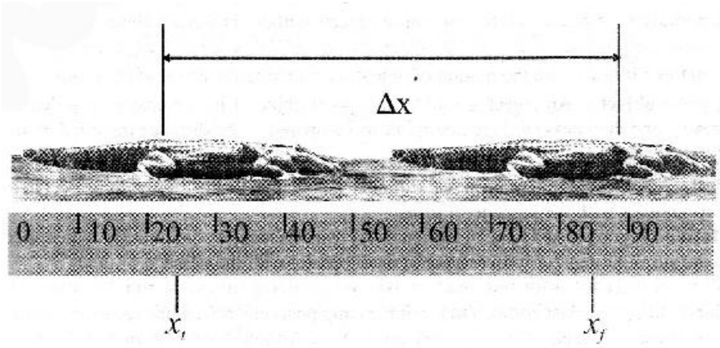
2. MOTION



Motion is an important part of our life. We can't perform our day-to-day activities without motion. We can't go to school without moving from our homes to our schools. We can't even take foods without moving our hands and mouths. We ride a bicycle or a car, we walk and we run. Even when we are sleeping, we breathe and air moves into and out of our lungs and blood flows in arteries and veins. Trains and aeroplanes carry people from one place to the other. We observe water flowing down a dam and leaves failing from trees. The earth on which all lives exist is in motion. The sun itself is not at rest but moves in the Milky Way.

When position of an object changes we say that the object is in motion. This chapter attempts to describe motion and its different aspects. For this we develop the concepts of velocity and acceleration. To describe the motion on a straight line, called rectilinear motion, with uniform acceleration, a set of simple equations can be obtained. The chapter will also enable us the proper use of these equations of motion.

MECHANICS :

Motion is caused by force. The branch of physics which deals with the effect of forces on objects is called Mechanics.

Mechanics can be classified into two categories - (i) Statics and (ii) Dynamics

Statics : It is the branch of mechanics which deals with objects at rest under the action of forces.

Dynamics: It is the branch of mechanics which deals with objects under motion. Dynamics can again be classified into two categories - (i) Kinematics and (ii) Kinetics.

Kinematics : It deals with the motion of objects without bothering about the cause of motion.

Kinetics : It deals with the motion of objects considering the cause of their motion.

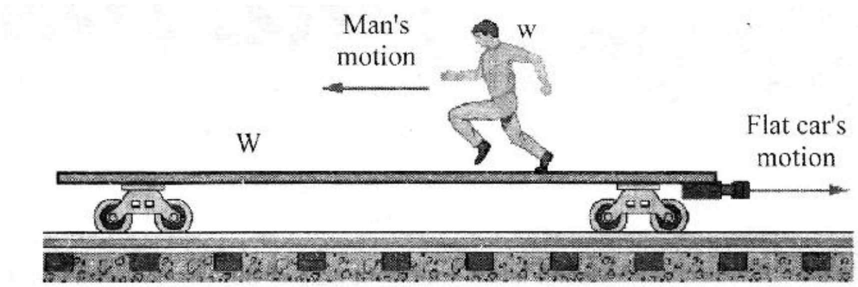
A point object : An object is said to be a point object if its dimensions (i.e. length, breadth and thickness etc.) are negligible as compared to the distance travelled by it.

Rest and Motion :

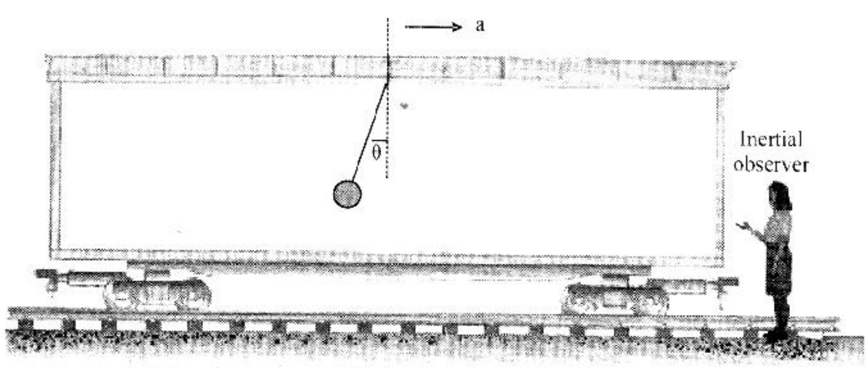
Rest: An object is said to be at rest if it does not change its position with respect to its surroundings with the passage of time.

Motion : A body is said to be in motion if its position changes continuously with respect to the surroundings (or with respect to an observer) with the passage of time. We know that earth is rotating about its axis and revolving around the sun. The stationary objects like your class-room, a tree and the lamp posts etc. do not change their position with respect to each other i.e., they are at rest. Although earth is in motion, to an observer situated outside the earth say in a spaceship, your classroom, trees etc. would appear to be in motion. Therefore, all motions are relative. There is nothing like absolute motion. If you move with book in your hand, book is not moving with respect to you.

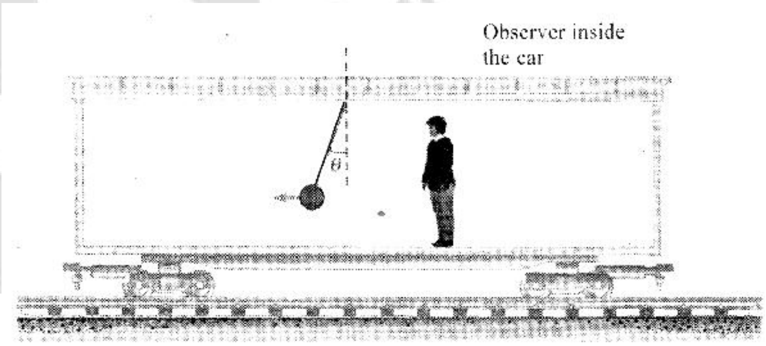
Observe like a science student : To the passengers in a moving bus or train, trees, buildings and people on the roadsides observe that the bus or the train and its passengers are moving in the forward direction. At the same time, each passenger in a moving bus or train finds that fellow passengers are not moving, as the distance between them is not changing. These observations tell us that the motion is relative. If you will observe the man moving on moving flat car from ground your observation will be different from what a man himself will observe. Similarly, if you will observe pendulum in moving car from ground your observation will be different from what person inside car will observe.



Man and flat car in relative motion with respect to an observer on the road.



(a) An observer outside the car observing the motion of a pendulum.



(b) An observer inside the car observing the motion of a pendulum

SCALARS AND VECTORS :

Physical quantities are of two kinds. They are scalars and vectors.

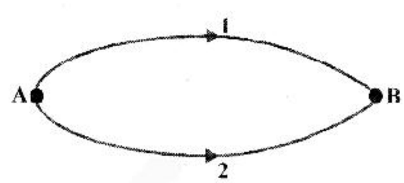
Scalars : Those physical quantities which have only magnitudes and no direction are called scalars. Speed, area, volume, distance etc. are some examples of scalars.

Vectors : Those physical quantities which have both magnitude and direction and follow the law of vector addition are called vectors. Velocity, acceleration, electric field intensity, force, magnetic field intensity etc. are some examples of vectors.

Representation of a vector: A vector is represented by a directed arrow ($\rightarrow$) such that the length of the arrow represents the magnitude and the direction of arrow head represents the direction of the vector.

Distance or path length : Distance is the actual length of the path. It is the characteristic property of any path i.e. path is always associated when we consider distance between two positions.

Distance between A and B while moving through path (1) *may or may not be equal to the distance between A and B. while moving through path* (2).



(i) It is a scalar quantity

(ii) Its dimensions are $[M^0 L^1 T^0]$

(iii) Its unit: in C.G.S. is centimetre (cm), and in M.K.S, metre (m)

Displacement :

It is the shortest distance between the initial and the final positions of an object. Its direction is taken from the initial position towards the final position. It is a vector quantity. Its S.I. unit is metre (m) and C.G.S. unit is centimetre (cm). Let an object starts moving from the point A and stops at C through the path ABC as shown in the figure.

Displacement of object = $\overrightarrow{AC}$

But distance covered

$= AB + BC$

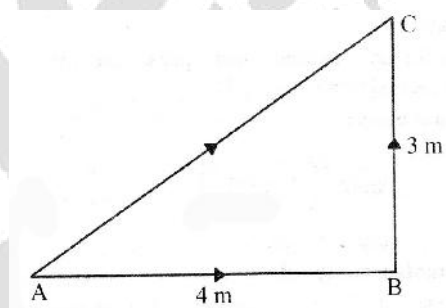
$= 4m + 3m$

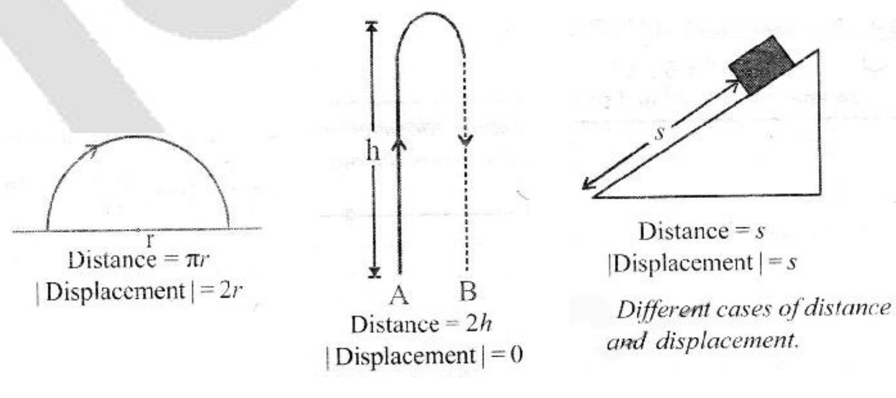
$= 7m$

Magnitude of displacement

$= \left|\overrightarrow{AC}\right|$

$= \sqrt{AB^2 + BC^2}$





Different cases of distance and displacement.

$= \sqrt{4^2 + 3^2} = \sqrt{25}$

$= 5m$

Comparative study of distance and displacement :

(i) Distance is scalar, while displacement is vector, both have same dimensions [L] and SI unit metre.

(ii) The magnitude of displacement is equal to minimum possible distance so, Distance $\geq$ | Displacement|

(iii) For motion between two points displacement is single valued while distance depends on actual path and so can have many values.

(iv) For *a* moving particle distance can never decrease with time while displacement can. Decrease in displacement means body is moving towards the initial position.

(v) For moving particle distance can never be negative or zero, while displacement can be (zero displacement means that body after motion has come back to initial position.)

Distance > 0 but | Displacement | > = or < 0

(vi) In general magnitude of displacement is not equal to distance. However it can be so if the motion is along a straight line without change in direction.

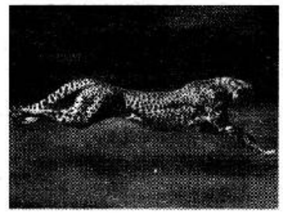
Speed :

Speed of an object is defined as the distance travelled in unit time.

Mathematically,

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

It is a scalar quantity.



A cheetah can maintain a very high speed but only for a short time.

Units :

The S.I. unit of speed is metre per second (m/s or m/s^{-1}) and the C.G.S. unit is centimetre per second (cm/s or cms^{-1}).

Other units :

$$kmh^{-1}\left(=\frac{5}{18}ms^{-1}\right)$$

miles h^{-1} etc.

Instantaneous speed :

The speed of a particle at a particular instant of time is caled its instantaneous speed.

Average speed :

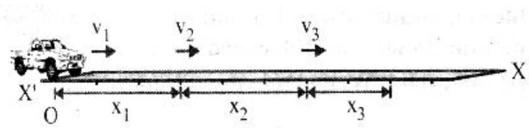
The average speed of an object is defined as the total distance covered to the total time taken to cover that distance. Mathematically,

$$\text{Average speed} = \frac{\text{Total distance}}{\text{Total Time}} \quad \text{or} \quad \bar{v} = \frac{s}{t}$$

Note : If any car covers distances x_1, x_2,...... in the time intervals t_1, t_2,....... then $\bar{v} = \dfrac{x_1 + x_2 + x_3 + ... + x_n}{t_1 + t_2 + ... + t_n}$

Some important cases related to average speed :

Case : 1



If car covers distances x_1, x_2, and x_3 with speeds v_1, v_2, and v_3 respectively in same direction then average speed of car.

$$\Rightarrow \bar{v} = \frac{x_1 + x_2 + x_3}{t_1 + t_2 + t_3};$$

here,

If car covers equal distances with different speeds the, $x_1 = x_2 = x_3 = x$

$$\bar{v} = \frac{3x}{\frac{x}{v_1} + \frac{x}{v_2} + \frac{x}{v_3}} = \frac{3}{\frac{1}{v_1} + \frac{1}{v_2} + \frac{1}{v_3}} = \frac{3v_1v_2v_3}{v_1v_2 + v_2v_3 + v_3v_1}$$

Case : 2

If any body travels with speeds v_1, v_2, v_3 during time intervals t_1, t_2, t_3 respectively then the average speed of the body will be

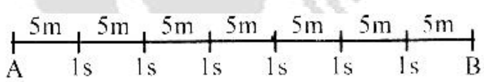
$$\bar{v} = \frac{x_1 + x_2 + x_3}{t_1 + t_2 + t_3} = \frac{v_1t_1 + v_2t_2 + v_3t_3}{t_1 + t_2 + t_3}$$

If $t_1 = t_2 = t_3 = t = \frac{(v_1 + v_2 + v_3) \times t}{3 \times t} = \frac{(v_1 + v_2 + v_3)}{3}$

Uniform Speed :

An object is said to be moving with a uniform speed if it covers equal distances in equal intervals of time, how so ever small these intervals may be. The uniform speed is shown by straight line tn distance-time graph.

Let us consider a car which covers 5m in first second of its motion. In next second, it covers again 5m and so in further seconds. So, in every interval of time, it covers equal distance. Hence, its speed is uniform.



Non-Uniform (or variable) Speed :

An object is said to be moving with a non-uniform speed if it covers equal distances in unequal intervals of time or unequal distances in equal intervals of time, howsoever small these intervals may be.

Example 1.

Find the distance travelled by the particle during the time $t = 0$ to $t = 3$ sec. from the figure.

Solution :

Distances = Area of OAB

$$\frac{1}{2} \times OA \times BA = \frac{1}{2} \times 3 \times 6 = 9 \text{ metre.}$$

Example 2.

What is the average speed of a cheetah that sprints 100 m in 4 seconds ? How about if it sprints 50 m in 2 s ?

Solution :

In both cases, the answer is 25 m/s :

$$\text{Average speed} = \frac{\text{total distance covered}}{\text{travelled time}} = \frac{100 \text{ metres}}{4 \text{ seconds}} = \frac{50 \text{ metres}}{2\text{seconds}} = 25 \text{ m/s}$$

Example 3.

If a car travels at an average speed of 60 km/h for an hour, it will cover a distance of 60 km. (i) How far would it travel if it moved at this rate for 4 h? (ii) For 10 h?

Solution :

The distance travelled is the average speed × time of travel, so

(i) Distance = 60 km/h × 4h = 240 km

(ii) Distance = 60 km/h × 10h = 600 km

VELOCITY :

The rate of change of displacement of a particle with time is called the velocity of the particle.

i.e. $\text{Velocity} = \dfrac{\text{Displacement}}{\text{Time interval}}$

It is a vector quantity.

It's unit is meter per second (m/s or ms^{-1}).

Instantaneous velocity :

The velocity of the object at a given instant of time or at a given position during motion is called instantaneous velocity.

Average velocity :

The average velocity of an object is equal to the ratio of the displacement, to the time interval or which the motion takes place *i.e.*, $\text{Average velocity} = \dfrac{\text{displacement}}{\text{time taken}}$

Unifrom velocity :

A body is said to move with uniform velocity, if it covers equal displacements in equal intervals of time, howsoever, small these intervals may be.

Non-uniform velocity :

The particle is said to have non-uniform motion if it covers unequal displacements in equal intervals of time, howsoever, small these time intervals may be. In this type of motion, velocity does not remain constant.

Example 4.

A car travels a distnace *A* to *B* at a speed of 40 km/h and returns to *A* at a speed of 30 km/h.

(i) What is the average speed for the whole journey ?

(ii) What is the average velocity ?

Solution :

(i) Let *AB* = *s*, time taken to go from *A* to *B*, $t_1 = \dfrac{s}{40}\text{h}$

and time taken to go from *B* to *A*, $t_2 = \dfrac{s}{30}\text{h}$

∴ Total time taken $t_1 + t_2 = \dfrac{s}{40} + \dfrac{3}{30} = \dfrac{(3+4)s}{120} = \dfrac{7s}{120}h$

Total distance travelled = *s* + *s* = 2*s*

∴ Average speed

$$= \frac{\text{total distance travelled}}{\text{total time taken}} = \frac{2s}{7s} = \frac{120 \times 2}{7} = 34.3 \text{ km/h}$$

(ii) Total displacement = zero, since the car returns to the original position.

$$\text{Therefore, average velocity} = \frac{\text{total displacement}}{\text{time taken}} = \frac{0}{2t} = 0$$

ACCELERATION :

Most moving things usually experience variations in their motion. We say they undergo acceleration. It is defined as the rate of change of velocity with time. Mathematically,

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

The Greek letter Δ (delta) is often used for "change in" or "difference in". In this rotation

$$\text{Acceleration, } a = \frac{\Delta v}{\Delta t}$$

Where, Δv = change in velocity

Δt = change in time

When a car makes a turn, even if its speed does not change, it is accelerating. Can you see why ? Acceleration occurs because the car's direction is changing. Acceleration refers to a change in velocity. So acceleration involves a change in speed, a change in direction, or a change in both speed and direction.

Important :

(i) Acceleration is a vector quantity.

(ii) It is positive if the velocity is increasing and is negative if the velocity is decreasing.

(iii) The negative acceleration is also called retardation or deceleration.

(iv) Unit: In S.I. system m/s^2; In C.G.S. system cm/s^2

(v) Dimension : $[M^0L^1T^{-2})$

Uniform acceleration :

An object is said to be moving with a uniform acceleration if its velocity changes by equal amount in equal intervals of time.

Variable acceleration :

An object is said to be moving with a variable acceleration if its velocity changes by unequal amount in equal intervals of time.

Average acceleration :

When an object is moving with a variable acceleration, then the average acceleration of the object for the given motion is defined as the ratio of the total change in velocity of the object during motion to the total time taken i.e.,

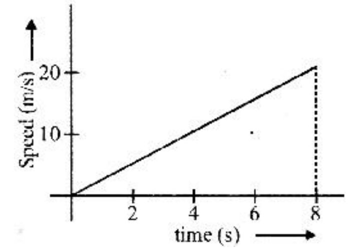
$$\text{Average acceleration} = \frac{\text{total change in velocity}}{\text{total time taken}}$$

Instantaneous acceleration :

The acceleration of the object at a given instant of time or at a given point of motion, is called its instantaneous acceleration.

Example 5.

The speed of a car as a function of time as shown in fig. Find the acceleration and distance travelled by the car in 8 secods.



Solution :

Distance travelled = Area under speed - time graph

$$\frac{1}{2}\times 20\times 8 = 80\text{m}$$

$$\text{Acc} = \frac{\Delta v}{\Delta t} = \frac{20}{8} = \frac{5}{2} = 2.5\ \text{m/s}^2$$

Equations of Motion :

Consider a body moving with an initial velocity u. Let it be travelling along a straight line with uniform acceleration a. Let v be its final velocity after time t. The displacement of the body in this time be S.

$v = u + at$ $\qquad$ $S = ut + \frac{1}{2}at^2$

$v^2 - u^2 = 2as$ $\qquad$ $S_n = u + \frac{a}{2}(2n-1)$

Gravity :

The force with which the earth pulls an object towards it is called the gravitational force of earth or gravity of the earth.

The equations of motion for a body falling down under gravity :

(i) The earth exerts a gravitational force on all bodies.

(ii) At a given place, acceleration due to this force 'g' is a constant that is directed towards the earth.

Therefore, bodies moving under gravity will be subjected to this uniform acceleration due to gravity 'g'.

Graphs :

In physics we often use graphs as important tools for analysing certain concepts.

Displacement-time graphs :

These graphs are very useful in studying the linear motion of the body. The displacement is plotted on the Y - axis and the time on X - axis.

These graphs are very helpful in finding the velocity of body, as the slope of graph

$$\left(\frac{\text{Y}-\text{axis}}{\text{X}-\text{axis}}\right) \text{ is equal to } \frac{\text{Displacement}}{\text{Time}}$$

Conclusions from Displacement - Time Graph :

(i) If the graph is parallel to time axis, then body is stationary.

(ii) If graph is a straight line, then body is moving with a uniform velocity. The velocity can be found out by finding the slope of the graph.

(iii) The graph can never be parallel to displacement axis, as it means that displacement increases indefinitely, without any increase in time, which is impossible.

(iv) If graph is a curve, it means the body is moving with a variable velocity, and hence, it has some acceleration.

Velocity-Time Graphs :

(a) In these graphs generally, the velocity is plotted on Y-axis and time on X-axis. The slope of such graphs gives acceleration.

(b) As, velocity ÷ time = acceleration, the acceleration will be positive if the slope is positive, and negative if the slope is negative.

(c) The area of graph under velocity - time curve, gives displacement of body. Displacement = Velocity x Time.

(d) If velocity – time graph is parallel to time axis, then:

(i) Body is moving with uniform velocity.

(ii) Its acceleration is zero.

(iii) Its displacement can be found by finding the area of the graph.

Conclusions :

(i) If velocity - time graph is a straight line but moving away from velocity time axis, then:

(a) Body is moving with variable velocity.

(b) It has uniform acceleration, which can be found by the slope of graph.

(c) Displacement can be found, by finding area under the velocity - time graph.

(d) If slope is positive, then the body has positive acceleration and vice – versa,

(ii) If the velocity - time graph is a curve, then:

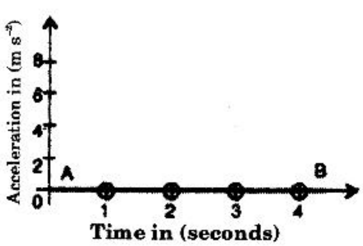
(a) The body has variable velocity and variable acceleration.

(b) Area under the curve represents displacement.

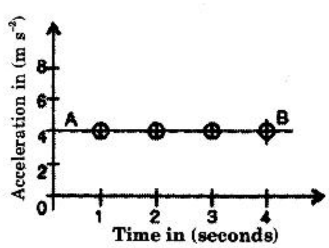
(c) Acceleration at any instant can be found by finding slope at that point.

Acceleration - time graph :

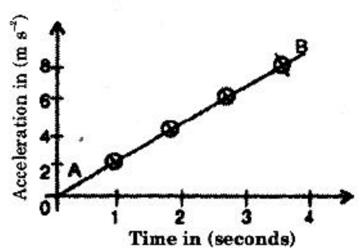
Figure (i) represents an acceleration - time graph, AB coinciding with time axis. From the figure it is clear that acceleration of the body is zero hence, it is moving with a uniform velocity.



(i)



(ii)



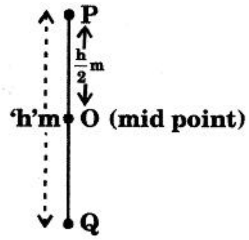
(iii)

Figure (ii) represents an acceleration - time graph, parallel to time axis. From figure it is clear that as acceleration does not change, therefore body is moving with a uniform acceleration and variable velocity. The area of graph, i.e., Acceleration × Time gives change in velocity.

Figure (iii) represents an acceleration - time graph moving away from time as well as acceleration axis. From the graph it is clear that the body is moving with variable velocity and variable acceleration. Area of the graph gives change in velocity.

Example 6.

A body drops a coin from top of a tower. Coin takes ‘t’ seconds to come down from the top of a tower. Calculate time taken to cover half the height of the tower.



Solution :

Case – I

Time taken by coin be t_n

acceleration $a_1 = g$

initial velocity $u_1 = 0$

distance travelled by coin $s_1 = h$

$$h = \frac{1}{2}gt_n^2 \quad ......(1)$$

Case – II

Time taken by coin to cover half height of tower be t^1

acceleration $a_2 = g$

initial velocity $u_2 = 0$

distance travelled by coin $s_2 = \frac{h}{2}$

$$\therefore \frac{h}{2} = \frac{1}{2}gt^{1^2} \quad ...(2)$$

Dividing (1) by (2) we get

$$\frac{(1)}{(2)} = \frac{h}{\frac{h}{2}} = \frac{\frac{1}{2}gt^2}{\frac{1}{2}gt^{1^2}} \Rightarrow 2 = \frac{t^2}{t^{1^2}} \Rightarrow t^{1^2} = \frac{t^2}{2} = t^1 = \frac{t}{\sqrt{2}}s$$

Example 7.

A rock is dropped from a top of hill and strikes the ground 6 seconds later. How much is the height of hill in metres?

Solution :

Given,

Initial velocity of the rock, $u = 0$

Time taken, $t = 6$ S

acceleration due to gravity, $g = 9.8 \text{ m s}^{-2}$

height of the hill $h = ?$

$$h = \frac{1}{2}gt^2$$

$$h = \frac{1}{2} \times 9.8 \times (6)^2 = \frac{1}{2} \times 9.8 \times 36$$

$h = 176.4$ metre

The height of the hill is 176.4 m

Example 8.

A ball is dropped from a tower of height 30 meters. Find time taken to fall through this height.

Solution :

Initial velocity of ball $u = 0$

height of tower h = 30 m

acceleration due to gravity $g = 9.8\ m\ s^{-2}$

time taken 't' = ?

$v^2 - u^2 = 2gh$

$v^2 - (0)^2 = 2 \times 9.8 \times 30$

$v^2 = 588 = \sqrt{588}$

$v = 24.24\ m\ s^{-1}$

Substitute this 'v' value in equation v = u + gt

$v = gt\ (\therefore\ u = 0)$

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

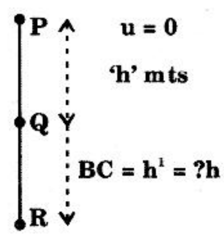
$$t = \frac{24.24}{9.8} = 2.47\ s$$

Example 9.

A body falling from rest has a velocity 'v' after its fall through a distance 'h'. Find the distance it has a fall down in terms of h further, for its velocity to become double.

Solution :

Let a body starting from rest travel a distance of 'h' m from P to Q during which acquires a velocity v_1 Its velocity becomes 2 v point R.



Case- I	**Case - II**
PQ	QR
$S_1 = h$	$S_2 = BC = h' = ?$
$v_1 = v$	$v_2 = 2v$
$u_1 = 0$	$u_2 = 0$
Let $a_1 = g$	$a_2 = g$

Applying $v^2 - u^2 = 2as$ in both cases we get

$v^2 - 0^2 = 2gh$ $\qquad$ $(2v)^2 - v^2 = 2gh'$

$\Rightarrow v^2 = 2gh$ ....(1) $\qquad$ $\Rightarrow 3v^2 = 2gh'$ ...(2)

dividing equation (2), (1) we get

$$\frac{(2)}{(1)} = \frac{3v^2}{v^2} = \frac{2gh'}{2gh'} = h' = 3h$$

Example 10.

A ball takes t seconds to fall from a height h_1 and 2t seconds to fall from height h_2 then find the ratio of h_1 and h_2.

Solution :

Case- 1	**Case - II**
height $h = h_1$	height $h = h_2$
Time taken $t_1 = t$	time $t_2 = 2t$

we know that, $t = \sqrt{\frac{2h}{g}}$

since $h \sim t^2$, as the ratio of both cases given us

$$\frac{h_1}{h_2} = \frac{t^2}{(2t)^2} = \frac{t^2}{4t^2} = \frac{1}{4}$$

The ratio of h_1 and h_2 is 1 : 4

Example 11.

A stone is dropped from the top of the tower and reaches ground is 4 s. Find the height of tower.

Solution :

acceleration due to gravity (g), = 9.8 ms^{-2}

time taken by stone to reach ground, t = 3 s

height of tower h = ?

we know that

$$h = \frac{1}{2}gt^2$$

$$h = \frac{1}{2} \times 9.8 \times (4)^2$$

$$h = \frac{1}{2} \times 9.8 \times 16 = 78.4 \text{ m}$$

$\therefore$ The height of the tower is 78.4 m

Example 12.

A body falling from rest covered distances S_1, S_2, and S_3 in first, second, third seconds of its fall. Calculate the ratio of S_1, S_2 and S_3 respectively.

Solution :

Initial velocity of the body u = 0

We know that $S = \frac{1}{2}at^2$

for body covers distance $S_1 = \frac{1}{2}g \times (1)^2 = \frac{1}{2}g$

$$\therefore S_1 = \frac{1}{2}g$$

$$S_1 + S_2 = \frac{1}{2}g \times (2)^2 = 2g$$

$$S_1 + S_2 + S_3 = \frac{1}{2}g \times (3)^2 = 4.5\text{ g}$$

$$S_1 = \frac{1}{2}g$$

$$S_2 = 2g - \frac{1}{2}g = 1.5\ g$$

$$S_3 = 4.5\ g - 2g = 2.5\ g$$

$$\therefore S_1 : S_2 : S_3 = \frac{1}{2}\ g : 1.5g : 2.5\ g = 1 : 3 : 5$$

Example 13.

A stone is thrown vertically upwards with an initial velocity of 45 m s^{-1}. Calculate the time taken by the stone to rise to its maximum height.

Solution :

Initial velocity of stone, u = 45 m s^{-1}

Acceleration due to gravity, g = 9.8 m s^{-2}

Time of ascent, $t = \frac{u}{g}$

$$t = \frac{45}{9.8}$$

t = 4.59 s

Example 14.

A ball is projected with a velocity 98 ms^{-1}. Calculate after how much time it will strikes the ground.

Solution :

Initial velocity of the ball, u = 98 m s^{-1}

Acceleration due to gravity, g = 9.8 m s^{-2}

Time of flight = ?

Time of flight t = $\frac{2u}{g} = \frac{2 \times 9.8}{9.8}$ = 20 s

Example 15.

A ball thrown vertically upwards with a speed of v attains a height h_1 Another ball thrown upwards from the same point with a speed of 2v attains a height h_2. Then find the value h_2 in terms of h_1

Solution :

$$h = \frac{u^2}{2g}$$

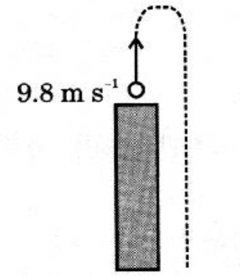
i.e., $h \sim u^2$

If velocity is doubled, then height becomes quadrupled $\therefore$ $h_2 = 4h_1$

Example 16.

From the top a building 39.2 m, ball is thrown vertically upward with a velocity 9.8 m s^{-2} find the time when the ball will hit the ground.

Solution :



Here u = + 9.8 m s^{-1} , h = 39.2 m, g = – 9.8 ms^{-2}

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

$$-39.2 = 9.8t - \frac{1}{2} \times 9.8\, t^2$$

$$4.9t^2 - 9.8t - 39.2 = 0$$

(t + 2) (t – 4) = 0

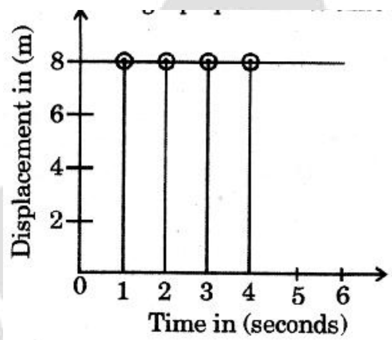
t = – 2 s, 4 s

t = 4 s

As time cannot be -ve

Example 17.

What does the displacement – time graph parallel to time axis as shown in figure imply?



Solution :

It means that the body is not changing its position with respect to time. In other words, body is stationary.

Example 18.

Plot a displacement-time graph of a body with the values of displacement and time are shown in the table below:

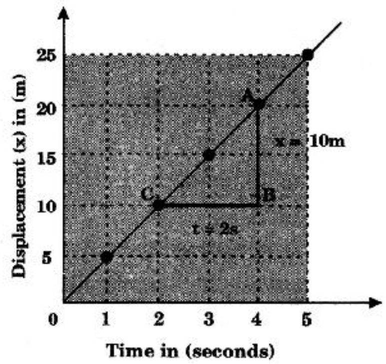
Displacement in metres	0	5	10	15	20	25
Time in seconds	0	1	2	3	4	5

Solution :

Since graph is a straight line, therefore it means that displacement is proportional to time. In other words, body is covering equal distances in equal intervals of time in specified direction, and hence, is moving with a uniform velocity. The slope of this graph gives uniform velocity.

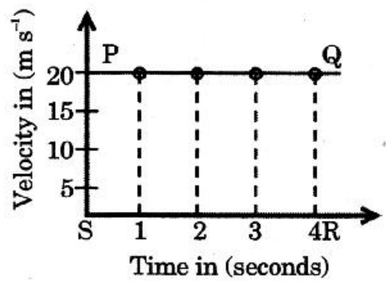
Thus, velocity of body = $\frac{\overrightarrow{\Delta x}}{\Delta t} = \frac{AB}{BC} = \frac{10\text{ m}}{2\text{ s}} = 5\text{ m s}^{-1}$

Where Δx is short distance and Δt is short interval of time



Example 19.

A velocity - time graph is plotted below. Find the acceleration and displacement.



Solution :

(i) Velocity-time graph PQ, when a body is moving with a uniform velocity of 20 m s^{-1} As the slope of graph is ero, therefore its acceleration is zero.

(ii) The distance covered by the body in specified direction (displacement) can be calculated by finding the area of rectangle PQRS.

Thus, Displacement = PS × SR = 20 m s^{-1} × 4 s = 80 m

❑ ❑ ❑ ❑

Level- 1

1. Which of the following is a vector quantity?

(A) Speed (B) Velocity

(C) Density (D) Temperature

2. Which of the following is a scalar quantity?

(A) Acceleration (B) Force

(C) Displacement (D) Distance

3. Which of the following is the unit of a vector quantity?

(A) centimetre/second^2 (B) degree Celsius

(C) gram (D) second

4. Which of the following units always represents a scalar quantity?

(A) centimetre/second (B) metre

(C) kliogram (D) newton

5. Which of the following statements is true?

(A) A scalar quantity has both magnitude and direction.

(B) A vector quantity has magnitude only.

(C) Mass is a vector quantity because it does not have any direction.

(D) Force is a vector quantity because it has direction.

6. A vehicle is moving in a circular path with uniform speed. Which of the following conclusion can be drawn from this?

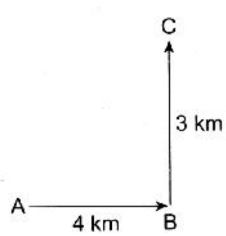
(A) The velocity of the vehicle is uniform.

(B) The vehicle is accelerating.

(C) The vehicle is retarding.

(D) Both (A) and (B)

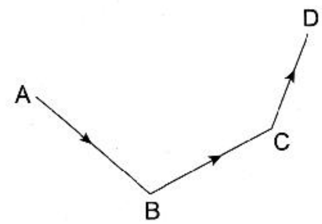
7. An object is moving along the path drawn below. Calculate the magnitude of the displacement.



(A) 5 km (B) 9 km

(C) 16 km (D) 7 km

8. The course of movement of an object is given below.



Which of the following represents the displacement of the object?

(A) $\overrightarrow{AB}$ (B) $\overrightarrow{BC}$

(C) $\overrightarrow{DA}$ (D) $\overrightarrow{AD}$

9. An object started travelling from one end of the semicircular track and reached the other end. If the length of the track is 12.56 m calculate the magnitude of its displacement.

(A) 4m (B) 8m

(C) 12m (D) 2m

10. An athlete is running along the edge of a circular field of 20 m diameter. He stopped after making 3/4th of the revolution. Calculate the magnitude of the displacement.

(A) $5\sqrt{2}$ m (B) $10\sqrt{2}$ m

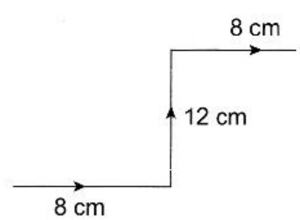
(C) $20\sqrt{2}$ m (D) None of the above

11. Calculate the displacement of the tip of the minutes hand in one hour if the length of the minutes hand is 2 cm.

(A) 6.28 cm (B) 12.56 cm

(C) 25.12 cm (D) 0 cm

12. Calculate the average velocity of an object travelling in the following path in 10 seconds.



(A) 2 cm s^{-1} (B) 4 cm s^{-1}

(C) 2.8 cm s^{-1} (D) 6 cm s^{-1}

13. Calculate the magnitude of the displacement of the tip of the seconds hand in an interval of 5 minutes 10 seconds, if the length of the seconds hand is 2 cm.

(A) 1cm (B) 2cm

(C) 3cm (D) 4cm

14. A wheel of 10 cm radius is rolling. If it rolls 5 times and then stops, calculate the displacement of the centre point of the wheel.

(A) 3.14cm (B) 50cm

(C) 314cm (D) None of these

15. A body starts moving along a circular path of radius 7/22 m. Calculate the distance travelled by the body when its displacement is maximum for the first time.

(A) 1 cm (B) 1 m

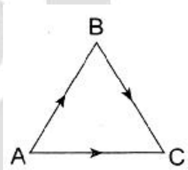
(C) 2m (D) 22/7 m

16. A mango fell on the ground from the topmost branch of a mango tree in 2 seconds. Calculate the approximate height of the tree.

(A) 9.8m (B) 98m

(C) 19.6m (D) 196m

17. The course of movement of a particle is given below. The particle takes time 't' to travel from A to C. Which of the following represents its displacement and distance respectively?



(A) $\overrightarrow{AB}$. AC (B) $\overrightarrow{BC}$. AB

(C) $\overrightarrow{AC}$, AB + BC (D) $\overrightarrow{AB}+\overrightarrow{BC}$, AC

18. When a simple pendulum is taken to the moon from the earth, its time period

(A) increases (B) decreases

(C) remains the same (D) None of the above

19. A vehicle is moving with a uniform speed of 36 Kmh^{-1}. How many times does the wheel completely rotate in one second if its radius is 20 cm?

(A) 8 (B) 7

(C) 9 (D) 10

20. A body moving along a straight line covers equal distances in equal intervals of time. Then which of the following is uniform?

(A) Speed (B) Velocity

(C) Both (A) and (B) (D) None of these

21. A train of 500 m length takes 5 minutes to cross a platfrom of length 1 km. Calculate the average speed of the train while crossing the platform.

(A) 200 m min^{-1} (B) 50 m s^{-1}

(C) 5 km h^{-1} (D) 5 m s^{-1}

22. A bullet acquires a velocity of 500 m s^{-1} when it is fired from a gun. If it hits a wall which is 1 km away from where the bullet is fired, calculate the time taken by the bullet to hit the wall.

(A) 2s (B) 2.2s

(C) 20s (D) 0.2s

23. A bird flies from one tree to another 10 times in 10 minutes. If its average speed is 1 m s^{-1}, calculate the distance between the two trees.

(A) 20m (B) 30m

(C) 40m (D) 60m

24. A boy runs straight and covers a distance 'x' towards north and then turns towards east and covers the same distance. If he repeats this action once, what is his displacement?

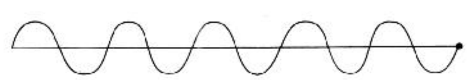
(A) $2\sqrt{2}\,x$ towards east

(B) 2x towards north

(C) $\sqrt{2}\,x$ towards north east

(D) $2\sqrt{2}\,x$ towards north east

25. A particle follows a path as shown in the below given figure. Calculate the distance covered by the particle and the displacement if the radius of the semi circular path is 2 cm.



(A) 20 cm and 62.80

(B) 62.80 cm and 40 cm

(C) 12.56 cm and 10 cm

(D) 10 cm and 12.56 cm

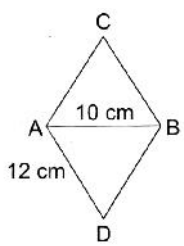
Level-2

1. A wheel of 5 cm radius is lifted vertically from the ground to 1 m height and then dropped. It started rolling after it touches the ground. It stops after completing 10 rotations. The total distance travelled by it is_______and its net displacement is_______.

(A) 31.4 cm, 51.4 cm (B) 314cm, 514cm

(C) 514 cm, 314 cm (D) 51.4cm,31.4cm

2. The course of movement of two particles X and Y is drawn below. Both the particles started from A and stopped at B, X moves along ACB and Y moves along ADB.



If both the particles take 5 seconds to reach B, calculate the speeds of X and Y respectively. Given that, ACB is an equilateral triangle and ADB is an isosceles triangle in which AD = DB =12 cm

$^{-1}$ and 4.8 cm s^{-1}

(B) 48 cms^{-1} and 4 cms^{-1}

(C) 4 cm s^{-1} and 4 cm s^{-1}

(D) 4.8 cms^{-1} and 4.8 cms^{-1}

3. A train travels from Vizag to Hyderabad and another train travels from Hyderabad to Vizag following the same route. Which of following statements is true, if they take same time to reach their destinations?

(A) Velocities of both the trains are same.

(B) Accelerations of both the trains are same.

(C) Retardations of both the train are same.

(D) Speed of both the trains are same.

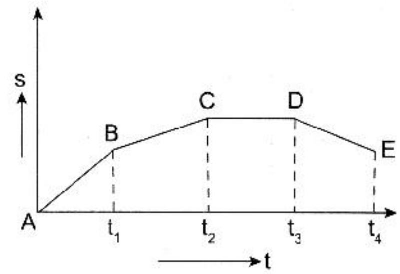
4. At a given place the time period of the pendulum ‘A’ is more than that of the pendulum ‘B’. Which of the following conclusions can be drawn from the given statement?

(A) The length of A is more than that of B.

(B) The length of B is more than that of A.

(C) The mass of the bob of pendulum A is slightly more than that of B.

(D) The bob of A is made up of iron and that of B is made up of aluminium.

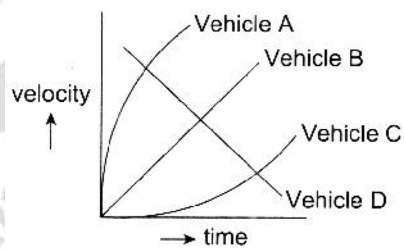
5. 

In the given displacement-time curve, t_1 = 5 s, t_2 = 10s, t_3 = 15 s. In which of the following parts of the given curve, the particle covers the maximum distance?

(A) AB (B) BC

(C) CD (D) DE

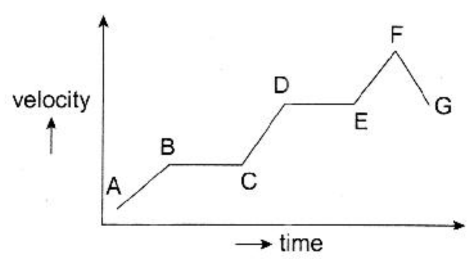
6. Four velocity-time graphs are plotted for four vehicles A, B, C and D respectively. Which among them is retarding ?



(A) A (B) B

(C) C (D) D

7. The velocity-time graph of a vehicle is given below. Which of the following parts of the curve represents zero acceleration ?



(A) AB and EF (B) CD and FG

(C) BC and DE (D) EF and FG

8. A body falls from a height of 200 m. If gravitational attraction ceases after 2 s, further time taken by it to reach the ground is (g = 10 m s^{-2}).

(A) 5s (B)9s

(C)13s (D)17s

9. A body thrown vertically up with a velocity 'u' reaches the maximum height 'h' after'T second. Correct the statement among the following is:

(A) at a height $\frac{h}{2}$ from the ground its velocity is $u/2$

(B) at a time T its velocity is 'u'

(C) at a time '2T' its velocity is $-u$

(D) at a time 2T its velocity is $-6u$

10. A stone is thrown with an initial speed of 4.9 m s^{-1} from a bridge in vertically upward direction. It falls down in water after 2 s. The height of the bridge is :

(A) 24.7m (B) 19.8m
(C)9.8m (D)4.9m

11. A particle is thrown vertically upwards. Its velocity at one fourth of the maximum height is 20 m s^{-1}. Then, the maximum height attained by it is

(A) 16m (B)10m

(C)8m (D)18m

12. A stone is dropped from certain height, which can reach the ground in 5 s. After 3 s of its fall, it is again allowed to fall. Then, the time taken by the stone to reach the ground for the remaining distance is:

(A) 3s (B)4s

(C)2s (D) none of these

13. Two bodies, one held 30 cm directly above the other, are released simultaneously and allowed to fall freely under gravity. After 2 s their relative separation will be:

(A) 10 cm (B) 20cm

(C) 30cm (D) zero

14. A ball is released from the top of height h metres. It takes 't' seconds to reach the ground. Where is the ball at the time t/2 s?

(A) At $\left(\frac{h}{4}\right)$ from the ground

(B) At $\left(\frac{h}{2}\right)$ from the ground

(C) At $\left(\frac{3h}{4}\right)$ from the ground

(D) Depends upon mass and volume of the ball

15. A particle starts moving from rest with uniform acceleration. It travels a distance X in the first three seconds and a distance Y in next three seconds, then:

(A)Y = X (B)Y = 3X

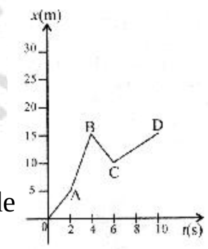
(C)Y = 2X (D)Y = 4X

16. A stone thrown vertically upwards with an initial velocity u from the top of tower, reaches the ground with a velocity $3u$. The height of the tower is :

(A) $3u^2/g$ (B) $4u^2/g$

(C) $6u^2/g$ (D) $9u^2/g$

17. From the x-t graph, one can draw the following conculsions



A : $v_{OA} < v_{AB}$

B : v_{BC} is negative

C : v_{CD} is the least by magnitude

D : acceleration is uniform

(A) Only A is correct

(B) Only B and C are correct

(C) Only A, B and C are correct

(D) Only D is correct

18. For a body moving in a straight line, there can be situations with

A : $v = 0,\ a \neq 0$ B : $a = 0,\ v \neq 0$

(A) Only A is correct

(B) Only B is correct

(C) Both A and B are correct

(D) Both are incorrect.

19. If the v-t graph is a straight line inclined to the time axis, then

(A) $a = 0$ (B) $a \neq 0$

(C) a = constant $\neq 0$ (D) $a \neq$ constant $\neq 0$

20. A car starting from rest is capable of acquiring 40 ms^{-1} in 20 seconds. The displacement is (in 10 seconds)

(A) 10m (B) 100m

(C) 50m (D) 25m

21. The numerical ratio of displacement to distance for a moving object is

(A) always less than 1 (B) always equal to 1
(C) always more than 1 (D) equal to less than 1

22. Choose the correct statements from the following

(A) The magnitude of instantaneous velocity of a particle is equal to its instantaneous speed

(B) The magnitude of the average velocity in an interval is equal to its average speed in that interval.

(C) It is possible to have a situation in which the speed of the particle is never zero but the average speed in an interval is zero.

(D) It is possible to have a situation in which the speed of particle is zero but the average speed is not zero.

23. The ratio of magnitude of displacement to distance is always

(A) less than 1 (B) greater than 1

(C) equal to 1

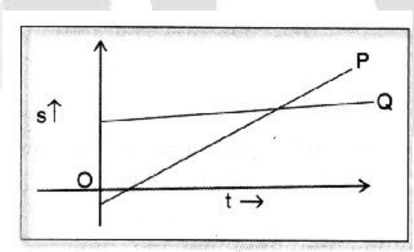
(D) lesser than or equal to 1

24. The ratio of the heights from which two bodies are dropped is 3 : 5 respectively. The ratio of their final velocities is

(A) $\sqrt{5}:\sqrt{3}$ (B) $\sqrt{3}:\sqrt{5}$

(C) 9 : 25 (D) 5 : 3

25. The figure given below shows the displacement-time curve of the particles P and Q. Which of the following statements is correct?



(A) Both P and Q move with uniform equal speed

(B) P is accelerated and Q is retarded

(C) Both P and Q move with uniform speed, but the speed of P is more than the speed of Q.

(D) Both P and Q move with uniform speeds but the speed of Q is more than the speed of P

26. When brakes are applied, the velocity of a car changes from 40 m s^{-1} to 10 m s^{-1} in 10 s. The acceleration produced in it is ____ m s^{-2}

(A) – 3 (B) 3

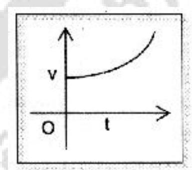
(C) – 5 (D) 5

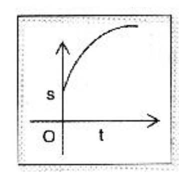
27. The ratio of the times taken by a body moving with uniform acceleration in reaching two points P and Q along a straight line path is 1 : 2. If the body starts from rest and moves linearly, the ratio of the distances of P and Q from the starting point is

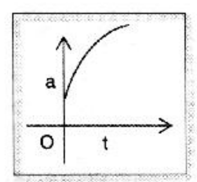
(A) 4 : 1 (B) 1 : 4

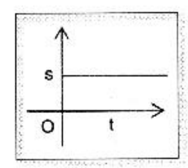
(C) 2 : 3 (D) 3 : 1

28. Which of the following graphs indicates that a body is undergoing retardation?

(A) 

(B) 

(C) 

(D) 

29. The velocity of a body is given by the equation v = 6 – 0.02 t, where t is the time taken. The body is undergoing

(A) uniform retardation

(B) uniform acceleration

(C) non-uniform acceleration

(D) zero- acceleration

ANSWER KEY

Level- 1

1.	(B)	**2.**	(D)	**3.**	(A)	**4.**	(C)	**5.**	(D)	**6.**	(B)
7.	(A)	**8.**	(D)	**9.**	(B)	**10.**	(B)	**11.**	(D)	**12.**	(A)
13.	(B)	**14.**	(C)	**15.**	(B)	**16.**	(C)	**17.**	(C)	**18.**	(A)
19.	(B)	**20.**	(C)	**21.**	(D)	**22.**	(A)	**23.**	(B)	**24.**	(D)
25.	(B)										

Level-2

1.	(C)	**2.**	(A)	**3.**	(D)	**4.**	(A)	**5.**	(A)	**6.**	(D)
7.	(C)	**8.**	(C)	**9.**	(C)	**10.**	(C)	**11.**	(C)	**12.**	(B)
13.	(C)	**14.**	(C)	**15.**	(B)	**16.**	(C)	**17.**	(C)	**18.**	(B)
19.	(C)	**20.**	(B)	**21.**	(D)	**22.**	(A)	**23.**	(D)	**24.**	(B)
25.	(C)	**26.**	(A)	**27.**	(B)	**28.**	(B)	**29.**	(A)		