2025-26

Physics 9

Comprehensive Notes with Short Questions, Long Questions, MCQs, and Problems

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1. What is Mechanics?

*Mechanics is the branch of physics that deals with the **motion** of objects and the **forces** that change it.*

2. What are the branches of Mechanics?

Mechanics is generally divided into two branches:

***Kinematics** – The study of motion without referring to forces.*

***Dynamics** – The study of forces and their effect on motion.*

**** 3. Define scalar and vector quantities. Give 5 examples each for scalar and vector quantities.**

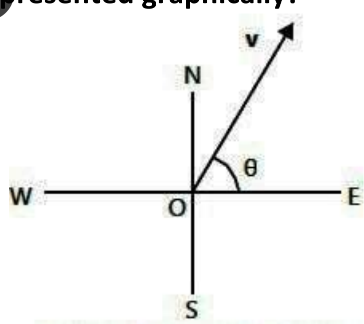
Scalar Quantity	Vector Quantity
A scalar is that physical quantity which can be described completely by its magnitude only.	A vector is that physical quantity which needs magnitude as well as direction to describe it completely.
Examples of scalers are distance, length, time, speed, energy, temperature.	Examples of vectors are displacement, velocity, acceleration, weight, force.
For example, mass of sugar (5 kg) is completely described by its magnitude.	For example, velocity of a car ($25\,ms^{-1}$ towards north) needs both magnitude and direction.
Scalars can be added like numbers (e.g., 5 m + 3 m = 8 m).	Vectors cannot be added like scalars; their directions must be considered.
Represented by a single numerical value with a unit.	Represented using arrows to show both magnitude and direction.

***4. How is a vector represented symbolically?**

In the textbook, a vector is represented by a boldface letter such as **A**, **v**, **F** etc. Since boldface cannot be written on paper, a vector is written with a small arrow over it, i.e., $\vec{A}$, $\vec{v}$, $\vec{F}$, $\vec{d}$. The magnitude of a vector is represented by an italic letter without an arrowhead.

**** 5. How can a vector be represented graphically?**

"A vector is graphically represented by drawing a straight line with an arrowhead at one end. The length of the line represents the magnitude of the vector according to a suitable scale, while the arrowhead indicates the direction of the vector."

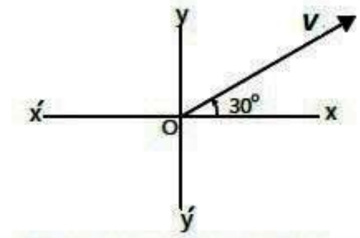


A vector **v** making an angle θ towards north from east

Note: To represent the direction of a vector, two mutually perpendicular lines are required. One line represents the east-west direction, and the other represents the north-south direction as shown in figure. The direction of a vector can be given with respect to these lines. Mostly, we use any two lines which are perpendicular to each other.

***6. What are the reference axes, and what is the origin?**

The horizontal line (XX') is called the x-$axis$, and the vertical line (YY') is called the y-$axis$.



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

The point where these axes meet is known as the **origin**, usually denoted by $\boldsymbol{O}$. These axes are called **reference axes**.

7. How is the direction of a vector specified?

A vector is drawn from the origin of the reference axes towards the given direction. The direction is usually given by an angle $\boldsymbol{\theta}$ (theta) with the x-$axis$. This angle is always measured from the right side of the x-axis in the anti-clockwise direction.

***8. What is a resultant vector, and how is vector addition different from scalar addition?**

*A **resultant vector** is a single vector obtained by adding two or more vectors. It has the same effect as the combined effect of all the vectors being added.*

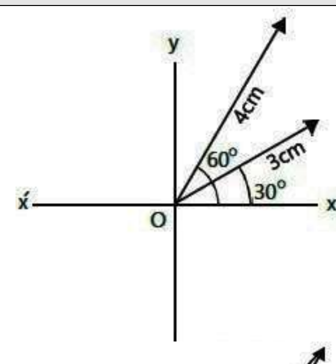
Unlike **scalar addition**, where only **magnitudes** are added, **vector addition** requires determining both **magnitude** and **direction**. One method of adding **vectors** is the **graphical method**.

**** 9. State head-to-tail rule for addition of vectors.**

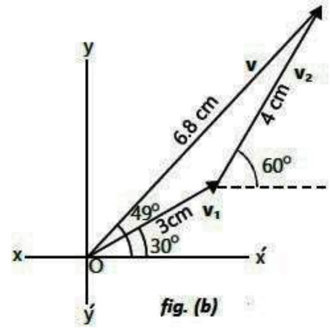
*To add a number of vectors, redraw their representative lines such that the **head** of one line coincides with the tail of the other. The **resultant vector** is given by a **single vector** which is directed from the **tail** of the first vector to the **head** of the **last vector**.*

10. How can we add two or more vectors using the head-to-tail rule?

Let us add two vectors $\boldsymbol{v_1}$ and $\boldsymbol{v_2}$ having magnitudes of $300\,N$ and $400\,N$ acting at angles of 30° and 60° with the x-axis. By selecting a **suitable scale** ($\boldsymbol{100N = 1cm}$), we can draw the vectors as shown in fig. (a).



The measured length of the resultant vector is $6.8\,cm$ fig. (b). According to the selected scale, the magnitude of the resultant vector $\boldsymbol{v}$ is $680\,N$, and its direction is 49° with the x-$axis$. We can find the **resultant vector** of more than two vectors by adding them in the same way using the **head-to-tail rule**.



**** 11. What is difference between rest and motion?**

Rest	Motion
If a body does not change its position with respect to its surroundings, it is said to be **at rest**.	If a body continuously changes its position with respect to its surroundings, it is said to be **in motion**.
Example: A motorcyclist **standing on the road** is at rest because he is not changing his position with respect to nearby buildings, trees, or poles.	Example: A **moving motorcyclist** is in motion because he is continuously changing his position with respect to his surroundings.
Objects like **buildings, trees, and electric poles** are in a state of rest as they do not change their position.	A moving car, running water, or a flying bird are examples of motion.
Rest and motion are relative. A person sitting inside a moving train is at rest **relative to other passengers** but in motion **relative to an observer on the platform**.	**Rest and motion are relative.** The same person is in motion with respect to someone standing outside the train.

**** 12. What are the different types of motion? Explain with examples.**

We observe different types of motion in our daily life. Generally, there are **three types of motion:**

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.*

For example, the motion of a train or a car.

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

For example, the motion of an electric fan or a spinning top.

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

For example, a swing in a children's park.

13. What are the types of translatory motion? Explain with examples.

Translatory motion can be of **three types:**

Linear Motion: *If the body moves along a straight line, it is called linear motion.*

For example, a freely falling body.

Random Motion: *If the body moves along an irregular path, the motion is called random motion.*

For example, the motion of a bee.

Circular Motion: *The motion of a body along a circle is called circular motion.*

For example, a Ferris wheel or a ball tied to a string and whirled in a circle.

***14. What is the difference between distance and displacement? Explain with examples.**

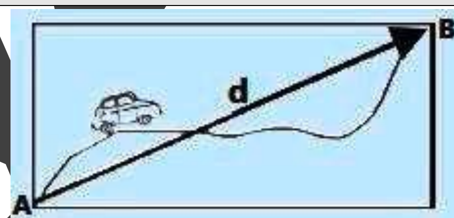
Distance: *The distance is the length of the actual path of the motion.*

Example: Let a person be travelling from **Lahore to Multan** in a car. On reaching **Multan**, he reads the speedometer and notices that he has travelled a **distance of 320 km**. This is the total distance he travelled. However, this is **not the shortest distance**, as the car took many turns along the way and did not travel in a straight line.

Displacement: *The displacement of an object is a vector quantity whose magnitude is the shortest distance between the initial and final positions of the motion. Its direction is from the initial position to the final position. We can also call this the change in position.*

OR

The shortest distance between the initial and final positions of a body is called its displacement.



Example: Suppose a car travels from a position A to B. The **curved line** is the actual path followed by the car as shown in figure, which represents the **distance**. The displacement ($\boldsymbol{d}$) is the straight line from A to B, as indicated by the arrow.

Position: *Position of any object is its distance and direction from a fixed point.*

Key Points:

(a) **Distance is a scalar quantity,** while **displacement is a vector quantity**.

(b) The **SI unit** for displacement is the same as that of distance ($meters, m$).

**** 15. What is speed? Write its formula and SI unit.**

Speed is the distance covered in unit time. It tells us how fast a body is moving.

The formula for **speed (v)** is:

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

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

Speed is a **scalar quantity**, and its **SI unit** is $\boldsymbol{ms^{-1}}$ or $\boldsymbol{kmh^{-1}}$.

***16. Differentiate between instantaneous speed and average speed.**

Instantaneous Speed: *The speed of a vehicle at any given instant is called instantaneous speed. It is the reading shown on a speedometer at that moment.*

Average Speed: *Since speed is not constant during a journey, we often use average speed, which is defined as:*

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

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

This helps us determine how fast an object moves **on average** over a period of time.

**** 17. What is velocity? Write its formula and SI unit.**

Velocity is the net displacement of a body in unit time.

It is a vector quantity, meaning it has both magnitude and direction. The formula for **average velocity** is:

$$Average\ velocity = \frac{Displacement}{Time}$$

$$\boldsymbol{v_{av}} = \frac{\boldsymbol{d}}{t}$$

The **SI unit** of velocity is $\boldsymbol{ms^{-1}}$ or $\boldsymbol{kmh^{-1}}$.

18. How is velocity different from speed?

- **Speed** only tells how fast an object is moving; it does not include direction.
- **Velocity** tells both how fast and in which direction an object is moving.
- **Speed is a scalar quantity**, while **velocity is a vector quantity**.

For example, if a car moves towards north at 70 kmh^{-1}, its speed is 70 kmh^{-1} (scalar), but its velocity is 70 kmh^{-1}towards north (vector).

***19. What is uniform and non-uniform velocity? Give an example.**

The velocity is said to be ***uniform*** *if the speed and direction of a moving body do not change. If the speed or direction or both of them change, it is known as variable velocity or* ***non-uniform*** *velocity.*

For example, the downward motion of a **paratrooper** is an example of **uniform velocity**. 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 downward on the paratrooper is balanced by the **resistance of air** on the parachute that acts upward. Consequently, the paratrooper moves down with **uniform velocity**.

***20. What is acceleration? Write its SI unit.**

Acceleration is defined as the time rate of change of velocity.

It is a **vector quantity**, meaning its direction is the same as that of the change in velocity.

If a body is moving with an initial velocity v_i and after some time t, its velocity changes to v_f, then the change in velocity is $\Delta v = v_f - v_i$

The **average acceleration** is given by:

$$Average\ acceleration = \frac{Change\ in\ velocity}{Time\ taken}$$

$$\boldsymbol{a_{av}} = \frac{\boldsymbol{v_f} - \boldsymbol{v_i}}{t} \cdots (i)$$

$$\boldsymbol{a_{av}} = \frac{\boldsymbol{\Delta v}}{t}$$

The **SI unit of acceleration** is meter per second square (ms^{-2}).

If acceleration a is constant, then Eq (i) can be written as $v_f = v_i + at$

***21. What are the types of acceleration?**

Acceleration is of two types:

Positive Acceleration: *If the velocity is increasing, the acceleration is positive. For example, when a car overtakes another vehicle, it accelerates to a greater velocity.*

Negative Acceleration (Deceleration or Retardation): *If the velocity is decreasing, the acceleration is negative. For example, when brakes are applied to slow down a bicycle or a car, the velocity decreases.*

Acceleration is a **vector quantity**, and its **direction** is that of the **change in velocity**.

***22. What is uniform and non-uniform acceleration?**

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

Non-Uniform Acceleration*: If anyone of the magnitude or direction or both changes, the acceleration is called variable or non-uniform acceleration.*

For example, a freely falling body experiences **uniform acceleration** due to gravity because its velocity increases by an equal amount in equal time intervals. While if a car moving in **traffic** experiences **non-uniform acceleration** as it speeds up, slows down, and changes direction frequently.

***23. What is a graph, and how is it drawn?**

A graph is a ***pictorial diagram*** *in the form of a straight line or a curve that shows the relationship between two physical quantities.*

Usually, we draw a graph on a paper on which equally spaced horizontal and vertical lines are drawn. Generally, every 10th line is a thick line on the graph paper.

24. How are the axes selected, and what is meant by the origin in a graph?

To draw a graph, two mutually perpendicular thick lines, XOX' and YOY', are selected as the $x\text{-}axis$ and $y\text{-}axis$.

The point where the two axes intersect each other is known as the **origin ($\boldsymbol{O}$)**.

25. How are positive and negative values placed on a graph?

Positive values along the x-axis are taken to the **right** side of the origin, and negative values are taken to the **left** side.

Positive values along the y-axis are taken **above** the origin, whereas negative values are taken **below** the origin.

26. How are variables assigned to the axes, and give an example?

Normally, the **independent** quantity is taken along the x-$axis$, and the **dependent** variable quantity along the y-$axis$.

For example, in a distance-time graph, t (time) is the independent variable, and S (distance) is the dependent variable. Therefore, t should be along the x-$axis$, and S along the y-$axis$.

27. Why is a suitable scale chosen for a graph?

To represent a **physical quantity** along any axis, a **suitable scale** is chosen by considering the **minimum and maximum values** of the quantity.

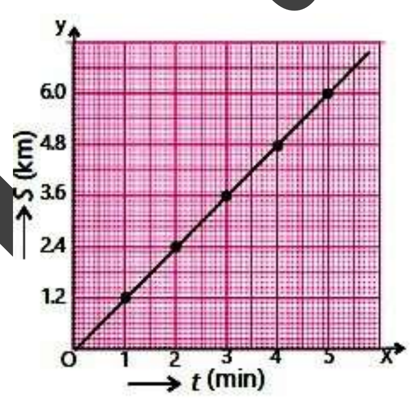
**** 28. What is a distance-time graph, and what does it represent?**

*A distance-time graph shows the **relation between distance (S)** and **time (t)** taken by a moving body.*

For example, suppose a car moves in a straight line on a motorway. We measure its distance from the starting point after every one minute and record it in a table:

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

29. How is a distance-time graph drawn? Write the steps.



To draw a distance-time graph on a centimetre graph paper, follow these steps:

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

(ii) Select suitable scales: ($1\ minute = 1\ cm$) on the x-axis and ($1.2\ km = 1\ cm$) on the y-axis.

(iii) Mark values on both axes according to the chosen scale.

(iv) Plot pairs of time and distance values from the table on the graph paper.

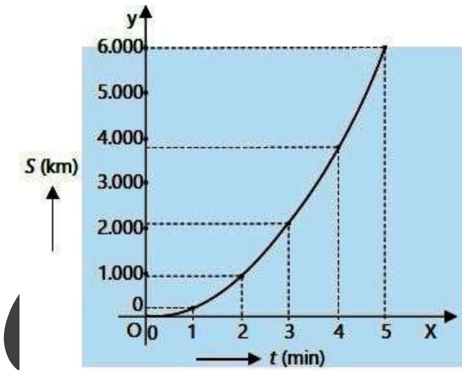
(v) Join the plotted points to obtain a **best straight line**.

30. What does a straight-line distance-time graph indicate? Give an example.

A straight-line distance-time graph indicates that the body is moving with **uniform speed**, covering equal distances in equal time intervals.

For example, in the first car journey, the graph from the table shows a **straight line**, indicating that the car moves with uniform speed.

31. What does an upward-curved distance-time graph represent? Explain with an example.



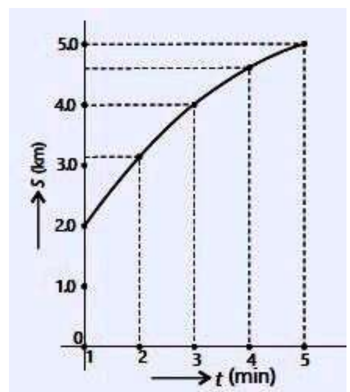
An upward-curved distance-time graph indicates that the body is moving with **acceleration** (its speed is increasing).

For example, in another journey of the car, the table shows:

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

The graph line curves upward, showing that the car's speed increases in equal intervals of time, which means the car is moving with **acceleration**.

32. What does a downward-curved distance-time graph show? Explain with an example.



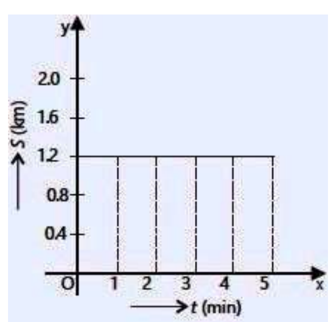
A downward-curved distance-time graph indicates motion with decreasing speed, which is called **deceleration** or **negative acceleration.**

For example, in another journey, the table shows:

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

The graph line curves downwards, showing that the distance traveled in the same time intervals decreases, which means the car is slowing down **(decelerating)**.

33. What does a horizontal distance-time graph represent? Explain with an example.



A horizontal distance-time graph shows that the distance remains **constant with time**, meaning the object is at rest **(not moving)**.

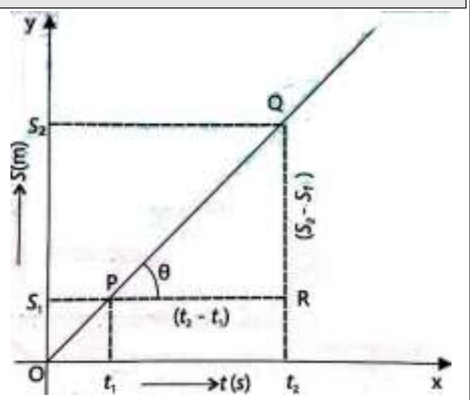
For example, in another case, the table shows:

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

The **graph line is horizontal**, indicating that the **car is stationary** because **distance does not change with time**.

****34. What is meant by the gradient of a distance-time graph? How is the gradient of a distance-time graph calculated, and what is its relation to average speed?**

The gradient is the measure of the slope of a line. In a distance-time graph, the gradient is equal to the average speed of the body.



To calculate the gradient:

(i) Select any two values of time t_1 and t_2.

(ii) Draw two vertical dotted lines at t_1 and t_2 on the x-$axis$.

(iii) These lines meet the graph at points P and Q.

(iv) From points P and Q, draw horizontal lines to meet the y-$axis$ at S_1 and S_2, respectively.

The slope or gradient of the graph is the measure of $tangent\ \theta$ of the triangle PQR:

$$Slope = \frac{y\ axis}{x\ axis} = \frac{RQ}{PR} = \frac{S_2 - S_1}{t_2 - t_1} = \frac{S}{t}$$

From Equation $v_{av} = \frac{S}{t}$, $S = vt$ where v is the average speed:

$$Slope = \tan\theta = \frac{S}{t} = Average\ speed$$

Therefore, the gradient of the distance-time graph is equal to the **average speed** of the body.

**** 35. What is a speed-time graph? How is it drawn?**

A speed-time graph shows the relationship between ***speed (v)*** *and* ***time (t)*** *taken by a moving body.*

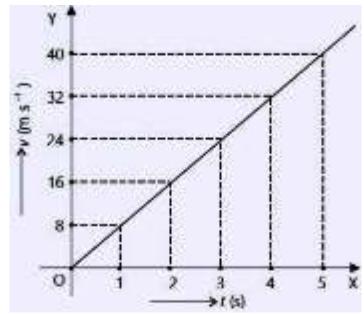
To draw a speed-time graph:

(i) Take time (t) along the x-$axis$ and speed (v) along the y-$axis$.

(ii) Select a suitable scale.

36. What is the shape of the speed-time graph for uniform acceleration and constant speed? Explain with examples.

For Uniform Acceleration: The speed-time graph is a straight line rising upward, showing that speed increases by the same amount in equal intervals of time.

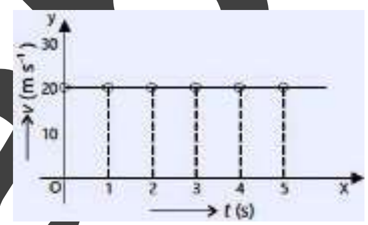


Example: When a car's speed is recorded every second:

Time t (s)	0	1	2	3	4	5
Speed v (m/s)	0	8	16	24	32	40

The graph is a straight line with a positive slope, indicating **uniform acceleration**.

For Constant Speed: The speed-time graph is a horizontal line, showing that speed remains the same over time.



Example: When a car moves at a constant speed:

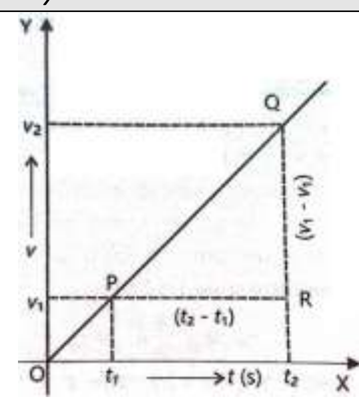
Time t (s)	0	1	2	3	4	5
Speed v (m/s)	20	20	20	20	20	20

The graph is a straight line **parallel to the time axis**, indicating **constant speed**.

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

The gradient (slope) of a speed-time graph is equal to the ***average acceleration*** *of the body.*

For Accelerating Motion: Consider the speed-time graph. The speeds at times t_1 and t_2 are v_1 and v_2 respectively. The change in speed over the time interval $(t_2 - t_1)$ is $(v_2 - v_1)$. Therefore,



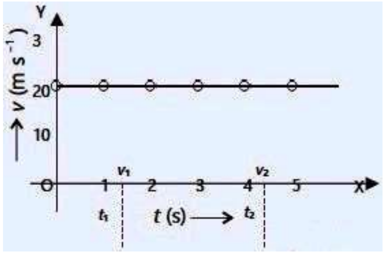
$$Slope = \frac{Change\ in\ speed}{Time\ taken} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}$$

Since **average acceleration** $a = \frac{\Delta v}{\Delta t}$, the slope represents:

$$\Rightarrow Slope = a \quad (average\ acceleration)$$

When a car moves with constant acceleration, the velocity-time graph is a **straight line** which rises through the same height for equal intervals of time. This indicates uniform acceleration.

For Zero Acceleration (Constant Speed): When a body moves at a **constant speed**, the speed-time graph is a **horizontal straight line** parallel to the time axis.



In this case, the speed at time t_1 is the same as the speed at time t_2. Therefore, the change in speed is zero:

$$v_2 - v_1 = 0$$

Hence, the slope is:

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

This shows that the **acceleration of this motion is zero**, meaning it is a motion **without any change in speed**.

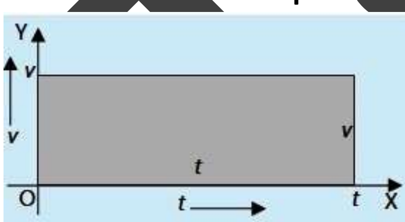
Conclusion:

- The **slope of a speed-time graph** is equal to the body's average acceleration.
- A **slanted straight line** represents uniform acceleration.
- A **horizontal line** parallel to the time axis represents zero acceleration (constant speed).

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

The distance moved by an object can be found by calculating the area under the speed-time graph.

1. When the Object Moves with Constant Speed: In Figure, the object moves with a constant speed v. For a time interval t, the distance covered is:



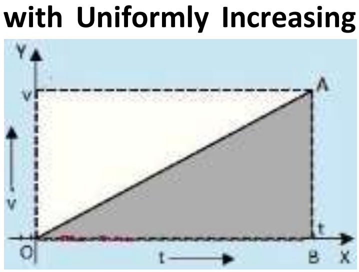
$$Distance = v \times t$$

The same distance is obtained by calculating the area under the speed-time graph, which is a rectangle with sides v and t:

$$Area\ of\ rectangle = v \times t$$

The area under the speed-time graph up to the time axis is numerically equal to the distance covered by the object**.**

2. When the Object Moves with Uniformly Increasing Speed (Acceleration): In figure, the object's speed increases uniformly from 0 to v in time t. The average speed is:



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

The distance covered is:

$$Distance = average\ speed \times time$$
$$= \frac{v}{2} \times t$$
$$= \frac{1}{2} vt$$

The area under the speed-time graph is a right-angled triangle with base t and perpendicular v:

$$Area\ of\ triangle = \frac{1}{2} \times base \times perpendicular$$
$$= \frac{1}{2} \times v \times t$$
$$= \frac{1}{2} vt$$

The area under the speed-time graph up to the time axis is numerically equal to the distance covered by the object.

Thus, whether the speed is constant or increasing uniformly, the area under the speed-time graph up to the time axis is numerically equal to the distance covered by the object.

39. Write the three equations of motion and state the assumptions made while applying them.

The three equations of motion are used to solve problems related to the motion of bodies. If:

- v_i is the initial velocity
- v_f is the final velocity
- t is the time taken
- S is the distance covered
- a is the acceleration

Then, the three equations of motion are:

$$v_f = v_i + at$$
$$S = v_i t + \frac{1}{2} a t^2$$
$$2aS = v_f^2 - v_i^2$$

Assumptions Made While Applying the Equations of Motion:

(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. Quantities in the same direction as the initial velocity are taken as **positive**, while those in the opposite direction are taken as **negative**.

**** 40. How equations of motion can be applied to the bodies moving under the action of gravity?**

When a body falls freely under the action of Earth's gravity, the acceleration acting on it is called ***gravitational acceleration*** *and is denoted by* $\boldsymbol{g}$*.*

The direction of gravitational acceleration is always **downwards**. Its value is $9.8\ ms^{-2}$, but for convenience, we use $10\ ms^{-2}$.

Since freely falling bodies move vertically downward in a straight line with uniform acceleration g, the three equations of motion can be applied to their motion by replacing a with g.

Thus, the **equations of motion for freely falling bodies** are:

$$v_f = v_i + gt$$

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

$$2gS = v_f^2 - v_i^2$$

Points to Consider While Using These Equations:

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

(ii) The gravitational acceleration g is taken as **positive** in the **downward direction**. All other quantities in the downward direction are also taken as positive, while those in the opposite direction are taken as negative.

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

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

No, a heavier object will not fall faster than a lighter object. According to the equations of motion for freely falling bodies:

- All objects experience the same gravitational acceleration ($\boldsymbol{g} = 9.8\, ms^{-2}$) near Earth's surface, regardless of their mass.
- This implies that both heavy and light objects will reach the ground simultaneously in a vacuum (where air resistance is negligible).

42. What is the universal speed limit and who proposed it?

In **1905**, the famous scientist **Albert Einstein** proposed his revolutionary **theory of special relativity**, which modified many basic concepts of physics.

According to this theory:

- The **speed of light** is a **universal constant** with a value of approximately $\mathbf{3 \times 10^8\, ms^{-1}}$.
- The **speed of light** remains the same for **all motions**, regardless of the observer's frame of reference.
- **No object with mass** can achieve speeds **equal to or greater** than that of light.

This is known as the **universal speed limit**.

**** 43. The vector quantities are sometimes written in scalar notation (not bold face). How is the direction indicated?**

When vector quantities are written in scalar notation (not boldface), their direction is indicated in the following different ways.

(i) By stating the direction in words: For example, a force of $10\, N$ towards the east or Velocity of $5\, ms^{-1}$ northward.

(ii) By giving the angle: For example, a displacement of $5\, m$ at 30° from the x-$axis$.

**** 44. A body is moving with uniform speed. Will its velocity be uniform? Give reason.**

A body is moving with uniform speed may or may not have uniform velocity**.**

Case I: If the direction of motion of body is changing, its velocity will get changed. For example: A care moving on circular path with constant speed.

Case II: If the direction of motion of body is constant/linear then its speed as well as its velocity will remain constant.

**** 45. Is it possible for a body to have acceleration when moving with: (i) constant velocity (ii) constant speed?**

(i) For Constant Velocity: No, when a body moves with constant velocity its acceleration becomes equal to zero because acceleration is the rate of change of velocity over time.

For example: A car is moving in a straight line with uniform velocity.

(ii) For Constant Speed: Yes, a body can have acceleration while moving with constant speed.

For example: When a body moves with constant speed on a circular path it has acceleration because the direction of its motion changes which is along the tangent speed.

Important Formulas

- **Distance** $S = v_{av} \times t$
- **Average acceleration**

$$Average\ acceleration = \frac{Change\ in\ velocity}{Time\ taken}$$

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

- **First Equation of Motion**

$$v_f = v_i + at$$

- **Second Equation of Motion**

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

- **Third Equation of Motion**

$$2aS = v_f^2 - v_i^2$$

- To concert ms^{-1} to kmh^{-1} **multiply** speed with $\mathbf{3.6}$
- To concert kmh^{-1} to ms^{-1} **multiply** speed with $\mathbf{\frac{10}{36}}$
- **First Equation of Motion Body Moving Under Gravity** $v_f = v_i + gt$
- **Second Equation of Motion Body Moving Under Gravity** $h = v_i t + \frac{1}{2}gt^2$
- **Third Equation of Motion Body Moving Under Gravity** $2gh = v_f^2 - v_i^2$
- For bodies **falling down** freely value of $\boldsymbol{g}$ **is positive** and $v_i = 0$
- For bodies **moving upward** value of $\boldsymbol{g}$ **is negative** and $v_f = 0$

2.1 Draw the representative lines of the following vectors:

(a) A velocity of $\mathbf{400\ ms^{-1}}$ making an angle of $\mathbf{60°}$ with $\boldsymbol{x}$-axis.

(b) A force of $\mathbf{50\ N}$ making an angle of $\mathbf{120°}$ with $\boldsymbol{x}$-axis.

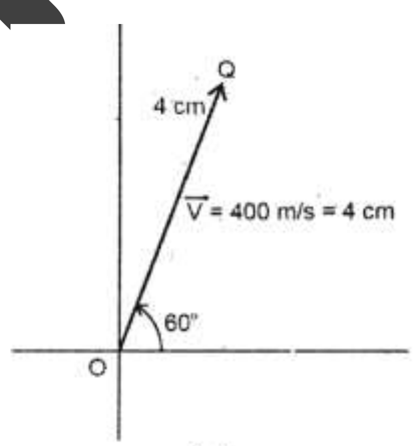
Solution

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

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

(ii) Select a suitable scale
If $100\ ms^{-1} = 1\ cm$
then $400\ ms^{-1} = 4\ cm$

(iii) Draw $4\ cm$ line OQ at angle of $60°$ with positive x-$axis$. The OQ is vector $\vec{V}$.



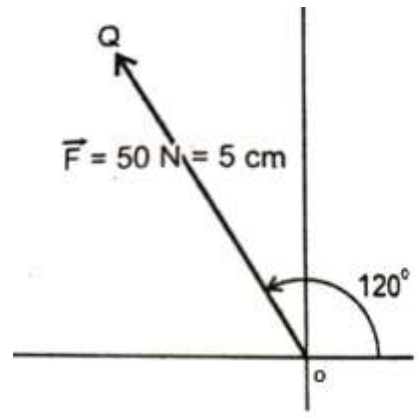
(a)

(b) A velocity of $50\ N$ making an angle of $120°$ with x-$axis$.

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

(ii) Select a suitable scale
If $10\ N = 1\ cm$
then $50N = 5\ cm$

(iii) Draw $5\ cm$ line OQ at angle of $120°$ with x-$axis$. The OQ is vector $\vec{F}$.



(b)

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

Given Data

$$Average\ speed\ of\ car = v_{av} = 72\ kmh^{-1}$$
$$Distance = S = 360\ km$$

To Find

$$Time = t = ?$$

Solution

By using formula of distance

$$S = v_{av} \times t$$
$$360 = 72 \times t$$
$$\frac{360}{72} = t$$
$$5 = t$$
$$\boldsymbol{t = 5\ hr}$$

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

Given Data

$$Initial\ velocity\ of\ truck = v_i = 0\ kmh^{-1}$$
$$Final\ velocity = v_f = 90\ kmh^{-1}$$
$$v_f = 90 \times \frac{10}{36}\ ms^{-1}$$
$$v_f = 25\ ms^{-1}$$
$$Time = t = 50\ s$$

To Find

$$Average\ acceleration = a_{av} = ?$$

Solution

By using formula of average acceleration

$$a_{av} = \frac{v_f - v_i}{t}$$
$$a_{av} = \frac{25 - 0}{50}$$
$$a_{av} = \frac{25}{50}$$
$$\boldsymbol{a_{av} = 0.5\ ms^{-2}}$$

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

Given Data

$$Initial\ velocity\ of\ car = v_i = 5\ ms^{-1}$$
$$Acceleration = a = 1.5\ ms^{-2}$$
$$Time = t = 5\ s$$

To Find

$$Final\ Velocity = v_f = ?$$

Solution

By using first equation of motion

$$v_f = v_i + at$$
$$v_f = 5 + (1.5)(5)$$
$$v_f = 5 + 7.5$$
$$\boldsymbol{v_f = 12.5\ ms^{-1}}$$

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

Given Data

$$Initial\ velocity = v_i = 18\ kmh^{-1}$$
$$v_i = 18 \times \frac{10}{36}\ ms^{-1}$$
$$v_i = 5\ ms^{-1}$$
$$Acceleration = a = 2\ ms^{-2}$$
$$Time = t = 10\ s$$

To Find

$$Distance\ moved = S = ?$$

Solution

By using second equation of motion

$$S = v_i t + \frac{1}{2}at^2$$
$$S = (5)(10) + \frac{1}{2}(2)(10)^2$$
$$S = 50 + \frac{1}{2}(2)(100)$$
$$S = 50 + 100$$
$$\boldsymbol{S = 150\ m}$$

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

Given Data

$$Initial\ velocity\ of\ wagon = v_i = 54\ kmh^{-1}$$
$$v_i = 54 \times \frac{10}{36}\ ms^{-1}$$
$$v_i = 15\ ms^{-1}$$
$$Distance\ coverd\ = S = 25\ m$$
$$Final\ velocity = v_f = 0\ ms^{-1}$$

To Find

$$Acceleration = a = ?$$

Solution

By using third equation of motion

$$2aS = v_f^2 - v_i^2$$
$$2(a)(25) = (0)^2 - (15)^2$$
$$50(a) = 0 - 225$$
$$a = \frac{-225}{50}$$
$$\boldsymbol{a = -4.5\ ms^{-2}}$$

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

Given Data

$$Height = h = 45\ m$$
$$Initial\ velocity = v_i = 0\ ms^{-1}$$
$$Acceleration\ due\ to\ gravity = g = 10\ ms^{-2}$$
$$Time = t = 5\ s$$

To Find

$$Time\ toreach\ ground = t = ?$$
$$Velocity\ just\ before\ hitting\ ground = v_f = ?$$

Solution

By using second equation of motion body moving under gravity

$$h = v_i t + \frac{1}{2}gt^2$$
$$45 = (0)(t) + \frac{1}{2}(10)(t)^2$$
$$45 = 0 + 5(t)^2$$
$$45 = 5(t)^2$$
$$\frac{45}{5} = t^2$$
$$9 = t^2$$
$$\sqrt{9} = \sqrt{t^2}$$
$$3 = t$$
$$\boldsymbol{t = 3\ s}$$

Now for final velocity by using first equation of motion under gravity

$$v_f = v_i + gt$$
$$v_f = 0 + (10)(3)$$
$$v_f = 0 + 30$$
$$\boldsymbol{v_f = 30\ ms^{-1}}$$

2.8 A car travels $10\ km$ 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.

Given Data

$$Distance\ traveld = S_1 = 10\ km$$
$$S_1 = 10 \times 10^3\ m$$
$$S_1 = 10000\ m$$
$$Average\ velocity = v_1 = 20\ ms^{-1}$$
$$Next\ distance\ traveld = S_2 = 0.8\ km$$
$$S_2 = 0.8 \times 10^3\ m$$
$$S_2 = 800\ m$$
$$Average\ velocity = v_2 = 4\ ms^{-1}$$

To Find

$$Average\ velocity\ for\ total\ journey = v_{av} = ?$$

Solution

For S_1 time taken by using formula $S = vt$

$$t_1 = \frac{S_1}{v_1}$$
$$t_1 = \frac{10000}{20}$$
$$t_1 = 500\ s$$

For S_2 time taken

$$t_2 = \frac{S_2}{v_2}$$
$$t_2 = \frac{800}{4}$$
$$t_2 = 200\ s$$
$$Total\ time = t = t_1 + t_2$$
$$t = 500 + 200$$
$$t = 700\ s$$
$$Total\ distance = S = S_1 + S_2$$
$$S = 10000 + 800$$

$$S = 10800\ m$$

Now by using formula of distance

$$S = v_{av} \times t$$
$$10800 = v_{av} \times 700$$
$$\frac{10800}{700} = v_{av}$$
$$15.4 = v_{av}$$
$$\boldsymbol{v_{av} = 15.4\ ms^{-1}}$$

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 it strikes the ground.

Given Data

$$Time\ taken = t = 5\ s$$
$$Initial\ velocity = v_i = 0\ ms^{-1}$$
$$Acceleration\ due\ to\ gravity = g = 10\ ms^{-2}$$

To Find

$$Height\ of\ tower = h = ?$$
$$Final\ velocity = v_f = ?$$

Solution

By using second equation of motion body moving under gravity

$$h = v_i t + \frac{1}{2} g t^2$$
$$h = (0)(5) + \frac{1}{2}(10)(5)^2$$
$$h = 0 + (5)(25)$$
$$\boldsymbol{h = 125\ m}$$

Now for final velocity by using first equation of motion under gravity

$$v_f = v_i + gt$$
$$v_f = 0 + (10)(5)$$
$$\boldsymbol{v_f = 50\ ms^{-1}}$$

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

Given Data

$$Time\ to\ reach\ the\ highest\ point = t = 3\ s$$
$$Final\ velocity = v_f = 0\ ms^{-1}$$
$$Acceleration\ due\ to\ gravity = g = -10\ ms^{-2}$$

To Find

$$Initial\ velocity = v_i = ?$$
$$Height\ of\ ball\ 1\ m\ above\ the\ ground = h_t = ?$$

Solution

For initial velocity by using first equation of motion under gravity

$$v_f = v_i + gt$$
$$0 = v_i + (-10)(3)$$
$$0 = v_i - 30$$
$$30 = v_i$$
$$\boldsymbol{v_i = 30\ ms^{-1}}$$

Now by using second equation of motion body moving under gravity

$$h = v_i t + \frac{1}{2} g t^2$$
$$h = (30)(3) + \frac{1}{2}(-10)(3)^2$$
$$h = 90 + (-5)(9)$$
$$h = 90 - 45$$
$$h = 45\ m$$
$$Required\ total\ height = h_t = h_{gain} + h_{initial}$$
$$h_t = 45\ m + 1\ m$$
$$\boldsymbol{h_t = 46\ m}$$