Kinematics

Exercise

Section I: Multiple Choice Questions

Select the correct answer.

1. **Change in position of a body from initial to final point is called:**

   A) Distance
   B) Displacement
   C) Speed
   D) Velocity

2. **The moving wings of a turning fan is an example of:**

   A) Circular motion
   B) Random motion
   C) Vibratory motion
   D) Rotatory motion

3. **A cyclist is travelling in a westward direction and produces a deceleration of $8\ ms^{-2}$ to stop. The direction of its acceleration is towards**

   A) North
   B) West
   C) East
   D) South

4. **Two balls of masses 5 kg and 3 kg respectively are dropped freely from a tower. Which of these balls will reach ground first? (Neglect air resistance)**

   A) Both at same time
   B) 3 kg ball
   C) 5 kg ball
   D) Both will escape the gravity

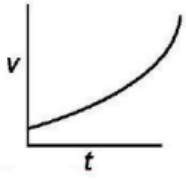
5. **The area under a speed-time graph represents:**

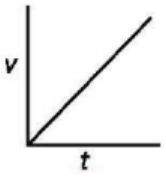
   A) Acceleration
   B) Speed
   C) Distance
   D) Velocity

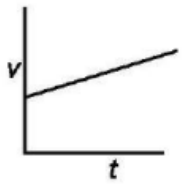
6. **A ball is thrown straight up, what is its acceleration at the top of its path?**

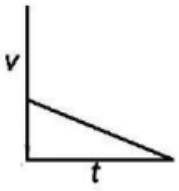
   A) Zero
   B) $5\ ms^{-2}$
   C) $10\ ms^{-2}$
   D) $15\ ms^{-2}$

7. **A car accelerates uniformly from $80.5\ \text{kmh}^{-1}$ at $t = 0$ to $113\ \text{kmh}^{-1}$ at $t = 9$ s. Which graph best describes the motion of the car?**

A) 

B) 

C) 

D) 

8. **A body is moving with constant acceleration starting from rest. It covers a distance in 4 s. How much time does it take to cover one-fourth of this distance?**

A) 1 s
B) 2 s
C) 4 s
D) 16 s

9. **A ball is dropped from the top of a tower, the distance covered by it in the first second is:**

A) 5 m
B) 10 m
C) 50 m
D) 100 m

10. **The numerical ratio of displacement to distance is:**

A) Always less than one
B) Always equal to one
C) Always greater than one
D) Equal to or less than one

11. **A car is moving with velocity of $10\ \text{ms}^{-1}$. If it has acceleration of $2\ \text{ms}^{-2}$ for 10 s. What is final velocity of the car?**

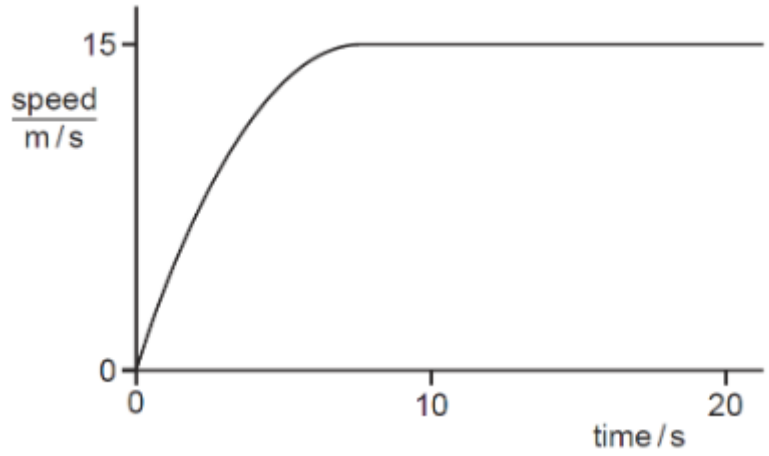
A) $30\ \text{ms}^{-1}$
B) $20\ \text{ms}^{-1}$
C) $10\ \text{ms}^{-1}$
D) $15\ \text{ms}^{-1}$

12. **When the slope of a body's displacement-time graph increases, the body is moving with:**

A) Increasing velocity
B) Decreasing velocity

C) Constant velocity D) All of these

13. The graph shows how the speed of a car varies with time. Which statement about the acceleration of the car between 10 s and 20 s is correct?



A) Acceleration decreases. B) Acceleration increases.

C) Acceleration is constant, but not zero. D) Acceleration is zero.

Section II: Short Answer Questions

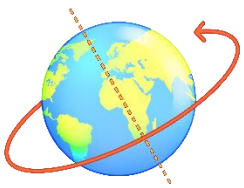
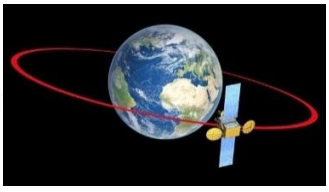
1. Differentiate between rest and motion.

Ans.

Rest	Motion
A body is said to be at rest if its position does not change with respect to its surroundings.	A body is said to be in motion if its position changes with respect to its surroundings.
No change in position with time.	Position changes with time.
Example: A book lying on a table.	Example: A moving car on the road.

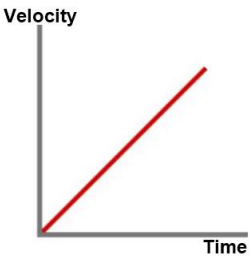
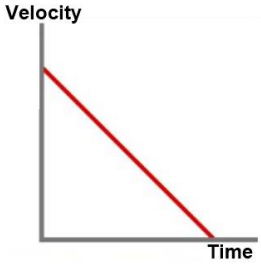
2. Differentiate between rotatory motion and circular motion. Give example for each.

Ans.

Rotatory Motion	Circular Motion
Motion in which a body rotates about its own axis.	Motion in which a body moves along a circular path.
Every point of the body moves in a circle around the axis.	The whole body moves around a fixed center.
Axis lies within the body.	Axis lies outside the body.
Example: Ceiling fan, Earth spinning.	Example: Stone tied to a string, satellite around Earth.
	

3. Differentiate between positive and negative acceleration. Show these quantities graphically.

Ans.

Positive Acceleration	**Negative Acceleration (Deceleration)**
Acceleration in the same direction as velocity.	Acceleration in the opposite direction to velocity.
Velocity increases with time.	Velocity decreases with time.
Example: Car speeding up.	Example: Car slowing down (braking).
Graph: 	Graph: 

4. With the help of daily life example, describe the situations in which acceleration is zero and body is in motion

Ans.

Example

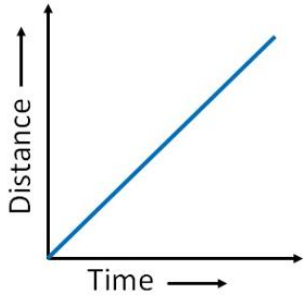
A car moving with constant speed on a straight road.

Explanation

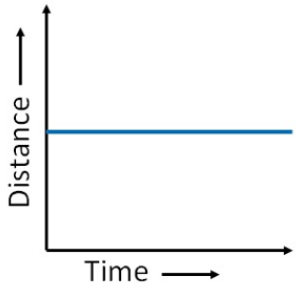
In the example car is moving with constant velocity so the acceleration will be zero as there is no change in the velocity.

5. Sketch the distance-time graph for the given states:

a. When object moves with constant speed



b. When the object is at rest

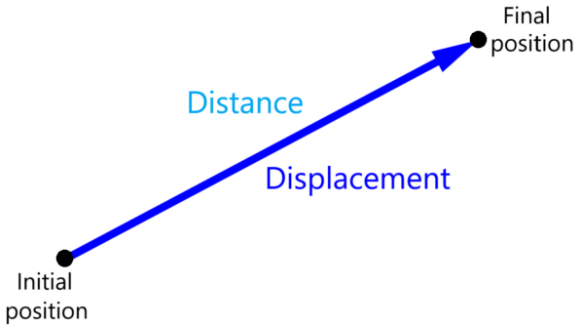


6. Distance and displacement may or may not be equal in magnitude. Explain this statement.

Ans. Distance is the total path covered, while displacement is the shortest distance in a specific direction.

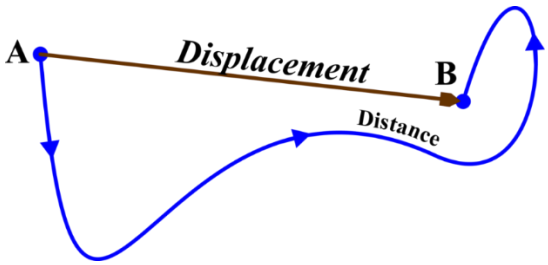
- If motion is in a straight line without changing direction, then:

$$\text{Distance} = \text{Displacement}$$



- If motion involves turning or circular path, then:

$$\text{Distance} > \text{Displacement}$$



7. **When a bullet is fired, its velocity with which it leaves the barrel is called the muzzle velocity of the gun. The muzzle velocity of one gun with a longer barrel is lesser than that of another gun with a shorter barrel. In which gun is the acceleration of the bullet larger? Explain your answer.**

Ans. We know that acceleration is:

$$a = \frac{\text{Change in velocity}}{\text{Time}} = \frac{\Delta v}{\Delta t}$$

$$a \propto \frac{1}{\Delta t}$$

From the above formula, it depends on change in velocity and time and for a constant change in velocity it is inversely proportional to time. A longer barrel means the bullet takes more time to reach muzzle velocity. A shorter barrel means less time.

8. **For a complete trip, average velocity was calculated. Its value came out to be positive. Is it possible that its instantaneous velocity at any time during the trip had the negative value? Give justification of your answer.**

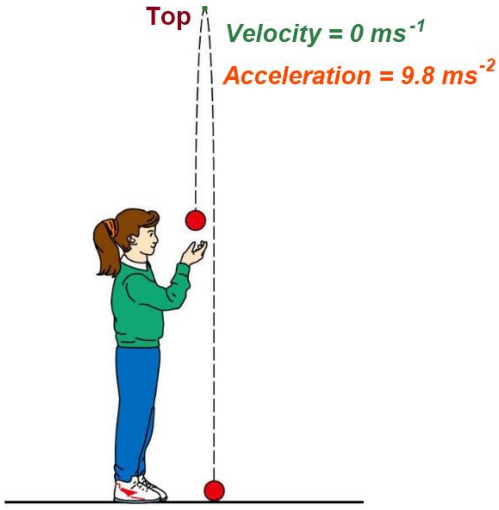
Ans. Yes, it is possible. Average velocity depends on total displacement, while instantaneous velocity depends on direction at a particular moment.

Example:

A person moves forward from point A to point B and then move backward to point C. At point B in below diagram, instantaneous velocity is negative, but overall displacement is positive, so average velocity will be positive.

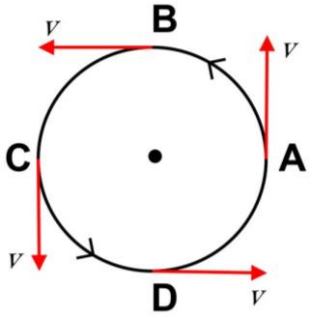
9. Is it possible that the velocity of an object is zero at an instant of time, but its acceleration is not zero? If yes, give an example of such a case.

Ans. Yes, it is possible. When a body is thrown upward, at the top it stops for a moment and then fall. At the top of the path, the velocity is zero but the acceleration is non-zero. The acceleration is gravitational acceleration and its value at this point is 9.8 ms^{-2}.



10. Is it possible to accelerate an object without speeding it up or slowing it down?

Ans. Yes, it is possible. Acceleration depends on change in velocity, and velocity includes direction, so when an object is moving in a circular path with constant speed then it will have some acceleration due to change in the direction during motion but the speed is constant.



11. A 10 g ball is just released (from rest) and another is thrown downward with velocity of 10 ms^{-1}, which will have greater acceleration? (Neglect the air resistance).

Ans. Both balls have the same acceleration equal to gravitational acceleration $g = 9.8\ ms^{-2}$, which is independent of mass and initial velocity. Gravity acts equally on both objects regardless of how they are released or thrown. The only difference is in initial velocity, so the thrown ball reaches the ground earlier, but acceleration remains the same.

Section III: Extensive Answer Questions

1. Differentiate between distance and displacement.

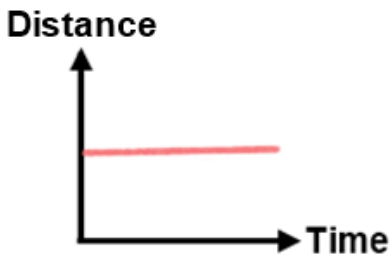
Ans.

Distance	Displacement
Distance is the total length of the actual path travelled by a body.	Displacement is the shortest straight-line distance from the initial position to the final position.
It is a scalar quantity.	It is a vector quantity.
It has magnitude only.	It has magnitude as well as direction.
It is always positive or zero.	It may be positive, negative, or zero, depending on direction.
It depends on the actual path followed.	It depends only on the initial and final positions.
Distance can never be less than displacement.	Displacement can be equal to or less than distance.
In a round trip, distance is not zero.	In a round trip, displacement is zero.

2. Draw distance-time graphs for rest, uniform speed, increasing speed and decreasing speed.

Ans.

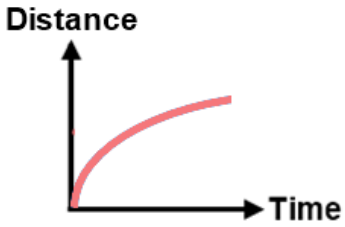
<u>Distance-time Graph for Rest</u>



Distance-time Graph for Uniform Speed

Distance-time Graph for Increasing Speed

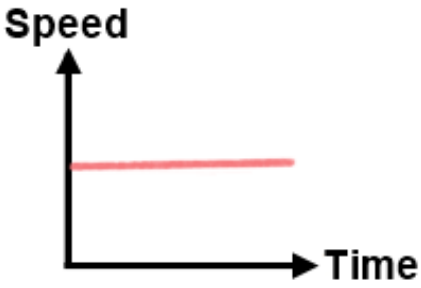
Distance-time Graph for Decreasing Speed



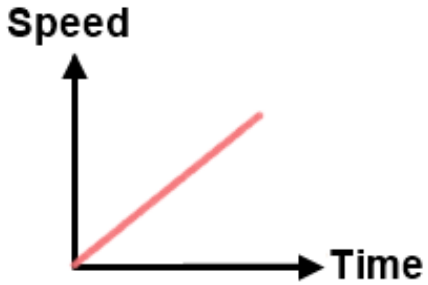
3. Draw speed-time graphs for zero acceleration, uniform acceleration, uniform deceleration. Also show that area under speed-time graph represents distance covered by the body.

Ans.

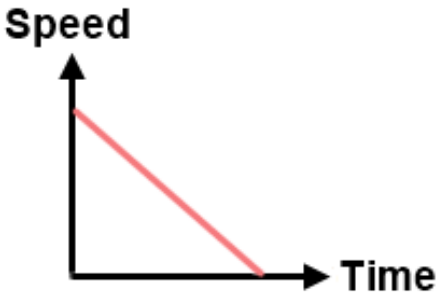
Speed-time Graph for Zero Acceleration



Speed-time Graph for Uniform Acceleration

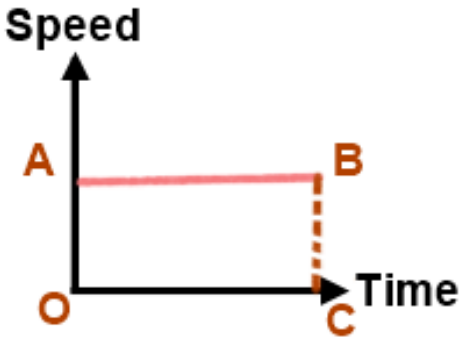


Speed-time Graph for Uniform Deceleration



Area under speed-time graph

Suppose a body is moving with constant speed ***v*** for some time t. The speed-time graph for this motion is shown in below diagram.



The area under speed-time graph is equal to the area of rectangle OABC:

$$\text{Area under speed} - \text{time graph} = \text{Area of rectangle OABC}$$

$$= \text{Length} \times \text{Width}$$

$$= \text{Time} \times \text{Speed} \qquad \ldots. \text{ eq } 1$$

As we know,

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

$$\text{Time} \times \text{Speed} = \text{Distance}$$

Put the value in eq 1,

$$\text{Area under speed} - \text{time graph} = \text{Distance}$$

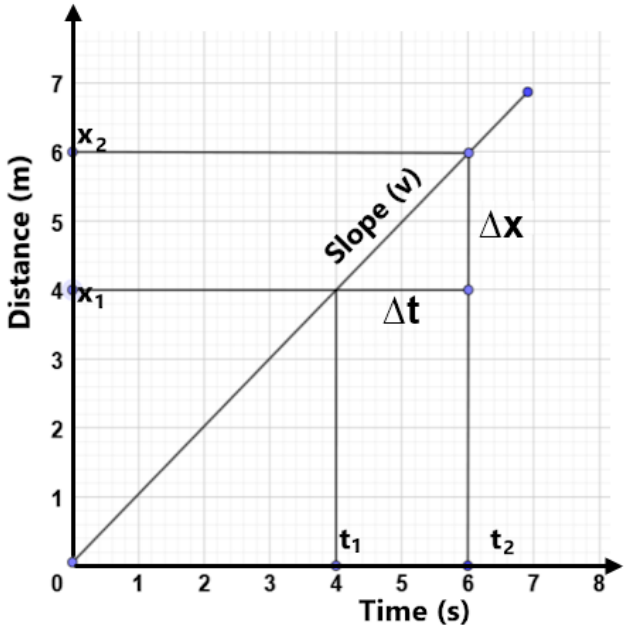
Hence proved that Area under speed-time graph is equal to the total distance covered by the body during the motion for some time.

4. What do gradients of distance-time graph and speed-time graph represent? Explain it by drawing diagrams.

Ans.

<u>Gradient (Slope) of Distance-time graph</u>

Suppose a body is moving and cover distance x_1 in time t_1 and then covered distance x_2 in time t_2 with constant speed v. The distance-time graph for this motion is shown in below diagram.



The slope of the distance-time graph

$$\text{Slope} = \frac{\text{Change in y} - \text{axis}}{\text{Change in x} - \text{axis}}$$

From the graph:

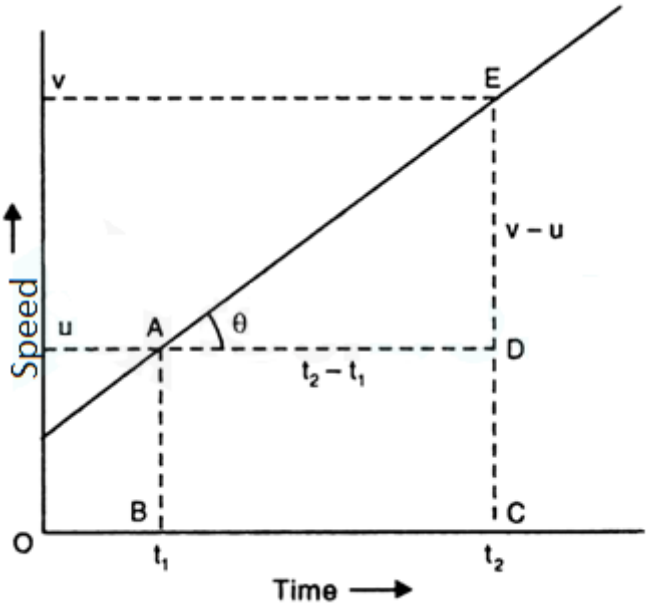
$$\text{Slope} = \frac{\text{Distance}}{\text{Time}} = \text{Speed}$$

$$\text{Slope} = \text{Speed}$$

Therefore, the slope (gradient) of distance-time graph will give us the speed.

Gradient (Slope) of Speed-time graph

Suppose a body is moving with a speed v_1 in time t_1 and then changes its speed uniformly to v_2 in time t_2. The speed-time graph for this motion is shown in below diagram.



The slope of the speed-time graph

$$\text{Slope} = \frac{\text{Change in y} - \text{axis}}{\text{Change in x} - \text{axis}}$$

From the graph:

$$\text{Slope} = \frac{\text{Change in speed}}{\text{Time}} = \text{Magnitude of acceleration}$$

$$\text{Slope} = \text{Magnitude of acceleration}$$

Therefore, the slope (gradient) of speed-time graph will give us the magnitude of acceleration.

5. What are different types of motion? Define each type of motion with examples from daily life.

Ans.

Motion

Motion is the change in position of a body with time with respect to its surroundings. There are different types of motion depending on how a body moves.

Types of Motion

a. Translatory motion
b. Rotatory motion
c. Vibratory motion

Translatory Motion

Translatory motion is the motion in which all parts of the body move in the same direction.

It has three further types.

- Rectilinear motion
- Curvilinear motion
- Random Motion

Rectilinear Motion

When a body moves along a straight line, its motion is called rectilinear motion.

Examples:

- A car moving on a straight road

- A train moving on a straight track
- A falling stone

Curvilinear Motion

When a body moves along a curved path, its motion is called curvilinear motion.

Examples:

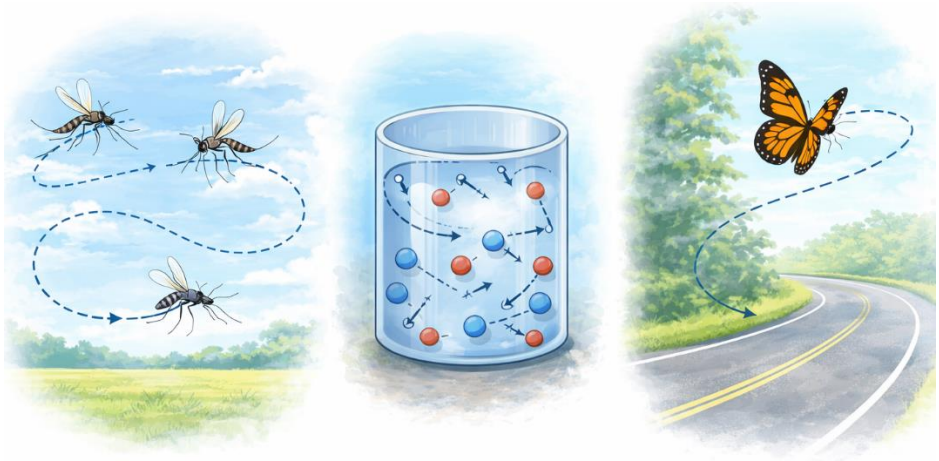
- A ball thrown in air with some angle.
- A car moving on a curved road

Random Motion

Random motion is the irregular and unpredictable motion in which a body moves in no fixed direction.

Examples:

- Motion of mosquitoes in air
- Motion of gas molecules
- Motion of a butterfly



Vibratory Motion

Rotatory motion is the to-and-fro motion of a body about its mean position.

Examples:

- A spinning top
- Earth rotating about its axis

Rotatory Motion

Rotatory motion is the motion in which a body rotates about its own axis.

Examples:

- Motion of a simple pendulum
- Motion of guitar strings
- Motion of tuning fork

Section IV: Numerical Problems

Q1. Find the retardation produced when a car moving at a velocity of 30 m s^{-1} slows down uniformly to 15 m s^{-1} in 5 s.

Given

Initial velocity $(u) = 30\,\text{ms}^{-1}$

Final Velocity $(v) = 15\,\text{ms}^{-1}$

Time $(t) = 5\,\text{s}$

Solution

We know that acceleration is the rate of change of velocity:

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

Substituting the values:

$$a = \frac{15 - 30}{5}$$

$$a = \frac{-15}{5}$$

$$a = -3\,\text{ms}^{-2}$$

The negative sign shows that the car is slowing down, so the **retardation** is:

$$\boxed{3\,\text{ms}^{-2}}$$

Q2. A car slows down from 100 kmh^{-1} with a uniform retardation of 2 ms^{-2}. How long will it take to attain a speed of 20 kmh^{-1}?

Given

Initial velocity $(u) = 100\,\text{kmh}^{-1}$

Final Velocity $(v) = 20\,\text{kmh}^{-1}$

Acceleration (retardation) $(a) = -2\,\text{ms}^{-2}$

Solution

First convert the speeds from kmh^{-1} to ms^{-1}.

$$100\,\text{kmh}^{-1} = 100 \times \frac{1000}{3600} = 27.78\,\text{ms}^{-1}$$

$$20\,\text{kmh}^{-1} = 20 \times \frac{1000}{3600} = 5.56\,\text{ms}^{-1}$$

Using:

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

So,

$$-2 = \frac{5.56 - 27.78}{t}$$

$$-2 = \frac{-22.22}{t}$$

Now multiply both sides by t:

$$-2t = -22.22$$

Divide both sides by -2:

$$t = \frac{22.22}{2}$$

$$t = 11.11\,\text{s}$$

Therefore, the required time is:

$$\boxed{11.1\,\text{s}}$$

Q3. A car starts its motion and accelerates at $2\,\text{ms}^{-2}$. Find its velocity after covering a distance of 1 km.

Given

Since the car starts its motion, its initial velocity $(u) = 0\,\text{ms}^{-1}$

Acceleration (retardation) $(a) = -2\,\text{ms}^{-2}$
Distance $(s) = 1\,\text{km} = 1000\,\text{m}$

Solution

For uniform acceleration:

$$\text{Average velocity} = \frac{u + v}{2}$$

Since $u = 0$:

$$\text{Average velocity} = \frac{v}{2}$$

Also,

$$\text{Distance} = \text{Average velocity} \times \text{time}$$

So,

$$1000 = \frac{v}{2} \times t$$

$$1000 = \frac{vt}{2}$$

Now from the definition of acceleration:

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

Since $u = 0$:

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

Given $a = 2$:

$$2 = \frac{v}{t}$$

$$v = 2t$$

Now substitute this in

$$1000 = \frac{vt}{2}$$

$$1000 = \frac{(2t)t}{2}$$

$$1000 = t^2$$

$$t = \sqrt{1000} = 31.62\,\text{s}$$

Now find v:

$$v = 2t = 2(31.62)$$

$$v = 63.24\,\text{ms}^{-1}$$

Therefore, the velocity of the car is:

$$\boxed{63.2\,\text{ms}^{-1}}$$

Q4. A stone is dropped from the top of a tower. If it takes 6 s to hit the ground, find the height of the tower and the velocity with which the stone hits the ground. (Take g = 10 ms^{-2})

Given

Since the stone is dropped, its initial velocity $(u) = 0\,\text{ms}^{-1}$

Gravitational acceleration $(g) = 10\,\text{ms}^{-2}$

Time $(t) = 6\,\text{s}$

Solution

Using the definition of acceleration:

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

Since $u = 0$:

$$10 = \frac{v}{6}$$

$$v = 10 \times 6$$

$$v = 60\,\text{ms}^{-1}$$

So, the stone hits the ground with velocity:

$$\boxed{60\,\text{ms}^{-1}}$$

For uniformly accelerated motion:

$$\text{Average velocity} = \frac{u + v}{2}$$

$$\text{Average velocity} = \frac{0 + 60}{2} = 30\,\text{ms}^{-1}$$

Now,

$$\text{Distance} = \text{Average velocity} \times \text{time}$$

$$h = 30 \times 6$$

$$h = 180\,\text{m}$$

Therefore, the height of the tower is:

$$\boxed{180\,\text{m}}$$

Q5. A cricket ball is hit vertically upwards and returns to the ground 10 s later. Calculate the maximum height reached by the ball. ($\mathbf{g = 10\,ms^{-2}}$)

Given

Total Time (t) = 10 s

At the highest point, the velocity becomes zero.

So,

Final velocity at highest point $(u) = 0\,\text{ms}^{-1}$
Gravitational acceleration $(g) = 10\,\text{ms}^{-2}$

Solution

Since the ball goes up and comes down symmetrically, the time taken to reach the highest point is:

$$t_{\text{up}} = \frac{10}{2} = 5\,\text{s}$$

Using:

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

$$10 = \frac{u - 0}{5}$$

$$u = 10 \times 5$$

$$u = 50\,\text{ms}^{-1}$$

So the initial upward velocity is:

$$50\,\text{ms}^{-1}$$

Now find the maximum height using average velocity.

$$\text{Average velocity} = \frac{u + v}{2}$$

$$\text{Average velocity} = \frac{50 + 0}{2} = 25\,\text{ms}^{-1}$$

Now,

$$\text{Height} = \text{Average velocity} \times \text{time}$$

$$h = 25 \times 5$$

$$h = 125\,\text{m}$$

Therefore, the maximum height reached by the ball is:

$$\boxed{125\,\text{m}}$$

Q6. In 10 seconds, a cyclist increases its speed from 5 kmh^{-1} to 7 kmh^{-1}, while a car moves from rest to 20 kmh^{-1} in the same time. Calculate and compare the acceleration in each case.

For Cyclist:

Given

Initial velocity $(u) = 5\,\text{kmh}^{-1}$

Final Velocity $(v) = 7\,\text{kmh}^{-1}$

Time $(t) = 10\,\text{s}$

Solution

Convert speeds into ms^{-1}:

$$5\,\text{kmh}^{-1} = 5 \times \frac{1000}{3600} = 1.39\,\text{ms}^{-1}$$

$$7\,\text{kmh}^{-1} = 7 \times \frac{1000}{3600} = 1.94\,\text{ms}^{-1}$$

Using:

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

$$a = \frac{1.94 - 1.39}{10}$$

$$a = \frac{0.55}{10}$$

$$a = 0.055\,\text{ms}^{-2}$$

So, acceleration of cyclist is:

$$\boxed{0.055\,\text{ms}^{-2}}$$

For Car:

Given

The car starts from rest, so the Initial velocity $(u) =$ ms^{-1}

Final Velocity $(v) = 20\,\text{kmh}^{-1}$

Time $(t) = 10\,\text{s}$

Solution

Convert $20\,\text{kmh}^{-1}$ into ms^{-1}:

$$20\,\text{kmh}^{-1} = 20 \times \frac{1000}{3600} = 5.56\,\text{ms}^{-1}$$

Using:

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

$$a = \frac{5.56 - 0}{10}$$

$$a = 0.556\,\text{m s}^{-2}$$

So, acceleration of car is:

$$\boxed{0.556\,\text{ms}^{-2}}$$

Comparison:

$$0.556 > 0.055$$

Hence, the acceleration of the car is greater than that of the cyclist.

In fact:

$$\frac{0.556}{0.055} \approx 10$$

So, the car's acceleration is about **10 times** the cyclist's acceleration.

Q7. A car is moving with uniform velocity of 20 ms^{-1} for 20 s. Then brakes are applied and it comes to rest with uniform deceleration in 30 s. Plot the graph to calculate the distance using speed-time graph.

Given

Initial uniform velocity $(u) = 5\,ms^{-1}$

Final Velocity $(v) = 0\,ms^{-1}$

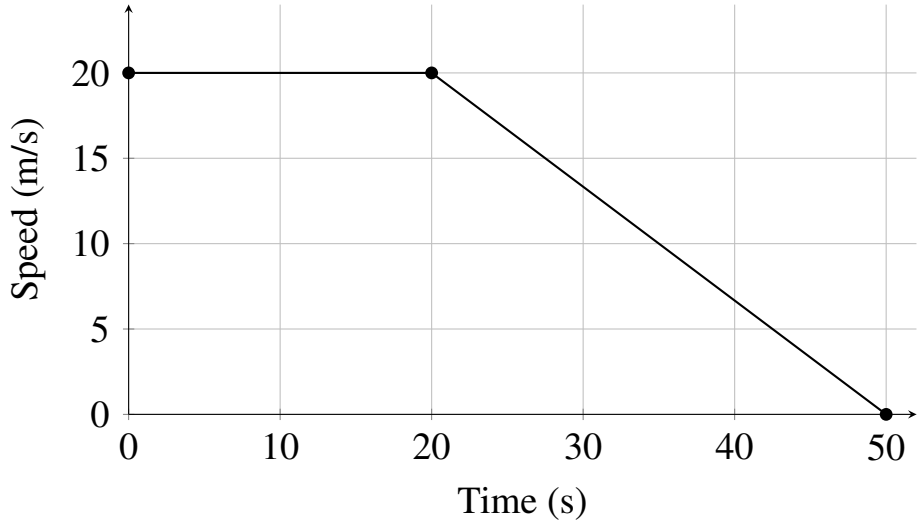
Time for initial uniform velocity $(t_1) = 20\,s$

Time for uniform deceleration $(t_2) = 30\,s$

Solution

Here it is the speed-time graph for the motion;

Speed-Time Graph:



The speed-time graph consists of two parts:

- From 0 to 20 s, the speed remains constant at 20 ms^{-1}.
- From 20 to 50 s, the speed decreases uniformly from 20 ms^{-1} to 0.

Distance in first part

Distance covered equals area under the speed-time graph.

From 0 to 20 s, the graph is a rectangle.

$$\text{Area of rectangle} = \text{length} \times \text{breadth}$$

$$= 20 \times 20$$

$$= 400\,\text{m}$$

Distance in second part

From 20 to 50 s, the graph is a triangle.

$$\text{Area of triangle} = \frac{1}{2} \times \text{base} \times \text{height}$$

$$= \frac{1}{2} \times 30 \times 20$$

$$= 300\,\text{m}$$

Total distance

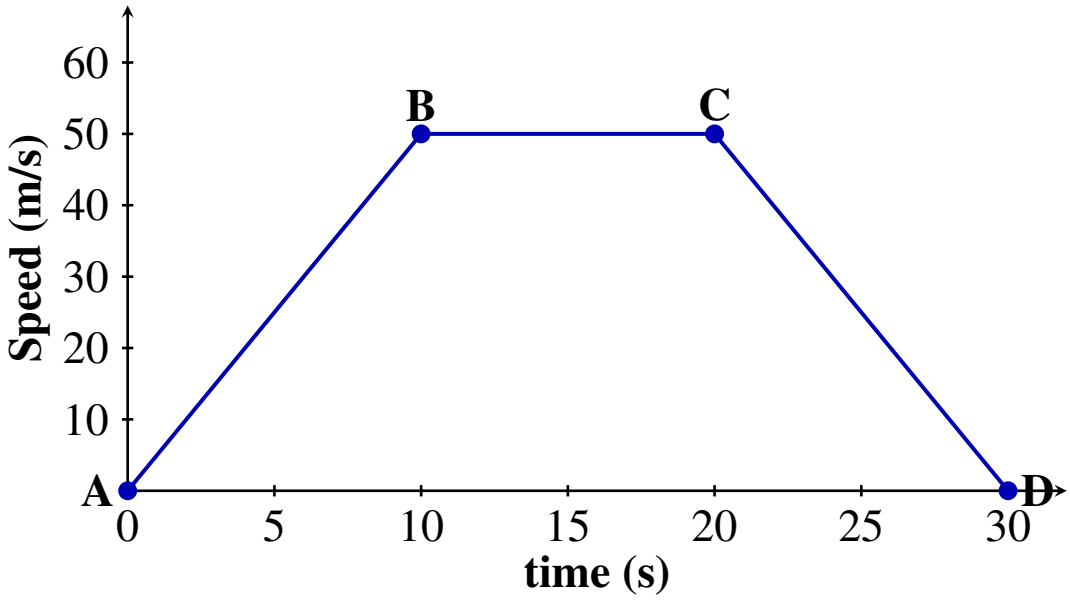
$$\text{Total distance} = 400 + 300$$

$$\text{Total distance} = 700\,\text{m}$$

Therefore, the total distance covered is:

$$\boxed{700\,\text{m}}$$

Q8. Consider the following speed-time graph. Tell:



a. Which part of the graph is showing acceleration, deceleration and zero acceleration?

b. Calculate covered distance from 10 s to 20 s from the graph.

Given

The graph has the following points:

$$A(0,0), \qquad B(10,50), \qquad C(20,50), \qquad D(30,0)$$

Solution

(a) Identification of parts

- **AB** shows **acceleration** because speed is increasing from 0 to 50 ms^{-1}.
- **BC** shows **zero acceleration** because speed remains constant at 50 ms^{-1}.
- **CD** shows **deceleration** because speed decreases from 50 ms^{-1} to 0.

Therefore:

AB = acceleration, BC = zero acceleration, CD = deceleration

(b) Distance covered from 10 **s to** 20 **s**

From 10 s to 20 s, the speed is constant at:

$$50\,\text{ms}^{-1}$$

Distance covered in this interval is the area of the rectangle under the graph.

$$\text{Distance} = \text{speed} \times \text{time}$$

$$= 50 \times (20 - 10)$$

$$= 50 \times 10$$

$$= 500\,\text{m}$$

Therefore, the distance covered is:

$$\boxed{500\,\text{m}}$$

Q9. A car passes a green traffic signal while moving with a velocity of 5 ms^{-1}. It then accelerates to 1.5 ms^{-2}. What is the velocity of the car after 5 s?

Given

Initial velocity $(u) = 0\,\text{ms}^{-1}$

Acceleration $(a) = 1.5\,\text{ms}^{-2}$

Time $(t) = 10\,\text{s}$

Solution

Using:

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

Substituting the values:

$$1.5 = \frac{v - 5}{5}$$

Multiply both sides by 5:

$$7.5 = v - 5$$

Add 5 to both sides:

$$v = 12.5\,\text{ms}^{-1}$$

Therefore, the velocity of the car after 5 s is:

$$\boxed{12.5\,\text{ms}^{-1}}$$

Q10. A car travels 10 km with an average velocity of 20 ms^{-1}. It then travels in the same direction through a diversion at an average velocity of 4 ms^{-1} for the next 0.8 km. Determine the average velocity of the car for the total journey.

Given

Distance covered in the first part $(s_1) = 10\,\text{km}$
Average velocity in the first part $(v_1) = 20\,\text{ms}^{-1}$
Distance covered in the second part $(s_2) = 0.8\,\text{km}$
Average velocity in the second part $(v_2) = 4\,\text{ms}^{-1}$

Solution

Average velocity for the whole journey is:

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

Since the car moves in the same direction throughout, total displacement is equal to total distance.

Convert distances into metres

$$10\,\text{km} = 10000\,\text{m}$$

$$0.8\,\text{km} = 800\,\text{m}$$

Time for first part

$$\text{Time} = \frac{\text{Distance}}{\text{Velocity}}$$

$$t_1 = \frac{10000}{20} = 500\,\text{s}$$

Time for second part

$$t_2 = \frac{800}{4} = 200\,\text{s}$$

Total displacement

$$\text{Total displacement} = 10000 + 800 = 10800\,\text{m}$$

Total time

$$\text{Total time} = 500 + 200 = 700\,\text{s}$$

Average velocity for whole journey

$$\text{Average velocity} = \frac{10800}{700}$$

$$\text{Average velocity} = 15.43\,\text{ms}^{-1}$$

Therefore, the average velocity of the car for the total journey is:

$$\boxed{15.43\,\text{ms}^{-1}}$$