROM THE SHAPE OF A SPEED-TIME GRAPH WHEN A BODY IS

(1) AT REST,

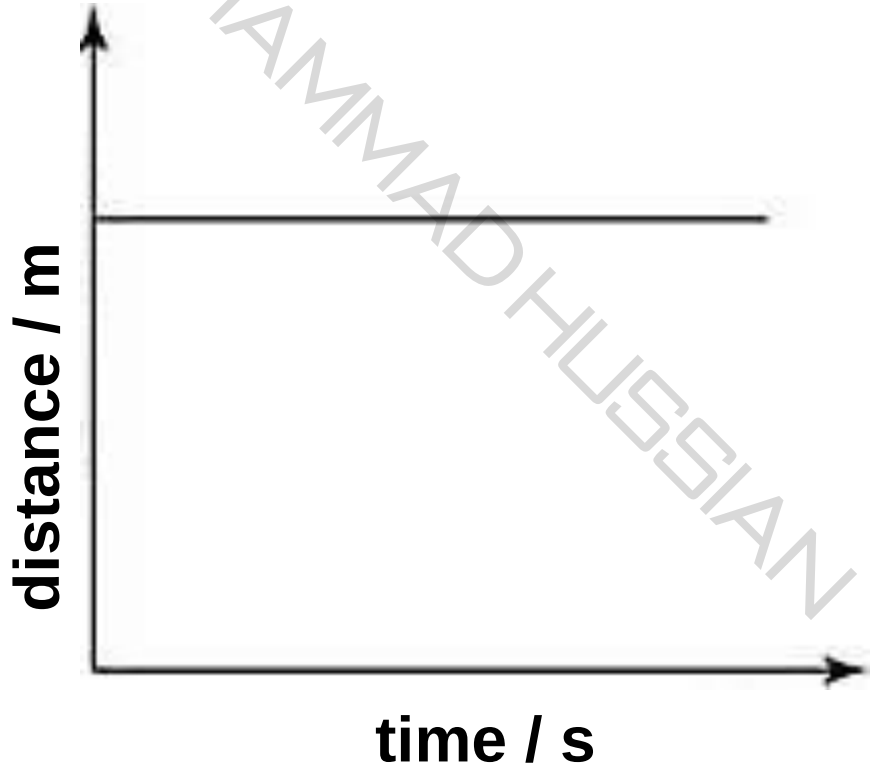
(2) MOVING WITH UNIFORM SPEED,

(3) MOVING WITH UNIFORM ACCELERATION,

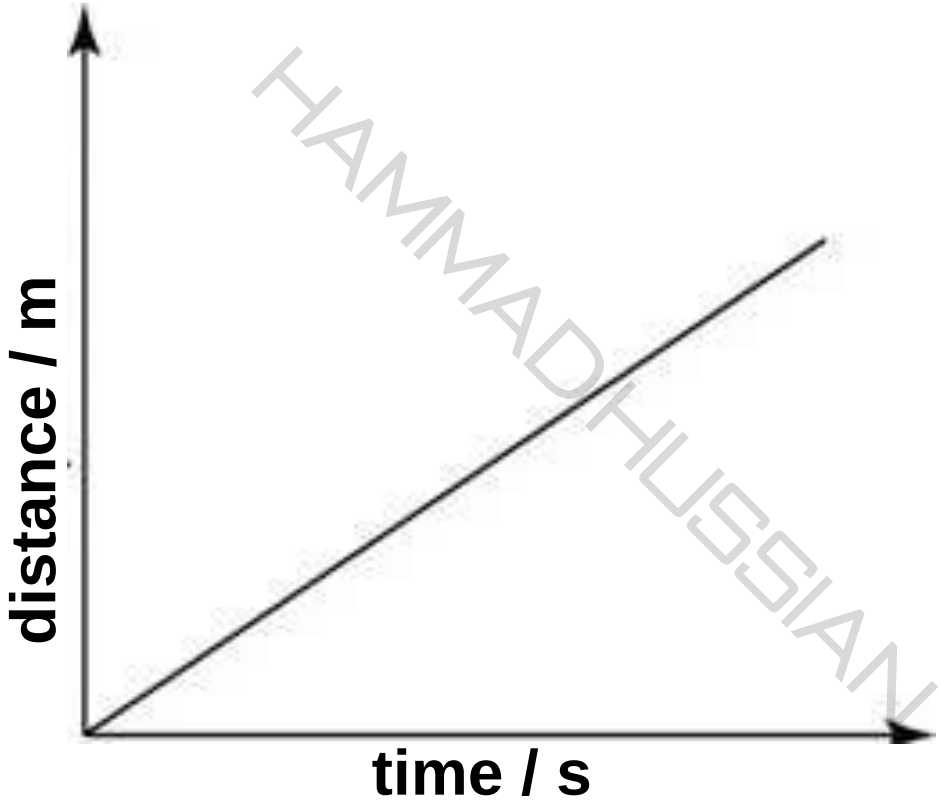
(4) MOVING WITH NON-UNIFORM ACCELERATION.

Distance – Time Graph

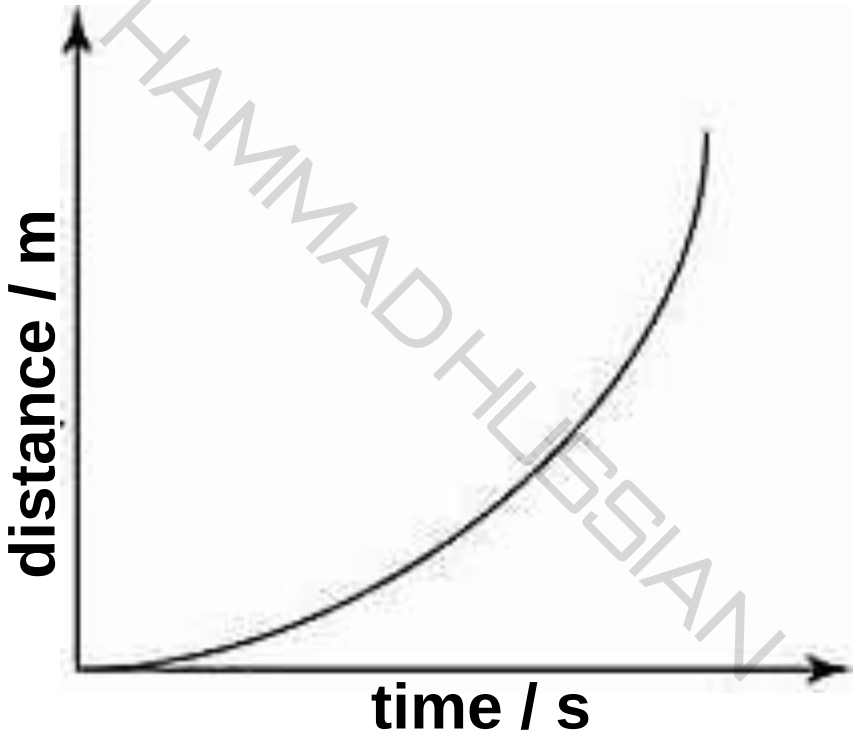
At rest



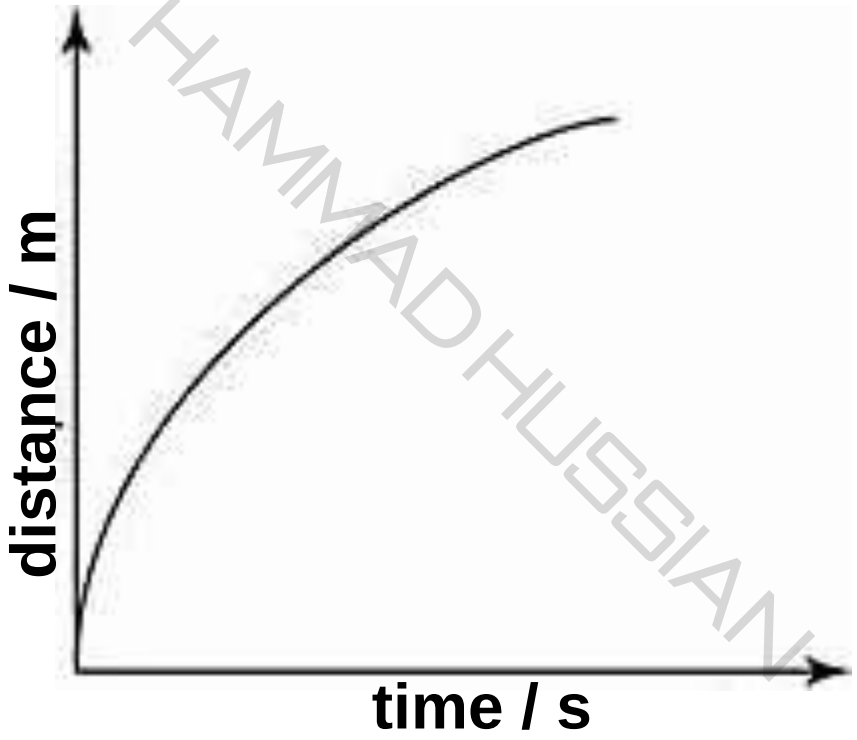
UNIFORM VELOCITY



ACCELERATION

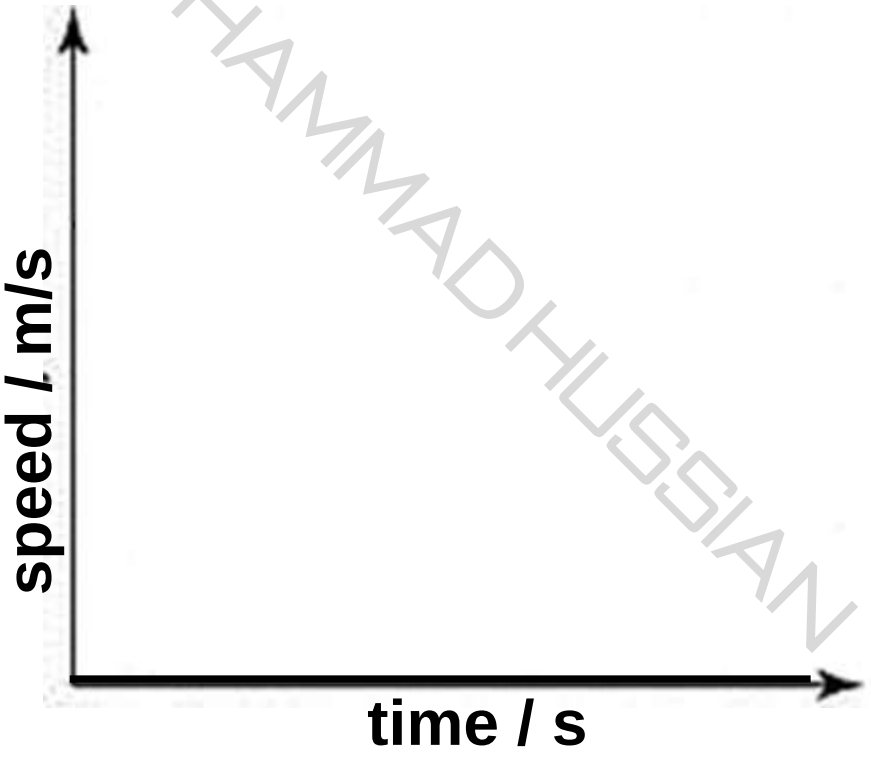


DECELERATION

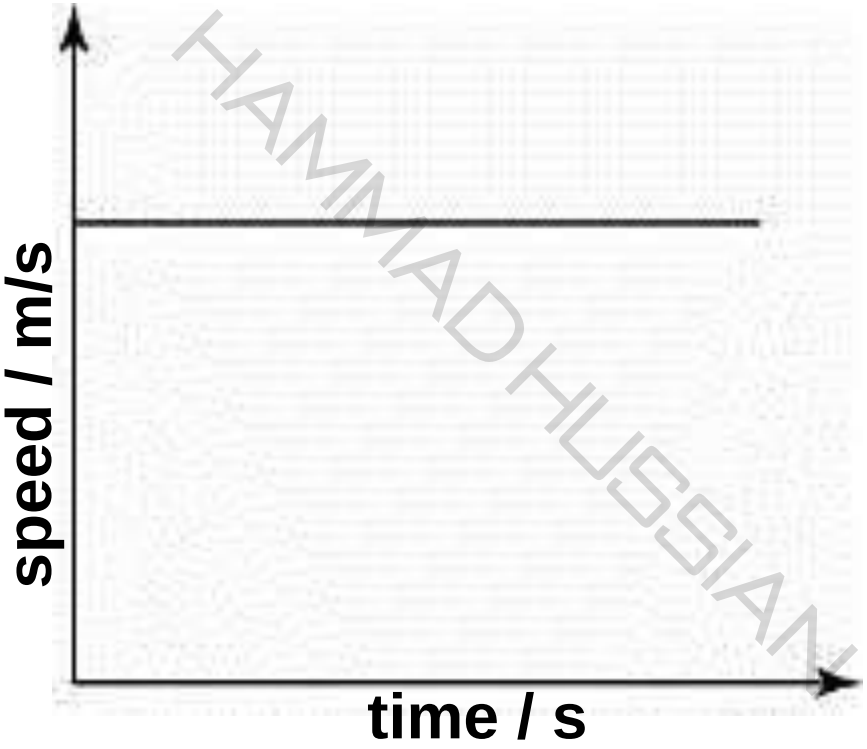


Speed - Time Graph

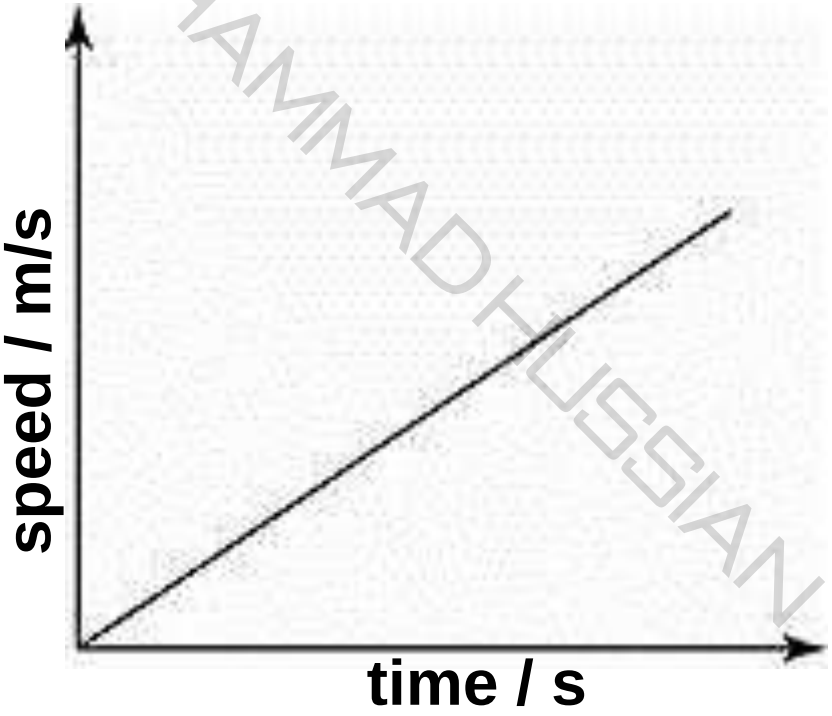
At rest



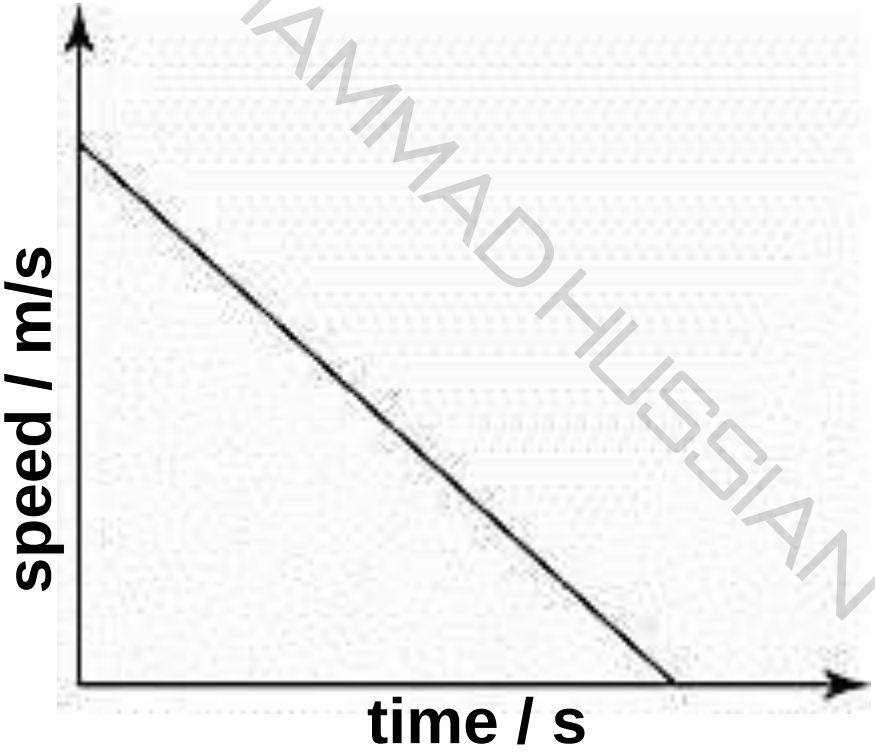
UNIFORM VELOCITY



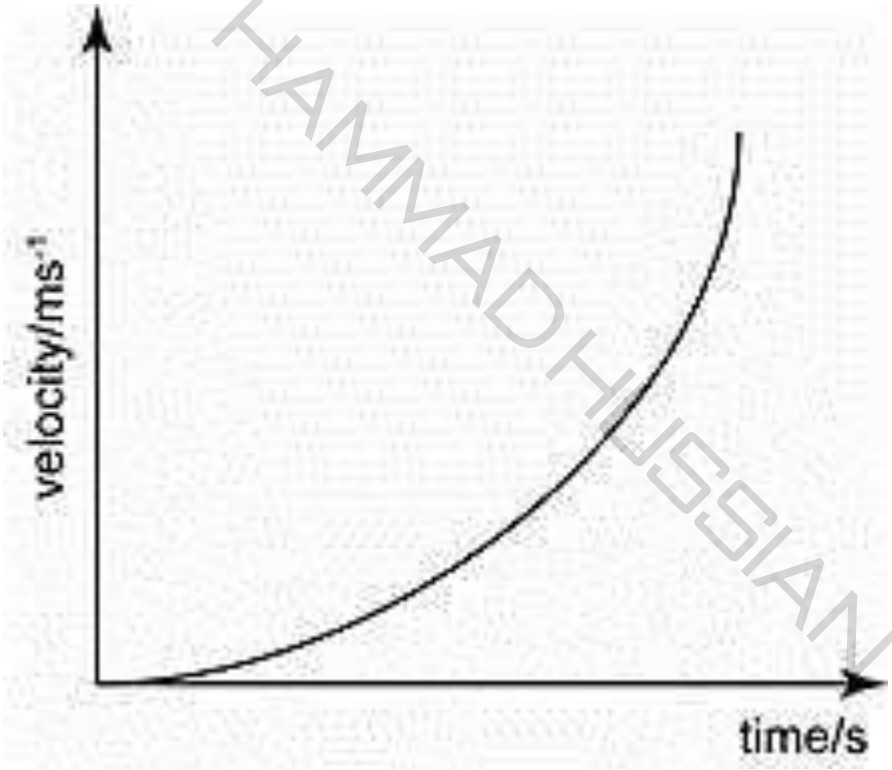
UNIFORM ACCELERATION



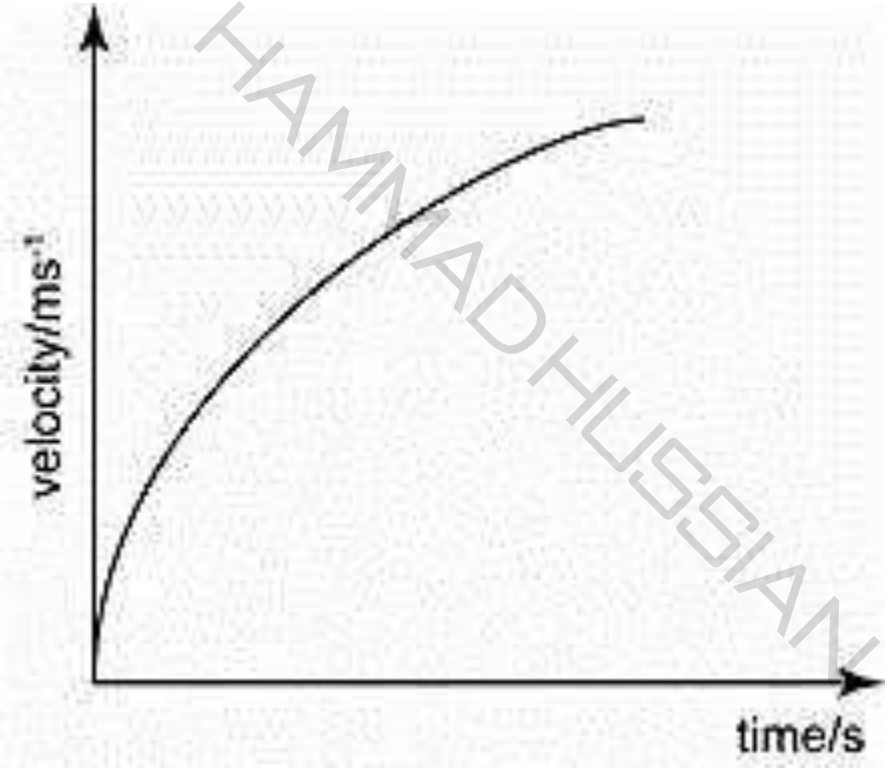
Uniform deceleration



NON-UNIFORM ACCELERATION



Non- uniform deceleration

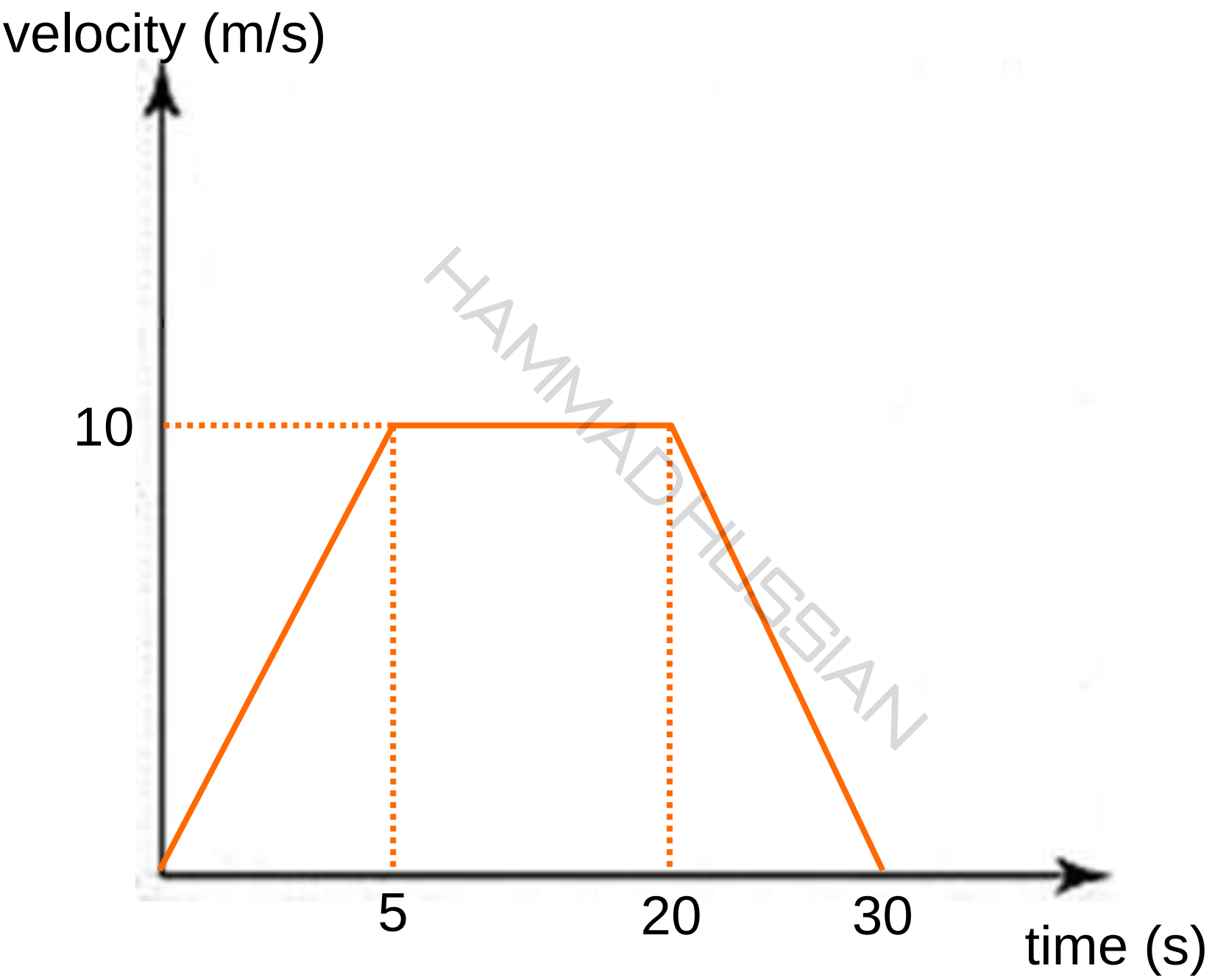


INTERPRETING GRAPH

- From the displacement-time graph
  - Its gradient gives the velocity of the moving object.
- From velocity-time graph
  - Its gradient gives the acceleration of the moving object.
    - the acceleration is slower because the slope is less steep
    - the acceleration is negative because the slope is downwards.
  - The area under the graph gives the distance travelled by the object

Problem Solving 4

- A cyclist started from rest achieved a speed of 10 m/s^1 in 5 s. He then cycled at this speed constantly for the next 15 s. Finally he decelerate to complete his 30 s journey.
  1. Sketch a velocity-time graph for the whole journey?
  2. Calculate his deceleration in the last 10 seconds of the journey.
  3. Calculate the distance that he travelled during the journey.

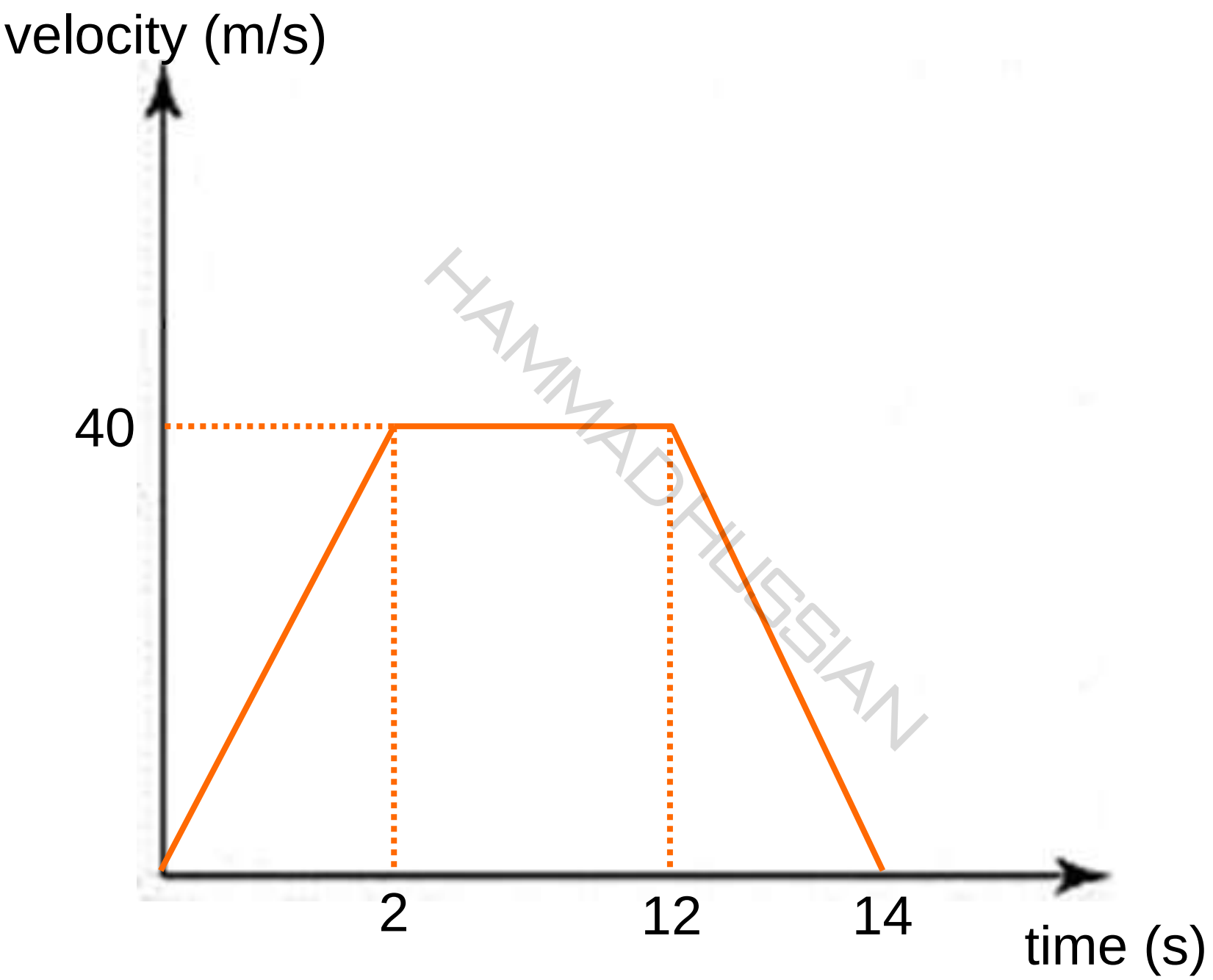


EXAMPLE 5

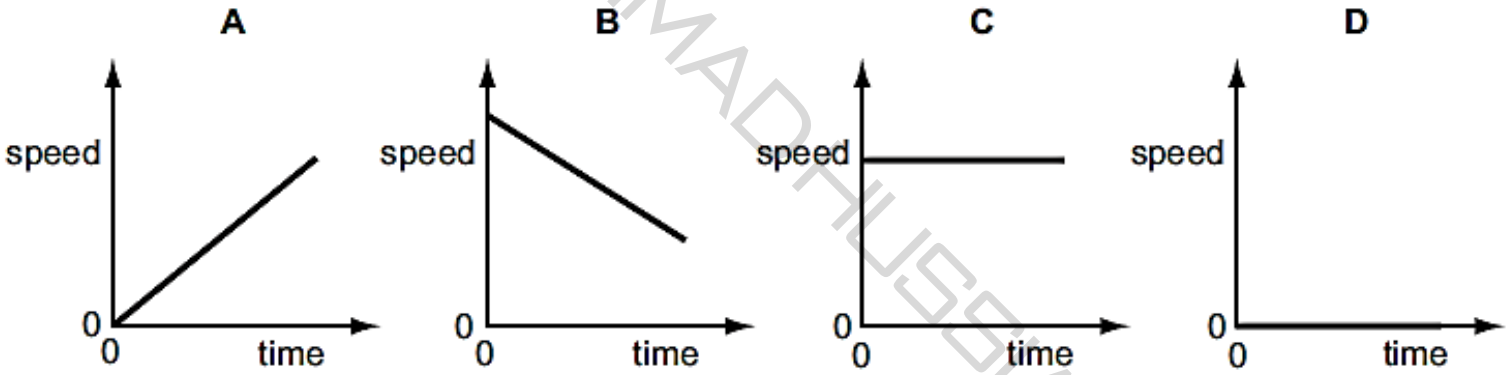
- A locomotive pulling a train out from one station travels along a straight horizontal track towards another station. The following describe the velocity of the train varies with time over the whole journey.
  - It started from rest and gain a speed of 40 ms^{-1} in 2 s.
  - It then travel with this speed constantly for 10 s.
  - Finally it decelerates and reach the other station within 2 s.

EXAMPLE 5

- Using the information given
  1. Sketch a velocity-time graph for this journey.
  2. Find
     1. the acceleration of the train in the first 2 s.
     2. the total distance travel between the two stations.
     3. the average velocity of the train.



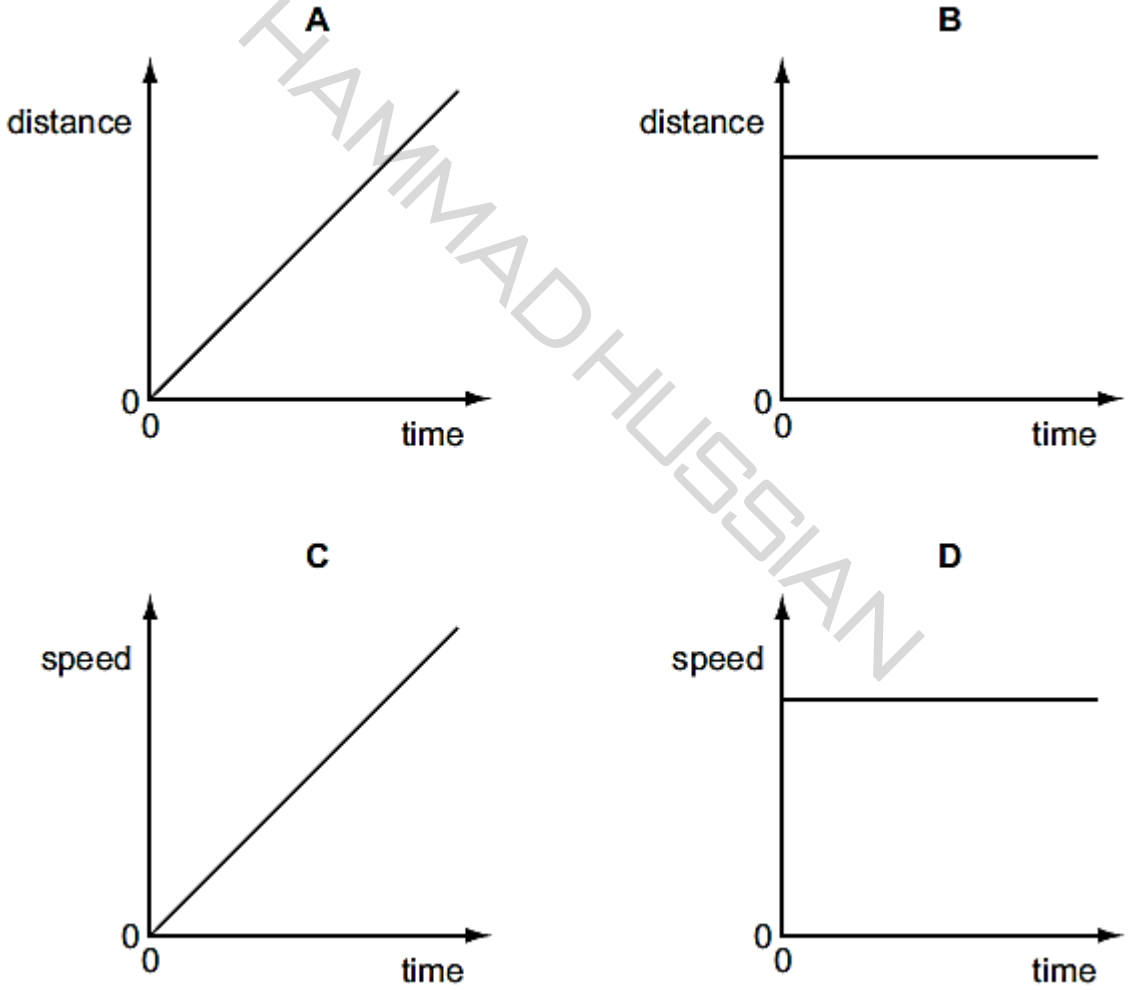
1. Which speed / time graph applies to an object at rest?



D

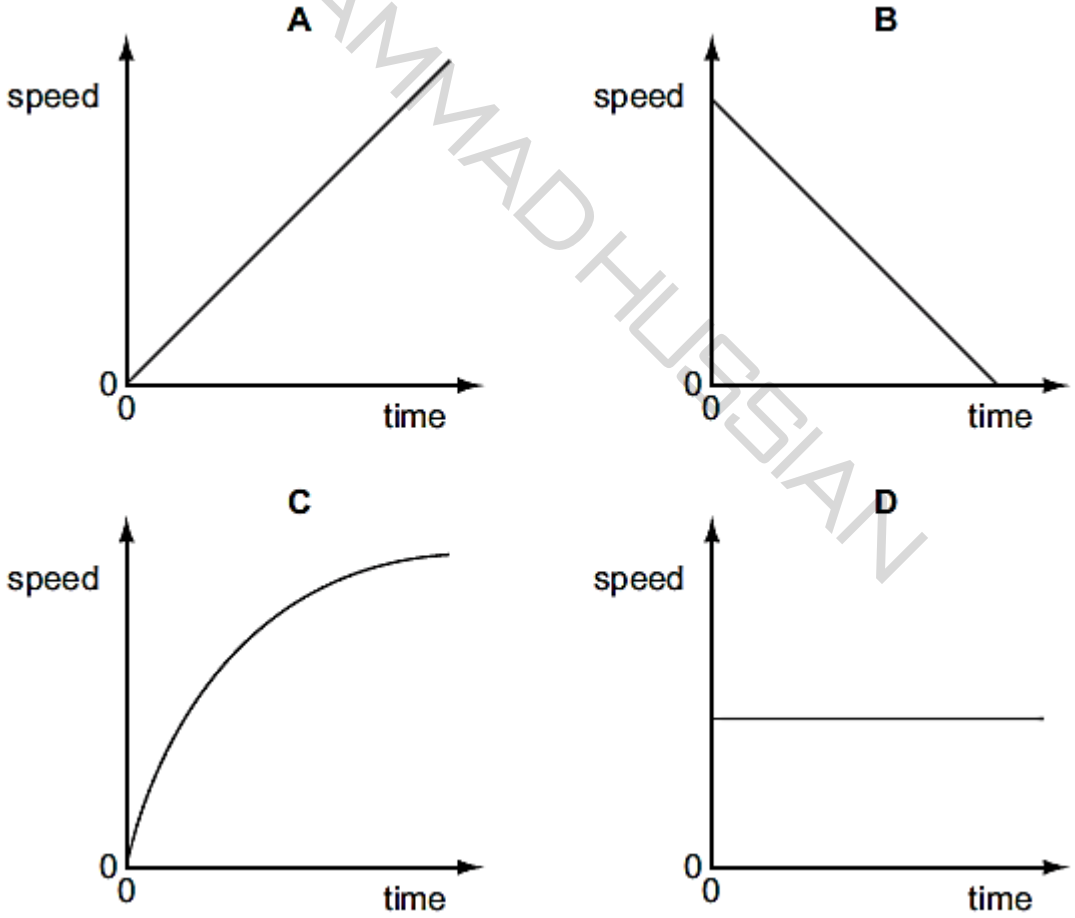
2. Two distance/time graphs and two speed/time graphs are shown.

Which graph represents an object that is at rest?



B

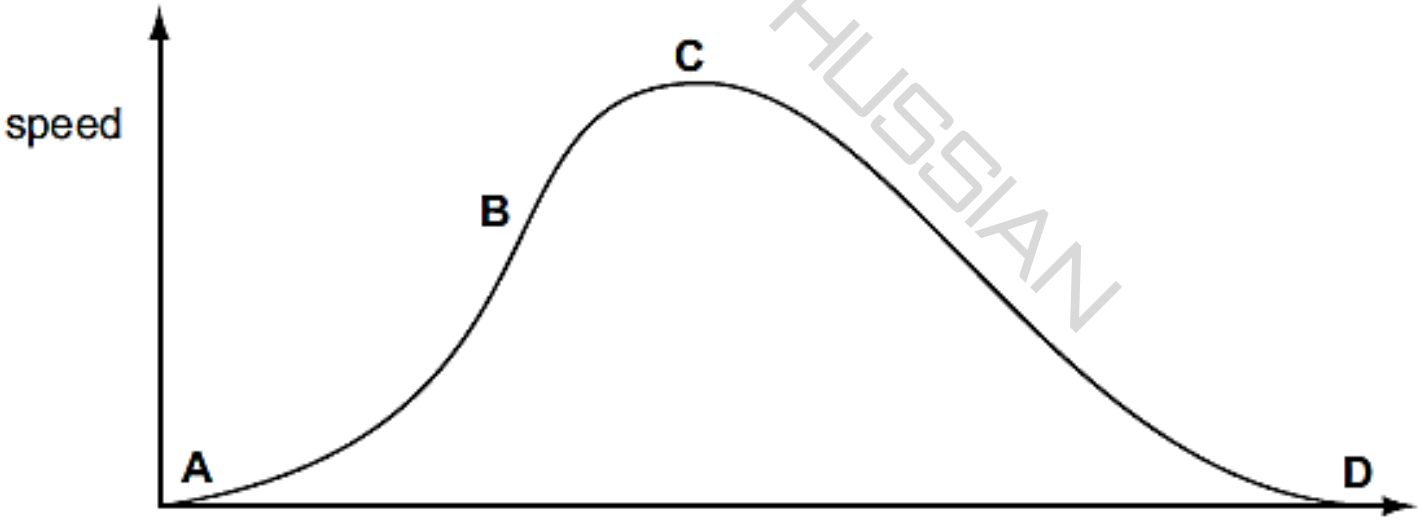
3. Which speed-time graph shows an object moving with non-uniform acceleration?



C

4. The speed-time graph shown is for a bus travelling between stops.

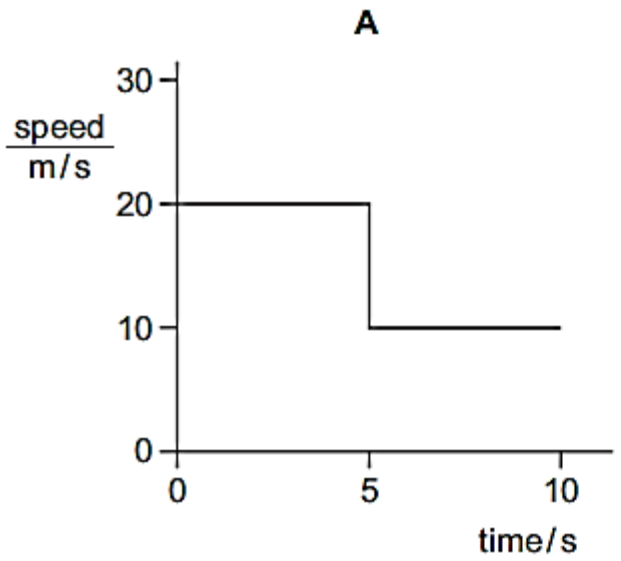
   Where on the graph is the acceleration of the bus the greatest?

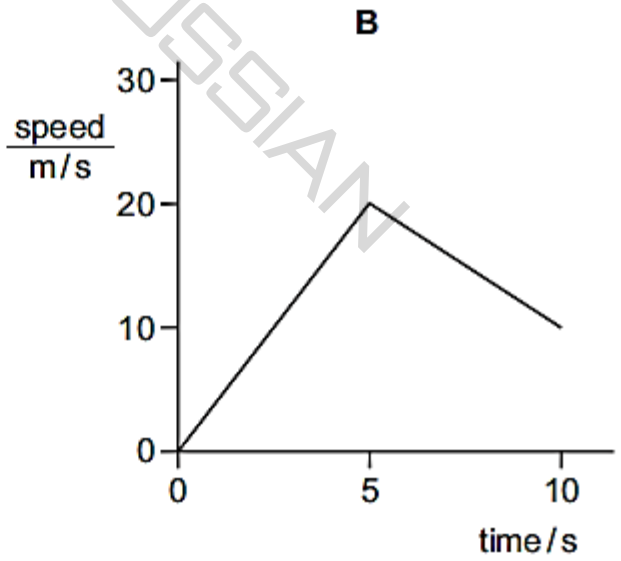


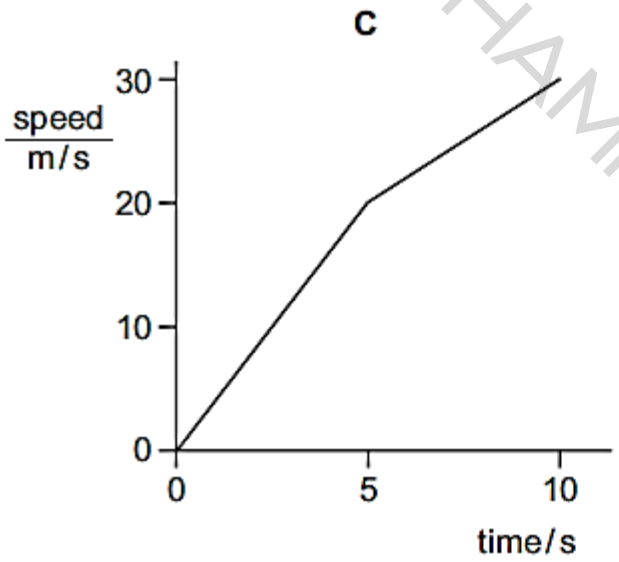
B

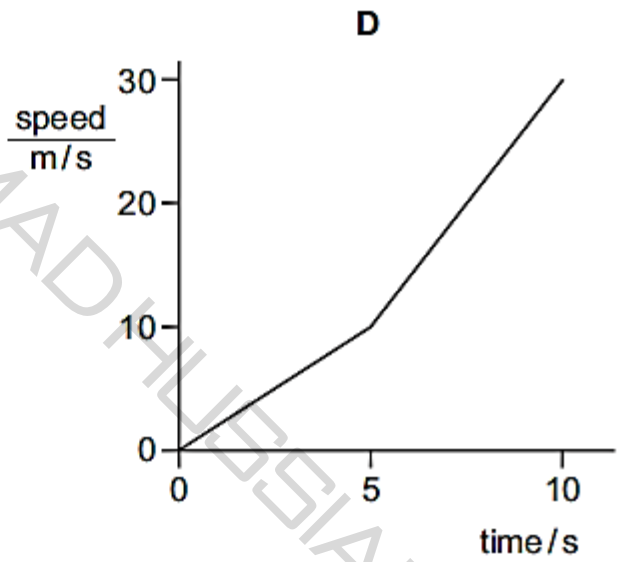
5. A skier is travelling downhill. The acceleration on hard snow is 4 m/s^2 and on soft snow is 2 m/s^2.

   Which graph shows the motion of the skier when moving from hard snow to soft snow?





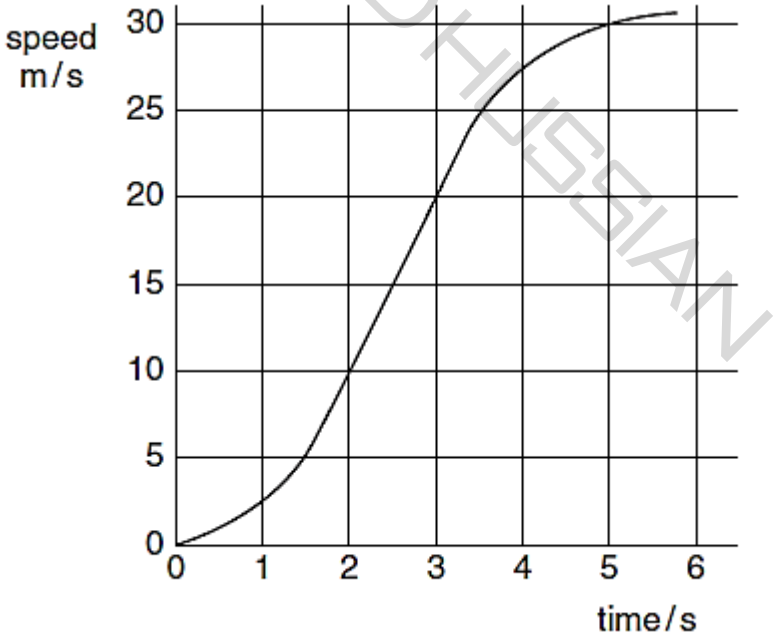




C

6. The graph shows the speed of a car as it accelerates from rest.

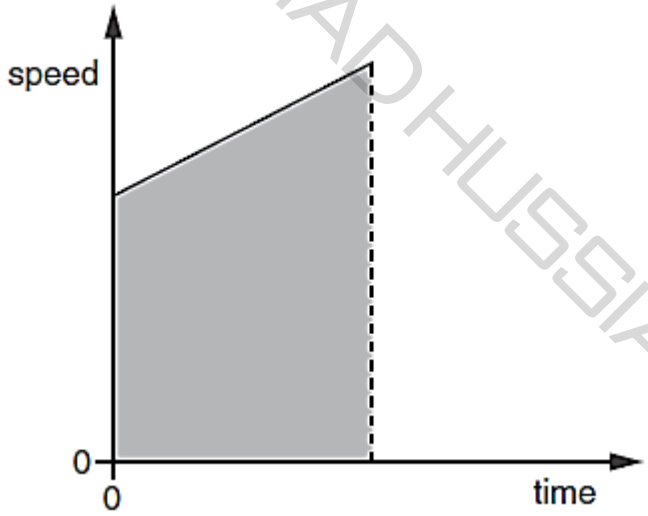
   During part of this time the acceleration is uniform.



What is the size of this uniform acceleration?

A. 5 m/s^2
B. 6 m/s^2
C. 10 m/s^2
D. 20 m/s^2

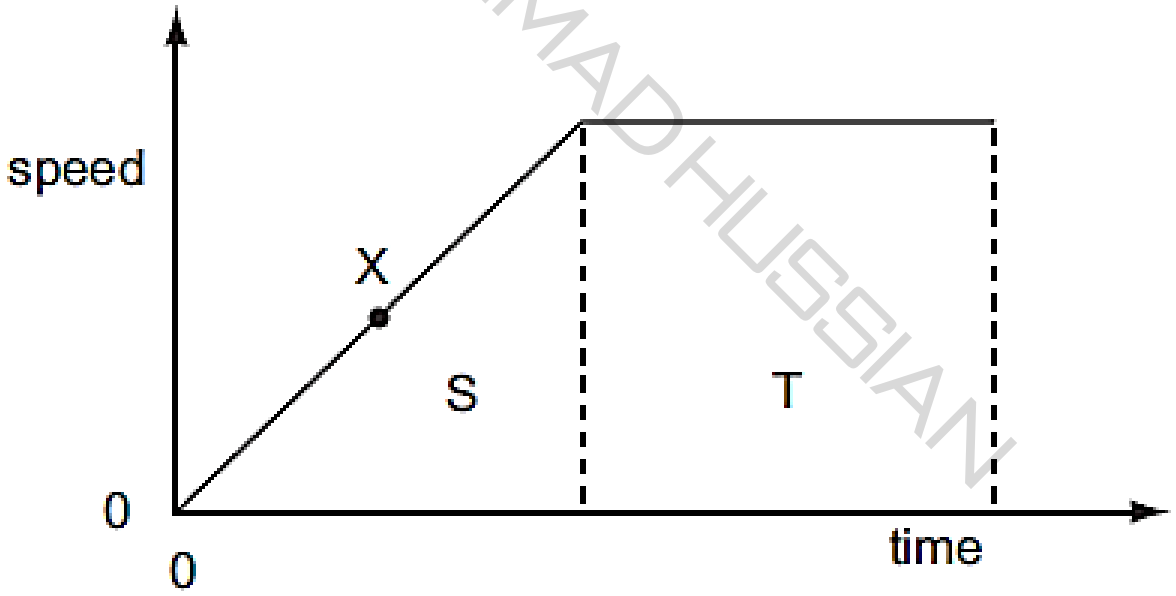
7. The diagram shows a speed-time graph for a body moving with constant acceleration.



What is represented by the shaded area under the graph?

A. acceleration
B. distance
C. speed
D. time

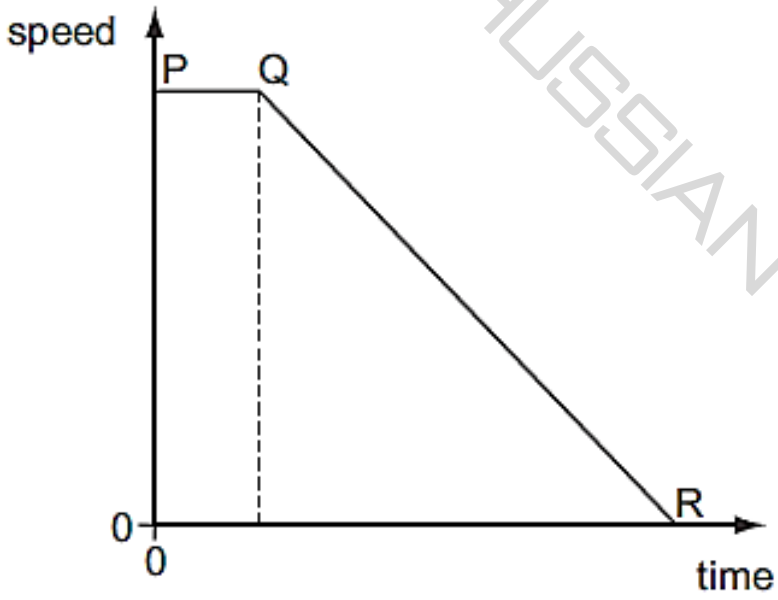
8. The graph illustrates the motion of an object.



Which feature of the graph represents the distance travelled by the object whilst moving at a constant speed?

A. area S
B. area S + area T
C. area T
D. the gradient at point X

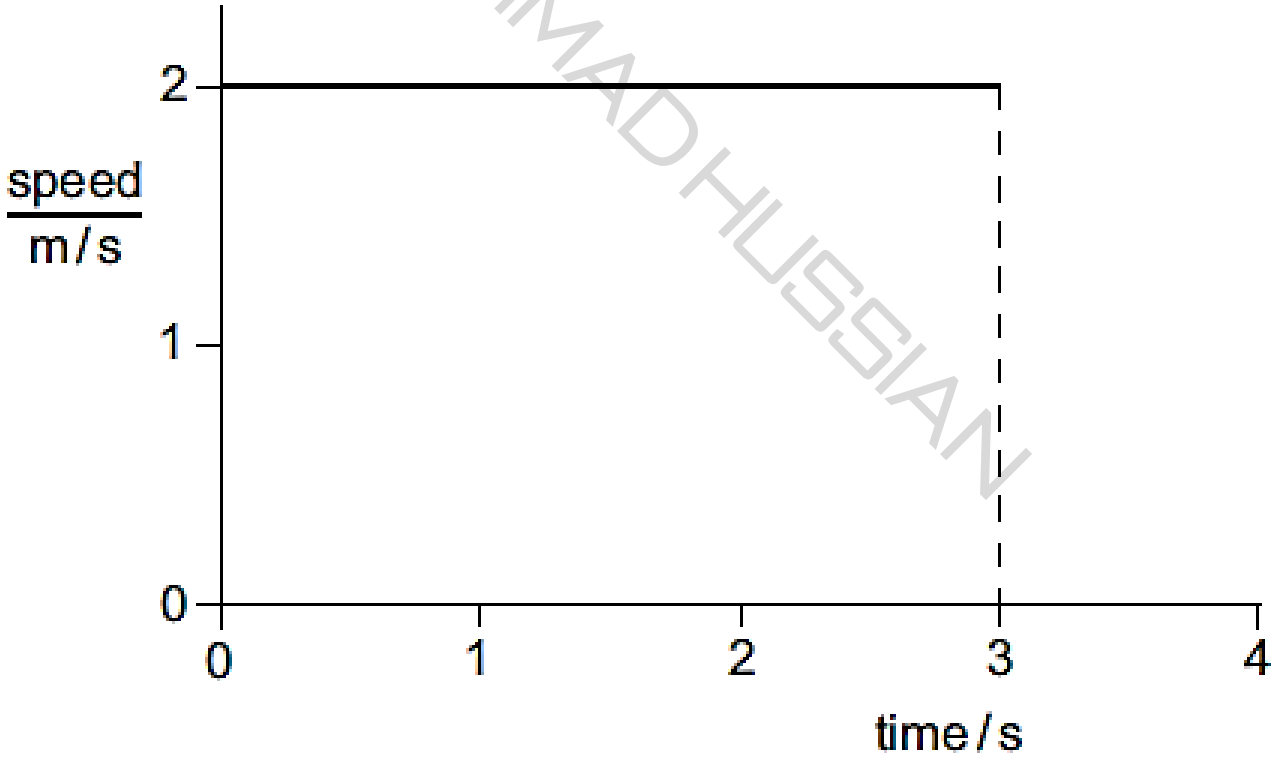
9. A cyclist is riding along a road when an animal runs in front of him. The graph shows the cyclist's motion. He sees the animal at P, starts to brake at Q and stops at R.



What is used to find the distance travelled after he applies the brakes?

A. the area under line PQ
B. the area under line QR
C. the gradient of line PQ
D. the gradient of line QR

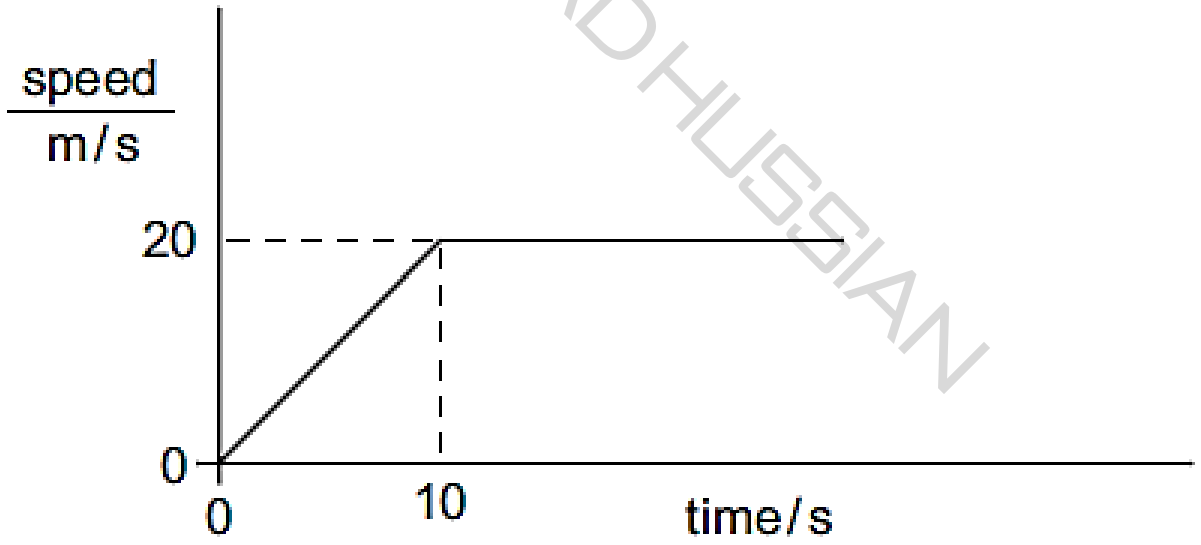
10. The diagram shows the speed-time graph for an object moving at constant speed.



What is the distance travelled by the object in the first 3 s?

A. 1.5 m
B. 2.0 m
C. 3.0 m
D. 6.0 m

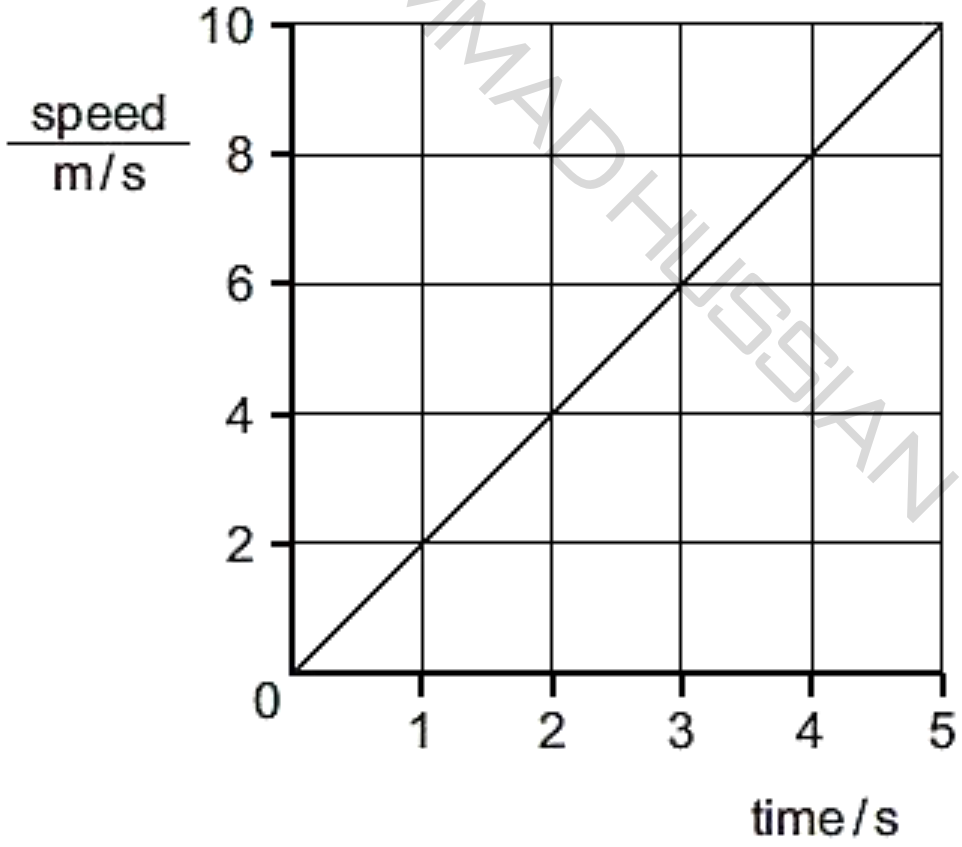
11. A car accelerates from traffic lights. The graph shows how the car's speed changes with time.



How far does the car travel before it reaches a steady speed?

A. 10 m
B. 20 m
C. 100 m
D. 200 m

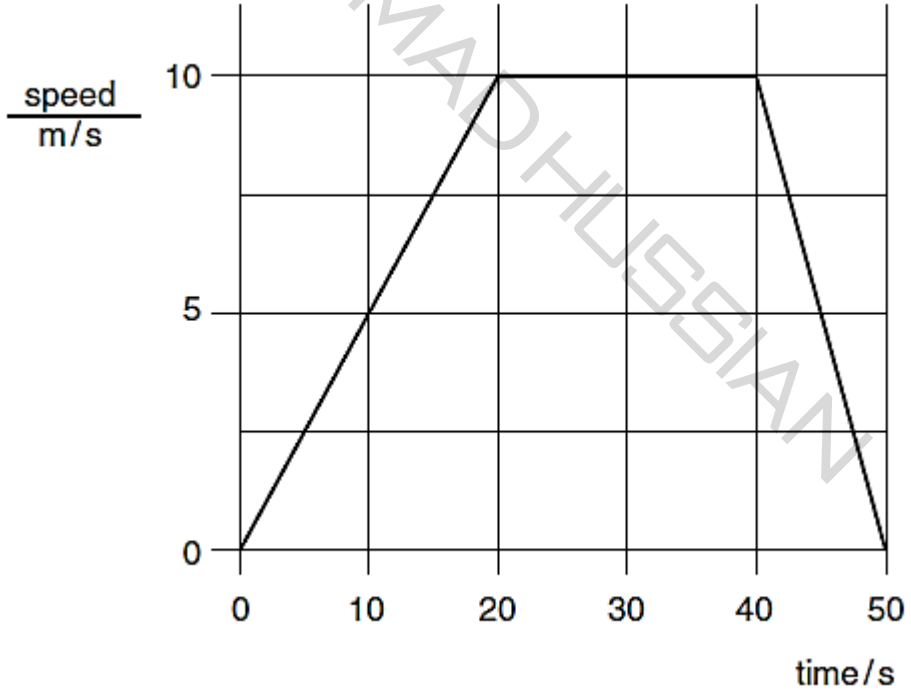
12. The graph represents the movement of a body accelerating from rest.



After 5 seconds how far has the body moved?

A. 2 m
B. 10 m
C. 25 m
D. 50 m

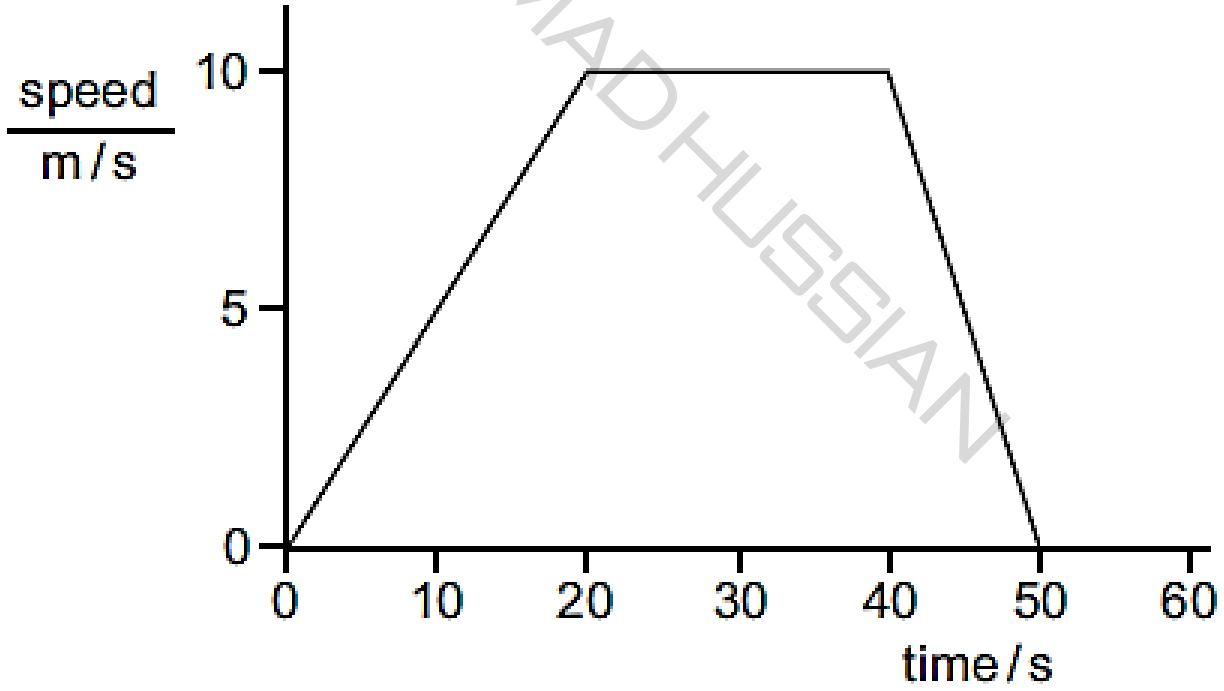
13. The graph shows the movement of a car over a period of 50 s.



What was the distance travelled by the car during the time when it was moving at a steady speed?

A. 10 m
B. 100 m
C. 200 m
D. 400 m

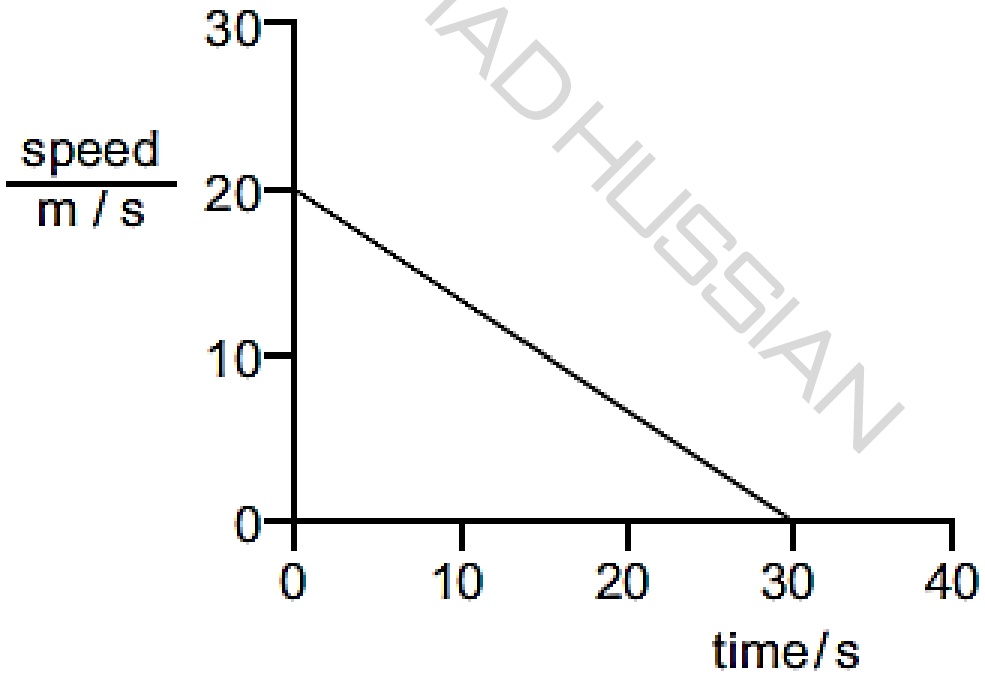
14. The graph shows the movement of a car over a period of 50 s.



What was the distance travelled by the car while its speed was increasing?

A. 10 m
B. 20 m
C. 100 m
D. 200 m

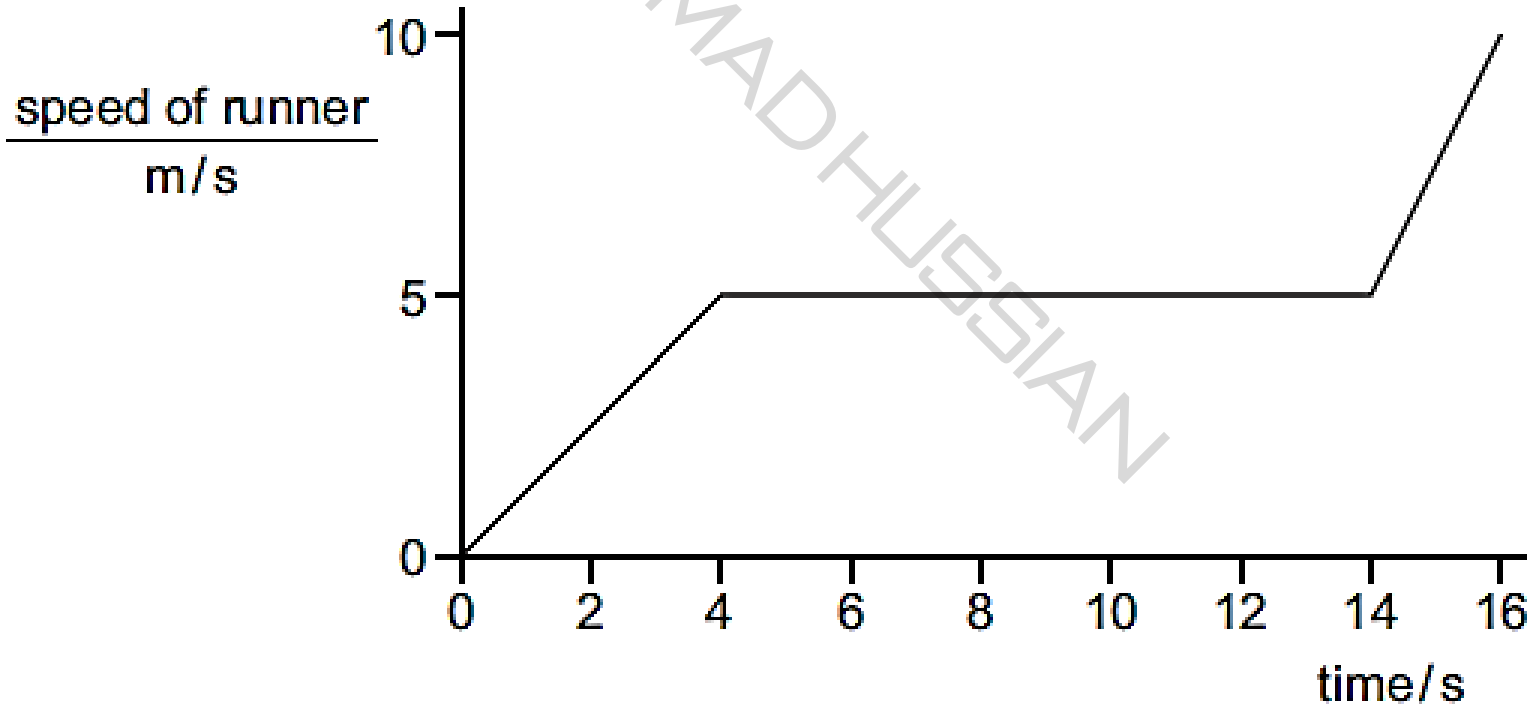
15. The graph represents part of the journey of a car.



What distance does the car travel during this part of the journey?

A. 150 m
B. 300 m
C. 600 m
D. 1200 m

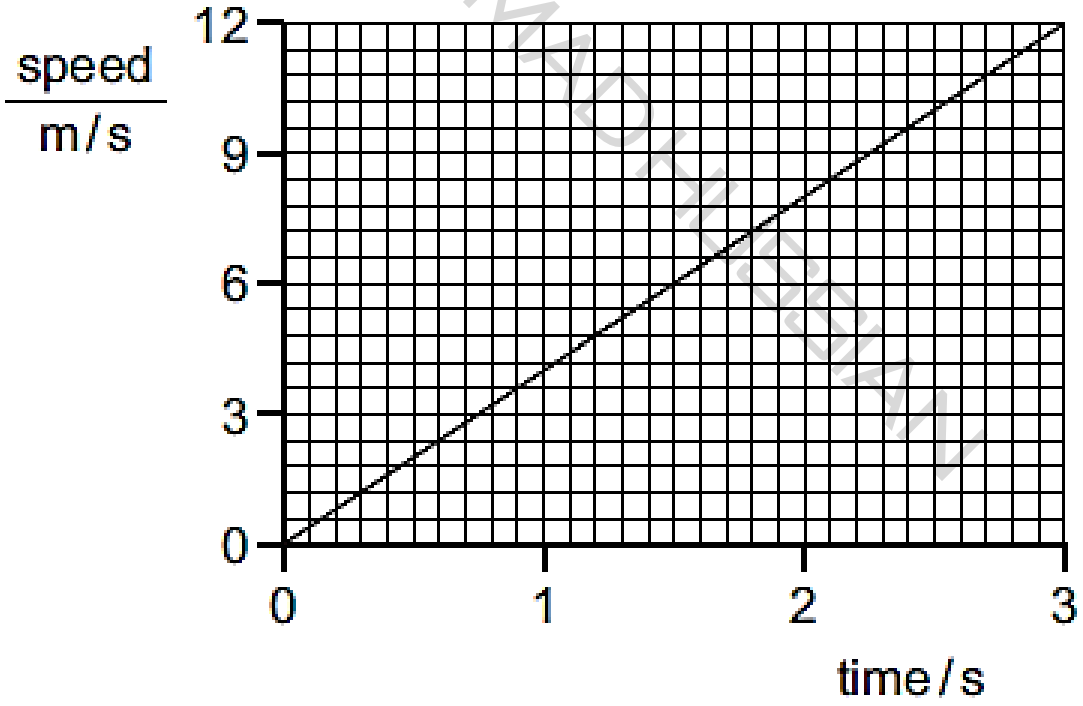
16. The graph shows the speed of a runner during a race.



What is the distance travelled by the runner during the race?

A. 50 m
B. 65 m
C. 75 m
D. 90 m

17. The graph shows the speed of a car as it moves from rest.



What is the average speed of the car during the first 3 s?

A. 4 m/s
B. 6 m/s
C. 18 m/s
D. 36 m/s

Free fall

STATE THAT THE ACCELERATION OF FREE-FALL FOR A BODY NEAR TO THE EARTH IS CONSTANT AND IS APPROXIMATELY 10 M/S^2.

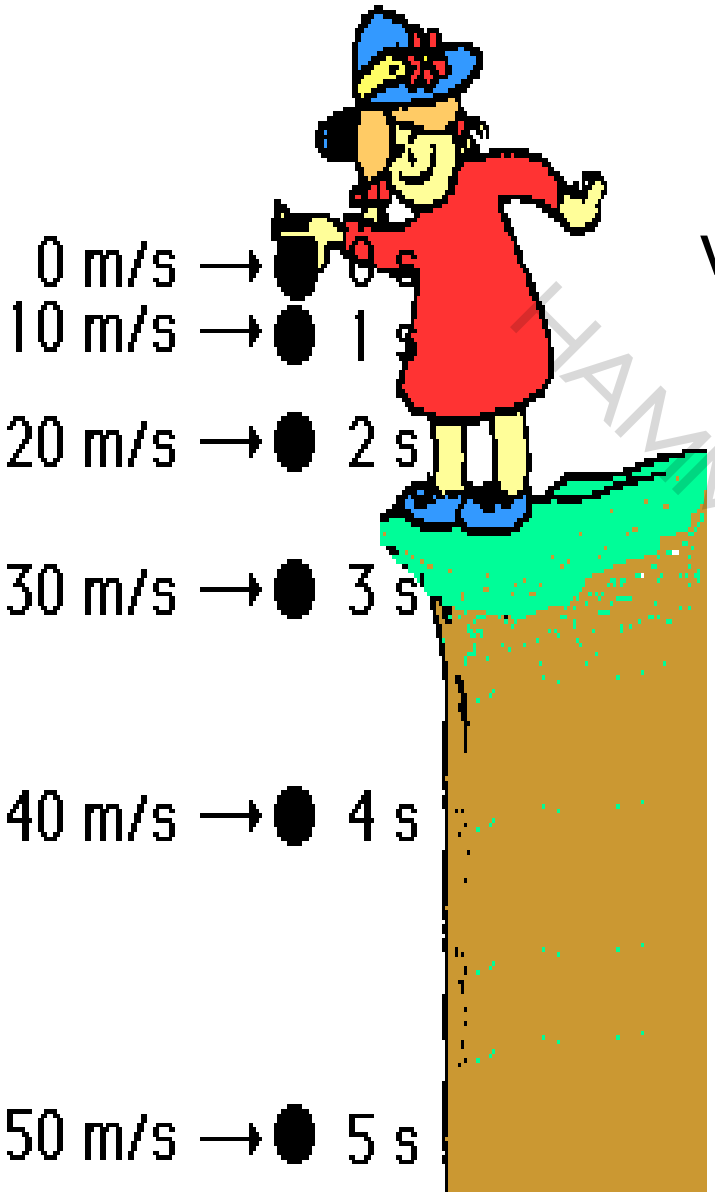
Free fall

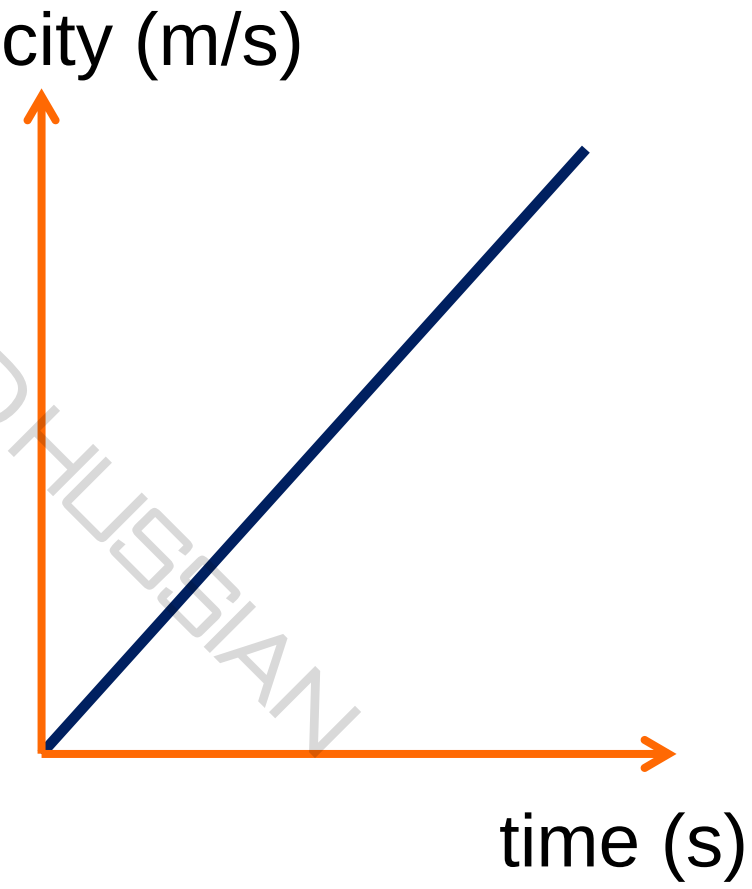
110

DESCRIBE QUALITATIVELY THE MOTION OF BODIES WITH CONSTANT WEIGHT FALLING WITH AND WITHOUT AIR RESISTANCE (INCLUDING REFERENCE TO TERMINAL VELOCITY).

Falling freely

- Any object that is being acted upon only by the force of gravity is said to be in a state of **free fall**.
- There are three important motion characteristics that are true of free-falling objects:
  - Free-falling objects do not encounter air resistance.
  - All free-falling objects (on Earth) accelerate downwards at a rate of 10 m/s^2.
  - Not affected by mass and shape of the object.





SKYDIVING

At the start of his jump the air resistance is zero so he accelerate downwards.

SKYDIVING

As his speed increases his air resistance will also increase

SKYDIVING

Eventually the air resistance will be big enough to balance the skydiver's weight.

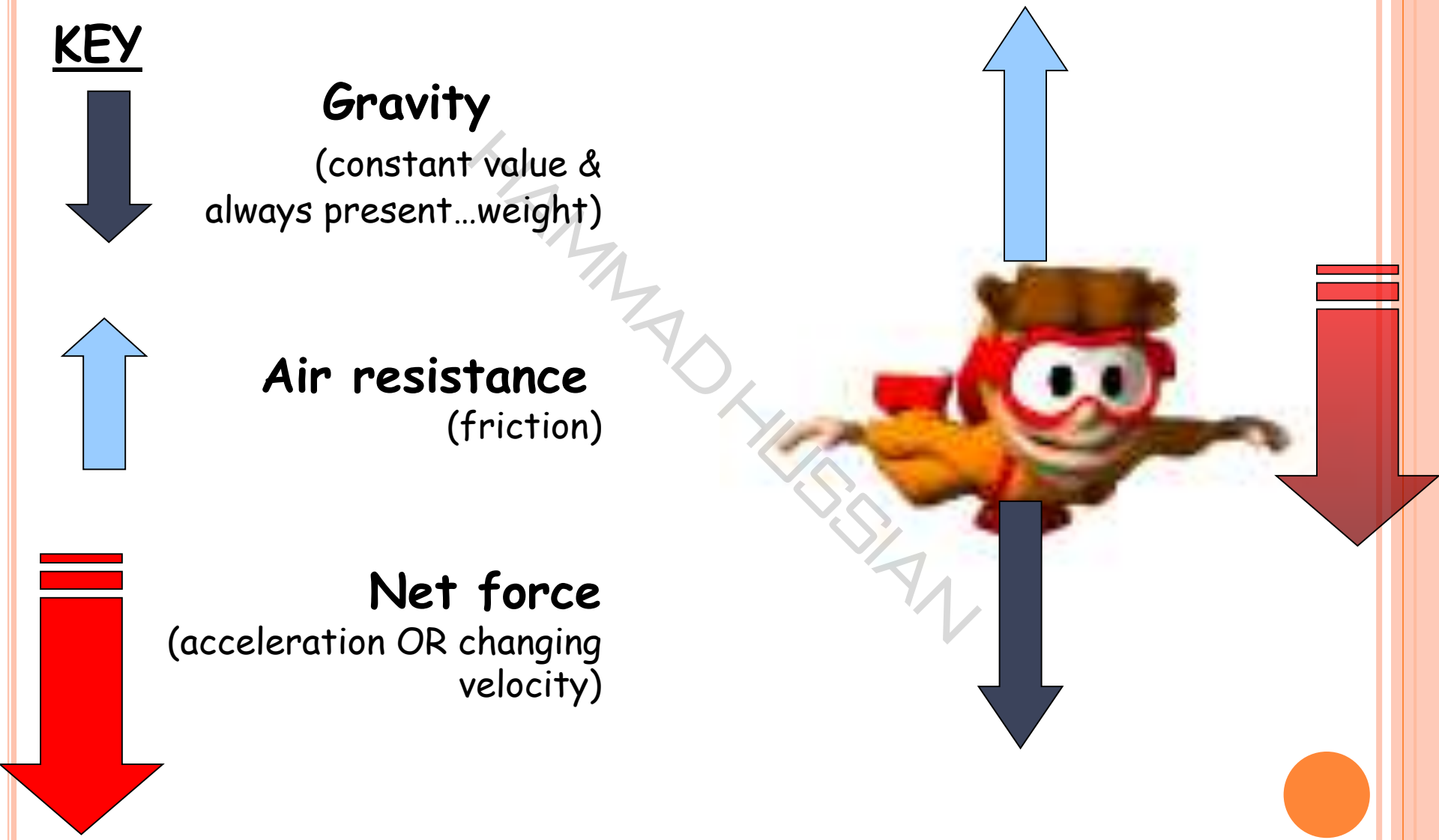
How the forces change with time.

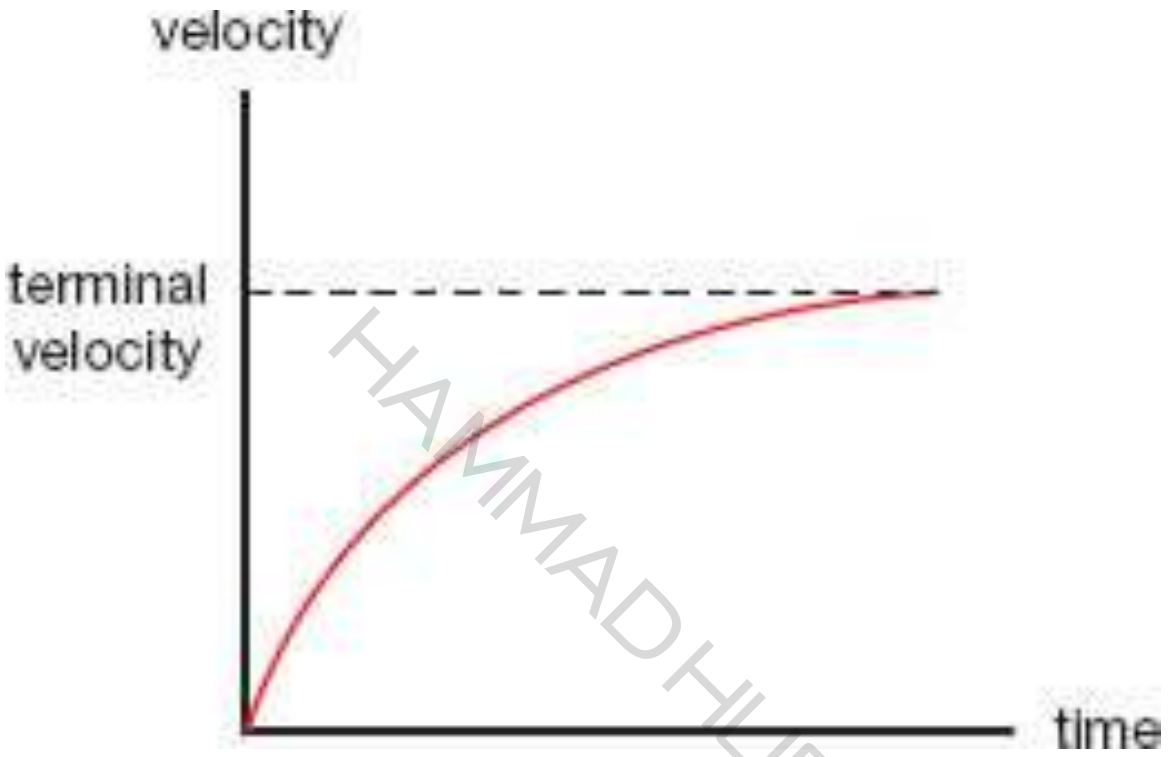
KEY

Gravity
(constant value & always present…weight)

Air resistance
(friction)

Net force
(acceleration OR changing velocity)



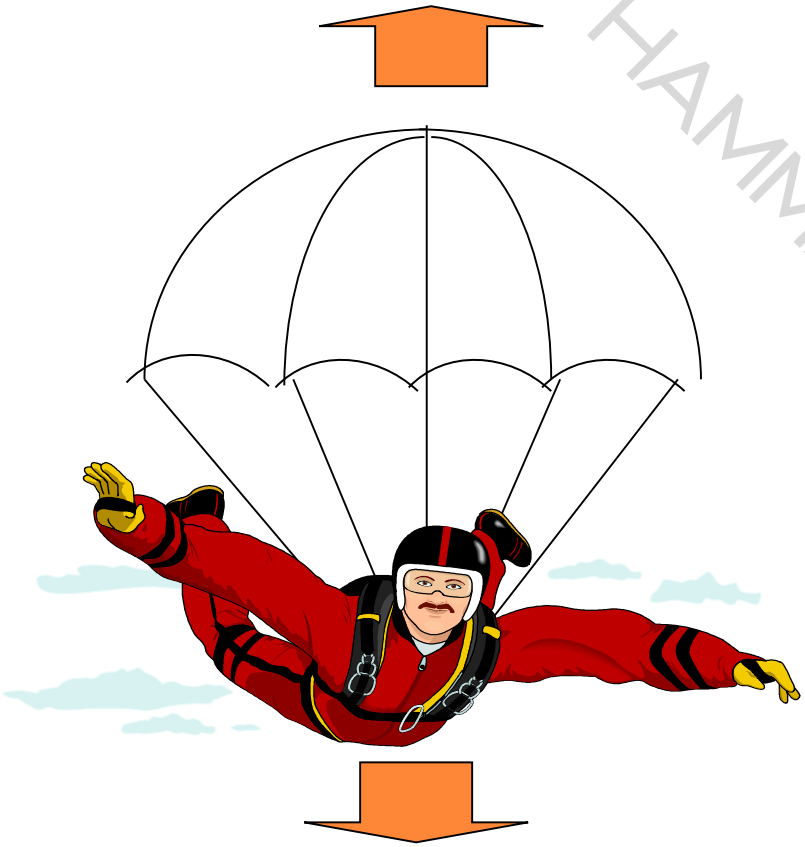


- The size of the air resistance on an object depends on the area of the object and its speed;
  - the larger the area, the larger the air resistance.
  - the faster the speed, the larger the air resistance.

SKYDIVING

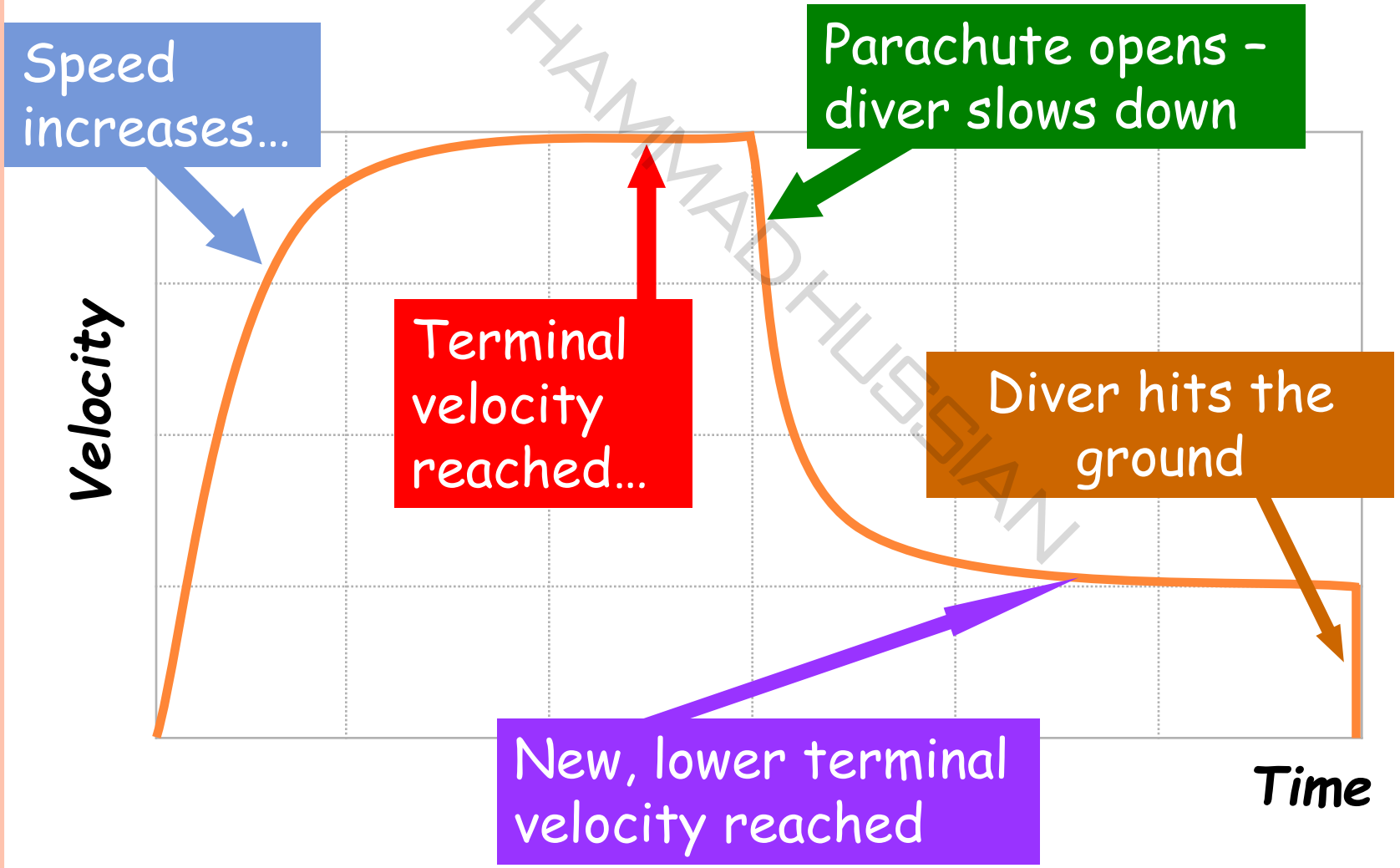
When he opens his parachute the air resistance suddenly increases, causing him to start slow down.

SKYDIVING



Because he is slowing down his air resistance will decrease until it balances his weight. The skydiver has now reached a new, lower terminal velocity.

Velocity-time graph for the sky diver



1. A small steel ball is dropped from a low balcony. Ignoring air resistance, which statement describes its motion?
   A. It falls with constant acceleration.
   B. It falls with constant speed.
   C. It falls with decreasing acceleration.
   D. It falls with decreasing speed.

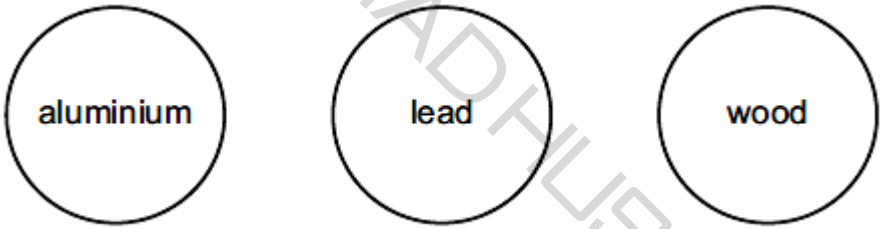
2. Two stones of different weight fall at the same time from a table. Air resistance may be ignored.

What will happen and why?

	what will happen	why
A	both stones hit the floor at the same time	the acceleration of free fall is constant
B	both stones hit the floor at the same time	they fall at constant speed
C	the heavier stone hits the floor first	acceleration increases with weight
D	the heavier stone hits the floor first	speed increases with weight

A

3. The three balls shown are dropped from a bench. Which balls have the same acceleration?



A. alumin
B. aluminium and wood only
C. lead and wood only
D. aluminium, lead and wood

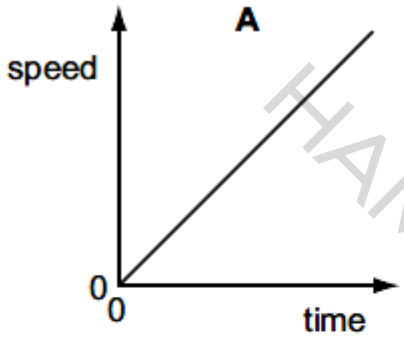
4. A student drops a table-tennis ball in air.

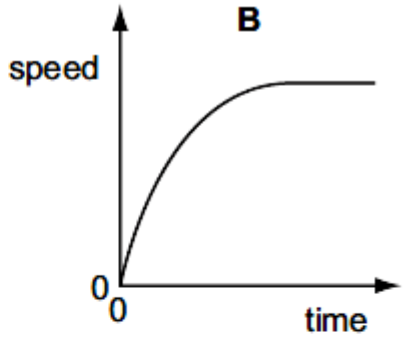
What happens to the velocity and to the acceleration of the ball during the first few seconds after release?

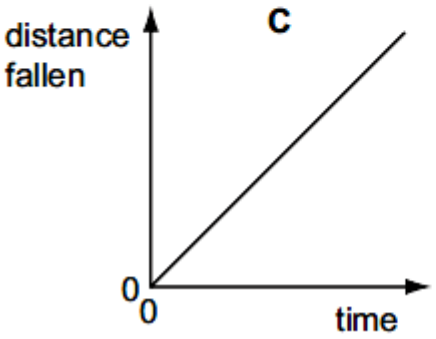
	velocity	acceleration
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

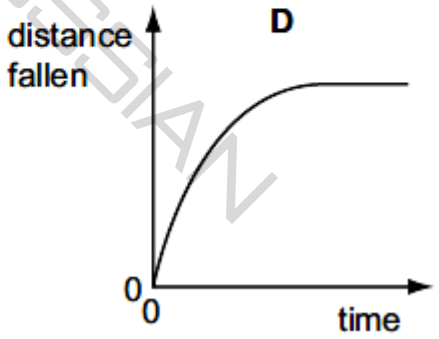
C

5. Which graph shows the motion of a heavy, steel ball falling from a height of 2 m?





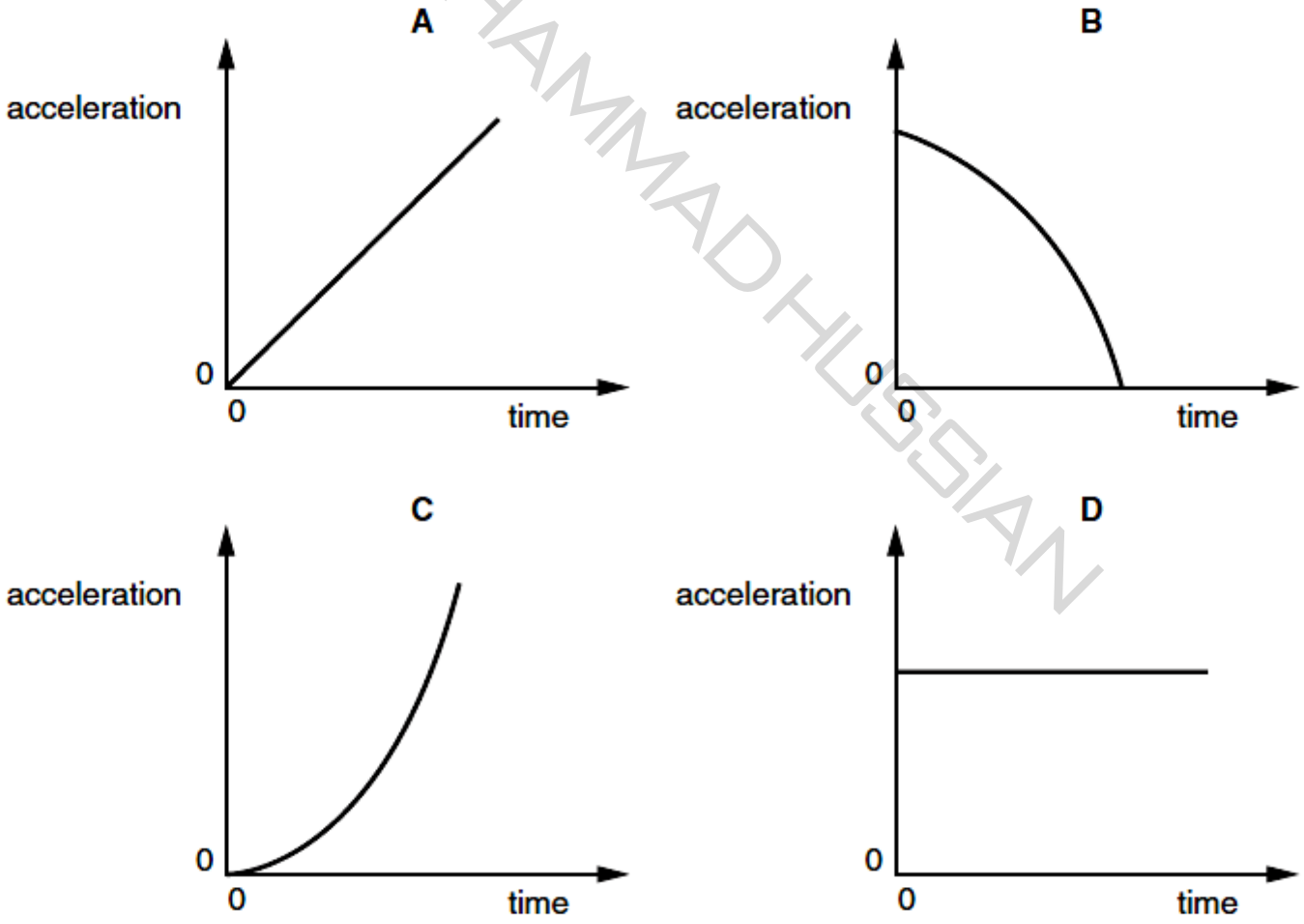




A

6. A stone falls freely from the top of a cliff into the sea. Air resistance may be ignored.

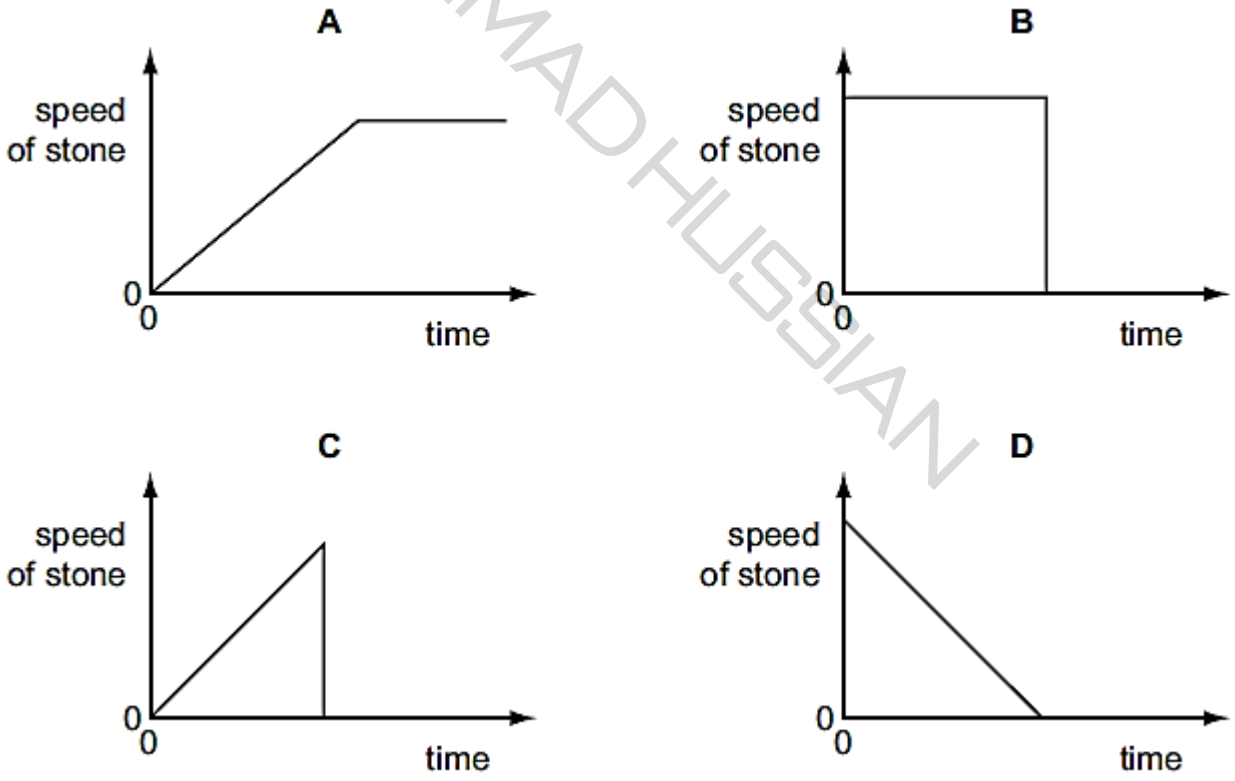
Which graph shows how the acceleration of the stone varies with time as it falls?



D

7. A small stone is dropped from the top of a ladder, falls and hits the ground. It does not rebound.

   Which speed-time graph is correct?



C

8. An object is falling under gravity with terminal velocity.

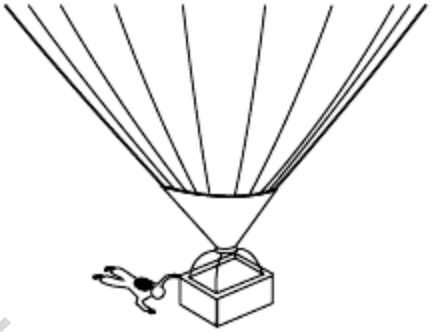
   What is happening to its speed?

   A. It is decreasing to a lower value.
   B. It is decreasing to zero.
   C. It is increasing.
   D. It is staying constant.

9. The diagrams show a parachutist in four positions after she jumps from a high balloon.

At which position does she have terminal velocity?

A not yet moving



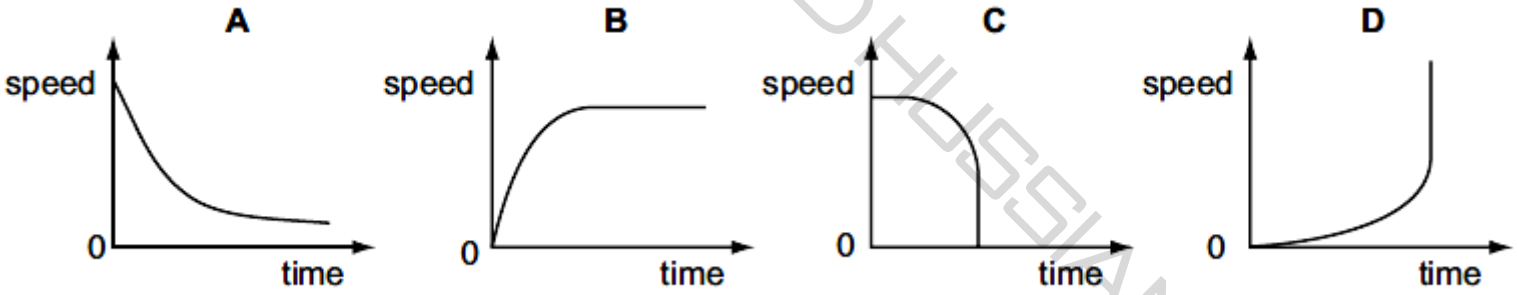
B accelerating

C not accelerating

D not moving

C

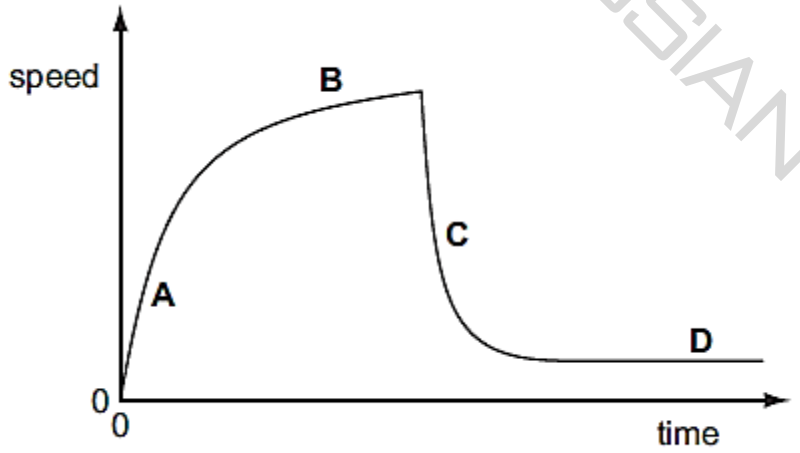
10. Which graph represents the motion of a body falling vertically that reaches a terminal velocity?



B

11. The speed-time graph for a falling skydiver is shown below. The skydiver alters his fall first by spreading his arms and legs and then by using a parachute.

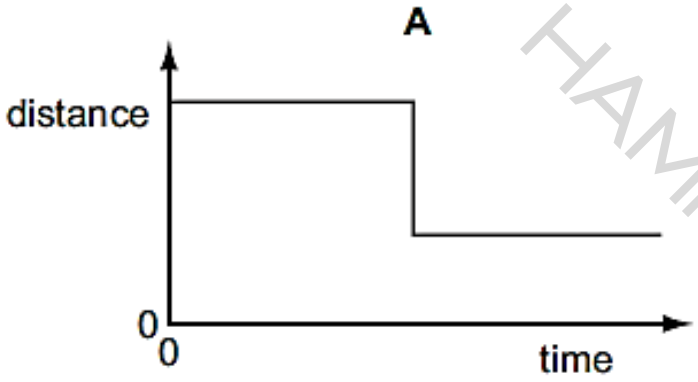
Which part of the graph shows the diver falling with terminal velocity?

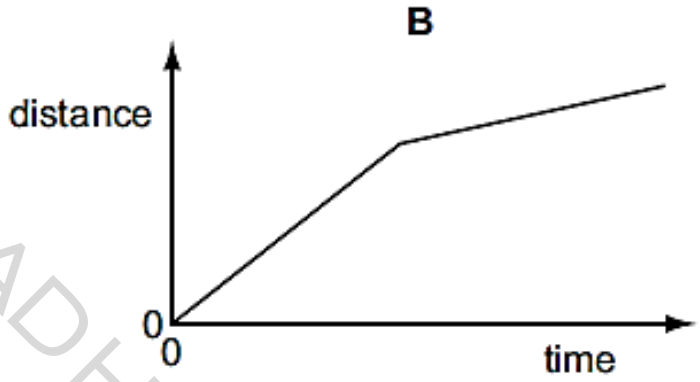


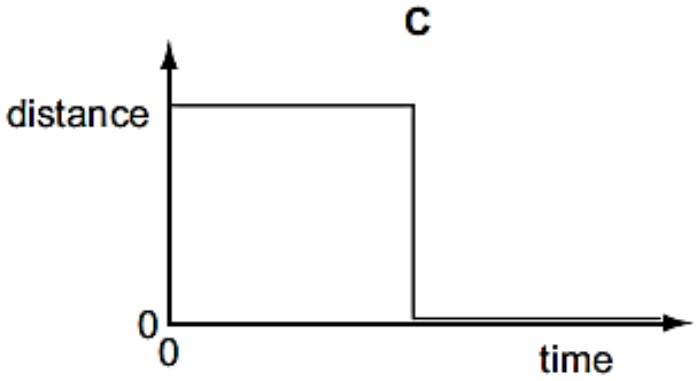
D

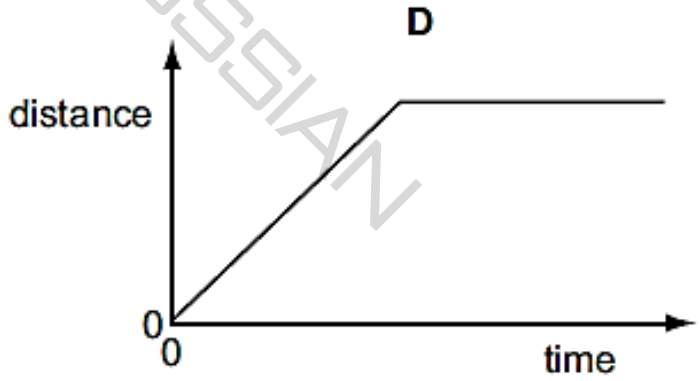
12. A free-fall parachutist falls at a constant speed. He then opens his parachute and continues to fall to Earth at a lower, constant speed.

    Which diagram shows how the distance fallen by the parachutist varies with time?



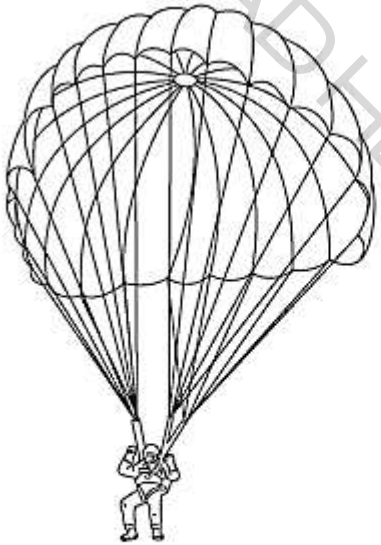






B

13. Two men jump out of an aeroplane at the same time. One of the men opens his parachute and the other man remains in free-fall.



Why is the man in free-fall moving faster than the parachutist?

A. The man in free-fall experiences greater air resistance.
B. The man in free-fall has a greater mass.
C. The parachutist experiences greater air resistance.
D. The parachutist has not reached terminal velocity.