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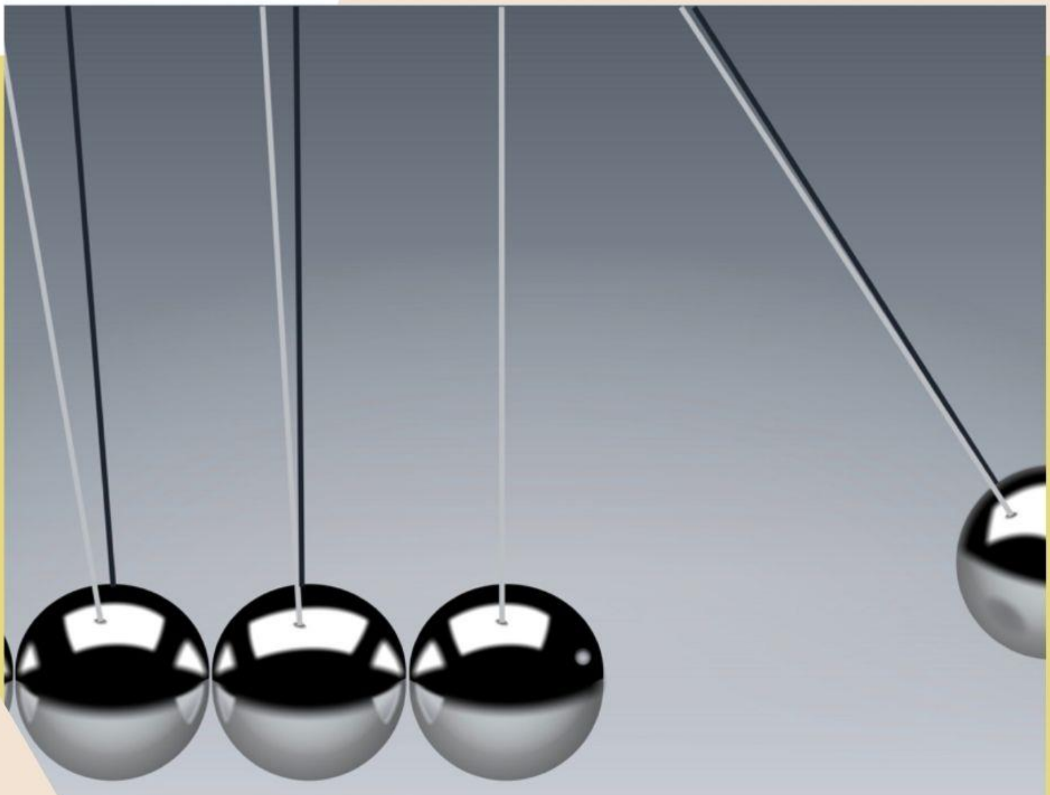
POLITEKNIK MALAYSIA
TUN SYED NASIR

FOCUS ON LINEAR MOTION

IN ENGINEERING SCIENCE

FAZLINA BINTI YUNUS
ASIAH BINTI IBRAHIM

FOCUS ON LINEAR MOTION IN ENGINEERING SCIENCE



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REALLY GREAT MOTION

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PREFACE

The purpose of this e-book is to introduce to students the ideas in Engineering Science and Physics that are necessary in engineering disciplines. This e-book focuses solely on the topic of linear motion. The uniform and non-uniform motion, distance, displacement, speed, velocity, average velocity, acceleration, and deceleration are all covered in the linear motion topic. Aside from that, there are solutions to linear motion problems based on velocity-time graphs that can be evaluated depending on the situation. This e-book is suitable for polytechnic students throughout Malaysia because it covers the polytechnic syllabus. It also includes examples and exercises for students to complete.

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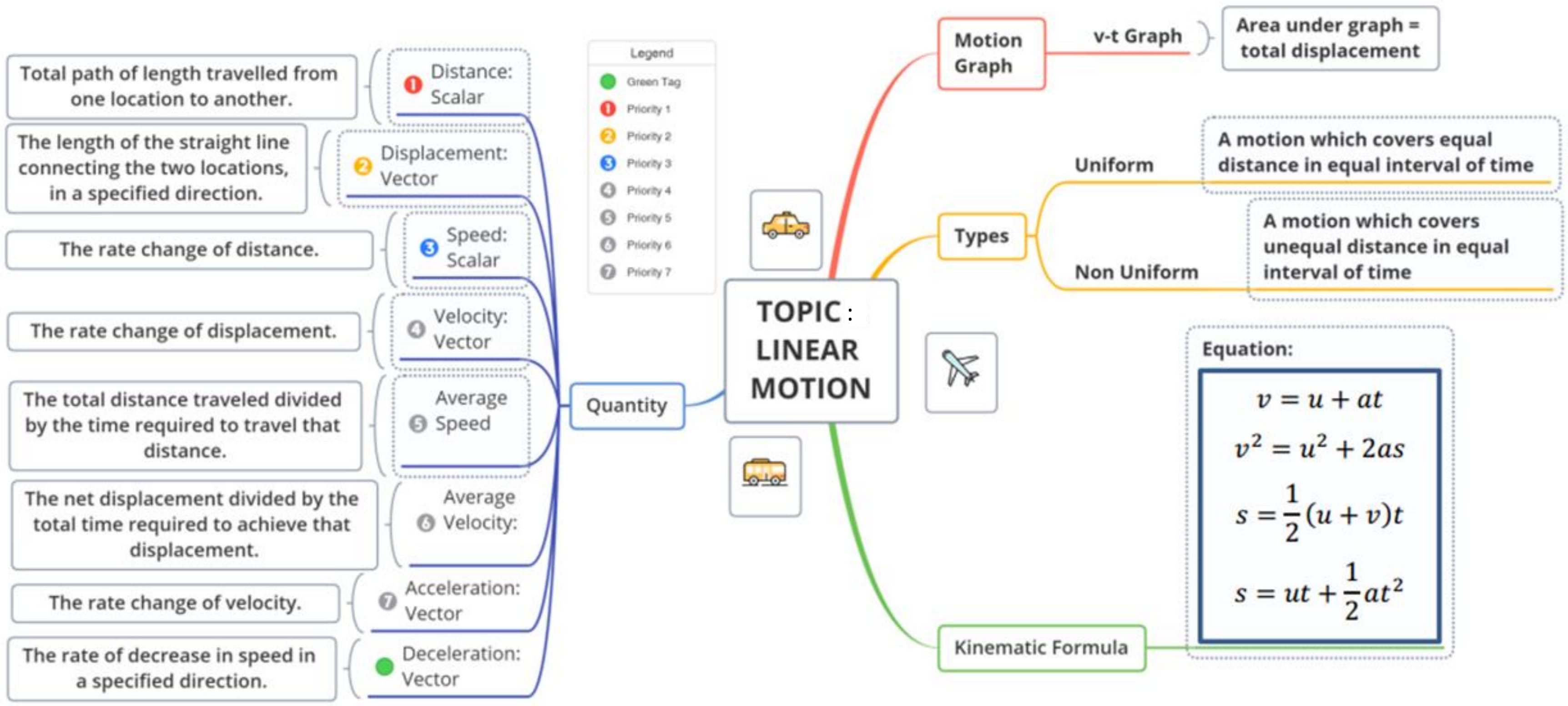
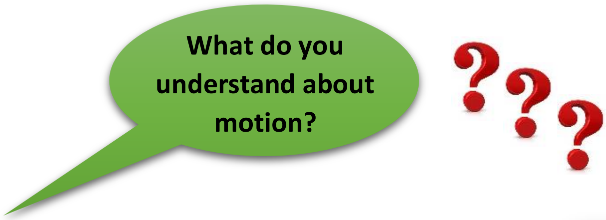


Types	Distance, d	Displacement, s	Speed, v	Velocity, v	Average Speed, v_{av}	Average Velocity, $\overrightarrow{v_{av}}$	Acceleration, $a = +ve$	Deceleration, $a = -ve$
Formula	-	-	$v = \frac{d}{t}$	$v = \frac{s}{t}$	$v_{av} = \frac{\text{total distance}}{\text{total time}}$	$\overrightarrow{v_{av}} = \frac{\text{total displacement}}{\text{total time}}$	$a = \frac{v-u}{t}$	$a = \frac{u-v}{t}$
Unit	m	m	ms^{-1}	ms^{-1}	ms^{-1}	ms^{-1}	ms^{-2}	ms^{-2}

1.1 THE CONCEPT OF MOTION



Motion is a phenomenon in which an object changes its position with respect to time as shown in Figure 1.1. Motion is mathematically described in terms of **displacement, distance, velocity, acceleration, speed** and **time**.

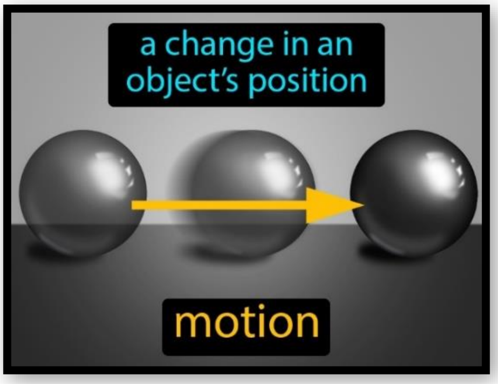


Figure 1.1: Object's position

The motion of a body is observed by attaching a frame of reference to an observer and measuring the change in position of the body relative to that frame with change in time. The branch of physics describing the motion of objects without reference to its cause is **kinematics** while the branch studying forces and their effect on motion is **dynamics.**

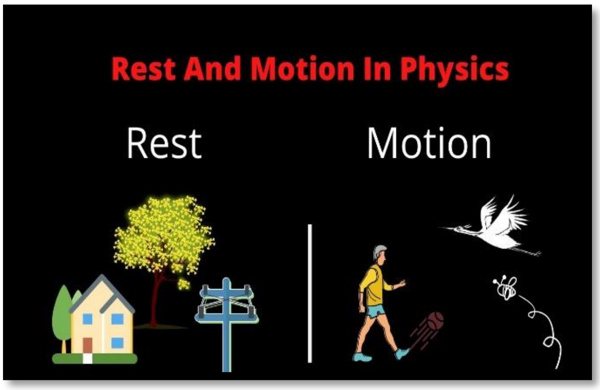


Figure 1.2: Differences between rest and motion

If an object is **not changing** relative to a given frame of reference, the object is said to be at **rest, motionless, immobile, stationary**, or to have a constant or time-invariant position with reference to its surroundings.

Scan to watch the video

1.1.1 DEFINITION OF LINEAR MOTION

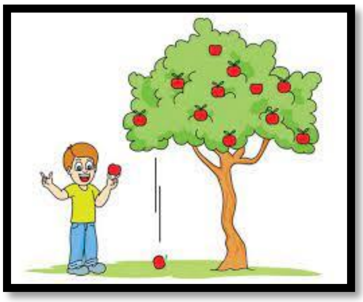
What is linear motion?

Linear motion is a ***motion along a straight line***.

As shown in Figure 1.3, there are an example of linear motion.

a. 

An athlete running 100 m along a straight track.

b. 

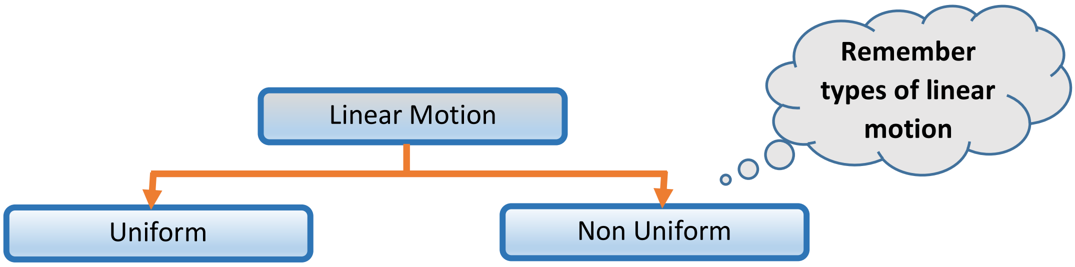
An apple free fall from tree.

c. 

An elevator moves up and down with the help of an electrically powered pulley mechanism. The motion of the elevators is along a straight line.

Figure 1.3 (a), (b) and (c): Example of Linear Motion

1.1.2 TYPES OF LINEAR MOTION



1.1.3 UNIFORM MOTION

Definition:

- This type of motion is defined as the motion of an object in which the object travels in a straight line and its velocity remains constant along that line as it covers **equal distances** in **equal intervals of time**, irrespective of the duration of the time.
- The bodies moving with ***constant speed or velocity*** (a=0 m/s^2) or ***increase at the uniform rate***.

Example:

- The Figure 1.4 shows the distance covered by a car after every 2 seconds.

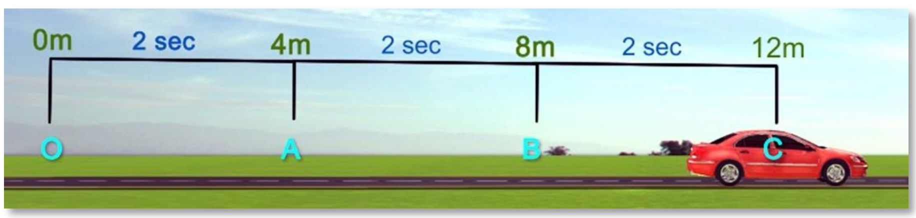


Figure 1.4: Distance of a car

- The car covers 12 m in every 2 seconds. The speed with which the car is moving at any point between O and C is 6 m/s. That is, the object is moving with uniform speed.

1.1.3 NON-UNIFORM MOTION

Definition:

- This type of motion is defined as the motion of an object in which the object travels with varied speed and it does not **cover same distance** in **equal time intervals**, irrespective of the time interval duration
- The bodies executing non uniform motion have ***varying speed or velocity*** *as shown in Figure 1.5*.

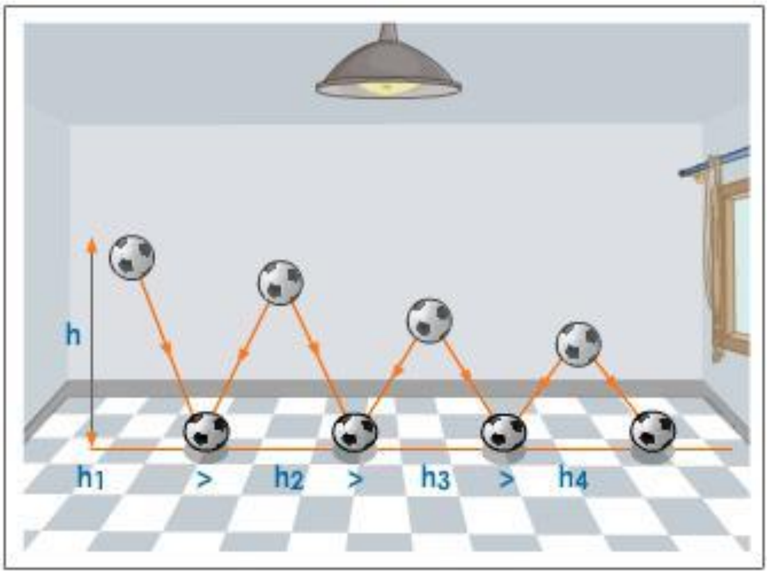


Figure 1.5: Non-uniform Motion

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1.1.4 DIFFERENCES BETWEEN UNIFORM MOTION AND NON-UNIFORM MOTION

There are differences between Uniform Motion and Non-Uniform Motion in a long straight line as shown in Table 1.1 and Figure 1.6.

Table 1.1: Differences between Uniform Motion and Non-Uniform Motion

UNIFORM MOTION	NON-UNIFORM MOTION
Implies the movement of a body along a straight line with steady speed	Alludes to a movement of an object along a straight line with variable speed
Cover equal distances in equal time interval	Cover unequal distances in equal time interval
Is similar to actual speed of the object	Is different to actual speed of the object
Distance time-graph shows a straight line	Distance time-graph shows a curved line
Zero acceleration	Non-zero acceleration

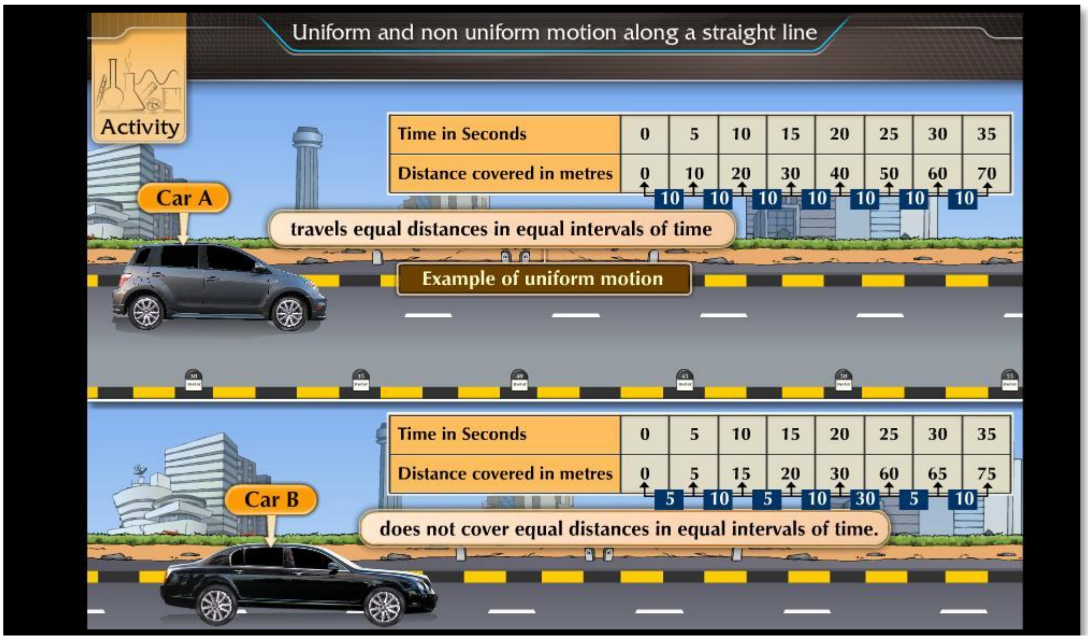


Figure 1.6: Differences between Uniform Motion and Non-uniform Motion

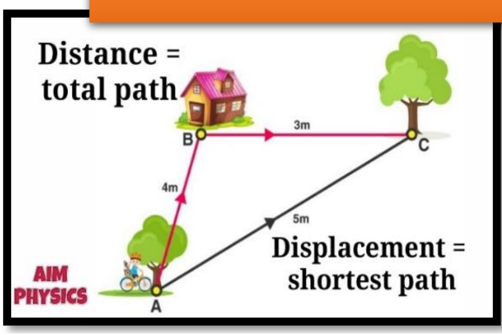
1.1.5 DISTANCE AND DISPLACEMENT

Table 1.2 shows the differences between distance and displacement.

Table 1.2: Distance and Displacement

DISTANCE	DISPLACEMENT
Total path of length travelled **from one location to another**	The **length of the straight line connecting the two locations**, in a specified direction.
Scalar **quantity** (has **magnitude** only)	**Vector** quantity (have **magnitude and direction**)
Measured is always **positive.**	Can be **positive** or **negative** depending on the reference points.
There is always a distance covered whenever there is a motion.	Displacement will be **zero** if the body comes back to its initial position.
SI unit: meter (m)	SI unit: meter (m)

How to calculate Distance and Displacement in Figure 1.7 (a)?



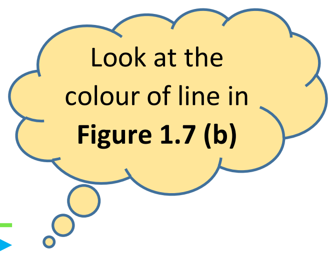
Point A to B = 4m

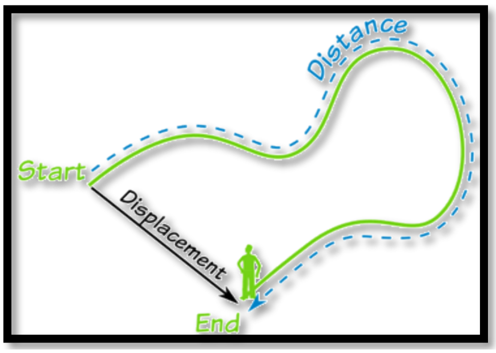
Point B to C = 3m

Total **distance** = 7m

But **displacement** is from point A to C = 5m.

Figure 1.7 (a): Distance and Displacement





Distance line

Displacement line

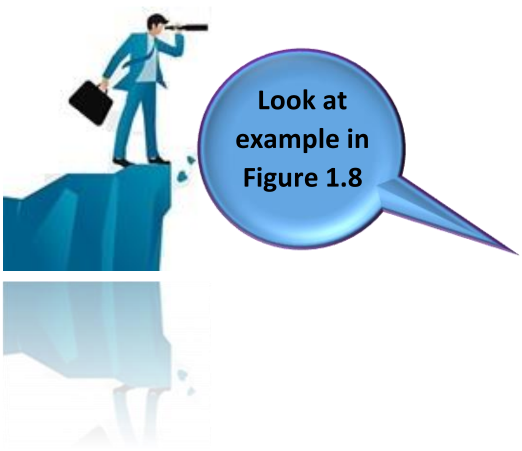
Figure 1.7(b): Recognize Distance and Displacement

1.1.6 SPEED AND VELOCITY

Table 1.3 shows the information about speed and velocity.

Table 1.3: Speed and Velocity

SPEED	VELOCITY
The ***rate of change of distance***	The ***rate of change of displacement***
Formula: $v = \frac{d}{t}$ Where: $v = speed$, $d = distance$, $t = time$	**Formula:** $v = \frac{s}{t}$ Where: $v = velocity$, $d = displacement$, $t = time$
Scalar **quantity (has** magnitude only)	**Vector** quantity (has both **magnitude and direction)**
It **cannot be zero**	It can be **zero**
SI unit: ms^{-1}	**SI unit: ms^{-1}**



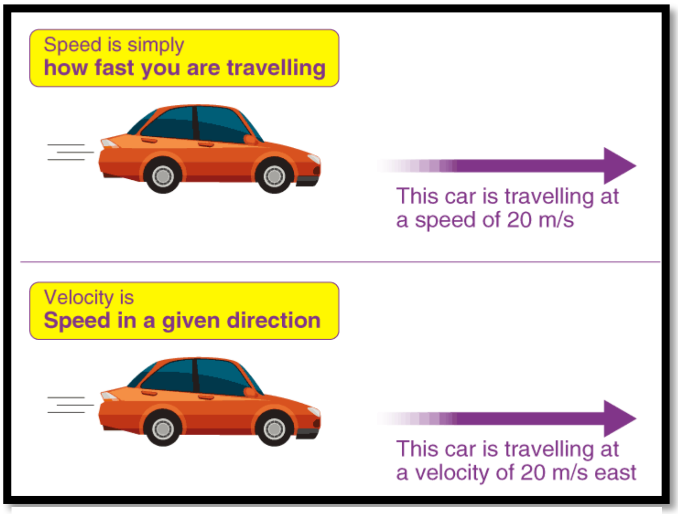


Figure 1.8: Speed and Velocity

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1.1.7 AVERAGE SPEED AND AVERAGE VELOCITY

How to solve this problem?

The differences and information about Average Speed and Average Velocity is shown in Table 1.4.

Table 1.4: Average Speed and Average Velocity

AVERAGE SPEED	AVERAGE VELOCITY
The total **distance traveled divided by the time required** to travel that distance.	The net ***displacement divided by the total time required*** to achieve that displacement.
Formula: $$v_{av} = \frac{\text{total distance}}{\text{total time}}$$	**Formula:** $$v_{av} = \frac{\text{displacement}}{\text{total time}}$$
Scalar **quantity (has** magnitude only)	**Vector** quantity (has both **magnitude and direction)**
SI unit: ms^{-1}	**SI unit: ms^{-1}**

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1.1.8 ACCELERATION

DID YOU KNOW?

- Acceleration is defined as the rate of change of velocity with respect to time.
- Acceleration are vector quantities (have magnitude and direction)
- The velocity of an object increases from an initial velocity, u to a higher final velocity, v.
- Unit SI : ms^{-2}
- $\boldsymbol{a = +ve}$ (speed increase)
- Equation: $a = \frac{v-u}{t}$ where: a=acceleration, v = final velocity, u = initial velocity, t = time taken

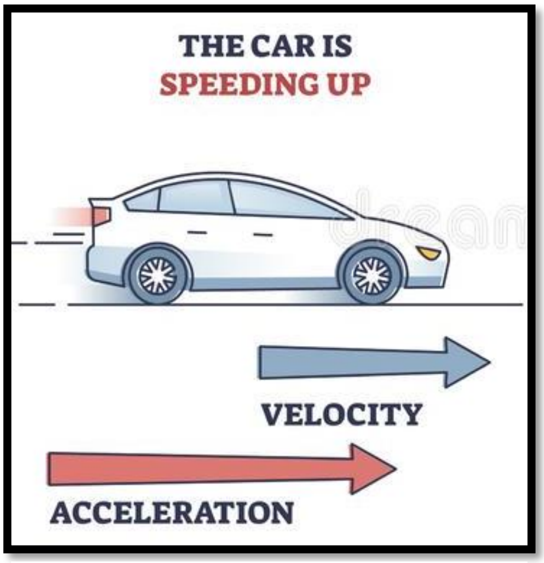


Figure 1.9: Acceleration

A vehicle starts from zero velocity and travels in a straight line at **increasing speeds**, it is accelerating in the direction of travel as shown in Figure 1.9.

If the vehicle turns, an acceleration occurs toward the new direction and changes its motion vector.

The acceleration of the vehicle in its current direction of motion is called a **linear**.

1.1.9 DECELERATION

DID YOU KNOW?

- Deceleration has actually referred to the acceleration in a reverse way.
- The ***rate of decrease in speed in a specified direction***.
- The ***velocity*** of an object ***decreases*** from an initial velocity, ***u*** to a lower final velocity, ***v***.
- Unit SI : ms^{-2}
- $\boldsymbol{a = -ve}$ (speed decrease)
- Equation: $a = \frac{v-u}{t}$ where: a=acceleration, v = final velocity, u = initial velocity, t = time taken

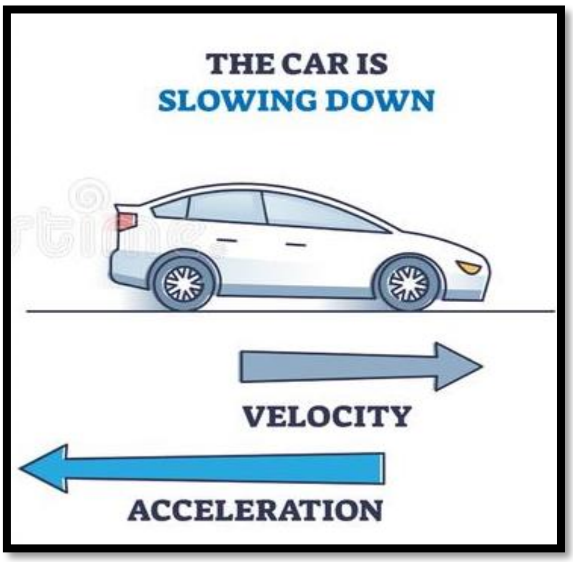


Figure 1.10: Deceleration

Decelerating refers to a vehicle travelling in a straight line at **decreasing** speeds as shown in Figure 1.10.

For example:

i. Stop at traffic light
ii. Suddenly break

1.1.10 EXAMPLES

EXAMPLE 1.1

Define the following terms and state their SI unit.

a. Displacement
b. Velocity

Solution;

a. Displacement is the distance travelled in a specific direction. SI unit for displacement is m.
b. Velocity is the rate of change of displacement SI unit for velocity is m/s.

EXAMPLE 1.2

An airplane travelling at 150m/s is accelerated uniformly at 25m/s^2.

a. What is the airplane's speed after 15s?
b. What distance has it travelled at that point of time?

Solution;

a. $v = at + u$

$$v = \left(\frac{25m}{s^2}\right)(15s) + \frac{150m}{s}$$

$$v = 525\ m/s$$

b. $v^2 = u^2 + 2as$

$$s = \frac{v^2 - u^2}{2a}$$

$$s = \frac{525^2 - 150^2}{2(25)}$$

$$s = 5062.5m$$

EXAMPLE 1.3

An aircraft accelerates uniformly from rest at 3.1 m/s^2 to reach its take-off velocity of 100 m/s.

a. How long does it take for the aircraft to leave the ground?

b. How far does it travel during the take-off?

Solution;

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

$$t = \frac{v-u}{a} = \frac{100-0}{3.1}$$

$$t = 32.258\, s$$

b. $s = \frac{1}{2}(u+v)t$

$$s = \frac{1}{2}(0+100)x\ 32.258$$

$$\boldsymbol{s = 1612.9m}$$

Or

$$s = ut + \frac{1}{2}at^2$$

$$s = (0)x32.258 + \frac{1}{2}(3.1)x[32.258^2]$$

$$\boldsymbol{s = 1612.9m}$$

You can solve using other method but make sure the answer is the **SAME!**!!

1.1.11 EXERCISE

Q1. State the definition of the following terms and their SI unit :

i. Displacement

ii. Acceleration

iii. Deceleration

iv. Velocity

v. Distance

Q2. State THREE (3) differences between :

i. Speed and velocity

Speed	Velocity

ii. Acceleration and deceleration

Acceleration	Deceleration

iii. Distance and displacement

Distance	Displacement

Q3. Give the definition of the following terms with ONE (1) examples.

i. Uniform motion

ii. Non-linear motion

Q4. A car started from a rest and accelerated at 10.23 m/s^2 for 5.5 seconds. Calculate the distance covered by the car if the car moves uniformly.

Suggestion formula: sutat^2

ANSWER: s=154.729s

Q5. Sadiq is driving his car with velocity of 70 m/s. He steps on his brake to reduce the velocity of the car to 30 m/s after travelling 50m. Calculate the deceleration and the time taken while the car decelerates.

Suggestion formula: avu/t, suvt

ANSWER : a=-40m/s^2, t=1s

Q6. A space-rocket is launched and it accelerated uniformly from rest to 160 m/s in 0.075 minutes. Calculate how far the rocket traveled within that time.

<u>Clue</u>: minute convert to second

<u>Suggestion formula</u>: suvt

ANSWER: s=360m

Q7. A motorcycle started moving with a velocity of 10 m/s. After travelling a distance of 5 m, it gets a velocity of 20 m/s. Find its:

a. Acceleration
b. Time taken for the journey

<u>Suggestion formula</u>: avu/t, suvt

ANSWER: i. $a=3m/s^2$, ii. t=3.33s

Q8. A motorcycle starts in a state of rest and accelerates at $10.23m/s^2$ for 5.5 seconds.Calculate the distance traveled by the motorcycle. Calculate the acceleration of a car that moves from the rest and achieves a velocity of 120 km/h in 20 minutes.

<u>Clue</u>: km/h convert to m/s

<u>Suggestion formula</u>: suvt, avu/t

ANSWER: a. s = 154.73m, b. $a=0.0278\ m/s^2$

Q9. A cyclist accelerates uniformly at 1.2 m/s^2 in 10s from state of rest. Calculate his displacement at this time.

Suggestion formula: suvt or sutat^2

ANSWER: s=60m

Q10. A boy starts form a rest state and accelerates to a velocity of 20 m/s in 10s. Determine the acceleration of the boy.

Suggestion formula: avu/t

ANSWER: a=2m/s^2

Q11. A body with initial velocity 8 m/s moves along straight line with constant acceleration and travels 640 m in 40 s. For the 40s interval, calculate:

a. the average velocity

b. the final velocity

c. the acceleration

Suggestion formula: b.suvt, c. avu/t

ANSWER: a. Ave velocity = 16m/s, b. v = 24m/s, c. a = 0.4m/s^2

Q12. A man started observing a car, its initial velocity was X m/s. If the car travel for 10s with uniform acceleration 2.5 m/s^2 and its velocity increases to 75 m/s. Calculate:

a. initial velocity of the car
b. displacement of the car within 10s

Suggestion formula: a. vuat, b. suvt

ANSWER: a. u = 50m/s, b. s = 625m

Q13. A truck start from rest and moves with constant acceleration of 5 m/s^2. Calculate its speed and the distance traveled after 4s has elapsed.

Suggestion formula: a. vuat, b. suvt or $sutat^2$

ANSWER: a. v = 20m/s, b. s = 40m

Q14. A box slides down an incline with uniform acceleration. It start from rest and attains a speed of 2.7m/s in 3s. Calculate:

a. acceleration of the box.
b. the distance moved in the first 3s.

Suggestion formula: a. avu/t , b. suvt or $sutat^2$

ANSWER: a. 0.9 m/s^2, b = 4.05m

Q15. A car is accelerated at $6 m/s^2$ from an initial velocity of 2 m/s for 10s. Calculate:

a. the final velocity

b. the distance moved within 10s.

Suggestion formula: a. avu/t , b. suvt or $sutat^2$

ANSWER: a. v=22m/s, b = s = 120m

Q16. A bicycle starts in a state of rest and accelerates at $5.8 m/s^2$ for 6s. Calculate the distance traveled by the motorcycle.

Suggestion formula: $sutat^2$

ANSWER: s = 104.4m

Q17. The safe take-off velocity of a particular passenger plane is set at 210km/h. Calculate the minimum acceleration that the airplane needs to move on a 2.2km runway.

Clues: km/h convert to m/s, km convert to m.

Suggestion formula: vuas

ANSWER: $a = 0.77 m/s^2$

Q18. A speedboat increase its speed uniformly from 20m/s to 30m/s in a distance of 0.2km. Calculate:

a. acceleration of the speedboat.

b. time for the boat to travel in distance 0.2km.

Suggestion formula: a. avu/t , b. suvt

ANSWER: a. a = 1.25 ms^{-1}, b. t = 8s

Q19. An airplane is travelling at 150m/s is accelerated uniformly at 25 m/s^2. Calculate:

a. the airplane's speed after 15 seconds.

b. distance it has travelled at that point of time.

Suggestion formula: a. vuat, b. suvt or sutat^2

ANSWER: a. v = 525 m/s, b. s = 5062.5m

Q20. A car is moving at a velocity of 2.7km/h stops after break is applied. The distance travelled when the brake is applied till its stop is 200m. Calculate:

a. the acceleration in m/s^2

b. time taken to stop the car in second.

Suggestion formula: a. avu/t , b. suvt

ANSWER: a. a = -0.00141ms^{-2}, b. t = 531.91s, @ 533.33s

Q21. A car started from rest and accelerated at $10.23ms^{-2}$ for 5.5s. Calculate the distance cover by the car.

<u>Suggestion formula</u>: sutat

ANSWER: s = 154.729m

Q22. Faqih drove a car with a velocity of 120km/h when he noticed a cow in the middle of the road 85m ahead of him. He suddenly braked and the car stop after 8 seconds.

a. Calculate the deceleration of the car

b. Calculate the distance traveled by the car from the time Faqih applied the break until it stops.

c. Was he able to avoid the cow?

<u>Clue:</u> convert 120km/h to m/s

<u>Suggestion formula</u>: a.vuat, b. sutat

ANSWER: a. a = $-4.17ms^{-2}$, b. s = 133.2m c. No, he was not able to avoid knocking the cow

Q23. A bus starting from rest moved up a hill with a constant acceleration of $5ms^{-2}$. Calculate the time taken for the bus to move 170m up the hill.

<u>Suggestion formula</u>: sutat

ANSWER: t = 8.25s

Q24. A plane flies from London Heathrow Airport to Dubai International Airport, a distance of approximately $5500\ km$ at an average speed of $1200\ km/h$. The return trip was made at an average speed of $1050 km/h$. Find the average speed for the whole journey.

Clue: find total time

Suggestion formula: ave speed

ANSWER: Ave Speed = 1120 km/hr

Q25. Mu'aadh lives in Jeddah and wants to travel to Makkah to perform a lesser pilgrimage. If the distance between his residence in Jeddah and Makkah is $85\ km$ and the maximum safe driving speed is $100\ km/h$, what is the longest time he can stop to rest if he must get to Makkah within $1.5 hr$?

Clue: first, find t_{min}

Suggestion formula: ave speed

ANSWER: Longest time = 39 min

Q26. A passenger bus starts from rest at a bus stop on a straight road and moves with a uniform acceleration of $2.4\ m/s^2$ for 30s before maintaining a constant speed. How far has it covered during the acceleration period?

Suggestion formula: sutat

ANSWER: s = 1080m

Q27. A car with an initial velocity of 5 m/s, accelerates uniformly at 3 m/s^2 until it reaches a velocity of 23m/s. Calculate the time taken and the distance travelled during this acceleration.

<u>Suggestion formula</u>: vuat, sutat

ANSWER: t = 6s, s = 84m

Q28. Towards the end of a 400m race, Faisal and Edward are leading and both are running at 6 m/s. While Faisal is 72m from the finish line, Edward is 100m from the finish line. Realising this and to beat Faisal, Edward decides to accelerate uniformly at 0.2m/s^2 until the end of the race while Faisal keeps on the same constant speed. Does Edward succeed in beating Faisal?

<u>Clue:</u> t_{faisal}, s_{faisal}

<u>Suggestion formula</u>: sutat

ANSWER: t_{faisal} = 6s, s_{faisal} = 86.4m, Edward did not succeed because when Faisal finished, Edward has 13.6 m distance to cover since he was 100m away from the finish line

Q29. As soon as the traffic light changed to green, Abdullah accelerates uniformly with his motorcycle at 2.6 m/s^2 for 5s. He then maintains a steady velocity for a two-third of his 150m journey.

a. How far does he travel from the traffic light junction until he reached a maximum velocity?

b. What maximum velocity does he reach?

<u>Suggestion formula</u>: sutat, vuat

ANSWER: s = 32.5m, v = 13 m/s

1.2 LINEAR MOTION FROM VELOCITY-TIME GRAPH

Linear motion graphs can be analysing by breaking the whole graph into segments related to uniform motion and non-uniform motion. Changes in the displacement will reflects on the velocity-time graph. To identify the differences in the characteristics of velocity-time graph, some basic forms need to be understood. **Figure 1.11** shows example of uniform and non-uniform motion graph.

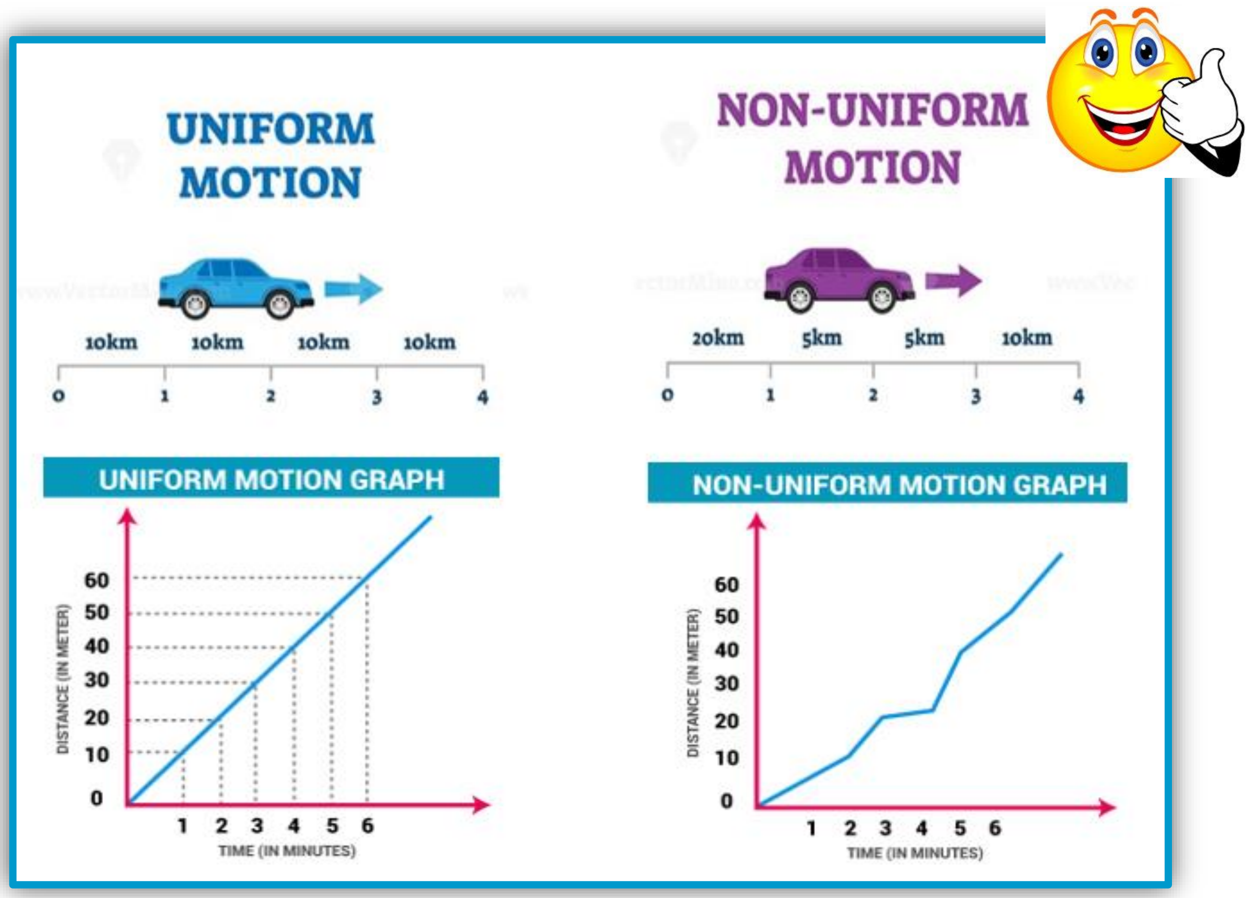


Figure 1.11: Example of distance-time graph (uniform and non-uniform motion)

1.2.1 Basic Linear Motion Graph

A basic linear motion graph will show the motion of an object. Any combination of these basic graphs will form a velocity-time graph, acceleration-time graph and others. **Figure 1.12 (a) to (c)** shows the basic linear motion of velocity – time graph (v-t graph);

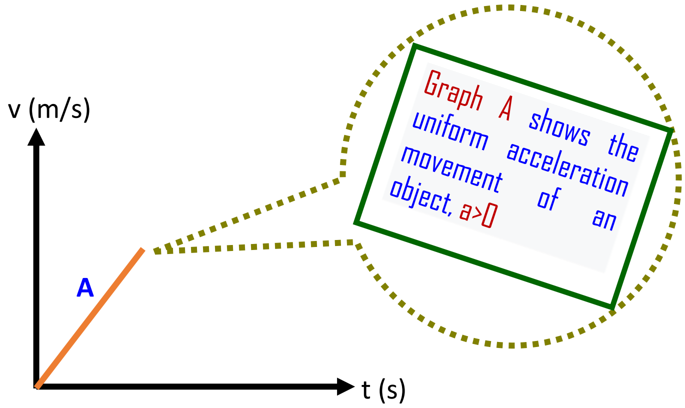


Figure 1.12 (a)

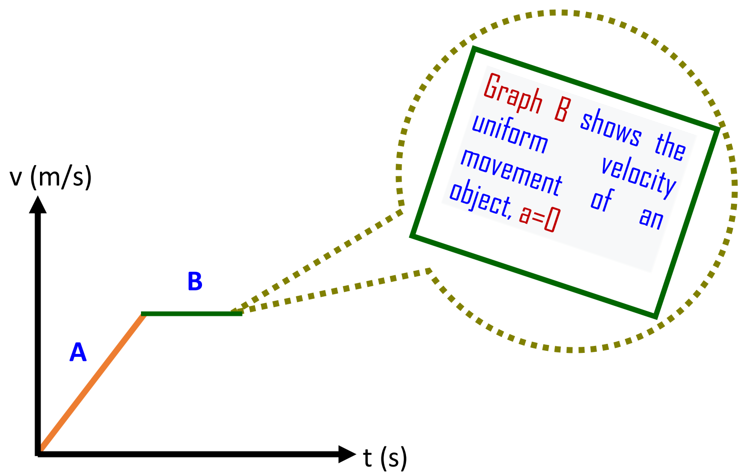


Figure 1.12 (b)

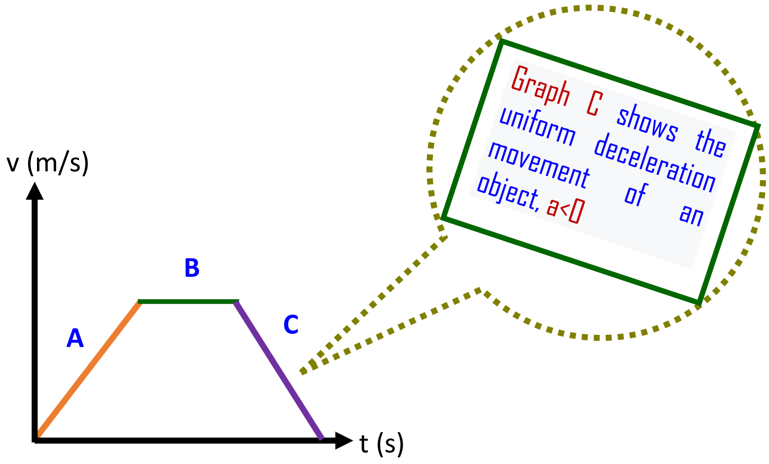
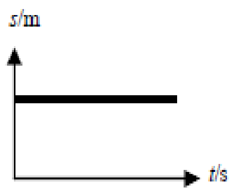
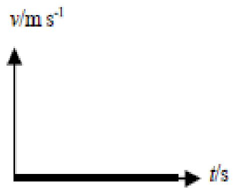
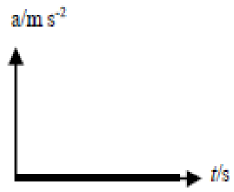
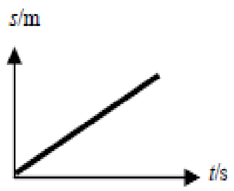
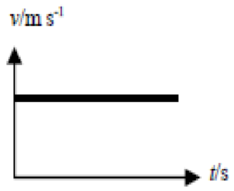
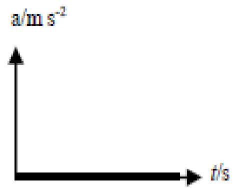
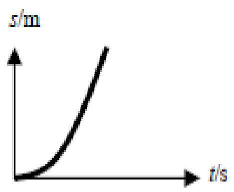
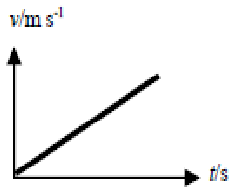
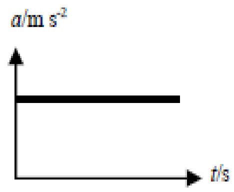


Figure 1.12 (c)

Table 1.5: The basic features of a linear motion graph

	Displacement-time graphs	Velocity-time graphs	Acceleration-time graphs
	Velocity = *slope of the graph*	Acceleration = *slope of the graph* Displacement = *area under the graph*	Velocity = *area under the graph*
$v = 0$ $(a = 0)$			
$v =$ constant $(a = 0)$			
$v\uparrow$ $a =$ constant			

1.2.2 Analysing Linear Motion Graph

- A velocity-time graph (or speed-time graph) is a method of visually expressing a motion of an object.
- Referring to a graph, time is always plotted in x-axis (horizontal) while y-axis (vertical) can be either velocity, speed, distance and acceleration as shown in **Figure 1.13 (a) to (e).** Graph form and analysis refers to graph title such as velocity-time graph, distance-time graph and others.
- To identify the characteristics of linear motion, each part of the graph is equipped with a motion shape label.

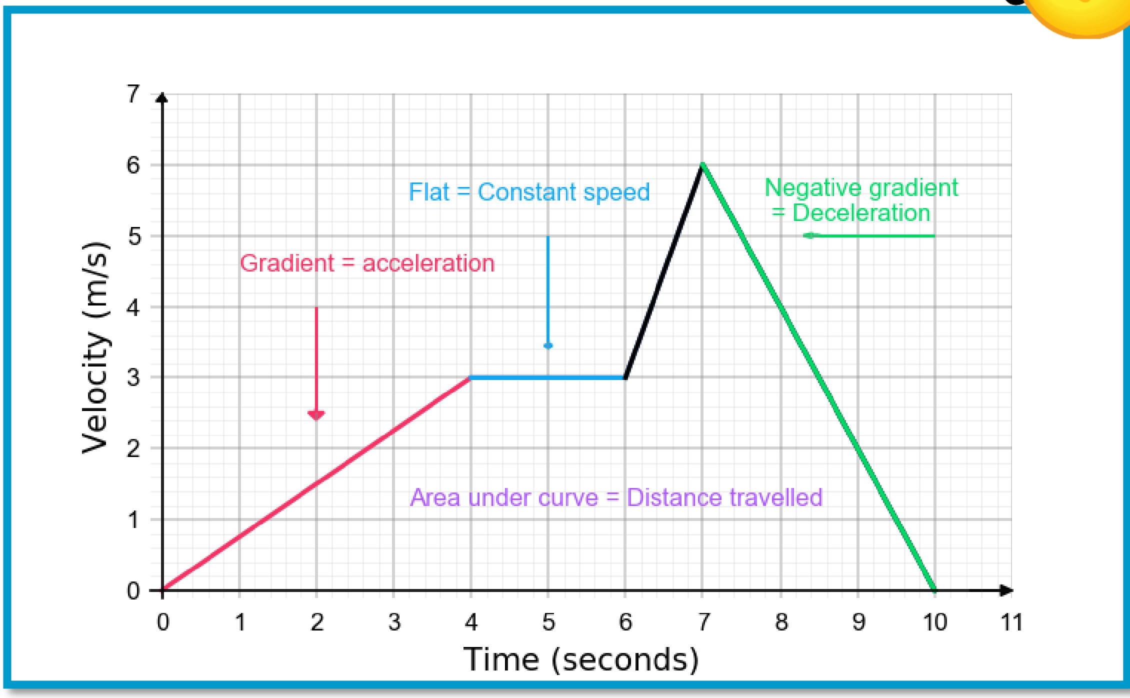


Figure 1.13 (a): Velocity- time graph

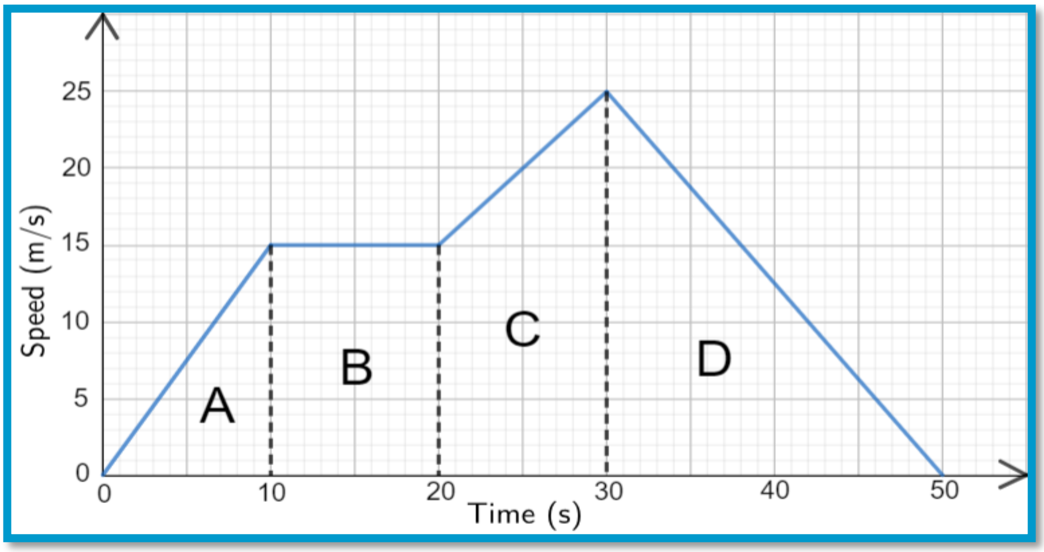


Figure 1.13 (b): Speed-time graph

- How to draw a graph? Referring to the graph as in **Figure 1.13 (b)**, the following are steps to draw the graph;

i. Determine the maximum quantity to be taken on each axis.

ii. Divide this maximum quantity in several parts, so that it is easy to mark or scale the points.

iii. Aim the size of the graph to be drawn so that it covers the maximum paper space that will make it look appropriate.

iv. Complete every axis and parts of the graph with related label.

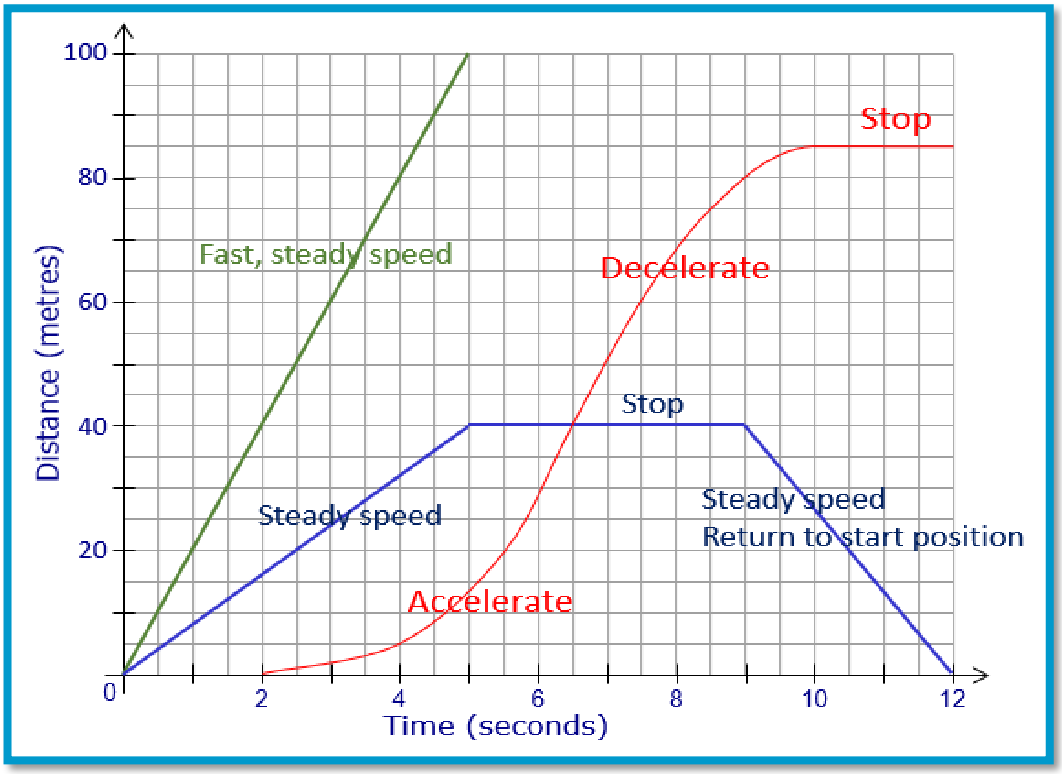


Figure 1.13 (c): Distance-time graph with acceleration and deceleration curve

According to Distance-time graph in **Figure 1.13 (c)** ;

- The **green line** shows a fast and steady speed with movement from 0 to 100 m in 5 seconds.
- The **blue line** shows a movement with a stop state and return to the starting position.
- The **red line** shows a movement starting from 2 seconds later than the others, continue with Initial acceleration, u and and lastly decelaration before stop.

- The motion and velocity of an object can be described through the form of a graph. While the area under the graph gives information for displacement.
- **Figure 1.13 (d)** displays a graph of velocity-time with acceleration and deceleration form. The motion is made by breaking graph into segments. Each form of graph will describes the motion of an object as below;
  i. The slope from 0 to 8 m/s of v-t graph is acceleration, a. Acceleration is the rate of change of velocity.
  ii. While the horizontal condition (4 to 7 seconds) indicates the zero acceleration or constant velocity.
  iii. The slope from 8 to 0 m/s of v-t graph is decceleration, -a or the object movement slowdown untill stop.
  iv. While the area under the graph gives information for displacement.

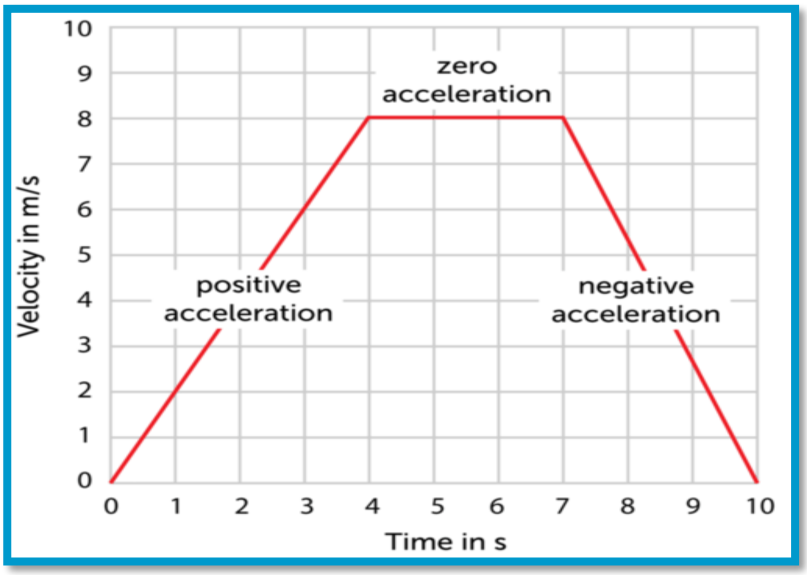


Figure 1.13 (d): Velocity-time graph with acceleration and deceleration form

- **Figure 1.13 (e)** displays a graph of distance-time. Each form of graph will describes the motion of an object as below;

  i. The gradient of the line shows the speed movement.

  ii. A flat section is rest condition.

  iii. The steeper slope is the greater the speed.

  iv. Negative form means returning to start point (come back).

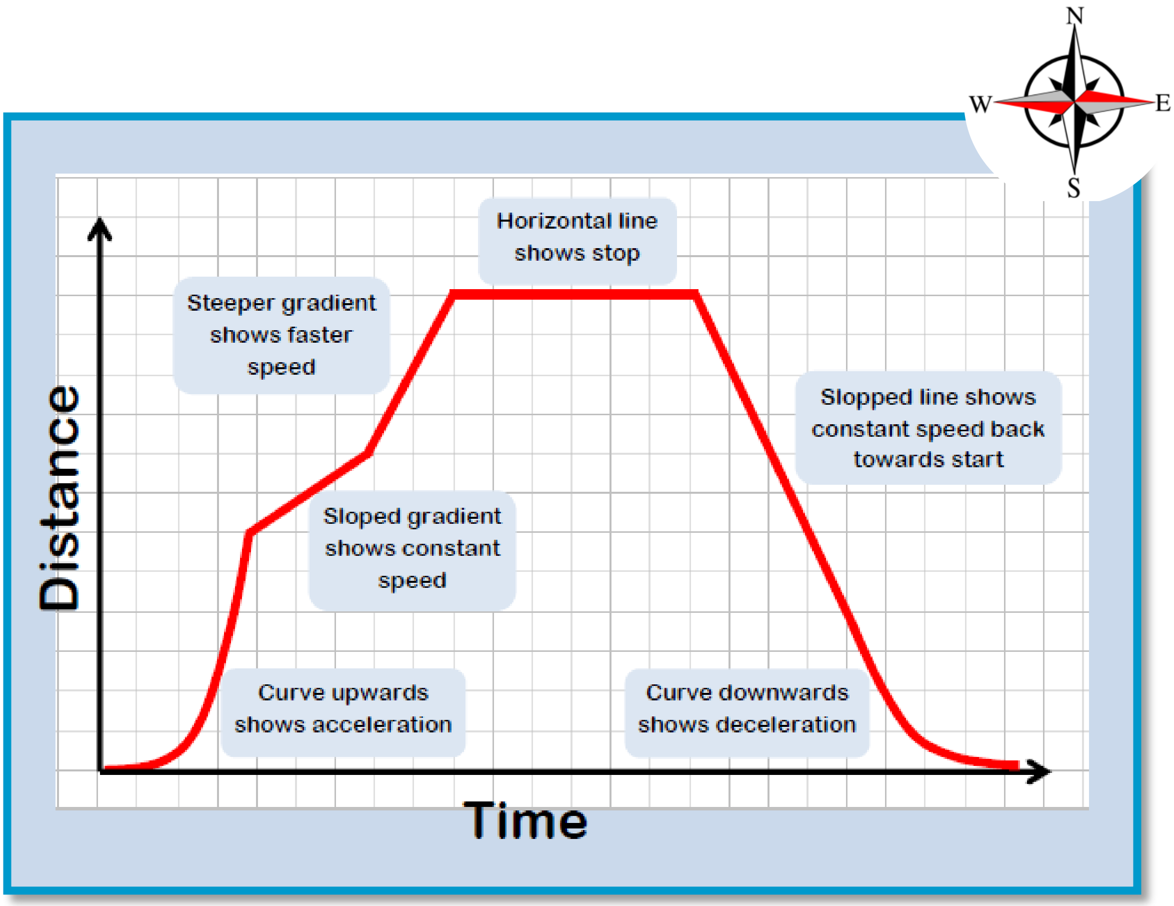


Figure 1.13 (e): Distance-time graph

WHAT I HAVE LEARNED IN LINEAR MOTION?

LINEAR MOTION

DISTANCE
SCALAR

SPEED

EQUATION OF LINEAR MOTION

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

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

$$v = u + at$$

$$v^2 = u^2 + 2as$$

$$s = ut + {}^1\!/_2\, at^2$$

$$s = {}^1{}_2\,(u + v)t$$

DISPLACEMENT
VECTOR

VELOCITY

RATE OF CHANGE

Acceleration

Decelaration

MOTION GRAPHICAL REPRESENTATIONS

s-t graph

v-t graph

Where;

a = acceleration

v = final velocity

u = initial velocity

t = time taken

VELOCITY – TIME GRAPH
TYPES OF QUESTION

SOLVE

TO SOLVE LINEAR MOTION PROBLEM FROM THE VELOCITY-TIME GRAPH

SKETCH

TO SOLVE LINEAR MOTION PROBLEM AFTER SKETCHING THE VELOCITY-TIME GRAPH

EXAMPLE 1.4

Figure 1.14 shows the velocity-time graph of the race car. It moves from a stationary state, undergous uniform acceleration for 280m in 5seconds. Based on Figure 1.14 graph ;

a. Calculate the acceleration of the race car for the first 5 seconds.

b. Calculate the deceleration of the race car

c. Calculate the total displacement of the race car

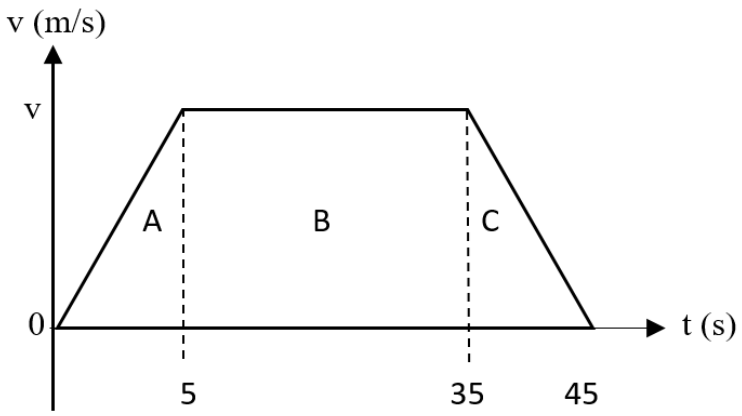


Figure 1.14: Velocity-Time Graph

Solution;

a. Calculate the acceleration of the race car for the first 5 seconds.

$$s = \frac{1}{2}(u + v)t$$

$$v = \frac{2s}{t} - u$$

$$v = \frac{2(280)}{5} - 0$$

$$v = 112 \text{ m/s}$$

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

$$a = \frac{112 - 0}{5}$$

$$\mathbf{a = 22.4\ m/s^2}$$

b. Calculate the deceleration of the race car

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

$$a = \frac{0 - 112}{10}$$

$$\mathbf{a = -11.2\ m/s^2}$$

Negative (-) symbol indicates deceleration of movement

c. Calculate the total displacement of the race car

A = ½ (112)(5) = 280 m,

B = (112)(30) = 3360 m,

C = ½ (112)(10) = 560 m

Total displacement = A + B + C

= 280 m + 3360 m + 560 m

= 4200 m

Displacement = total area under graph

Important to recognize the graph shape either rectangle, triangle or trapezium

EXAMPLE 1.5

Figure 1.15 shows the speed-time graph with 50-second of car movement. Describe the total of movement of every stage.

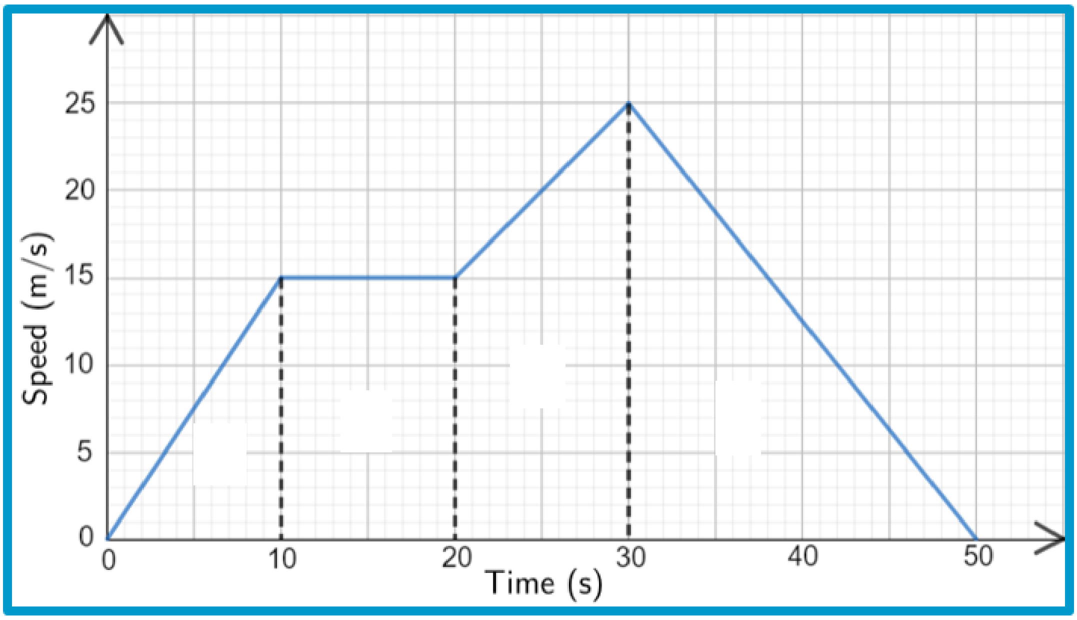
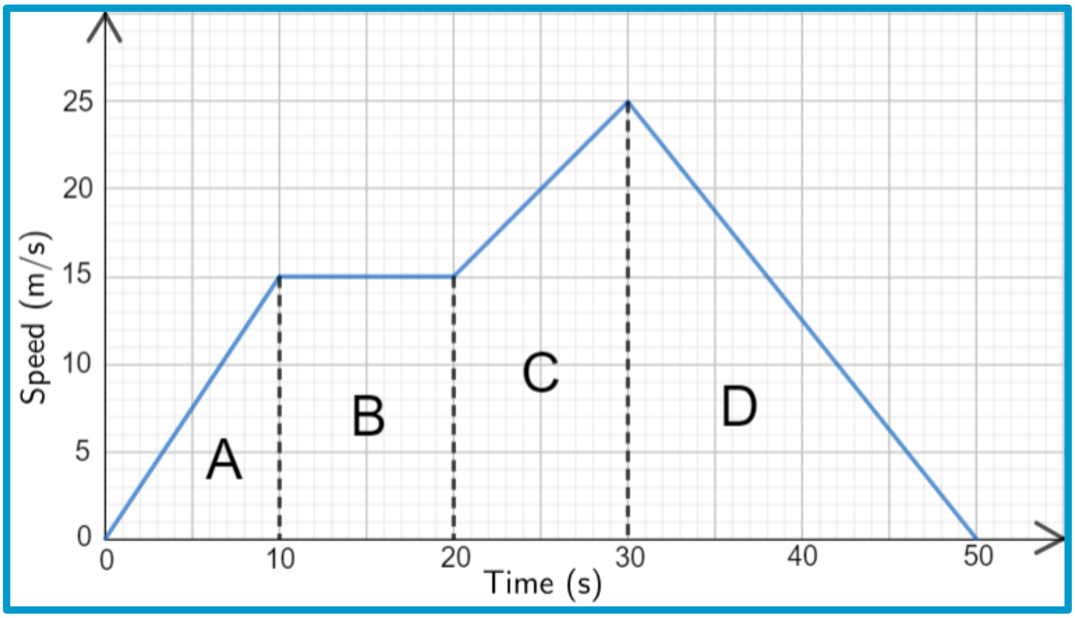


Figure 1.15: The speed-time graph



Solution;

Step 1: Split the graph into distinct sections, such as A, B, *C* and D to every graph shape.

Step 2: Describe each part of the movement as below;

Section A – The car **accelerated** from 0 to 15 m/s over the first 10 seconds (because the line is straight, the acceleration is **constant**).

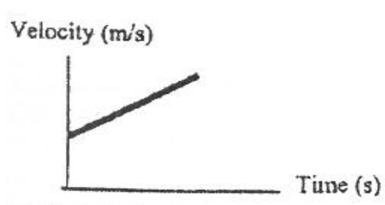
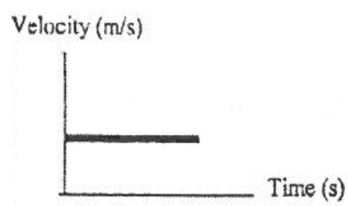
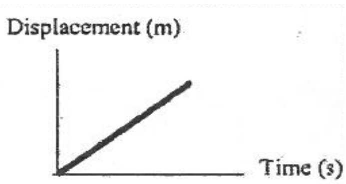
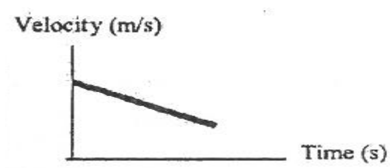
Section B – The line is flat, meaning the car's moving at a **constant speed** or accelaration is zero for the next 10 seconds.

Section C – The car **accelerated** up to 25 m/s over the next 10 seconds.

Section D – Finally the car's **decelerating in the last** 20 seconds back down to 0 m/s (stop).

EXERCISES

Q1 The following graphs show the movement of an object. Specify the types of movement that is represented in each line graph.

i.  Answer:	ii.  Answer:
iii.  Answer:	iv.  Answer:

Answer: (i) Acceleration (ii) Uniformly (ii) Constantly velocity (iv) Deceleration

Q2 **Figure 1.16** shows velocity-time graph of the object. Indicate when the object is;

i. Accelerates between times 0 to 15 seconds
ii. What is the net displacement of the object between curve A and B
iii. What is total displacement of the object
iv. Describe the object's entire motion.

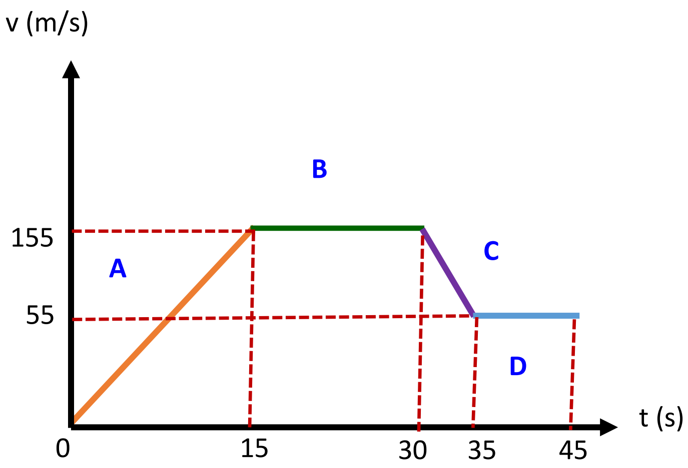


Figure 1.16: Velocity-time graph

Answer: (i) a = 10.33 ms^{-2} (ii) S_{AB}= 3487.5 m (iii) S_T = 4562.5 m

Q3 The graph in **Figure 1.17** represents the movement of a car. Calculate :

i. The initial acceleration

ii. The value of V if the acceleration is $-8 m/s^2$

iii. The total distance travelled by the car

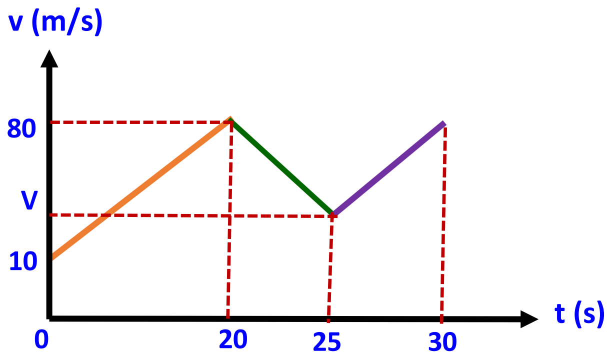


Figure 1.17: Velocity-time graph

Answer: (i) $a=3.5ms^{-2}$ (ii) $v=40m/s$ (iii) $S_T=1500$ m

Q4 A cyslist leaves her home and travels along a straigt road. She accelerates to speed of 12m/s in the first 5 sec. Then she travel at a constant speed for further 17s. A cat jumps out onto the road and she immediately applies brakes slows down uniformly before coming rest. The total motion takes 26s.

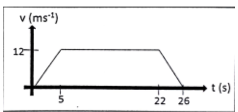
i. Sketch the velocity-time graph

ii. Calculate the value of acceleration

iii. Calculate the deceleration after brake is applied

iv. Calculate the total distance by the cyclist.

Answer: (i)



(ii) $2.4 ms^{-2}$ (iii) $-3 ms^{-2}$ (iv) 258 m

Q5 The speed of a car travelling along a straight road decreases uniformly from 12m/s to 8m/s over 88m before it stop.

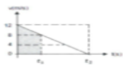
i. Sketch the velocity-time graph for the motion of the car.

ii. Time taken for the car to decrease from 12m/s to 8m/s.

iii. Deceleration of the car.

iv. Time taken for the car to stop from speed 12m/s

v. Total distance travelled by the car.

Answer: (i)  (ii) t_1= 8.8 sec (iii) -0.455ms^{-2} (vi)26.4 sec

(vii) total distance = 158.4 m

Q6 The graph in **Figure 1.18** shows a Camry is moving along a straight road decreases uniformly from 4m/s to 25m/s with constant acceleration of 2 m/s^2 continuous untill stopped with deceleration of 2 m/s^2. Total distance is 5 km. Calculate;

i. Distance during acceleration

ii. Distance traveled during deceleration

iii. Total time traveled by a camry

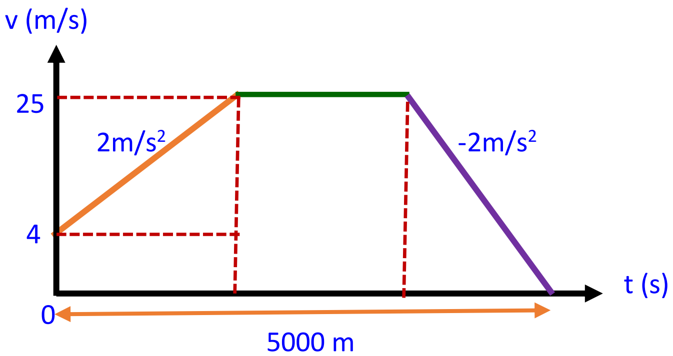


Figure 1.18: Velocity-time graph

Answer: (i) a=125.25 m (ii)156.25 m (iii) 210.66 s

Q7 The graph in **Figure 1.19** shows athletes Darwish, Syahir and Rumi in a 100m sprint race. Determine the following situation;

i. Who won the race? Prove it by calculation.

ii. Who stopped for a rest? For how long?

iii. What was Syahir's average speed?

iv. How long did Darwish have to wait for Rumi to finish?

v. Who was winning the race after 8 seconds? Prove it by calculation.

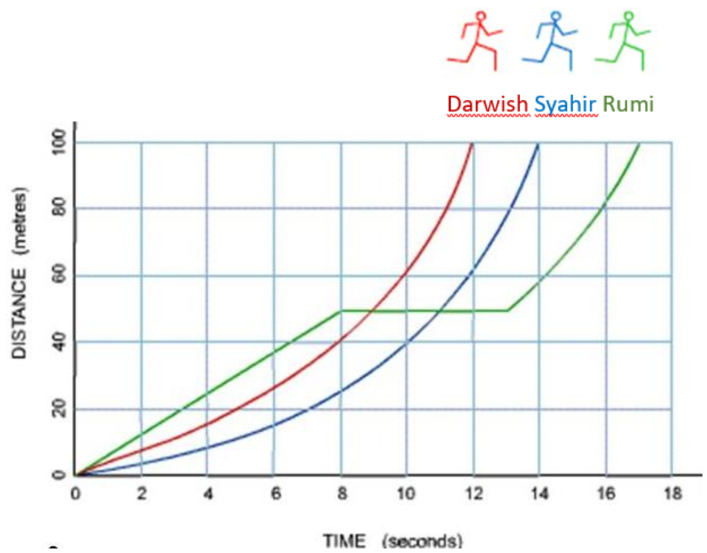


Figure 1.19: Distance-time graph

Answer: (i) Darwish, v = 8.33 m/s (ii)Rumi, 5 s (iii) 7.14 m/s (iv) 5 s (v) Rumi, 5.63 m/s

Q8 The graph in **Figure 1.20** shows a speed-time graph of a 50 second Harley-Davidson journey.

i. Calculate the acceleration in section A.

ii. Explain the state of section B.

iii. Proof that section C = 1 m/s^2

iv. Calculate the acceleration in section D

v. Which section has the maximum acceleration?

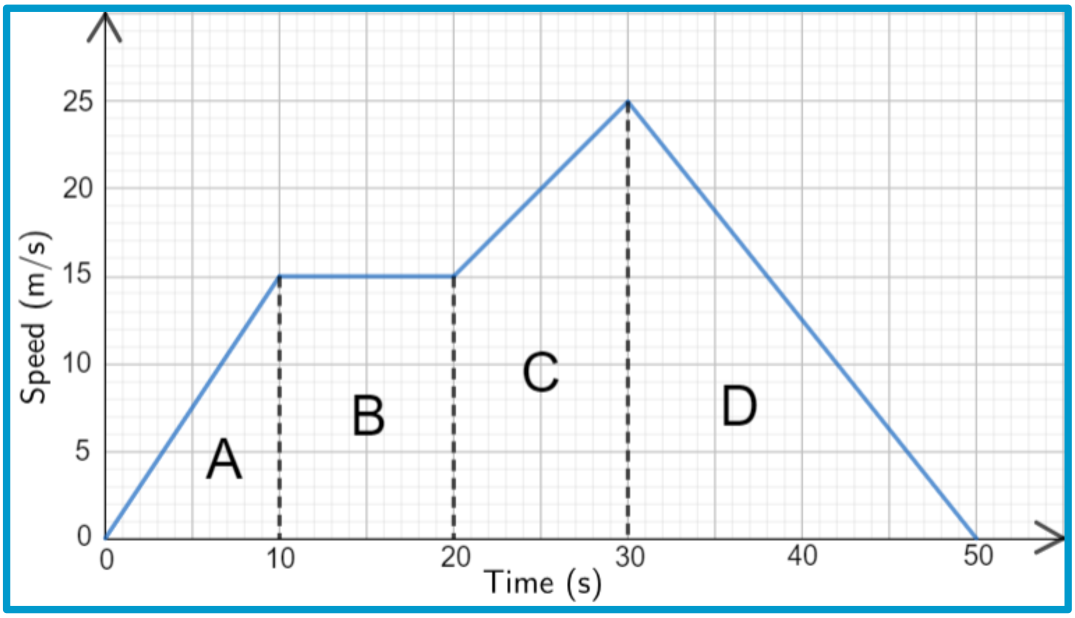


Figure 1.20: Speed-time graph

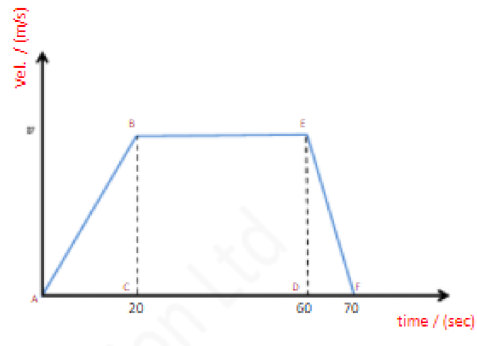
Answer: (i) 1.5 m/s^2 (ii) flat state = 0 (iii) (25-15)/(30-20) = 1 m/s^2 (iv) -1.25 m/s^2 (v) section A, 1.5 m/s^2

Q9 A bus passenger starts from a stop and travels with a uniform acceleration of 0.6 m/s^2 for 20 s until it reaches a maximum velocity. It travels with maximum velocity for another 40 s, the brake is then applied, so that a uniform deceleration is obtained and then come to a halt at the next bus stop after 10 s.

i. Sketch the velocity-time graph of this motion

ii. Calculate the total distance between the two bus stop

Answer: (i)



Answer: (ii)

The total distance travelled s during the journey is equal to the area of the trapezium ABEF

$$s = \frac{1}{2} \times 12 \times (70 + 40)$$

$$= 6 \times 110$$

$$\therefore s = 660\ m$$

Q10 A velocity-time graph in **Figure 1.21** shows the motion of a lift.

i. Describe qualitatively the motion of the lift from 0 to 50 s.

ii. Determine the total distance travelled by the lift.

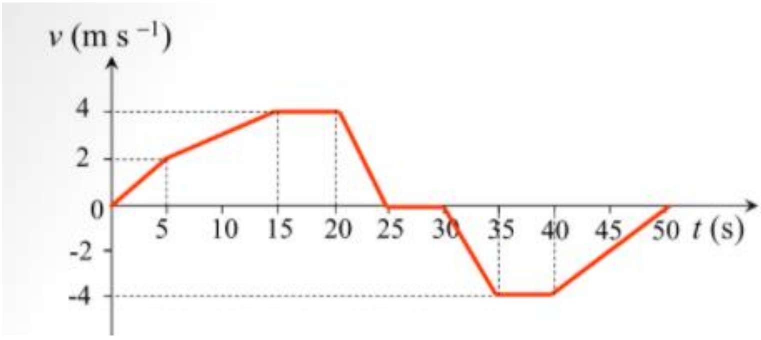
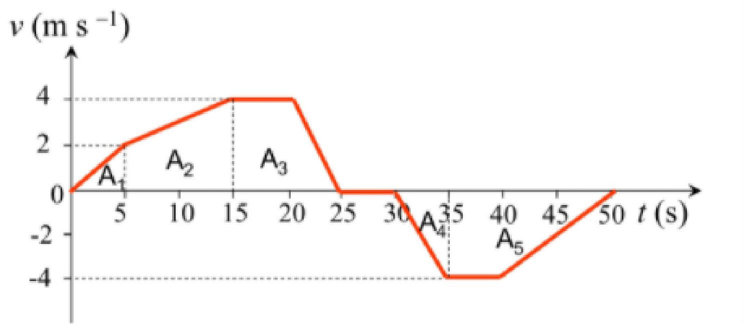


Figure 1.21: Velocity-time graph

Answer: (i)

0 to 5 s	: Lift moves upward from rest with a constant acceleration of 0.4 m s^{-2}.
5 to 15 s	: The velocity of the lift increases from 2 m s^{-1} to 4 m s^{-1} but the acceleration decreasing to 0.2 m s^{-2}.
15 to 20 s	: Lift moving with constant velocity of 4 m s^{-1}.
20 to 25 s	: Lift decelerates at a constant rate of 0.8 m s^{-2}.
25 to 30 s	: Lift at rest or stationary.
30 to 35 s	: Lift moves downward with a constant acceleration of 0.8 m s^{-2}.
35 to 40 s	: Lift moving downward with constant velocity of 4 m s^{-1}.
40 to 50 s	: Lift decelerates at a constant rate of 0.4 m s^{-2} and comes to rest.

Answer: (ii) Total distance = area under graph = 115 m



1.3 Glossary

No.	Glossary
1.	**Linear motion:** Motion along a straight line.
2.	**Uniform motion:** A motion which covers equal distance in equal interval of time
3.	**Non-uniform motion:** A motion which covers unequal distance in equal interval of time.
4.	**Distance:** Total path of length travelled from one location to another
5.	**Displacement:** The length of the straight line connecting the two locations, in a specified direction.
6.	**Speed:** The rate of change of distance.
7.	**Velocity:** The rate of change of displacement.
8.	**Acceleration:** The rate of change of velocity.
9.	**Deceleration:** The rate of decrease in speed in a specified direction.
10.	**Constant velocity:** The acceleration is zero (the slope of the graph is 0)

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