UNIT 02

Kinematics

Q.1. Define mechanics and also Differentiate between the two main branches of mechanics. 09102001

Ans: Mechanics:

Mechanics is the branch of physics that deals with the motion of objects and the forces that cause or change this motion. It helps us study and predict how objects behave when in motion or when forces are applied to them.

Two Main Branches of Mechanics:

i. **Kinematics:**

Kinematics is the study of motion without referring to the forces that cause it. It focuses on describing how objects move by examining parameters like displacement, velocity, acceleration, and time.

Example: Describing the motion of cars, buses, or motorcycles moving on the road without considering what causes them to move.

ii. **Dynamics:**

Dynamics deals with the study of forces and their effect on the motion of objects. It explains why an object moves and considers the forces that cause or change this motion.

Example: The motion of an object falling from a table to the ground by analyzing the force of gravity acting on it.

Q.2. Differentiate between scalar and vector quantities with examples. 09102002

Ans: Scalars:

A **scalar** is a physical quantity that can be described completely by its **magnitude only**. **Magnitude** includes a **number** and an appropriate **unit**. For example, when we ask a shopkeeper for 5 kilograms of sugar, the shopkeeper fully understands the quantity we want based solely on the magnitude of the mass.

Examples:

Mass, length, time, speed, volume, work, energy, pressure, and power etc.

Addition of Scalars:

Scalar quantities can be added using simple arithmetic operations. For example:

$$5 \text{ meters} + 3 \text{ meters} = 8 \text{ meters}$$

Vectors:

A **vector** is a physical quantity that requires both **magnitude** and **direction** to be described completely.

Examples:

Velocity, displacement, force, momentum, torque, acceleration, and weight etc.

Addition of Vectors:

Vectors cannot be added like scalars because vector quantity need magnitude and direction. Vector quantities are added by head to tail rule.

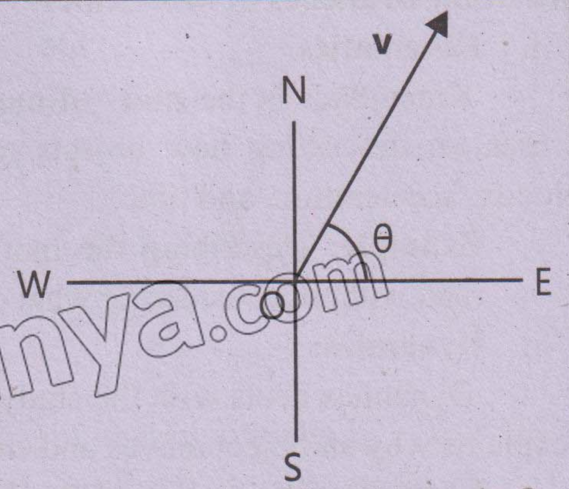
Importance in Kinematics:

Understanding the distinction between scalars and vectors is very important in kinematics because motion involves both the magnitude and direction of quantities like velocity and displacement. While scalar quantities describe "how much," vector quantities describe "how much and in which direction." This distinction helps accurately describe and analyze the motion of objects.

Q.3. How are vectors represented symbolically and graphically? Explain. 09102003

Ans: Symbolic Representation of Vectors:

Vectors are represented in textbooks using **boldface letters**, such as **A**, **V**, **F**, and **d**. However, when writing by hand, vectors are denoted with a **small arrow** over the letter, like $\vec{A}$,$\vec{V}$, $\vec{F}$ and $\vec{d}$. The **magnitude** of a vector is shown using the same letter without the arrow, written in italics, such as *A, V, F and d*.



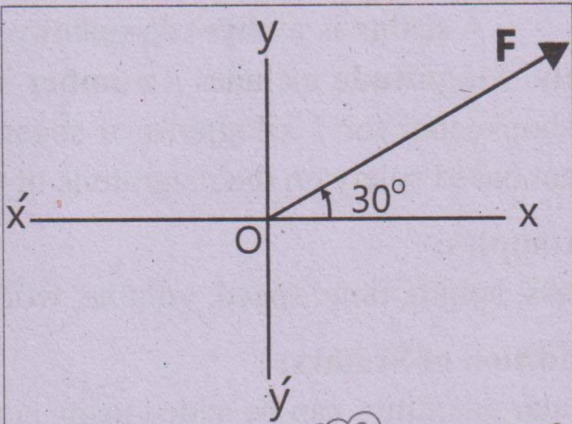
A vector **v** making an angle θ towards north from east

Fig 2.1 (a)

Graphical Representation of Vectors:

Vectors can be represented graphically by drawing a **straight line** with an **arrowhead** at one end.

- **Magnitude:** The length of the line corresponds to the vector's magnitude, determined according to a suitable scale.
- **Direction:** The arrowhead indicates the vector's direction.



A Vector **F** making angle 30° with x-axis

Fig. 2.1 (b)

Reference Axes for Direction:

To define the direction of a vector, we use two **mutually perpendicular lines:**

- **Horizontal Line:** Represents the **east-west** direction and is called the **x-axis**.
- **Vertical Line:** Represents the **north-south** direction and is called the **y-axis**.

These axes intersect at a point called the **origin**, denoted as **O**.

Figure 2.1(a) Illustrates two **mutually perpendicular lines** representing the **east-west** and **north-south** directions.

Drawing Vectors on Axes:

Vectors are usually drawn starting from the **origin** of the reference axes and extending toward the specified direction. The direction is defined by an **angle θ (theta)** with respect to the **x-axis**.

Figure 2.1(b) Shows the **x-axis** (horizontal) and **y-axis** (vertical) intersecting at the **origin (O)**. A vector is drawn starting from this origin, and its direction is indicated by an **angle θ** with respect to the x-axis.

Measurement of Angle θ:

- The angle **θ** is measured from the **right side of the x-axis** in an **anti-clockwise direction**.
- This angle helps specify the vector's orientation relative to the reference axes.

Conclusion:

Vectors are represented both symbolically and graphically to illustrate their magnitude and direction. Reference axes (x and y) provide a framework for defining the vector's orientation, while the angle θ specifies its direction relative to the x-axis. Understanding this representation is essential for accurately describing vector quantities in physics.

Q.4. Define resultant vector. How vectors are added by heat-to-tail rule? Explain with the help of a suitable example. **09102004**

Ans: Resultant Vector

A **resultant vector** is a single vector that represents the **combined effect** of two or more vectors. It has the **same effect** as all the individual vectors acting together. When we add multiple vectors, the resultant vector gives us the total effect in terms of both **magnitude** and **direction**.

Head-to-Tail Rule:

The **head-to-tail rule** is a graphical method used to add vectors. It states that to add two or more vectors, redraw their representative lines such that the **head of one vector** coincides with the **tail of the other**. The resultant vector is the single vector directed from the **tail of the first vector** to the **head of the last vector**.

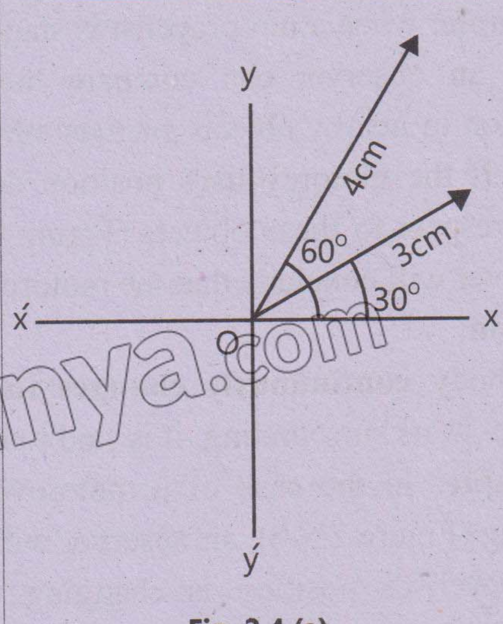


Fig. 2.4 (a)

Illustration of addition of vectors:

Let's take two vectors $\mathbf{v_1}$ and $\mathbf{v_2}$ having magnitudes of 300 N and 400 N, acting at angles of 30° and 60° with the x-axis. So,

Vector $\mathbf{v_1}$: Magnitude = **300 N**, Angle = **30°** with the x-axis.

Vector $\mathbf{v_2}$: Magnitude = **400 N**, Angle = **60°** with the x-axis.

Graphical Representation:

Choosing a Scale:

The selected scale is **100 N=1 cm**. Therefore, $\mathbf{v_1}$ is drawn as **3 cm** (300 N) and **v_2** is drawn as **4 cm** (400 N).

Drawing the Vectors:

Figure 2.4(a) Shows the vectors v_1 and v_2 are drawn using the head-to-tail rule, maintaining their magnitudes and angles.

Step 1: Draw v_1 as a straight line, making an angle of **30°** with the x-axis.

Step 2: Draw v_2 starting from the **head of v_1** and making an angle of **60°** with the x-axis.

Determination of Resultant Vector:

Figure 2.4(b) Illustrates the resultant vector formed by connecting the tail of **v_1** to the head of **v_2**.

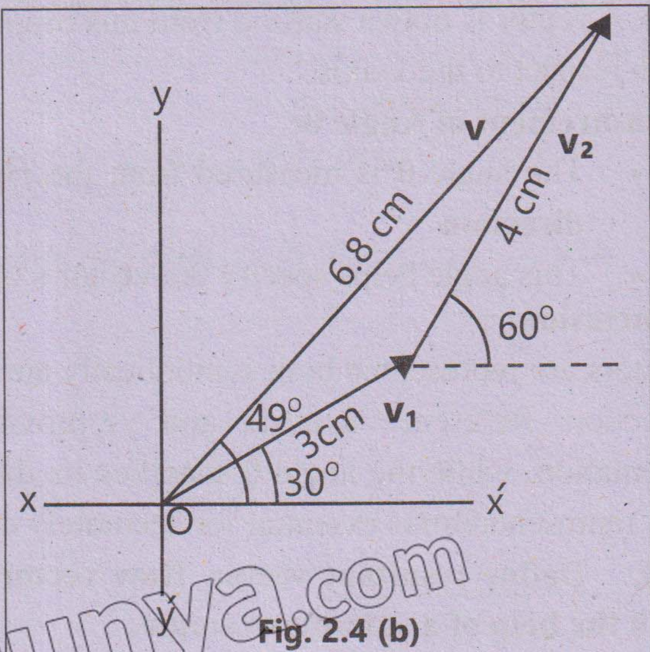


Fig. 2.4 (b)

Magnitude:

- The resultant vector is measured as **6.8 cm**.
- Using the scale (100 N = 1 cm), the **magnitude of the resultant v** is calculated as:

$$v = 6.8\text{cm} \times 100\ \text{N/cm} = 680\text{N}$$

Direction:

The direction is measured as an angle of 49° with the x-axis. So, magnitude of resultant vector is 680 N and its direction is angle 49^0 with x-axis.

Q.5. Define and explain rest and motion with the help of example. Show that rest and motion are relative to observer. **09102005**

Ans: Rest:

If a body **does not change** its position with respect to its surrounding, it is said to be at rest.

Example: when a motorcyclist is standing still on the road, an observer can compare the motorcyclist's position to nearby objects such as a building, tree, or pole. If the motorcyclist's position does not change with respect to these objects (Figure 2.5-a), then the observer will conclude that the motorcyclist is at rest.


Fig 2.5(a)

Motion:

If a body **continuously changes its position** with respect to its surrounding, it is said to be in motion.

Example: In the case of a motorcyclist who starts driving (Figure 2.5-b), an observer will notice that the motorcyclist's position is changing relative to the


Fig 2.5(b)

same surroundings, such as the building, tree, or pole. Therefore, the observer will conclude that the motorcyclist is in motion.

Relativity of Rest and Motion:

The concepts of rest and motion are **relative**, meaning they depend on the observer's frame of reference. A body can be at rest in one frame of reference and in motion in another.

Example: Consider a person standing inside a moving train. To other passengers inside the train, the person appears to be **at rest** because their position does not change relative to the train's interior. However, an observer standing on the railway platform will see that the same person is **in motion** because their position changes relative to the stationary platform.

Q.6. Explain different types of motion and give examples. Further explain types of translatory motion. **09102006**

Ans: In our daily life, we observe various types of motion. Generally, these can be categorized into **three main types**:

i. Translatory Motion **ii.** Rotatory motion **iii.** Vibratory motion

i. Translatory Motion

If the motion of a body is such that every particle of the body moves uniformly in the same direction, it is called translatory motion.

Example:

(i) The motion of a train or a car is translatory motion.

(ii) Riders moving in a ferries wheel.

Types of Translatory Motion:

Translatory motion can be classified into three subtypes:

(a) Linear motion

If the body moves along a straight line, it is called linear motion.

Example:

(i) Motion of freely falling body.

(ii) Aeroplane flying straight in air.

(b) Random motion

If the body moves along an irregular path, the motion is called random motion.

Example:

(i) The motion of bee

(ii) The motion of gas molecules along a zig-zag path.

(c) Circular motion

The motion of a body along a circle is called circular motion.

Example:

(i) Motion of ball tied to one end of string.

(ii) Motion of moon around the earth.

ii. Rotatory motion:

If each point of a body moves around a fixed point (axis), the motion of this body is called rotatory motion.

Example:

(i) The motion of an electric fan.

(ii) Motion of drum of a washing machine dryer.

(iii) Motion of top.

(iv) Motion of a cycle wheel.

iii. Vibratory motion:

When a body repeats its to and fro motion about a fixed position, the motion is called vibratory motion.

Example:

(i) The motion of a swing in a children park.

(ii) Motion of simple pendulum.

Q.7. Differentiate between Distance and Displacement. 09102007

Ans: Distance:

Distance is the length of the actual path of motion.

Nature of quantity:

It is a **scalar quantity**, meaning it has only magnitude and no direction.

Displacement:

Displacement is shortest distance between initial and final position.

Nature of quantity:

The displacement of an object is a vector quantity whose magnitude is the shortest distance between the initial and final positions of the motion and its direction is from the initial position to the final position.

Example:

Let a person travel from Lahore to Multan in a car (Fig.2.6). On reaching Multan, the person notices on the speedometer that the distance traveled is 320 km. This represents the total path covered by the car, which is the distance. However, this is not the

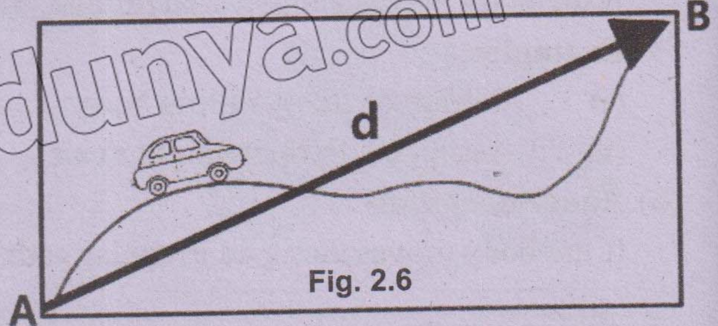


Fig. 2.6

shortest distance between Lahore and Multan, as the car took many turns along the way. The displacement, in this case, would be the shortest straight-line distance from Lahore to Multan, with a direction from Lahore to Multan.

Note: Distance is always greater than or equal to the magnitude of displacement.

Q.8. Explain the concepts of speed and velocity. Also discuss uniform and non-uniform velocity with an example. 09102008

Ans: Speed: Speed is defined as the **distance** covered in unit **time.**

Formula: If S is the distance covered by body in unit time 't', then.

$$\text{Speed} = \frac{\textit{Distance covered}}{\textit{time taken}}$$

i.e. $v = \frac{S}{t}$ or Distance = Speed × time or $S = v \times t$

Speed is a scalar quantity. The SI unit of speed is meters per second (m/s) or kilometers per hour (km/h).

Instantaneous Speed: The speed of a vehicle that is shown by its speedometer at any instant is called instantaneous speed.

Average Speed: Defined as the total distance divided by the total time taken.

$$\text{Average Speed} = \frac{\textit{Total Distance covered}}{\textit{total time taken}} \text{ or } v_{av} = \frac{S}{t}$$

Velocity: The net **displacement** of a body in unit **time** is called velocity.

$$\text{velocity} = \frac{\textit{Displacement}}{\textit{time}}$$

i.e. $\mathbf{v} = \frac{\mathbf{d}}{t}$ or $\mathbf{d} = \mathbf{v} \times t$

Example:

If a car is moving towards the north at the rate of 70 km/h, the speed of the car is 70 km/h, a scalar quantity. However, the velocity of the car is a vector quantity, with a magnitude of 70 km/h directed towards the north.

Uniform velocity: The velocity is said to be uniform if the speed and direction of a moving body does not change.

Non-uniform velocity: If the speed or direction or both of them changes, it is known as variable velocity or non-uniform velocity.

Example:

The example of a body moving with uniform velocity is the downward motion of a paratrooper. When a paratrooper jumps from an aeroplane, he falls freely for a few moments. Then the parachute opens. At this stage the force of gravity acting downwards on the paratrooper is balanced by the resistance of air on the parachute that acts upward. Consequently, the paratrooper moves down with uniform velocity.

Q.9. Explain the concept of acceleration and its types. Also discuss uniform and non-uniform acceleration. **09102009**

Ans: Acceleration:

Acceleration is defined as the time rate of change of velocity. It occurs when there is a change in the magnitude or direction of velocity, or both.

Types of Acceleration:

Positive Acceleration:

When the velocity of an object increases, it experiences positive acceleration.

Example: When a car overtakes another one, it accelerates to a greater velocity.

Negative Acceleration (Deceleration/Retardation):

When the velocity of an object decreases, the acceleration is negative.

Example: When brakes are applied to slow down a bicycle or a car, it undergoes deceleration

Formula: $$\text{Average acceleration} = \frac{\textit{change in velocity}}{\textit{time taken}}$$

$$a_{av} = \frac{v_f - v_i}{t} \quad \text{or} \quad a_{av} = \frac{\Delta v}{t}$$

The SI unit of acceleration is meters per second square (m/s^2).

If acceleration **a** is constant then above equation can be written as $\mathbf{v_f = v_i + at}$

Uniform and non-uniform acceleration:

Uniform Acceleration: If the rate of change of velocity is constant, the acceleration is said to be uniform.

Non-uniform acceleration: If anyone of the magnitude or direction or both of them changes it is called variable or non-uniform acceleration.

Q.10. What is a graph? How it is drawn? Explain. **09102010**

Ans: Graphical Analysis of Motion

A graph is a pictorial diagram, represented by a straight line or a curve, that shows the relationship between two physical quantities. It is commonly drawn on graph paper with equally spaced horizontal and vertical lines. The intersection points of the horizontal lines (**x-axis**) and vertical (**y-axis**) lines is called the **origin (O)**.

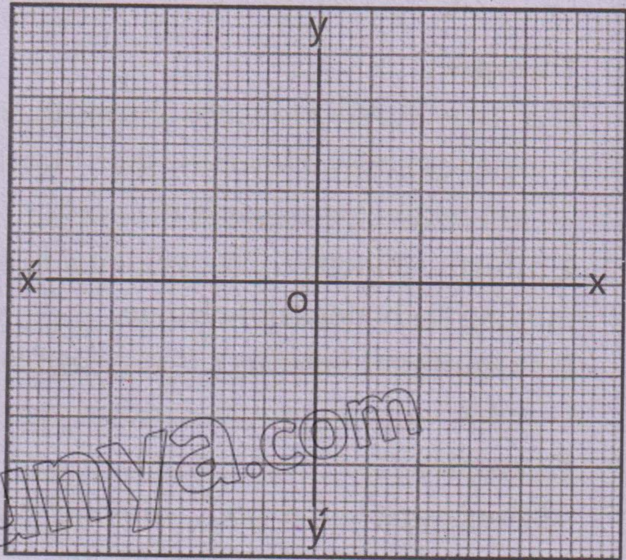


Fig. 2.7

Axes Representation:

X-axis (Horizontal): Represents the **independent variable**, usually time (t). Positive values are plotted to the right, and negative values to the left of the origin.

Y-axis (Vertical): Represents the **dependent variable**, such as distance (S). Positive values are above the origin, and negative values are below.

Steps to Draw a Distance-Time Graph:

(i) Select Axes: Place time (t) on the x-axis and distance (S) on the y-axis.

(ii) Choose a Suitable Scale: Based on the minimum and maximum values of the data, select appropriate scales for both axes (e.g., 1 minute = 1 cm on the x-axis, 1.2 km = 1 cm on the y-axis).

(iii) Mark Values: Mark values according to the selected scale along both axes.

(iv) Plot Data Points: Plot points for each pair of time and distance values.

(v) Draw the Line or Curve: Join the plotted points to create a straight line or curve, depending on the motion type.

Q.11. What is distance-time graph? Explain steps to draw a graph on a paper.

09102011

Ans: Distance-Time Graph

Distance-time graph shows the relation between distance S and time t taken by a moving body.

Let a car be moving in a straight line on a motorway. Suppose that we measure its distance from starting point after every one minute, and record it in the table given below:

Time t (min)	0	1	2	3	4	5
Distance S (km)	0	1.2	2.4	3.6	4.8	6.0

Follow the steps given below to draw a graph on a centimetre graph paper:

(i) Take time t along x-axis and distance S along y-axis.

(ii) Select suitable scales (1 minute = 1 cm) along x-axis and (1.2 km = 1 cm) along y-axis. The graph paper shown here is not to the scale.

(iii) Mark the values of each big division along x and y axes according to the scale.

(iv) Plot all pairs of values of time and distance by marking point on the graph paper.

(v) Join all the plotted points to obtain a best straight line as shown in Fig. 2.8. from the table, we can observe that car has covered equal distance in equal intervals of time. This shows that the car moves with uniform speed. Therefore, a straight line graph between time and distance represents motion with uniform speed.

(a) Now consider another journey of the car as recorded in the table given below:

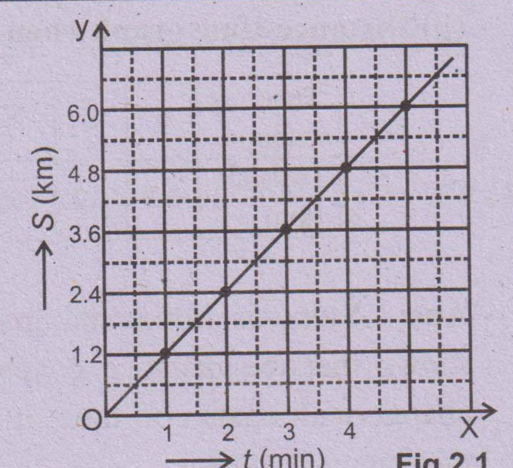


Fig 2.1

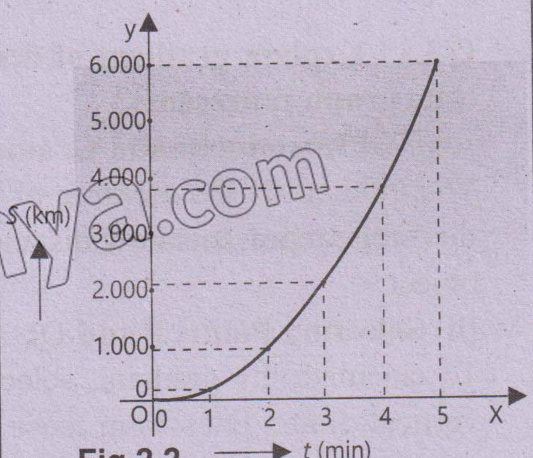


Fig 2.2

Time t (min)	0	1	2	3	4	5
Distance S (km)	0	0.240	0.960	2.160	3.840	6.000

Table shows that speed goes on increasing in equal intervals of time. This is very obvious from the graph as shown in Fig. 2.9. The graph line is curved upward. This is the case when the body (car) is moving with certain acceleration.

Q.12. Explain distance time graph for an object: **09102012**

(i) When speed of object decreases

(ii) When object is at rest

Ans: (i) Distance time graph when speed of an object decreases:

Time t (min)	0	1	2	3	4	5
Distance (km)	0	2.0	3.1	4.0	4.6	5.0

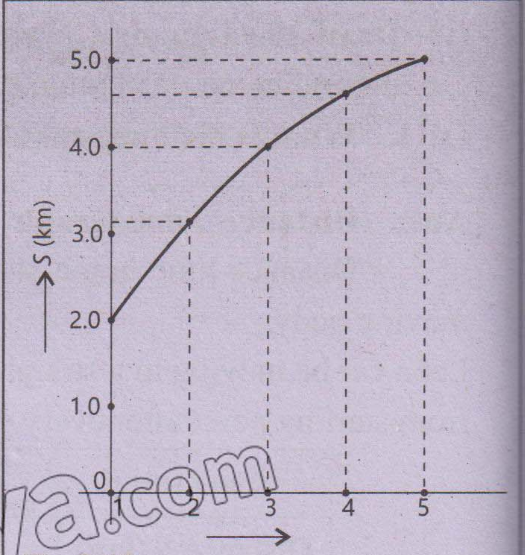


Fig 2.10

The slope of graph is curved downward. This shows that distance travelled in the same interval of time goes on decreasing, so speed is decreasing. This is the case of motion with deceleration or negative acceleration as shown in Fig. 2.10

(ii) Distance-time graphwhen object is at rest:

Time t (min)	0	1	2	3	4	5
Distance (km)	1.2	1.2	1.2	1.2	1.2	1.2

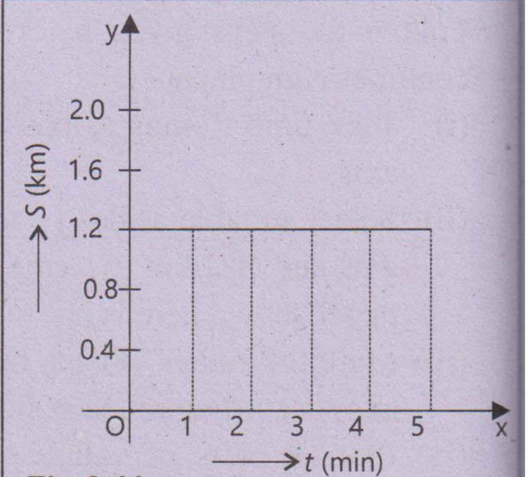


Fig 2.11

Ans: Slope is horizontal in this case (Fig 2.11). It shows that the distance covered by the car does not change with change in time. It means that the car is not moving; it is at rest.

Q.13. Explain gradient of distance-time graph. What does the gradient of distance-time graph represents? **09102013**

Ans: (i) Introduction to Gradient and Distance-Time Graph:

The gradient is the measure of the slope of a line on a graph. For a distance-time graph, this slope represents how distance changes with respect to time, indicating the speed of an object.

(ii) Selecting Points P and Q:

To calculate the gradient, select any two points in time, t_1 and t_2, on the x-axis. Draw vertical dotted lines from these points to meet the graph at points **P** and **Q**. These points represent the positions of the object at times t_1 and t_2.

(iii) Drawing Horizontal Lines for Distance:

From points P and Q, draw horizontal lines to intersect the y-axis at points S_1 and S_2. These intersections represent the distances S_1 and S_2 covered by the object at times t_1 and t_2, respectively.

(iv) Calculating the Change in Distance and Time:

The distance covered in the interval is given by:

$$S_2 - S_1 = \Delta S$$

The time taken for this interval is:

$$t_2 - t_1 = \Delta t$$

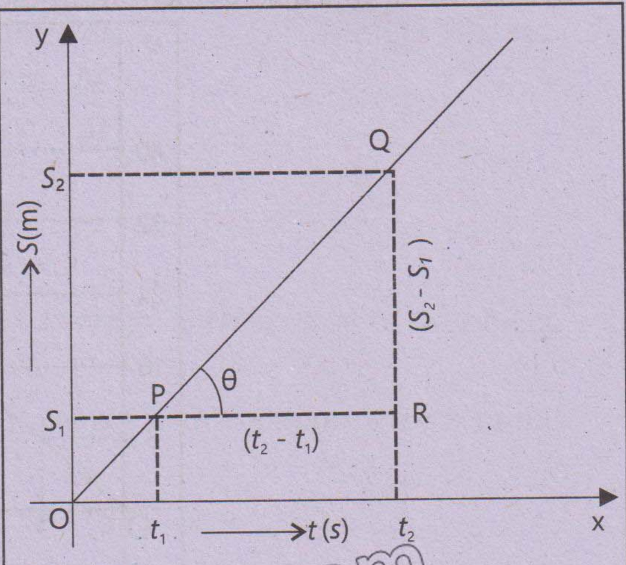


Fig 2.12

(v) Determining the Gradient (Slope):

The slope or gradient of the line connecting points P and Q is calculated using:

$$\text{Slope} = \frac{PQ}{PR}$$

$$\text{Slope} = \frac{\text{change in distance}}{\text{change in time}} = \frac{S_2 - S_1}{t_2 - t_1} = \frac{\Delta S}{\Delta t}$$

(vi) Relationship with Average Speed:

The average speed of the object is:

$$v_{av} = \frac{\Delta S}{\Delta t}$$

This is the same as the slope of the distance-time graph. Therefore, the gradient of the distance-time graph is equal to the average speed.

(vii) Tangent θ and Graph Line:

The slope of the graph line is also expressed as the tangent of the angle θ formed between the graph line and the time axis:

$$\tan\theta = \frac{\Delta S}{\Delta t}$$

Conclusion: Gradient of distance-time graph is equal to the average speed of the body.

Q.14. Explain speed-time graph when an object: 09102014

(i) moving with uniform acceleration

(ii) moving with constant speed

Ans: Speed Time Graph

Suppose we can note the speed of the same car after everyone second and record it in the table given below, we can draw the graph between speed *v* versus time *t*. This is called speed-time graph.

(i) When an object moving with uniform acceleration:

Table

Time t (s)	0	1	2	3	4	5
Speed v(ms^{-1})	0	8	16	24	32	40

Take t along x-axis and v along y-axis. Scale can be selected as 1s = 1 cm (x-axis) and speed $10ms^{-1}$= 1 cm along y-axis.

Slope of the graph is shown in Fig. 2.13. It is a straight line rising upward. This shows that speed increases by the same amount after every one second. This is a motion with uniform acceleration. It is also evident from the table.

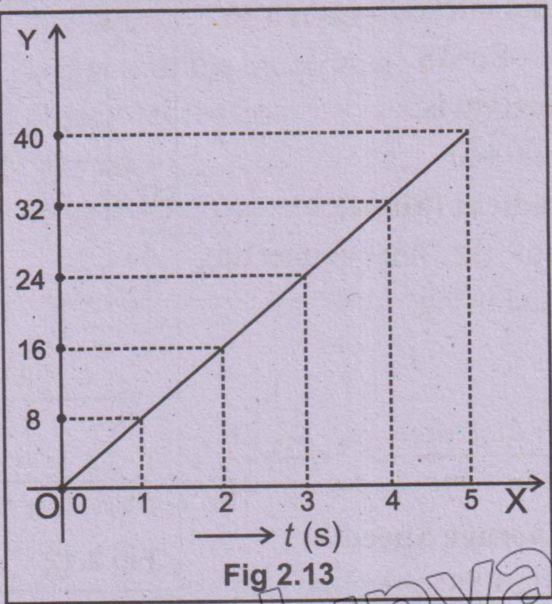


Fig 2.13

(ii) When an object moving with constant speed:

Now consider another case. The observations are recorded in the table given below:

Time t (s)	0	1	2	3	4	5
Speed v(ms^{-1})	20	20	20	20	20	20

In this case, graph line in horizontal (Fig 2.14) parallel to time x-axis. It shows that speed does not change with change in time. This is a motion with constant speed.

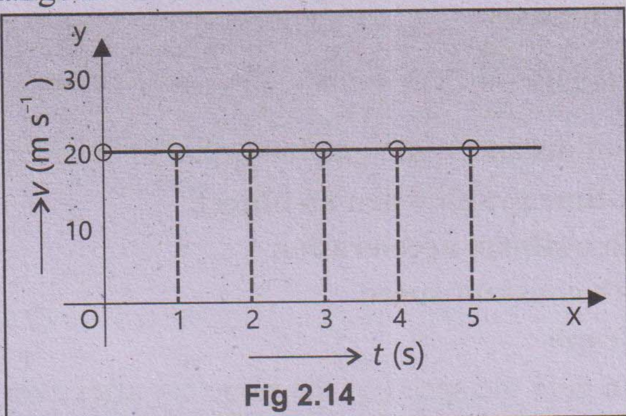


Fig 2.14

Q.15. Explain gradient of speed-time graph. What does gradient of speed-time represent? Find the gradient of speed-time graph for an object moving with constant speed.

09102015

Ans: The gradient (or slope) of a speed-time graph provides essential information about the acceleration of a moving object. Depending on the nature of the motion, the slope varies and reflects either a constant acceleration or constant speed.

Let's analyze these two scenarios in detail.

Motion with Constant Acceleration:
In this scenario, the speed of an object changes uniformly over time. Consider the speeds at times t_1 and t_2 as v_1 and v_2, respectively. The change in speed (Δv) over the time interval (Δt) is expressed as:

$$\Delta v = v_2 - v_1 \quad \text{and} \quad \Delta t = t_2 - t_1$$

The gradient (slope) of the speed-time graph is calculated as:

$$\text{Slope} = \frac{\textit{change in speed}}{\textit{change in time}} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}$$

From the definition of average acceleration (a):

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

Hence, the gradient of the speed-time graph equals the **average acceleration** of the object.

Motion with Constant Speed:
When the object's speed does not change with time, it moves with **constant speed**. In this case, the speeds at times t_1 and t_2 are the same:

$$v_2 - v_1 = 0$$

$$\text{Slope} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{0}{\Delta t} = 0$$

This shows that the acceleration of this motion is zero. It is the motion without the change in speed.

Q.16. Show that the area under speed-time graph is numerically equal to the distance covered by an object. **09102016**

Ans: The distance moved by an object can be determined by calculating the area under a **speed-time graph**.

(i) Distance for Motion with Constant Speed:
When an object moves with a **constant speed (v)** over a time interval (t), the speed-time graph is a **horizontal line** at speed v, as shown in **Figure 2.15**.

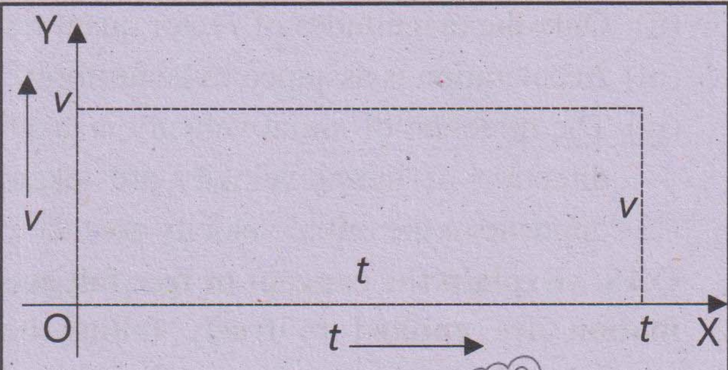


Fig 2.15

The distance covered (s) is given by the equation: $S = v \times t$

The speed-time graph forms a **rectangle** with Base **(t)** and Height **(v)**

The area of the rectangle is given by:

$$\text{Area} = \text{base} \times \text{height}$$

$$\text{Area} = t \times v$$

Hence, the area under the graph is numerically equal to the distance covered by the object.

(ii) Distance for Motion with Uniformly Increasing Speed:
If the speed of an object increases uniformly from 0 to v over time t, the speed-time graph forms a **right-angled triangle** (as shown in **Figure 2.16**).

The **average speed** (v_{av}) is given by:

$$v_{av} = \frac{0 + v}{2} = \frac{1}{2}v$$

The distance covered can then be calculated using the equation:

Distance covered= Average speed × time= $\frac{v}{2}\times t$

The speed-time graph forms a **triangle**, with base (t) and Height **(v)**

The area of the triangle is given by:

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

$$\text{Area} = \frac{1}{2} \times t \times v = \frac{v}{2}\times t$$

Hence, the **area under the graph equals the distance** traveled by the body.

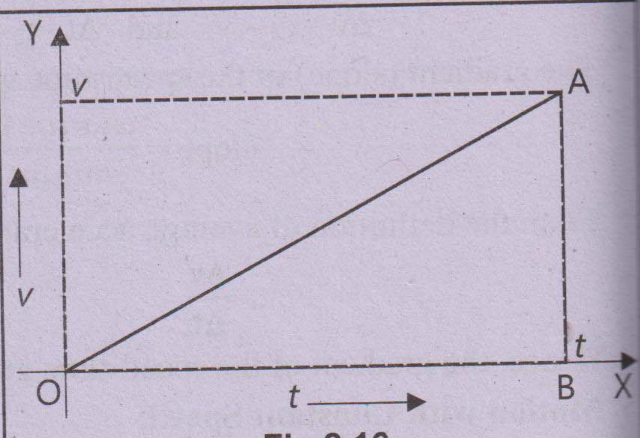


Fig 2.16

Q.17. Explain the three equations of motion used to solve problem of motion, and what are the assumptions made while applying these equations. 09102017

Ans: Three equations of motion are used to solve problems for motion of bodies. If v_i is the initial velocity of the body, v_f is the final velocity, t is the time taken, S is the distance covered and **a** is the acceleration, then:

$$v_f = v_i + at$$

$$S = v_i t + \frac{1}{2}at^2$$

$$2as = v_f^2 - v_i^2$$

Assumptions in Applying the Equations:

(i) Motion is always considered along a straight line

(ii) Only the magnitudes of vector quantities are used.

(iii) Acceleration is assumed to be uniform.

(iv) The direction of initial velocity is taken as positive. Other quantities which are in the direction of initial velocity are taken as positive. The quantities in the direction opposite to the initial velocity are taken as negative.

Q.18. Explain the concept of free fall acceleration and describe how the equations of motion are applied to freely falling bodies? What are the important points to consider when using these equations for objects in free fall? 09102018

Ans: When a body is falling freely under the action of gravity, the acceleration acting on it is called **gravitational acceleration**, denoted by **g**. This acceleration always acts **downward** towards the Earth. The standard value of gravitational acceleration is **9.8 m/s²**, but for convenience, it is often approximated as **10 m/s²**.

Since the body moves **vertically downward** in a straight line with **uniform acceleration** due to gravity, the **three equations of motion** can be applied to describe the motion of freely falling bodies. In these equations, the **acceleration a** is replaced by **g**, the acceleration due to gravity. The three equations of motion for freely falling bodies are:

$$v_f = v_i + gt$$

$$S = v_i t + \frac{1}{2}gt^2$$

$$2gh = v_f^2 - v_i^2$$

Important Points to Remember When Using These Equations:

It should be remembered that while using these equations, the following points should be kept in mind:

(i) If a body is released from some height to fall freely, its initial velocity v_i will be taken as zero.

(ii) The gravitational acceleration g will be taken as positive in the downward direction. All other quantities will also be taken as positive in the downward direction. The quantities in the direction opposite to the acceleration will be taken as negative.

(iii) If a body is thrown vertically upward, the value of g will be negative and the final velocity will be zero at the highest point.

Examples

Example 2.1 09102019

Draw the velocity vector v; a velocity of 300 $m\,s^{-1}$ at an angle of 60^0 to the east of north.

Solution:

(i) Draw two mutually perpendicular lines indicating N, S, E& W.

(ii) Select a suitable scale. If 100 $ms^{-1} = 1\ cm$, then 300 $m\,s^{-1}$ are represented by $3cm$ line.

(iii) Draw 3 cm line OP at an angle of 60^0 starting from N towards E.

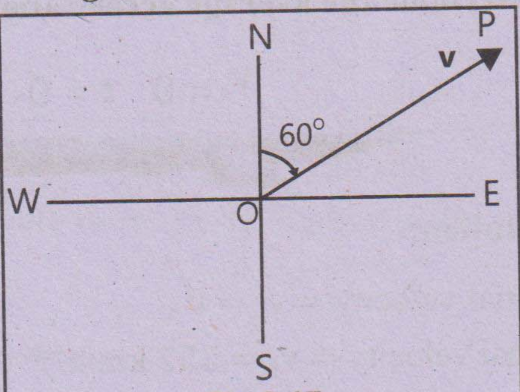


Fig 2.17

(iv) Make an arrow head at the end of line OP. The OP is the vector **v**.

Example 2.2 09102020

Draw a force vector F having magnitude of 350 N and acting at an angle of 60° with x-axis.

Solution:

(i) Draw horizontal and vertical lines to represent x-axis and y-axis as shown in Fig.

(ii) Scale: If 100 N = 1 cm, then 350 N = 3.5 cm

(iii) Draw 3.5 cm line OQ at an angle of 60° with x-axis.

(iv) Make an arrow head at the end of the line OQ. The OQ is the vector **F**.

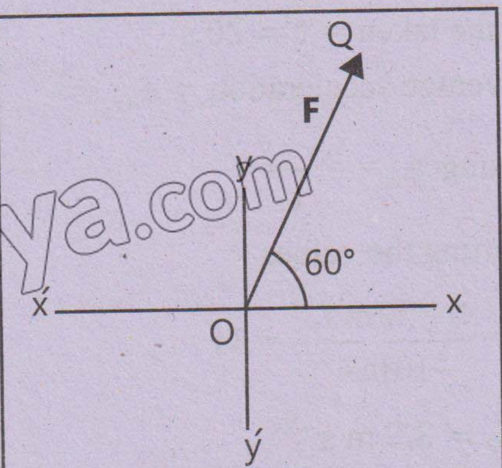


Fig 2.18

Example 2.3 09102021

An eagle dives to the ground along a 300 m path with an average speed of 60 $m\ s^{-1}$. How long does it take to cover this distance?

Solution:

Total distance covered = S = 300 m

Average speed = v_{av} = 60 m s^{-1}

Total time taken = t= ?

Using the equation $v_{av} = \frac{S}{t}$

or $t = \frac{S}{v_{av}}$

putting the values t = 300 m / 60 m s^{-1} = 5 s

Example 2.4: 09102022

A plane starts running from rest on a run-way as shown in the figure below. It accelerates down the run-way and after 20 seconds attains a velocity of 252 km h^{-1}. Determine the average acceleration of the plane.

Solution:

Initial velocity = v_i = 0

Final velocity = v_f = 252 km h^{-1}

$= \frac{252 \times 10^3 m}{60 \times 60 s} = 70 m s^{-1}$

Time taken = t = 20 s

Average acceleration = a_{av} =?

Using $a_{av} = \frac{v_f - v_i}{t}$

Putting the values

$t = \frac{0 - 30 m s^{-1}}{-10 m s^{-2}} = 3 s$

a_{av} = 3.5 m s^{-2}

Example 2.5 09102023

An iron bob is dropped from the top of a tower. It reaches the ground in 4 seconds. Find: (a) the height of the tower (b) the velocity of the ball as it strikes the ground.

Solution:

For freely falling body:

Initial velocity $= v_i = 0$

Acceleration $= g = 10\ m\ s^{-2}$

Time $= t = 4\ s$

Height (distance) $= S = h = ?$

Final velocity $= v_f = ?$

(a) According to second equation of motion,

$$S = v_i t + \frac{1}{2} g t^2$$

Putting the values, $h = 0 \times 4s + \frac{1}{2} \times 10\,m s^{-2} \times (4)^2\ s^2$

$$h = 80\ m$$

(b) From the first equation of motion, we have

$$v_f = v_i + gt$$

Putting the values, $v_f = 0 + 10\ m\ s^{-2} \times 4s = 40\ m\ s^{-1}$

Example 2.6 09102024

An arrow is thrown vertically upward with the help of a bow. The velocity of the arrow when it leaves the bow is $30\ m\ s^{-1}$. Determine time to reach the highest point? Also, find the maximum height attained by the arrow.

Solution:

Initial velocity $= v_i = 30\ m\ s^{-1}$

Final velocity $= v_f = 0$

Acceleration $= g = -10\ m\ s^{-2}$

Time $= t = ?$

Height $S = h = ?$

From first equation of motion:

$$v_f = v_i + gt$$

or $t = \frac{v_f - v_i}{-g}$

putting the values of $t = \frac{0 - 30\,m s^{-1}}{-10\,m s^{-2}} = 3s$

Exercise

(A) Multiple Choice Questions (Exercise)

1. **The numerical ratio of displacement to distance is:** 09102025
   (a) always less than one
   (b) always equal to one
   (c) always greater than one
   (d) equal to or less than one

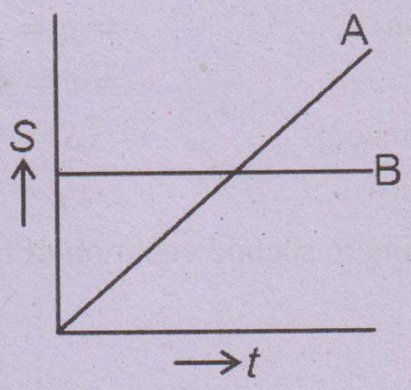
2. **If a body does not change its position with respect to some fixed point, then it will be in a state of:** 09102026
   (a) rest
   (b) motion
   (c) uniform motion
   (d) variable motion

3. **A ball is dropped from the top of a tower, the distance covered by it in the first second is:** 09102027
   (a) 5 m (b) 10 m
   (c) 50 m (d) 100 m

4. **A body accelerates from rest to a velocity of 144 km h^{-1} in 20 seconds. Then the distance covered by it is:** 09102028
   (a) 100 m (b) 400 m
   (c) 1400 m (d) 1440 m

5. **A body is moving with constant acceleration starting from rest. It covers a distance *S* in 4 seconds. How much time does it take to cover one-fourth of this distance?** 09102029
   (a) 1 s (b) 2 s
   (c) 4 s (d) 16 s

6. **The displacement time graphs of two objects A and B are shown in the figure. Point out the true statement from the following:** 09102030



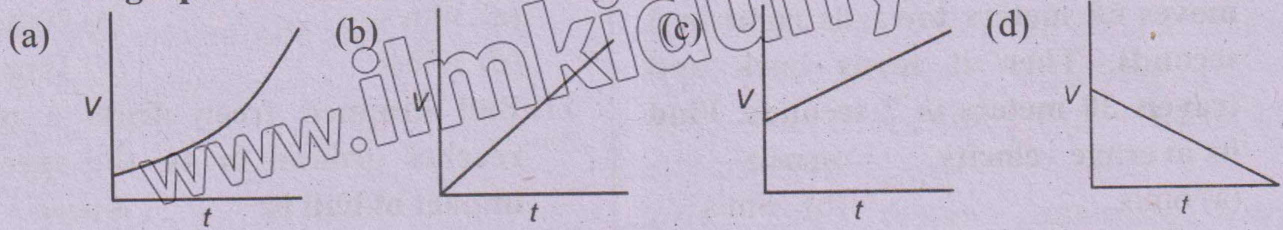
   (a) The velocity of A is greater than B
   (b) The velocity of A is less than B
   (c) The velocity of A is equal to that of B
   (d) The graph gives no information in this regard

7. **The area under the speed-time graph is numerically equal to:** 09102031
   (a) velocity
   (b) uniform velocity
   (c) acceleration
   (d) distance covered

8. **Gradient of the speed-time graph is equal to:** 09102032
   (a) speed
   (b) velocity
   (c) acceleration
   (d) distance covered

9. **Gradient of the distance-time graph is equal to the:** 09102033
   (a) speed
   (b) velocity
   (c) distance covered
   (d) acceleration

10. A car accelerates uniformly from $80.5\ kmh^{-1}$ at $t = 0$ to $113\ kmh^{-1}$ at $t = 9s$. Which graph best describes the motion of the car? 09102034



Answer Key

1.	(b)	2.	(a)	3.	(a)	4.	(b)	5.	(b)
6.	(a)	7.	(d)	8.	(c)	9.	(a)	10.	(c)

SLO based Additional MCQs

Displacement

1. Change in position of a body from initial to final point is called: 09102035

(a) distance
(b) displacement
(c) Speed
(d) Velocity

2. A girl walks 3 km towards west and 4km towards south. What is the magnitude of her total distance and displacement respectively? 09102036

(a) 7km, 7km
(b) 1km, 7km
(c) 7km, 1km
(d) 7km, 5km

Displacement-time graph

3. When the slope of a body's displacement-time graph increases, the body is moving with: 09102037

(a) increasing velocity
(b) decreasing velocity
(c) constant velocity
(d) all of these

Types of Motion

4. Motion of a screw of rotating fan is: 09102038

(a) Circular motion
(b) vibratory motion
(c) Random motion
(d) Rotatory motion

Acceleration

5. A cyclist is travelling in a westward direction and produces a deceleration of 8 m/s^2 to stop. 09102039

(a) North (b) East
(c) South (d) West

6. A ball is thrown straight up, what is the magnitude of acceleration at the top of its path? 09102040

(a) zero (b) $9.8 m/s^2$
(c) $4.9 m/s^2$ (d) $19.6 m/s^2$

7. In 5s a car accelerates so that its velocity increases by 20 m/s. The acceleration is: 09102041

(a) $0.25\ m/s^2$ (b) $4\ m/s^2$
(c) $25\ m/s^2$ (d) $100\ m/s^2$

Velocity

8. **A rider is training a horse. Horse moves 60 meters towards right in 3 seconds. Then it turns back and travels 30 meters in 2 seconds. Find its average velocity.** 09102042

(a) 6m/s (b) 18m/s
(c) 35m/s (d) 0m/s

9. **If a cyclist has acceleration of $2m/s^2$ for 5 seconds, the change in velocity of the cyclist is:** 09102043

(a) 2m/s
(b) 10m/s
(c) 20m/s
(d) 15m/s

10. **A car is moving with velocity of 10m/s. If it has acceleration of $2m/s^2$ for 10 seconds. What is final velocity of the car?** 09102044

(a) 30m/s (b) 20m/s
(c) 10m/s (d) 15m/s

11. **Ball dropped freely from a tower reaches ground in 4s, the speed of impact of ball is:** 09102045

(a) 0 m/s (b) 2.45 m/s
(c) 19.6 m/s (d) 39.2 m/s

Speed Time Graph

12. **Area under speed-time graph is equal to _______ of moving body:** 09102046

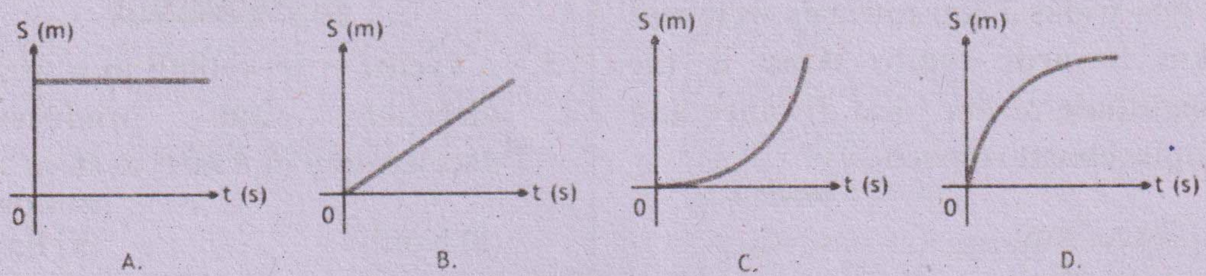
(a) distance
(b) change in velocity
(c) uniform velocity
(d) acceleration

Distance Time Graph

13. **slope of distance -time graph is:** 09102047

(a) velocity (b) acceleration (c) speed (d) displacement

14. **Which of following distance time graphs represents increasing speed of a car?** 09102048



Answer Key

1	(b)	2	(d)	3	(a)	4	(d)	5	(b)
6	(b)	7	(b)	8	(a)	9	(b)	10	(a)
11	(d)	12	(a)	13	(c)	14	(c)		

(B) Short Questions (Exercise)

2.1 Define scalar and vector quantities. 09102049

Ans: Scalar:

A **scalar** is a physical quantity that can be described completely by its **magnitude only**. **Magnitude** includes a **number** and an appropriate **unit**.

Examples: Mass, length, time and speed, etc.

Vector:
A **vector** is a physical quantity that requires both **magnitude** and **direction** to be described completely.
Examples: Velocity, displacement and force etc.

2.2 Give 5 examples each for scalar and vector quantities. 09102050

Ans: Scalar quantities: volume, work, energy, pressure, power
Vector quantities: force, momentum, torque, acceleration, weight

2.3 State head-to-tail rule for addition of vectors. 09102051

Ans: The **head-to-tail rule** is a graphical method used to add vectors. It states that to add two or more vectors, redraw their representative lines such that the **head of one vector** coincides with the **tail of the other**. The resultant vector is the single vector directed from the **tail of the first vector** to the **head of the last vector**.

2.4 What are distance-time graph and speed-time graph? 09102052

Ans: Distance-Time Graph: Shows how distance changes over time. The slope of this graph represents speed.
Speed-Time Graph: Shows how speed changes over time. The slope of this graph represents acceleration, and the area under the curve represents distance traveled.

2.5 Falling objects near the Earth have the same constant acceleration. Does this imply that a heavier object will fall faster than a lighter object? 09102053

Ans: No, a heavier object does not fall faster than a lighter object when dropped from the same height near the Earth's surface, assuming air resistance is negligible. Both objects will fall at the **same rate**. Near the Earth's surface, all objects fall with a constant acceleration of approximately **10ms^{-2}**, regardless of their mass. This is because gravity acts on all objects uniformly.

2.6 The vector quantities are sometimes written in scalar notation (not boldface). How is the direction indicated? 09102054

Ans: When vector quantities are written in scalar notation (without boldface), their direction is indicated through various means.

i. Positive and Negative Signs
ii. Directional Words
(North, south, east, west)
iii. Angles
iv. Unit Vectors

2.7 A body is moving with uniform speed. Will its velocity be uniform? Give reason. 09102055

Ans: No, a body moving with uniform speed may not have uniform velocity. Velocity includes both magnitude and direction, if the direction changes, the velocity changes even if the speed remains constant.

2.8 Is it possible for a body to have acceleration? When moving with:
(i) constant velocity
(ii) constant speed 09102056

Ans: (i) Constant velocity:
No, a body moving with **constant velocity** (both speed and direction remain unchanged) has **zero acceleration**. Acceleration is the rate of change of velocity, so if the velocity does not change, the acceleration is zero.

(ii) Constant speed:

Yes, a body moving with **constant speed** can have acceleration if its **direction** is changing. For example, an object moving in a circular path with constant speed is continuously changing direction, which results in **centripetal acceleration** directed toward the center of the circle, even though the speed remains constant.

SLO based Additional Short Questions

Speed and velocity

2.1 The car while moving on a circular road may have constant speed, but its velocity is changing at every instant. Why? **09102057**

Ans: The car's velocity changes at every instant on a circular road because velocity is a vector quantity. While the speed remains constant, the direction of motion changes continuously along the circular path, causing a change in velocity.

Free fall acceleration

2.2 Write down the equations of motion for freely falling bodies. **09102058**

Ans:

(i) $v_f = v_i + gt$

(ii) $h = v_i t + \frac{1}{2}gt^2$

(iii) $2gh = v_f^2 - v_i^2$

2.3 With the help of daily life examples, explain the situations in which: **09102059**

(i) Acceleration is in the direction of motion

(ii) Acceleration is against the direction of motion

(iii) Acceleration is zero and body is in motion

Ans. Following are the three daily life examples in which acceleration is in the direction of motion, against the direction of motion and zero.

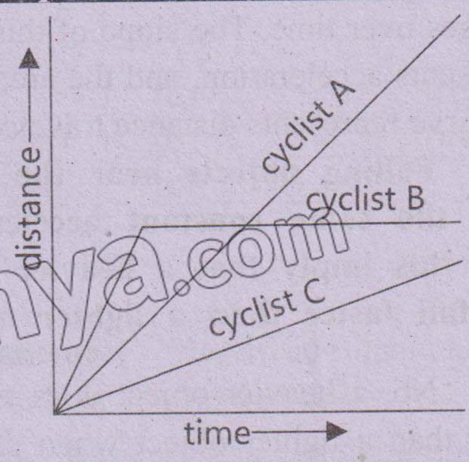
Explanation:

(i) A freely falling object has direction of motion downward and acceleration due to gravity is also downward. An apple falling from a tree is an example of acceleration in the direction of motion.

(ii) A body throwing upward has direction of motion upward and direction of acceleration downward. An upward throwing cricket ball is an example of acceleration against the direction of motion.

(iii) A uniformly moving body is a fixed direction has zero acceleration. A uniformly moving car in the right direction is an example of zero acceleration and the body is in motion.

Graphical analysis of motion



2.4 (a)What does each line on the graph represent? **09102060**

(b) Which cyclist traveled the most distance?

(c)Which cyclist traveled at the greatest speed? The lowest speed? At constant speed?

Ans:

(a) Each line on the graph represents the motion of a cyclist (A, B, and C) in terms of the distance traveled over time at a constant speed.

(b) Cyclist **A** traveled the most distance as its line is the highest on the graph.

(c)

- The greatest speed: **Cyclist A** (steepest slope).
- The lowest speed: **Cyclist C** (least steep slope).
- All cyclists traveled at constant speeds as their lines are straight.

2.5 What does the gradient of a distance-time graph represent? 09102061

Ans: The gradient of a distance-time graph represents the **speed** of the object. A steeper gradient indicates a higher speed, while a flatter gradient indicates a lower speed.

2.6 What does the gradient of a speed-time graph represent? 09102062

Ans: The gradient of a speed-time graph represents the **acceleration** of the object. A positive gradient indicates increasing speed (positive acceleration), while a negative gradient indicates decreasing speed (negative acceleration).

2.7 What does the area under a speed-time graph represent? 09102063

Ans: The area under a speed-time graph represents the distance traveled by an object.

Distance and Displacement

2.8 Is it possible that displacement is zero but not the distance? Under what condition displacement will be equal to distance? 09102064

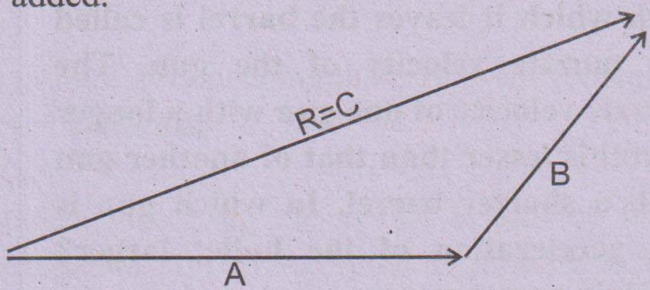
Ans. If a body starts motion and finally reaches its initial position, then in such a case displacement is zero but not the distance.

Displacement and distance are equal when the body goes straight from initial point to the final point. A car moves straight to the school. Hear distance and displacement are equal.

Vector

2.9 Define resultant vector. 09102065

Ans. We can add two or more vectors to get a single vector. This is called as resultant vector. It has the same effects as the combined effect of all the vectors to be added.



2.10 How a vector is represented graphically? Explain. 09102066

Ans. A vector can be represented graphically by drawing a straight line with an arrow head at one end. The length of line represents the magnitude of the vector quantity according to a suitable scale while the direction of arrow indicates the direction of the vector.

Relativity

2.11 What is meant by universal speed limit? 09102067

Ans. In 1905, famous scientist Albert Einstein proposed his revolutionary theory of special relativity which modified many of the basic concepts of physics. According to this theory, speed of light is a universal constant. Its value is approximately $3 \times 10^8\ ms^{-1}$. Speed of light remains the same for all motions. Any object with mass cannot achieve speeds equal to or greater than that of light. This is known as universal speed limit.

(C) Constructed Response Questions

2.1 Distance and displacement may or may not be equal in magnitude. Explain this statement. 09102068

Ans: Distance and displacement may or may not be equal in magnitude. Distance is the total path length traveled, while displacement is the straight-line distance between the initial and final positions, with direction. They are equal in magnitude only if the object moves in a straight line without changing direction. If the object changes direction, the distance will be greater than the displacement.

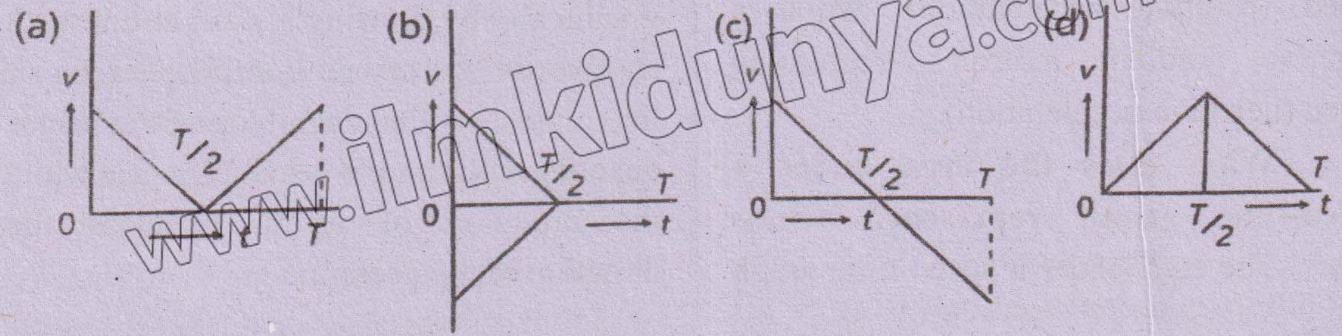
2.2 When a bullet is fired, its velocity with which it leaves the barrel is called the muzzle velocity of the gun. The muzzle velocity of one gun with a longer barrel is lesser than that of another gun with a shorter barrel. In which gun is the acceleration of the bullet larger? Explain your answer. 09102069

Ans: The acceleration of the bullet is larger in the **gun with the shorter barrel**. This is because the bullet has less distance and time to reach its muzzle velocity, resulting in a higher acceleration compared to a gun with a longer barrel, where the bullet has more time to accelerate and reaches a higher velocity.

2.3 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. 09102070

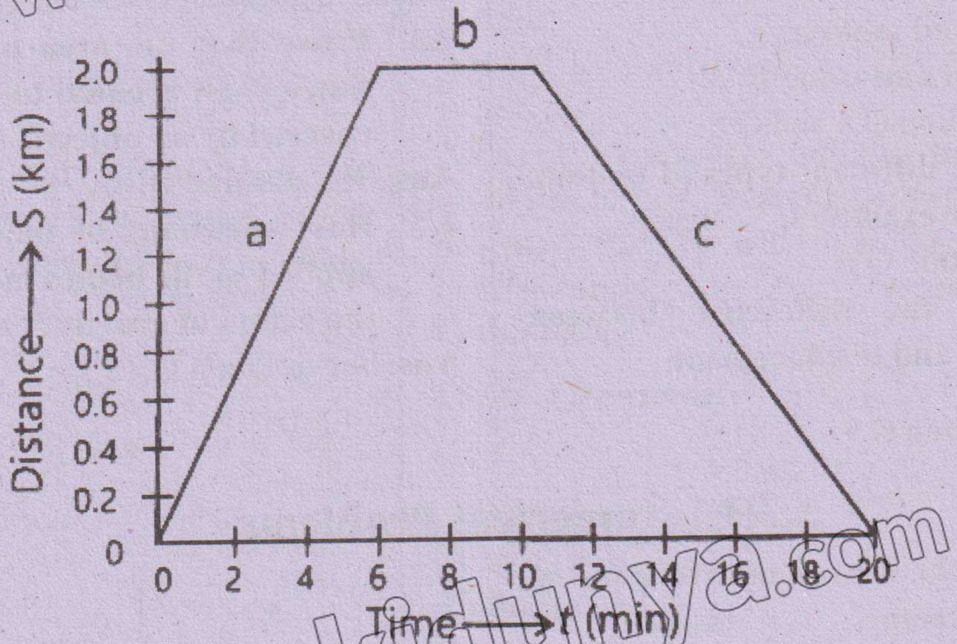
Ans: Yes, the instantaneous velocity can be negative even if the average velocity is positive. The average velocity is based on the overall displacement, but at any given moment, the object could be moving in the opposite direction, resulting in a negative instantaneous velocity.

2.4 A ball is thrown vertically upward with velocity v. It returns to the ground in time T. Which of the following graphs correctly represents the motion? 09102071



Ans. Graph **d** is correct because it shows a triangular shape, indicating a constant rate of change of velocity in both directions. This graph is correct because it accurately reflects the constant acceleration due to gravity and the symmetry of the upward and downward motion

2.5 Figure given below shows the distance-time graph for the travel of a cyclist. Find the velocities for the segments a, b and c. **09102072**



Ans. i. Segment a (0 to 5 minutes):

This segment shows a **steady increase** in distance, indicating constant velocity. The velocity can be calculated as the slope of the distance-time graph.

$$v = \frac{change\ in\ distance}{change\ in\ time} = \frac{2km - 0km}{5min - 0min} = \frac{2}{5} = \mathbf{0.4\ km/min}$$

ii. Segment b (5 to 10 minutes):

This segment shows a **constant distance** (a flat line), meaning there is no movement during this time. Therefore, the velocity is: **v = 0 km/min**

iii. Segment c (10 to 20 minutes):

This segment shows a **decrease** in distance, indicating the cyclist is moving back towards the starting point. The velocity is negative since the cyclist is moving in the opposite direction:

$$v = \frac{change\ in\ distance}{change\ in\ time} = \frac{0km - 2km}{20min - 10min} = \frac{-2}{10} = -\mathbf{0.2\ km/min}$$

2.6 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. **09102073**

Ans: Yes, it is possible for the velocity of an object to be zero at an instant, but its acceleration is not zero.

Example: When an object is thrown upwards. At the highest point of its motion, the velocity is zero for an instant, but the object still has acceleration due to gravity, acting downward. This shows that velocity and acceleration are independent and can have different values at a given time.

(D) Comprehensive Questions

2.1 How a vector can be represented graphically? Explain. 09102074

Ans: See question Q.3

2.2 Differentiate between: 09102075
(i) rest and motion
(ii) speed and velocity

Ans: See question Q.5 and Q.8

2.3 Describe different types of motion. Also give examples. 09102076

Ans: See question Q.6

2.4 Explain the difference between distance and displacement. 09102077

Ans: See question Q.7

2.5 What do gradients of distance-time graph and speed-time graph represent? Explain it by drawing diagrams. 09102078

Ans: See question Q.15 and Q.18

2.6 Prove that the area under speed-time graph is equal to the distance covered by an object. 09102079

Ans: See question Q.16

2.7 How equations of motion can be applied to the bodies moving under the action of gravity? 09102080

Ans: See question Q.18

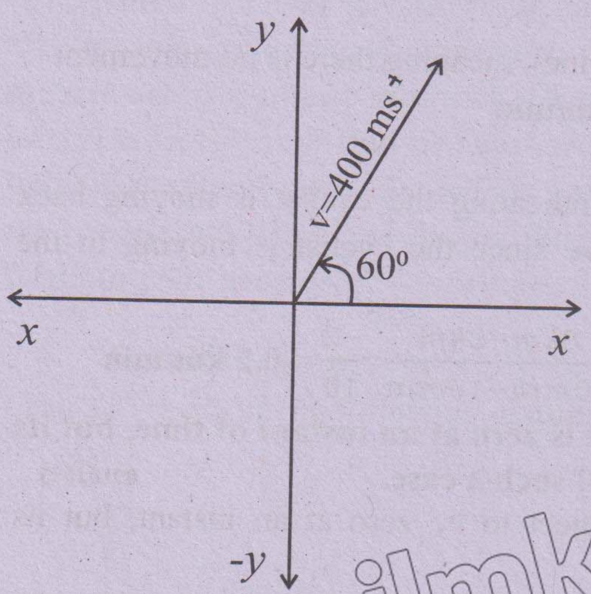
(E) Numerical Problems

2.1 Draw the representative lines of the following vectors: 09102081

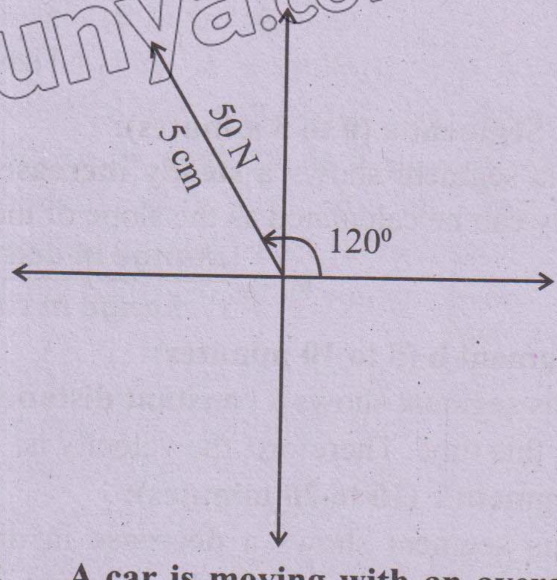
(a) A velocity of 400 ms^{-1} making an angle of 60^0 with x – axis.

(b) A force of 50 N making an angle of 120^0 with x – axis.

Solution:(a) Scale: 1 cm = 100 ms^{-1}



(b) Scale: 1 cm = 1N



2.2 A car is moving with an average speed of 72 $km\,h^{-1}$. How much time will it take to cover a distance of 360 km? 09102082

Given Data:

Average speed = v = 72 kmh^{-1}

Distance covered = S = 360 km

To Find:

Time = t = ?

Solution:

As we know that

Distance = speed × time

So,

$$\text{Time} = t = \frac{\text{distance}}{\text{speed}}$$

$$t = \frac{360\text{ km}}{72\text{kmh}^{-1}}$$

t = 5 hours

Result:

The car will take 5 hours to cover 360 km.

2.3 A truck start from rest. It reaches a velocity of 90 kmh^{-1} in 50 seconds. Find its average acceleration.

09102083

Given data:

Initial velocity = v_i = 0ms^{-1}

final velocity = v_f = 90 kmh^{-1} = $90\times\frac{1000}{3600}$

= 25 ms^{-1}

Time = t = 50 sec

To find:

Average acceleration = ?

Solution:

$$a = \frac{v_f - v_i}{t}$$

$$a = \frac{25-0}{50}$$

$$a = \frac{25}{50}$$

a = 0.5 ms^{-2}

Result:

The average acceleration of the truck is 0.5 ms^{-2}.

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

09102084

Given data:

Initial velocity = v_i = 5 ms^{-1}

Acceleration = a = 1.5 ms^{-2}

Time = t = 5 sec

To Find:

Final velocity = v_f = ?

Solution:

By using first equation of motion

$v_f = v_i + at$

$v_f = 5 + (1.5)(5)$

$v_f = 5 + 7.5$

v_f = 12.5 ms^{-1}

Result:

The velocity of car after 5 second is 12.5 ms^{-1}.

2.5 A motorcycle initially travelling at 18 km h^{-1} accelerates at constant rate of 2 ms^{-2}. How far will the motorcycle go in 10 seconds?

09102085

Given data:

Initial velocity = v_i = 18 km h^{-1} = $18\times\frac{1000}{3600}$

V_i = 5ms^{-1}

Acceleration = a = 2 ms^{-2}

Time = t = 10 sec

To find:

Distance = S =

Solution:

By using 2nd equation of motion

$$S = v_i t + \frac{1}{2}at^2$$

$$S = (5)(10) + \frac{1}{2}(2)(10)^2$$

S = 50 + (1)(100)

S = 150 m

Result: The motor cycle travel 150 m in 10 sec.

2.6 A wagon is moving on the road with a velocity of 54 km h^{-1}. Brakes are applied suddenly. The wagon covers a distance of 25m before stopping. Determine the acceleration of the wagon.

09102086

Solution:

Given data:

Initial velocity = v_i = 54 kmh^{-1} = $54\times\frac{1000}{3600}$ ms^{-1}

v_i = 15 ms^{-1}

Distance = S = 25m

Final velocity = $v_f = 0\ ms^{-1}$

To find:

Acceleration = a = ?

By using 3rd equation of motion

$2as = v_f^2 - v_i^2$

$2(a)(25) = (0)^2 - (15)^2$

$(50)a = -225$

$a = -\frac{225}{50}$

$a = -4.5\ ms^{-2}$

Result:

The acceleration of the wagon is $-4.5ms^{-2}$. (The negative sign indicates deceleration)

2.7 A stone is dropped from a height of 45m. How long will it take to reach the ground? What will be its velocity just before hitting the ground? 09102087

Solution:

Given data:

Height = h = 45m

Gravitational acceleration = g = 10 ms^{-2}

Initial velocity = $v_i = 0\ ms^{-1}$

To find:

(a) Time = t = ?

(b) Final velocity = v_f = ?

(a) For time.

By using 2nd equation of motion

$h = v_i t + \frac{1}{2}gt^2$

$45 = (0)(t) + \frac{1}{2}(10)(t)^2$

$45 = (5)(t)^2$

$\frac{45}{5} = t^2$

$t^2 = 9$

taking square root on both sides

$\sqrt{t^2} = \sqrt{9}$

$t = 3\ ms^{-1}$

(b) For final velocity:

By using 1st equation of motion

$v_f = v_i + gt$

$v_f = (0) + (10)(3)$

$v_f = 0 + 30$

$v_f = 30\ ms^{-1}$

Result:

Time to reach the ground in 3 sec and velocity just before hitting the ground is $30ms^{-1}$.

2.8 A car travel 10 km with an average velocity of 20 ms^{-1}. Then it 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. 09102088

Solution:

Given data:

(a) First part of journey =

Distance = d_1 = 10km = 10000m

Average velocity = v_1 = 20 ms^{-1}

(b) Second part of the journey:

Distance = d_2 = 0.8 km = 800m

Average velocity = $v_2 = 4ms^{-1}$

To find:

Average velocity of car for total journey = V_{av} = ?

First of all we calculate the time for each part of journey.

(a) Time for first part of journey

$t_1 = \frac{d_1}{v_1} = \frac{10000}{20} = 500$ seconds

(b) Time for second part of journey

$t_2 = \frac{d_2}{v_2} = \frac{800}{4} = 200$ seconds

Now, we calculate total distance and total time.

Total distance = $d_1 + d_2$

= 1000 + 800

= 10800m

Total time = $t_1 + t_2$

= 500 + 200

$= 700$ seconds

So, Average velocity $= V_{av} = \frac{d_{total}}{t_{total}}$

$V_{av} = \frac{10800}{700}$

$V_{av} = 15.4286 ms^{-1}$

Result:

The average velocity of total journey is $15.4 \ ms^{-1}$.

2.9 A ball is dropped from the top of a tower. The ball reaches the ground in 5 seconds. Find the height of the tower and the velocity of the ball with which strikes the ground. 09102089

Solution:

Given data:

Time to reach the ground = t = 5 sec

Acceleration due to gravity = g = $10ms^{-2}$

Initial velocity = $V_i = 0ms^{-1}$

To find:

(1) Height of tower = h = ?

(2) Velocity of ball with which it strikes the ground = V_f = ?

By using 2nd equation of motion

$h = v_i t + \frac{1}{2} gt^2$

$h = (0)(5) + \frac{1}{2}(10)(5)^2$

$h = (0) + (5)(25)$

$h = 5(25)$

$h = 125$ m

Now, for finding "final velocity" we will use 1st equation of motion:

$V_f = v_i + gt$

$V_f = (0) + (10)(5)$

$V_f = 0 + 50$

$V_f = 50 \ ms^{-1}$

Result:

(i) Height of tower is 125m

(ii) Velocity of ball with which it strikes the ground is $50 \ ms^{-1}$.

2.10 A cricket ball is hit so that it travel straight up in the air. An observer note that it took 3 seconds to reach the highest point. What was the initial velocity of the ball? If the ball was hit 1m above the ground, how high did it rise from the ground? 09102090

Solution:

Given data:

Time to reach maximum height = t = 3 sec

Velocity at maximum height = $v_f = 0 \ ms^{-1}$

Acceleration due to gravity = $-10 \ ms^{-2}$

Height from which the ball is hit from the ground = h_o = 1m

To find:

Initial velocity of ball = v_i = ?

Total height from ground = h_{total} = ?

By using 1st eq of motion

$V_f = v_i + gt$

$0 = v_i + (-10)(3)$

$0 = v_i - 30$

$v_i = 30 \ ms^{-1}$

Now by using 2nd equation of motion

$h = v_i t + \frac{1}{2} gt^2$

$h = (30)(3) + \frac{1}{2}(-10)(3)^2$

$h = (90) - (5)(9)$

$h = 90 - 45$

$h = 45$ m

This is height from the paint where the ball was hit. To find the total height from the ground, we add the initial height h_o

$h_{total} = h + h_o$

$= 45 + 1$

$h_{total} = 46m$

Result:

The initial velocity of the ball is $30ms^{-1}$ and total height the ball reaches from the ground is 46m