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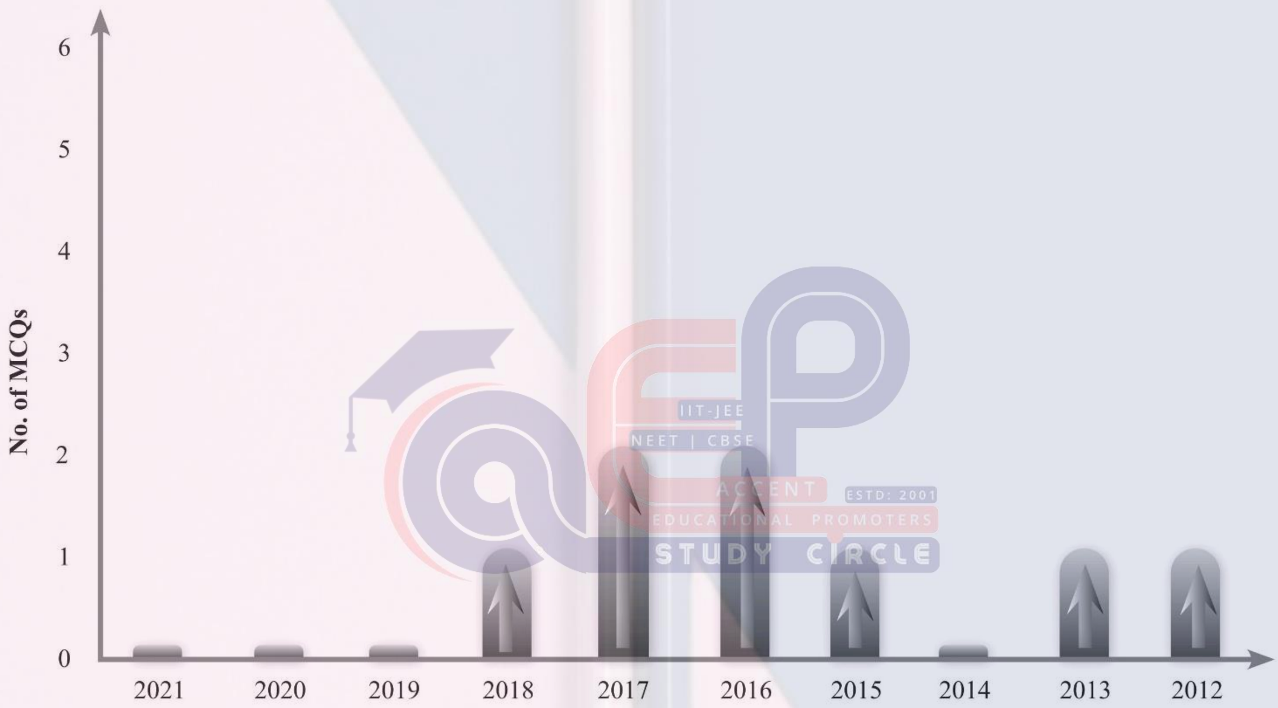
Motion
IN A STRAIGHT LINE

Past Years NEET Trend



Investigation Report

TARGET EXAM	PREDICTED NO. OF MCQs	CRITICAL CONCEPTS
NEET	0-1	• Rectilinear motion, motion under gravity

Perfect Practice Plan

Topicwise Questions	Learning Plus	Multiconcept MCQs	NEET Past 10 Years Questions	Total MCQs
56	25	15	8	104

INTRODUCTION

The branch of physics in which motion and the forces causing motion are studied is called mechanics.

As a first step in studying mechanics, we describe the motion of particles and bodies in terms of space and time without studying the cause of motion. This part of mechanics is called kinematics. We first define displacement, velocity and acceleration. Then, using these concepts, we study the motion of the objects moving under different conditions. In the second section of mechanics we study the motion of particles with the reason behind the motion that is force. That section will be known as dynamics

From everyday experience, we recognize that motion represents continuous change in position, so we begin our study with change in position i.e. with displacement.

BASIC DEFINITIONS

Displacement ($\vec{S}$ or $\Delta\vec{r}$) :

Change in position vector of any particles or group of particles is called displacement.

Its magnitude is minimum distance between final and initial point, and is directed from initial position to final position.

For a particle moving along x axis, motion from one position x_1 to another position x_2 is displacement, Δx where,

$\Delta x = x_2 - x_1$

If the particle moves from x_1 = 4m to x_2 = 12 m, then Δx = (12m) – (4m) = + 8m. The positive result indicates that the motion is in the positive direction. If the particle then returns to x = 4m, the displacement for the full trip is zero. The actual number of meters covered for the full trip is irrelevant displacement involves only the original and final position.

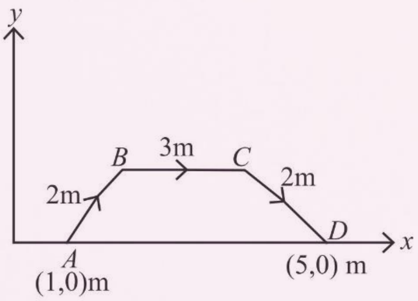
In general if initial position vector and final position vector are $\vec{r}_{in}$ and $\vec{r}_f$ respectively, then $\vec{S} = \vec{r}_f - \vec{r}_{in} = \overrightarrow{\Delta r}$

Distance

Length of total path traversed by a body during its motion is called distance.

It is dependent on the path chosen, thus for motion between two fixed points A and B we can have many different values of distance traversed. It is a scalar quantity, as length of path has no indication of direction in it. Its SI unit is metre (m) and dimensions is (L).

eg. Suppose a particle moves from position A to B as shown after travelling from A to B to C to D.



Here Displacement S = $\vec{S} = \overrightarrow{AD} = 5\hat{i} - \hat{i} = 4\hat{i}$ m

$\therefore$ |displacement| = 4 m

Also distance covered, $1 = |\overrightarrow{AB}| + |\overrightarrow{BC}| + |\overrightarrow{CD}|$ = 2 + 3 + 2 = 7 m

Here |displacement| < Distance

Average Velocity

The average velocity $\vec{V}_{avg}$ is the ratio of the total displacement $\overrightarrow{\Delta r}$ and total time (Δt) taken to complete that displacement. It should be noted that $\vec{V}_{avg}$ is independent of path as displacement is independent of path.

$$\vec{V}_{avg} = \frac{\Delta\vec{r}}{\Delta t} = \frac{\vec{r}_f - \vec{r}_{in}}{\Delta t} \quad ....(2\text{-}2)$$

Unit for V_{avg} is the meter per second (m/s). The average velocity V_{avg} always has the same sign as the displacement $\overrightarrow{\Delta r}$

Average Speed

$$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{Total time interval}} = \frac{l}{\Delta t}$$

It is a scalar and always has positive sign.

> **KEY NOTE**
>
> Magnitude of displacement would be equal to distance travelled if there is no change in direction during the whole motion.
>
> In general, |Displacement| ≤ |Distance|
>
> |Average Velocity| ≤ |Average speed|

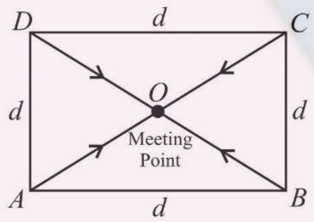
TRAIN YOUR BRAIN

Q. Four persons A,B,C and D initially at the corners of a square of side length 'd'. If every person starts moving with same speed v such that each one faces the other person diagonally opposite to him always, the person will meet after time

(a) $\frac{d}{v}$ (b) $\frac{\sqrt{2}d}{v}$

(c) $\frac{d}{2v}$ (d) $\frac{d}{\sqrt{2}v}$

Sol. (d)



$$AO = BO = CO = DO = \frac{\sqrt{2}d}{2}$$

$$= \frac{d}{\sqrt{2}}$$

hence Total time taken will be

$$= \frac{\text{distance}}{\text{velocity}}$$

$$= \frac{d}{\sqrt{2}v}$$

Instantaneous Velocity

Instantaneous Velocity is defined as the value approached by the average velocity when the time interval for measurement becomes closer and closer to zero, i.e. $\Delta t \to 0$. Mathematically

$$v(t) = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$$

Thus instantaneous velocity function is the derivative with respect to time of the displacement function. $v(t) = \frac{dx(t)}{dt}$

Instantaneous Speed

It is the measure of how fast a particle or a body is moving at a particular instant. It is the magnitude of instantaneous velocity. Thus particle moving with instantaneous velocity of + 5m/s and another moving with –5m/s will have same instantaneous speed of 5 m/s.

✍ KEY NOTE

The speedometer in a car measure the instantaneous speed not the instantaneous velocity, because it cannot determine the direction.

Average Acceleration

$$\vec{a}_{av} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v} - \vec{v}_1}{\Delta t}$$

The direction of average acceleration vector is the direction of the change in velocity vector.

Instantaneous Acceleration

The **Instantaneous Acceleration** (or simply acceleration) is the derivative of the velocity with respect to time.

$$\vec{a} = \frac{d\vec{v}}{dt}$$

In words, the acceleration of a particle at any instant is the rate at which its velocity is changing at that instant.

$$\vec{a} = \frac{d\vec{v}}{dt} = \frac{d}{dt}\left(\frac{d\vec{r}}{dt}\right) = \frac{d^2\vec{r}}{dt^2}$$

In another words, the acceleration of a particle at any instant is the second derivative of its position vector with respect to time.

Acceleration has both magnitude and direction (it is yet another vector quantity).

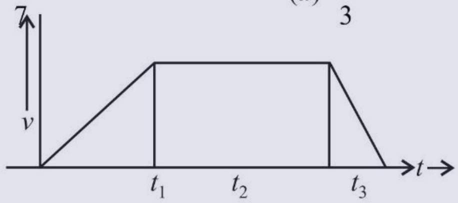
TRAIN YOUR BRAIN

Q. A body starts from rest and travels a distance S with uniform acceleration, then moves uniformly a distance 2S and finally comes to rest after moving; further 5S under uniform retardation. Find the ratio of average velocity to maximum velocity

(a) $\frac{4}{7}$ (b) $\frac{7}{4}$

(c) $\frac{3}{7}$ (d) $\frac{7}{3}$

Sol. (a)



$$S = \frac{1}{2}V_{max}t_1 \text{ or } t_1 = \frac{2S}{V_{max}}; \quad 2S = V_{max}t_2 \text{ or } t_2 = \frac{2S}{V_{max}}$$

$$5S = \frac{1}{2}V_{max}\,t_3 \text{ or } t_3 = \frac{10S}{V_{max}}; \quad V_{av} = \frac{\text{Total displacement}}{\text{Total time}}$$

$$V_{av} = \frac{S+2S+5S}{\frac{2S}{V_{max}} + \frac{2S}{V_{max}} + \frac{10S}{V_{max}}}; \qquad \frac{V_{av}}{V_{max}} = \frac{8S}{14S} = \frac{4}{7}$$

(OR)

$$\frac{V_{av}}{V_{max}} = \frac{\text{Total displacement}}{2\left(\begin{array}{l}\text{total displacement}\\ \text{during acceleration}\\ \text{and reatardaton}\end{array}\right) + \left(\begin{array}{l}\text{Displacement}\\ \text{During uniform}\\ \text{velocity}\end{array}\right)}$$

$$\therefore \frac{V_{av}}{V_{max}} = \frac{8S}{2(S+5S)+2S} = \frac{8}{14} = \frac{4}{7}$$

✍ KEY NOTE

For motion on a straight line its algebraic sign represents its direction on an axis just as for displacement and velocity; that is, acceleration with a positive value is in the positive direction of an axis, and acceleration with a negative value is in the negative direction.

Uniform acceleration: A body is said to have uniform acceleration if magnitude and direction of the acceleration remains constant during particle motion.

Non-uniform acceleration: A body is said to have non-uniform acceleration, if magnitude or direction or both, change during motion.

TRAIN YOUR BRAIN

Q. A car starts from rest and travels with uniform acceleration α for some time and then with uniform retardation β and comes to rest. If the total time of travel of the car is 't', the maximum velocity attained by it is given by

(a) $\frac{\alpha\beta}{(\alpha+\beta)}t$ (b) $\frac{1}{2}\frac{\alpha\beta}{(\alpha+\beta)}t^2$

(c) $\frac{\alpha\beta}{(\alpha-\beta)}t$ (d) $\frac{1}{2}\frac{\alpha\beta}{(\alpha-\beta)}t^2$

Sol. (a) maximum velocity $v = \alpha t_1 = \beta t_2$ and $t = t_1 + t_2$

$$\Rightarrow \frac{v}{\alpha}+\frac{v}{\beta}=t \Rightarrow v=\frac{(\alpha\beta)t}{(\alpha+\beta)}$$

DERIVATION OF FIRST EQUATION OF MOTION

For the derivation, let us consider a body moving in a straight line with uniform acceleration. Then, let the initial velocity be u, acceleration is denoted as a, time period is denoted as t, velocity is denoted as v, and the distance travelled is denoted as s.

Derivation of First Equation of Motion by Algebraic Method

We know that the acceleration of the body is defined as the rate of change of velocity.

Mathematically, acceleration is represented as follows:

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

where v is the final velocity and u is the initial velocity.

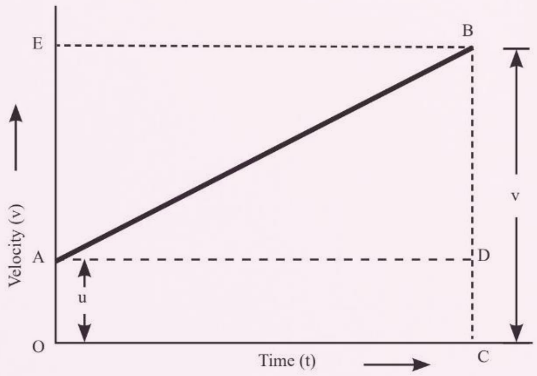
Rearranging the above equation, we arrive at the first equation of motion as follows:

v = u + at

Derivation of First Equation of Motion by Graphical Method

The first equation of motion can be derived using a velocity-time graph for a moving object with an initial velocity of u, final velocity v, and acceleration a.

Derivation of first equation of motion by graphical method



In the above graph,

The velocity of the body changes from A to B in time t at a uniform rate.

BC is the final velocity and OC is the total time t.

A perpendicular is drawn from B to OC, a parallel line is drawn from A to D, and another perpendicular is drawn from B to OE (represented by dotted lines).

Following details are obtained from the graph above:

The initial velocity of the body, u = OA

The final velocity of the body, v = BC

From the graph, we know that

BC = BD + DC

Therefore, v = BD + DC

v = BD + OA (since DC = OA)

Finally,

v = BD + u (since OA = u) ...1

Now, since the slope of a velocity-time graph is equal to acceleration a,

So,

a = slope of line AB

a = BD/AD

Since AD = AC = t, the above equation becomes:

BD = at ...2

Now, combining Equation 1 & 2, the following is obtained:

v = u + at

Derivation of First Equation of Motion by Calculus Method

Since acceleration is the rate of change of velocity, it can be mathematically written as:

$$a = \frac{dv}{dt}$$

Rearranging the above equation, we get

adt = dv

Integrating both the sides, we get

$$\int_0^t a\,dt = \int_u^v dv$$

at = v − u

Rearranging, we get

v = u + at

Derivation of Second Equation of Motion

For the derivation of the second equation of motion, consider the same variables that were used for derivation of the first equation of motion.

Derivation of Second Equation of Motion by Algebraic Method

Velocity is defined as the rate of change of displacement. This is mathematically represented as:

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

Rearranging, we get

Displacement = Velocity × Time

If the velocity is not constant then in the above equation we can use average velocity in the place of velocity and rewrite the equation as follows:

$$\text{displacement} = \left(\frac{\text{initial velocity} + \text{final velocity}}{2}\right) \times \text{time}$$

Substituting the above equations with the notations used in the derivation of the first equation of motion, we get

$$s = \frac{u+v}{2} \times t$$

From the first equation of motion, we know that v = u + at. Putting this value of v in the above equation, we get

$$s = \frac{u+(u+at)}{2} \times t$$

$$s = \frac{2u+at}{2} \times t$$

$$s = \left(\frac{2u}{2} + \frac{at}{2}\right) \times t$$

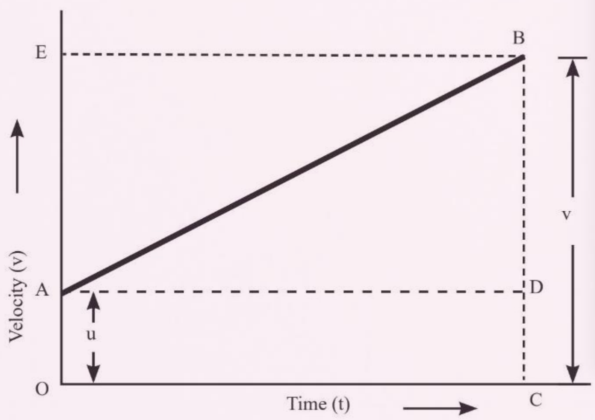
$$s = \left(u + \frac{1}{2}at\right) \times t$$

On further simplification, the equation becomes:

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

DERIVATION OF SECOND EQUATION OF MOTION BY GRAPHICAL METHOD

Derivation of second equation of motion by graphical method



From the graph above, we can say that

Distance travelled (s) = Area of figure OABC = Area of rectangle OADC + Area of triangle ABD

$$s = \left(\frac{1}{2}AD \times BD\right) + (OA \times OC)$$

Since BD = EA, the above equation becomes

$$s = \left(\frac{1}{2}AD \times EA\right) + (u \times t)$$

As EA = at, the equation becomes

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

On further simplification, the equation becomes

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

Derivation of Second Equation of Motion by Calculus Method

Velocity is the rate of change of displacement.

Mathematically, this is expressed as

$$v = \frac{ds}{dt}$$

Rearranging the equation, we get

ds = vdt

Substituting the first equation of motion in the above equation, we get

ds = (u + at)dt

ds = (u + at)dt = (udt + atdt)

On further simplification, the equation becomes:

$$\int_0^s ds = \int_0^t udt + \int_0^t atdt$$

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

DERIVATION OF THIRD EQUATION OF MOTION

Derivation of Third Equation of Motion by Algebraic Method

We know that, displacement is the rate of change of position of an object. Mathematically, this can be represented as:

$$\text{displacement} = \left(\frac{\text{initial velocity} + \text{final velocity}}{2}\right) \times t$$

Substituting the standard notations, the above equation becomes

$$s = \left(\frac{u+v}{2}\right) \times t$$

From the first equation of motion, we know that

v = u + at

Rearranging the above formula, we get

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

Substituting the value of t in the displacement formula, we get

$$s = \frac{(v+u)}{2}\frac{(v-u)}{a}$$

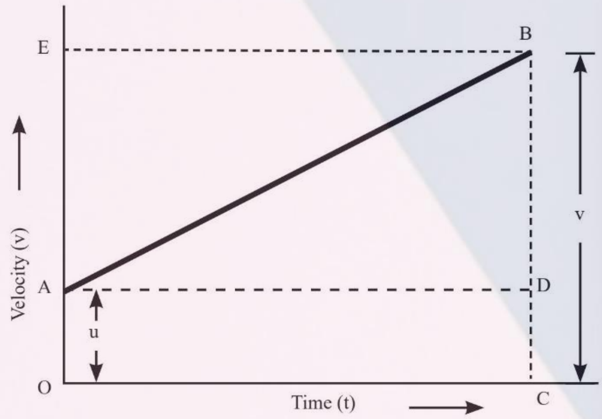
$$s = \left(\frac{v^2 - u^2}{2a}\right)$$

$2as = v^2 - u^2$

Rearranging, we get

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

DERIVATION OF THIRD EQUATION OF MOTION BY GRAPHICAL METHOD



From the graph, we can say that

The total distance travelled, s is given by the Area of trapezium OABC.

Hence,

S = ½ (Sum of Parallel Sides) × Height

S = (OA + CB) × OC

Since, OA = u, CB = v, and OC = t

The above equation becomes

S = ½ (u + v) × t

Now, since t = (v – u)/ a

The above equation can be written as:

S = ½ ((u + v) × (v – u))/a

Rearranging the equation, we get

S = ½ (v + u) × (v – u)/a

$S = (v^2 - u^2)/2a$

Third equation of motion is obtained by solving the above equation:

$v^2 = u^2 + 2aS$

DERIVATION OF THIRD EQUATION OF MOTION BY CALCULUS METHOD

We know that acceleration is the rate of change of velocity and can be represented as:

$$a = \frac{dv}{dt} \quad \text{...............(1)}$$

We also know that velocity is the rate of change of displacement and can be represented as:

$$v = \frac{ds}{dt} \quad \text{...............(2)}$$

Cross multiplying (1) and (2), we get

$$a\frac{ds}{dt} = v\frac{dv}{dt}$$

$$\int_0^s a\,ds = \int_u^v v\,ds$$

$$as = \frac{v^2 - u^2}{2}$$

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

RECTILINEAR OR ONE DIMENSIONAL MOTION

To study it we can choose an axis so that it coincides with the path of the object.

We may divide this topic in the following different situations.

(*i*) Motion with constant velocity

(*ii*) Motion with variable velocity but constant acceleration

(*iii*) Motion with variable acceleration.

Motion with constant velocity or uniform motion or zero acceleration

$$v = \frac{dx}{dt} \Rightarrow \int_{x_0}^{x} dx = \int_0^t v\,dt$$

Since velocity is constant, it comes out of the integration $[x]_{x_0}^{x} = v[t]_0^t$

$x - x_0 = vt$ i.e., displacement $\Delta \boldsymbol{x} = \boldsymbol{vt}$

Motion with variable velocity but constant acceleration

Basic formula

(*i*) $a = \frac{dv}{dt}$

(*ii*) $a = \frac{dv}{dx}\cdot\frac{dx}{dt} = v\frac{dv}{dx}$ (By chain rule)

From formula (i)

$$a = \frac{dv}{dt} \Rightarrow dv = a\,dt;$$

$$\int_u^v dv = \int_0^t a\,dt$$

Since acceleration is constant so it comes out of the integration

$$[v]_u^v = a\int dt$$

$\therefore\ v - u = at$

$\Rightarrow \boldsymbol{v = u + at}$ ... (*i*)

$$\frac{dx}{dt} = u + at$$

$dx = udt + at\,dt$

on further integrating

$$\int_{x_0}^{x} dx = u\int_0^t dt + a\int_0^t t\,dt$$

$$[x]_{x_0}^{x} = ut + \frac{at^2}{2}$$

$$x - x_0 = ut + \frac{1}{2}at^2$$

$$\Rightarrow \Delta x = ut + \frac{1}{2}at^2 \qquad ...(ii)$$

From formula (ii)

$$a = v\frac{dv}{dx}$$

$$\int_u^v v\,dv = a\int_{x_0}^{x} dx$$

$$\frac{v^2}{2} - \frac{u^2}{2} = a(x - x_0)$$

$$\mathbf{v^2 = u^2 + 2a(\Delta x)} \qquad ...(iii)$$

Taking $a = \frac{v-u}{t}$ from equation (i) and putting it in equation (ii), we get

$$\Delta x = ut + \frac{1}{2}\left(\frac{v-u}{t}\right)t^2$$

$$\Rightarrow \Delta x = \left(\frac{v+u}{2}\right)t \qquad ...(iv)$$

Equation (i), (ii) & (iii) are the three basic equations of uniformly accelerated motion.

TRAIN YOUR BRAIN

Q. A person is running at his maximum speed of 4 m/s to catch a train. When he is 6m from the door of the compartment the train starts to leave the station at a constant acceleration of 1 m/s^2. Find how long it takes him to catch up the train

(*a*) 2 sec (*b*) 3 sec

(*c*) 4 sec (*d*) None

Sol. (*a*) $4t = 6 + \frac{1}{2}at^2$

$\Rightarrow 4t = 6 + \frac{1}{2}\times 1\times t^2$

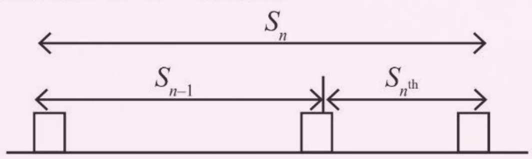
$\Rightarrow t^2 - 8t + 12 = 0$

$\Rightarrow (t-6)(t-2) = 0$

$\Rightarrow t = 2, 6$

Hence, after 2 sec man will catchup the train

Displacement in n^{th} second



Displacement in n^{th} second = Displacement in n sec. – Displacement in (n–1) sec.

$$S_{n^{th}} = S_n - S_{n-1^{th}} = [u(n) + \frac{1}{2}an^2] - [u(n-1) + \frac{1}{2}a(n-1)^2]$$

$$\therefore \mathbf{S_{n^{th}} = u + \frac{a}{2}(2n-1)} \qquad ...(v)$$

TRAIN YOUR BRAIN

Q. A body travels 200cm in the first two seconds and 220cm in the next 4 seconds with deceleration. The velocity of the body at the end of the 7th second is

(*a*) 20 cm/s (*b*) 15 cm/s

(*c*) 10 cm/s (*d*) 0 cm/s

Sol. (*c*) Let initial velocity and initial acceleration are '*u*' and '*a*' respectively

According to question,

$200 = u \times 2 + \frac{1}{2}a\times 2^2$

$\Rightarrow \quad 200 = 2u + 2a$ ....(i)

$(200 + 220) = u \times (2+4) + \frac{1}{2}\times a\times(2+4)^2$

$\Rightarrow \quad 420 = 6u + 18a$ .... (ii)

Solving eq. (i) and (ii) we get

u = 115 cm/s

a = – 15 cm/s^2

(– ve sign shows deaccelaration)

Now,

v = u + at

$\Rightarrow \quad v = 115 + (-15) \times 7$

= 10 cm/s

✍ KEY NOTE

- If a body starts from rest and moves with uniform acceleration then distance covered by the body in t sec is proportional to t^2 (i.e. $s \propto t^2$).
  - So we can say that the ratio of distance covered in 1 sec, 2 sec and 3 sec is $1^2 : 2^2 : 3^2$ or 1 : 4 : 9.
- If a body starts from rest and moves with uniform acceleration then distance covered by the body in nth sec is proportional to (2n – 1) (i.e. $s_n \propto (2n-1)$)
  - So we can say that the ratio of distance covered in I sec, II sec and III sec is 1 : 3 : 5.
- A body moving with a velocity u is stopped by application of brakes after covering a distance s. If the same body moves with velocity nu and same braking force is applied on it then it will come to rest after covering a distance of n^2s.

- As $v^2 = u^2 - 2as \Rightarrow 0 = u^2 - 2as \Rightarrow$, $s = \dfrac{u^2}{2a}$,
- $s \propto u^2$, [since a is constant]
- So we can say that if u becomes n times then s becomes n^2 times that of previous value.

- A particle moving with uniform acceleration from A to B along a straight line has velocities v_1 and v_2 at A and B respectively. If C is the mid-point between A and B then velocity of the particle at C is equal to $u = \sqrt{\dfrac{u_1^2 + u_2^2}{2}}$

Motion With Variable Acceleration

Relations:

(i) $\dfrac{dv}{dt} = a \Rightarrow \int_{v_1}^{v_2} dv = \int_{t_1}^{t_2} a\,dt$

(ii) $\dfrac{dx}{dt} = v \Rightarrow \int_{x_1}^{x_2} dx = \int v\,dt$

(iii) $a = \dfrac{dv}{dt} = \dfrac{dv}{dx} \cdot \dfrac{dx}{dt}$ (By chain rule)

$\therefore\ a = v\dfrac{dv}{dx}$

$\therefore\ \int_{v_1}^{v_2} v\,dv = \int_{x_1}^{x_2} a\,dx$

- Ratio of displacements in the $1^{st} s$, $2^{nd} s$, $3^{rd} s$... $n^{th} s$ = 1 : 3 : 5:.....:(2n–1)

  Ratio of displacements in the first 1s, first 2s, first 3s .... etc.... is 1 : 4 : 9:.... etc.
- Moving with uniform acceleration, a body crosses a point 'x' with a velocity 'u' and another point 'y' with a velocity 'v'. Then it will cross the mid point of 'x' and 'y' with velocity of $\sqrt{\dfrac{v^2 + u^2}{2}}$.
- If a bullet looses $(1/n)^{th}$ of its velocity while passing through a plank, then the no. of such planks required to just stop the bullet is $\dfrac{n^2}{2n-1}$.
- The velocity of a body becomes $\left(\dfrac{1}{n}\right)^{th}$ of its initial velocity after a displacement of 'x' then it will come to rest after a further displacement of $\dfrac{x}{n^2 - 1}$.
- Starting from rest a body travels with an acceleration 'α' for some time and then with deceleration 'β' and finally comes to rest. If the total time of journey is 't', then the maximum velocity, displacement and average velocity are respectively

(i) $v_{max} = \dfrac{\alpha\beta t}{\alpha + \beta}$

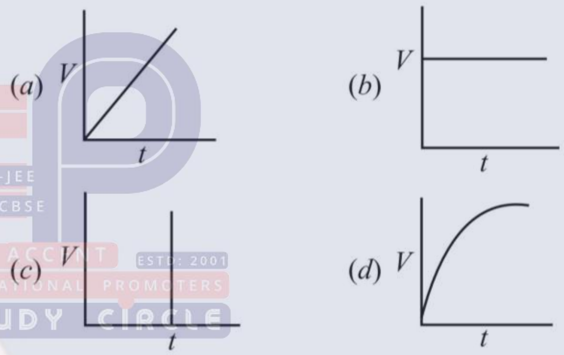
(ii) $s = \dfrac{\alpha\beta t^2}{2(\alpha + \beta)}$

(iii) average velocity $= \left(\dfrac{v_{max}}{2}\right)$

- If a particle starts from rest and moves with uniform accelaration 'a' such that it travels distances s_m and s_n in the m^{th} and n^{th} seconds then $a = \dfrac{s_m - s_n}{(m-n)}$

TRAIN YOUR BRAIN

Q. The velocity of a particle moving in the positive direction of the X-axis varies as $V = K\sqrt{S}$ where K is a positive constant. Draw V–t graph.

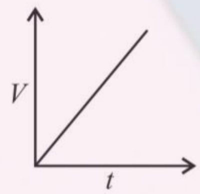


Sol. (a) $V = K\sqrt{S}$

$\dfrac{dS}{dt} = K\sqrt{S}$ $\therefore \int_0^S \dfrac{dS}{\sqrt{S}} = \int_0^t K\,dt$

$\therefore\ 2\sqrt{S} = Kt$ and $S = \dfrac{1}{4}K^2t^2$

$\Rightarrow\ V = \dfrac{dS}{dt} = \dfrac{1}{4}K^2 2t = \dfrac{1}{2}K^2 t$



$\therefore\ V \propto t$

$\therefore$ The V–t graph is a straight line passing through they origin.

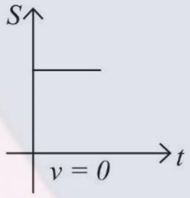
GRAPHS

Characteristics of S-t and V-t graphs

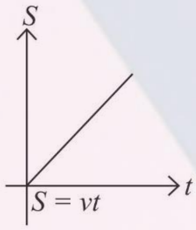
Slope of displacement-time graph gives velocity
Slope of velocity-time graph gives acceleration
Area under velocity-time graph gives displacement
Area under acceleration-time graph gives change in velocity

S-t Graphs

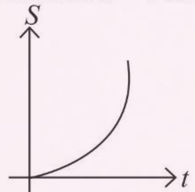
Body at rest



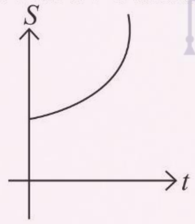
Uniform motion



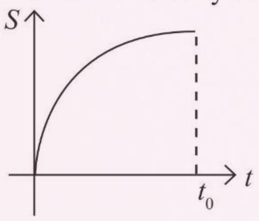
Uniformly accelerated motion $u = 0$ and $S = 0$ at $t = 0$



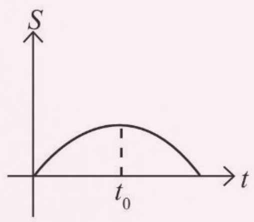
Uniformly accelerated with $u \neq 0$ and $S \neq 0$ at $t = 0$



Uniformly retarded motion till velocity becomes zero

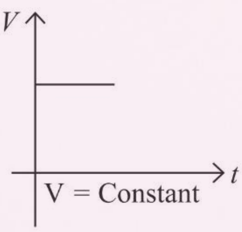


Uniformly retarded then accelerated

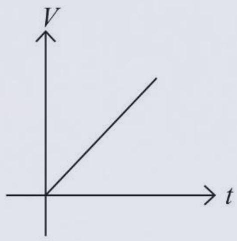


V-t Graphs

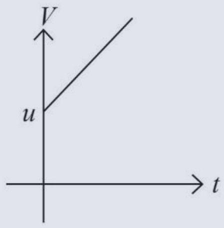
Uniform motion



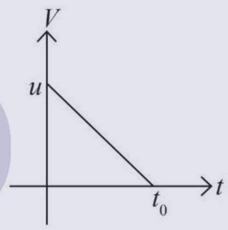
Uniformly accelerated motion, $u = 0$ $(S = 0)$ at $t = 0$



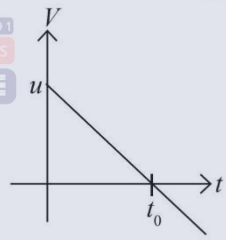
Uniformly accelerated motion, $u = u$ $(S = 0)$ at $t = 0$



Uniformly retarded motion till velocity becomes zero

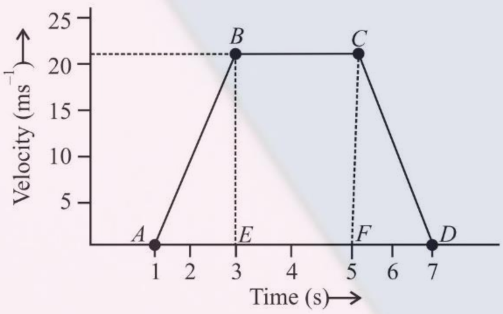


Uniformly retarded then accelerated in opposite direction



TRAIN YOUR BRAIN

Q. For the velocity-time graphs shown in figure, the total distance covered by the particle in the last two seconds of its motion is what fraction of the total distance covered by it in all the seven seconds?



(*a*) 1/8 (*b*) 1/6

(*c*) 1/4 (*d*) 1/2

Sol. (c) Distance = area under V-t graph

So, The distance covered in past two seconds is

$$S_1 = \frac{1}{2} \times 20 \times (7 - 5)$$

$= 20$ m

And, The total distance covered is

$$S_2 = \frac{1}{2}\times 20\times(3-1)+20\times(5-3)+20$$

$= 20 + 40 + 20$

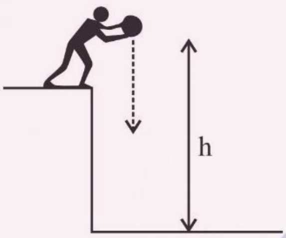
$= 80$ m

Therefore, required ratio $= \frac{S_1}{S_2} = \frac{20}{80} = \frac{1}{4}$

MOTION UNDER GRAVITY

Body projected vertically downwards and a freely falling body:

For a body dropped from height h (initial velocity = 0)



Final velocity $v = \sqrt{(2gh)}$

Time taken to fall $t = \sqrt{(2h/g)}$

When a body is projected vertically down then $a = g$; $s = h$, and the equation of motion can be written as follow:

(a) $v = u + gt$ (b) $h = ut + \frac{1}{2}gt^2$

(c) $v^2 - u^2 = 2gh$ (d) $S_n = u + \frac{g}{2}(2n-1)$

In the presence of air resistance, the acceleration of a denser body is greater.

A freely falling body passes through two points A and B in time intervals of t_1 and t_2 from the start, then the distance between the two points A and B is $= \frac{g}{2}\left(t_2^2 - t_1^2\right)$

A freely falling body passes through two points A and B at distances h_1 and h_2 from the start, then the time taken by it to move from A to B is

$$T = \sqrt{\frac{2h_2}{g}} - \sqrt{\frac{2h_1}{g}} = \sqrt{\frac{2}{g}}\left(\sqrt{h_2} - \sqrt{h_1}\right)$$

Two bodies are dropped from heights h_1 and h_2 simultaneously. Then after any time the distance between them is equal to $(h_2 - h_1)$.

A stone is dropped into a well of depth 'h', then the sound of splash is heard after a time of 't'

$$t = \sqrt{\frac{2h}{g}} + \frac{h}{v_{sound}}$$

A stone is dropped into a river from the bridge and after 'x' seconds another stone is projected down into the river from the same point with a velocity of 'u'. If both the stone reach the water simultaneously then $S_{1(t)} = S_{2(t-x)}$

$$\frac{1}{2}gt^2 = u(t-x) + \frac{1}{2}g(t-x)^2$$

TRAIN YOUR BRAIN

Q. A parachutist after bailing out falls 50m without friction. When parachute opens, it decelerates at 2m/s². He reaches the ground with a speed of 3m/s. At what height, did he bail out ?

(a) 91 m (b) 182 m

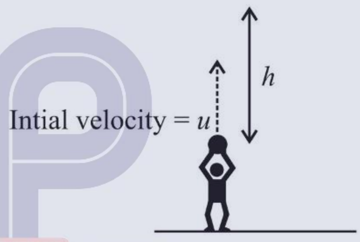
(c) 293 m (d) 111 m

Sol. (c) $\mu = \sqrt{2g\times 50}$ (g = 9.8 m/s²)

$v^2 - u^2 = 2as$, $a = -2$ m/s²

height at which he bails out = $(50 + s)$

Body Projected Vertically up:



Maximum height reached h = u²/(2g)

Time taken to reach maximum height = u/g

Time taken to fall back down distance h = u/g

Acceleration (a) = $-g$ and the equation of motion can be written as follow:

(a) $v = u - gt$ (b) $s = ut - \frac{1}{2}gt^2$

(c) $v^2 - u^2 = -2gh$ (d) $s_n = u - \frac{g}{2}(2n-1)$

Angle between velocity vector and acceleration vector is 180° until the body reaches the highest point.

At maximum height, $v = 0$ and $a = g$

$H_{max} = \frac{u^2}{2g} \Rightarrow H_{max} \propto u^2$ (Independent of mass of the body)

In the absence of air resistance, time of ascent and time of descent are equal. $(t_a = t_d)$

$$t_a = t_d = \frac{u}{g} \Rightarrow T = t_a + t_d = \frac{2u}{g}$$

In the presence of air resistance, the time of ascent is less than the time of descent.

At any point of the journey, a body possess the same speed while moving up and while moving down.

Irrespective of velocity of projection, all the bodies pass through a height $\frac{g}{2}$ in the last second of ascent.

The change in velocity over the complete journey is '$2u$' (downwards)

KEY NOTE

If a vertically projected body rises through a height 'h' in n^{th} second, then in $(n-1)^{th}$ second it will rise through a height $(h+g)$ and in $(n+1)^{th}s$ it will rise through height $(h-g)$.

If velocity of body in n^{th} second is 'v' then in $(n-1)^{th}$ second it is $(v + g)$ and that in $(n+1)^{th}$ it is $(v - g)$ while ascending

TRAIN YOUR BRAIN

Q. A person sitting on the top of a tall building is dropping balls at regular intervals of one second. When the 6th ball is being dropped, the positions of the 3rd, 4th, 5th balls from the top of the building are respectively

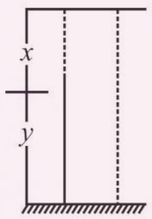
(*a*) 4.9m, 19.6m, 44.1m
(*b*) 4.9m, 14.7m, 24.5m
(*c*) 44.1m, 19.6m, 4.9m
(*d*) 24.5m, 14.7m, 4.9m

Sol. (c) Hint: $h=\frac{1}{2}gt^2$

Q. A stone projected vertically up from the ground reaches a height y in its path at t_1 seconds and after further t_2 seconds reaches the ground. The height y is equal to

(*a*) $\frac{1}{2}g(t_1+t_2)$ (*b*) $\frac{1}{2}g(t_1+t_2)^2$
(*c*) $\frac{1}{2}gt_1t_2$ (*d*) gt_1t_2

Sol. (c)



Distance		Time
y	→	t_1
y + 2x	→	t_2
x	→	$\frac{t_2-t_1}{2}$
y + x	→	$\frac{t_2+t_1}{2}$

Now, $y+x=0+\frac{1}{2}g\left(\frac{t_1+t_2}{2}\right)^2$ ......(i)

$x=0+\frac{1}{2}g\left(\frac{t_2-t_1}{2}\right)^2$ ......(ii)

From (i) and (ii)

$y=\frac{1}{2}gt_1t_2$

A body projected vertically up crosses a point P at a height 'h' above the ground at time 't_1' seconds and at time 't_2' seconds to same point while coming down. Then total time of its flight $T=t_1+t_2$

(*a*) Height of P is $h=\frac{1}{2}gt_1t_2$

(*b*) Maximum height reached above the ground $H=\frac{1}{8}g(t_1+t_2)^2$

(*c*) Magnitude of velocity while crossing P is $\frac{g(t_2-t_1)}{2}$

A body is projected vertically up with velocity u_1 and after 't' seconds another body is projected vertically up with a velocity u_2.

(*a*) If $u_2 > u_1$, the time after which both the bodies will meet with each other is $\frac{u_2t+\frac{1}{2}gt^2}{(u_2-u_1)+gt}$ for the first body.

(*b*) If $u_1 = u_2 = u$, the time after which they meet is $\left(\frac{u}{g}+\frac{1}{2}\right)$ for the first body and $\left(\frac{u}{g}-\frac{1}{2}\right)$ for the second body.

A rocket moves up with a resultant acceleration a. If its fuel exhausts completely after time 't' seconds, the maximum height reached by the rocket above the ground is $h=\frac{1}{2}at^2\left(1+\frac{a}{g}\right)$

A body is projected vertically up with a velocity of 'u' from ground in the presence of constant air resistance 'R'. If it reaches the ground with a velocity 'V', then

(*a*) Height of ascent = Height of descent

(*b*) Time of ascent $t_a=\frac{mu}{mg+R}$

(*c*) Time of descent $t_d=\frac{mV}{mg-R}$

(*d*) $t_a < t_d$

(*e*) $\frac{V}{u}=\sqrt{\frac{mg-R}{mg+R}}\,(V<u)$

(*f*) For a body projected vertically up under air resistance, retardation during motion is $> g$

(*g*) If air resistance is considered, time of ascent decreases and time of descent increases $\Rightarrow t_d > t_a$.

An elevator is accelerating upwards with an acceleration a. If a person inside the elevator throws a particle vertically up with a velocity u relative to the elevator, time of flight is $t=\frac{2u}{g+a}$

In the above case if elevator accelerates down, time of flight is $t=\frac{2u}{g-a}$

KEY NOTE

The zero velocity of a particle at any instant does not necessarily imply zero acceleration at that instant. A particle may be momentarily at rest and yet have non-zero acceleration. For example, a particle thrown up has zero velocity at its uppermost point but the acceleration at that instant continues to be the acceleration due to gravity.

TRAIN YOUR BRAIN

Q. Water drops fall from a tap on to the floor 5.0m below at regular intervals of time. The first drop strikes the floor when the fifth drop beings to fall. The height at which the third drop will be from ground, at the instant when the first drop strikes the ground is (Take g = $10ms^{-2}$)

(*a*) 1.25 m (*b*) 2.15 m

(*c*) 2.75 m (*d*) 3.75 m

Sol. **(*d*)** Hint: $h=\frac{1}{2}gt^2$

Body Projected Vertically up from a Tower

A body projected vertically up from a tower of height '*h*' with a velocity '*u*' (or) a body dropped from a rising balloon (or) a body dropped from an helicopter rising up vertically with constant velocity '*u*' reaches the ground exactly below the point of projection after a time '*t*'. Then

(*a*) Height of the tower is $h=-ut+\frac{1}{2}gt^2$

(*b*) Time taken by the body to reach the ground $t=\frac{u+\sqrt{u^2+2gh}}{g}$

(*c*) The velocity of the body at the foot of the tower $v=\sqrt{u^2+2gh}$

(*d*) Velocity of the body after '*t*' sec. is $v=u-gt$

The height of the balloon by the time the body reaches the ground is $\frac{1}{2}gt^2$.

A body projected vertically down from a tower with a velocity '*u*' reaches the foot of the tower after a time 't_1' with a velocity 'v_1'. Another body projected vertically up from the tower with same velocity reaches the foot of the tower after a time 't_2' with a velocity 'v_2'. A freely dropped body reaches the foot of the tower after a time '*t*' with a velocity '*v*', then

(*a*) $t=\sqrt{t_1t_2}$

(*b*) $h=\frac{1}{2}gt_1t_2$

(*c*) $u=\frac{1}{2}g(t_1-t_2)$

(*d*) $v_1=v_2=\sqrt{u^2+2gh}$

(*e*) $v=\sqrt{2gh}$

Relative Motion in one dimensional motion

Velocity of one moving body with respect to other moving body is called Relative velocity.

Two bodies are moving in a straight line in the same direction then, $\overline{v}_{12}=\overline{v}_1-\overline{v}_2$

Two bodies are moving in a straight line in the opposite direction then, $\overline{v}_{12}=\overline{v}_1+\overline{v}_2$

Two bodies moving with same velocity and in same direction then, position between them does not vary with time.

Two bodies moving with unequal velocity and in same direction then, position between them first decreases to minimum and then increases.

Two bodies moving with unequal velocity and in opposite direction then, position between them first decreases to minimum and then increases.

TRAIN YOUR BRAIN

Q. A boy throws n balls per second at regular time intervals. When the first ball reaches the maximum height he throws the second one vertically up. The maximum height reached by each ball is

(a) $\frac{g}{2(n-1)^2}$ (*b*) $\frac{g}{2n^2}$

(c) $\frac{g}{n^2}$ (*d*) $\frac{g}{n}$

Sol. **(*b*)** Hint: $h=\frac{u^2}{2g}$

ILLUSTRATIONS

1. The displacement of a particle, starting from rest (at *t* = 0) is given by $s=6t^2-t^3$.

The time in seconds at which the particle will obtain zero velocity again is:

(*a*) 2

(*b*) 4

(*c*) 6

(*d*) 8

Sol. (b) $s = 6t^2 - t^3$

$$\frac{ds}{dt} = 12t - 3t^2$$

$v = 12t - 3t^2 = 0$

$3t(4 - t) = 0,\ t = 4, 0$

2. The coordinates of a moving particle at any time t are given by $x = \alpha t^3$ and $y = \beta t^3$. The speed of the particle at time t is given by:

(a) $3t\sqrt{\alpha^2+\beta^2}$ (b) $3t^2\sqrt{\alpha^2+\beta^2}$

(c) $t^2\sqrt{\alpha^2+\beta^2}$ (d) $\sqrt{\alpha^2+\beta^2}$

Sol. (b) $x = \alpha t^3,\ y = \beta t^3$

$$\frac{dx}{dt} = 3\alpha t^2, \frac{dy}{dx} = 3\beta t^2$$

$$V = \sqrt{\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2}, V = \sqrt{\left(3\alpha t^2\right)^2 + \left(3\beta t^2\right)^2}$$

$$V = 3t^2\sqrt{\alpha^2+\beta^2}$$

3. From the top of a tower a stone is thrown up and reaches the ground in time $t_1 = 9$s. A second stone is thrown down with the same speed and reaches the ground in time $t_2 = 4$s. A third stone is released from rest and reaches the ground in time t_3, which is equal to:

(a) 6.5 s (b) 6s

(c) $\frac{5}{36}s$ (d) 64 s

Sol. (b) t_1 = Thrown up with speed u

t_2 = Thrown down with speed u

t_3 = Dropped.

$t \Rightarrow t_3 = \sqrt{t_1 t_2}$

$t \Rightarrow t_3 = \sqrt{9 \times 4} = 6s$

4. When a ball is thrown up vertically with velocity v_0, it released from a height h. If one wishes to triple the maximum height then the ball should be thrown with velocity:

(a) $\sqrt{3}\,v_0$ (b) $3v_0$

(c) $9v_0$ (d) $3/2\ v_0$

Sol. (a) Ball is thrown vertically upward.

$\therefore$ g = –ve, s = +ve, v = +ve

$2(-g)h = 0^2 - v_0^2,\ v_o = \sqrt{2gh}$

Now h' = 3h v = +ve g = –ve

$2(-g) \times 3h = 0^2 - v^2$

$v = \sqrt{6gh}$

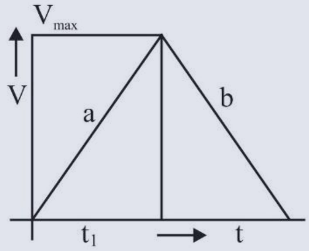
$$\therefore \frac{v}{v_0} = \frac{\sqrt{6gh}}{\sqrt{2gh}} = \sqrt{3}v_0 \Rightarrow v = v_0\sqrt{3}$$

5. A car starts from rest, moves with an acceleration a and then decelerates at a constant rate b for sometime to come to rest. If the total time taken is t. The maximum velocity of car is given by:

(a) $\frac{abt}{(a+b)}$ (b) $\frac{a^2t}{a+b}$

(c) $\frac{at}{(a+b)}$ (d) $\frac{b^2t}{a+b}$

Sol. (a)



$$a = \frac{V\max}{r} \qquad ....(1)$$

$$-b = \frac{-V\max}{(t-r)} \qquad ....(2)$$

from (1) and (2)

$$V_{max} = \frac{abt}{(a+b)}$$

6. A particle of unit mass undergoes one dimensional motion such that its velocity varies according to $v(x) = \beta x^{-2n}$ where β and n are constants and x is the position of the particle. The acceleration of the particle as a function of x, is given by:

(a) $-2n\beta^2 x^{-4n-1}$ (b) $-2\beta^2 x^{-2n+1}$

(c) $-2n\beta^2 e^{-4n+1}$ (d) $-2n\beta^2 x^{-2n-1}$

Sol. (a) $a = \frac{vdv}{dx}$

$= \beta x^{-2n}(-2n)\beta x^{-2n-1}$

$= -2n\beta^2 x^{-4n-1}$

7. The initial velocity of a particle is 10 m/s retardation is 2 m/s². The distance covered in the fifth second of the motion will be:

(a) 2 m (b) 1 m

(c) 50 m (d) 75 m

Sol. (b) $S_4 = 10 \times 4 - \frac{1}{2} \times 2 \times 16 = 40 - 16 = 24$

$S_5 = 10 \times 5 - \frac{1}{2} \times 2 \times 25 = 50 - 25 = 25$

$\therefore$ S in 5th second = 25 – 24 = 1 m

8. A moving train is stopped by applying brakes. It stops after traveling 80 m. If the speed of the train is doubled and retardation remains the same. It will cover a distance:

(*a*) Same as earlier

(*b*) Double the distance traveled earlier

(*c*) Four time the distance traveled earlier

(*d*) Half the distance traveled earlier

Sol. (***c***) $2as = v^2 - u^2$

Now $v = 0, u = u$
$2(-a)s = 0^2 - u^2$

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

$s \propto u^2$ ($\because$ a = constant)

$\therefore$ if u will be doubled s will be 4 time

9. A rocket is initialized from the earth surface so that it has a acceleration of 19.6 m/s^2. If its engine is scratched off after 5 second of its launch, then maximum height attained by the rocket will be:

(*a*) 245 m (*b*) 490 m
(*c*) 980 m (*d*) 735 m

Sol. (***d***) Distance travelled by rocket in 5sec

$$u = 0, s = \frac{1}{2} \times 19.6 \times 25 = 245 \text{ m}$$

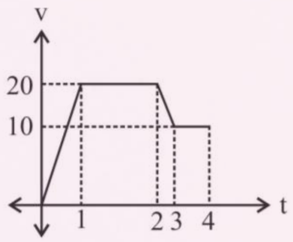
Velocity attained = 19.6 × 5 = 98 m/s

Distance travelled till velocity reached zero
$2 \times (-9.8)s = 0 - (98)^2$

$$s = \frac{98 \times 98}{98} \times \frac{10}{2} = 490 \text{ m}$$

$\therefore$ Height achieved = 490 + 245 = 735 m

10.



Find the distance traveled by body in 4 seconds:

(*a*) 70 m

(*b*) 60 m

(*c*) 40 m

(*d*) 55 m

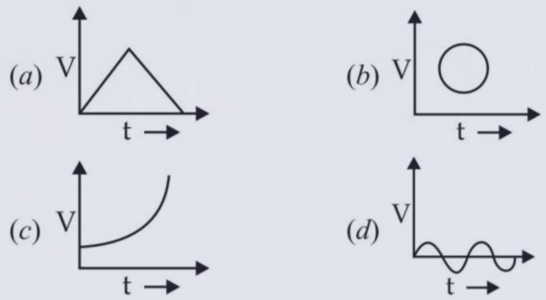
Sol. (***d***) Distance = Area under graph

$$= \frac{1}{2} \times 1 \times 20 + 1 \times 20 + \frac{1}{2}(30) \times 1 + 10$$

$= 10 + 20 + 15 + 10$

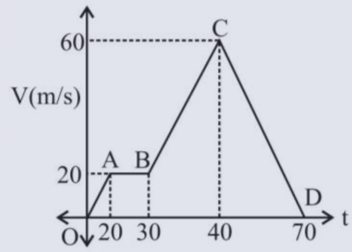
S = 55 m

11. Which one of the following curve do not represent motion in one dimension:



Sol. (***b***) There cannot be two value of velocity of a particle at a particular instant of time.

12.



Find the max acceleration:

(*a*) 18 m/s^2 (*b*) 4 m/s^2
(*c*) 2 m/s^2 (*d*) 10 m/s^2

Sol. (***b***) Slope OA $= \frac{20}{20} = 1 \text{ m/s}^2$

Slope AB = 0 m/s^2

Slope BC $= \frac{60-20}{40-30} = 4 \text{m/s}^2$ (maximum)

Slope CD $= \frac{-60}{70} = -\frac{6}{7} \text{m/s}^2$

13. Two trains of length 50 m are approaching each other on parallel rails. Their velocities are 10 m/sec and 15 m/sec. They will cross each other in:

(*a*) 2 sec (*b*) 4 sec
(*c*) 10 sec (*d*) 6 sec

Sol. (***b***) Total length to be travelled = 50 + 50 = 100 m

Relative velocity V_r = 15 + 10 = 25 m/s

$\therefore$ Time to cross $t = \frac{100}{25} = 4$ second

14. The displacement x of a particle moving in one dimensional motion is related to time by equation $t = \sqrt{x} + 3$ where x is in meters and t in seconds. The displacement when velocity is zero is:

(*a*) 0 m (*b*) 1 m
(*c*) 9 m (*d*) 4 m

Sol. (***a***) $t = \sqrt{x} + 3, x = (t-3)^2$

$$\frac{dx}{dt} = 2(t-3) = \text{velocity} = 0$$

$t = 3$
at t = 3 sec
$\therefore x = 0$ m

15. A bullet fired into a fixed block of wood loses half its velocity after penetrating 60 cm before coming to rest it penetrates a further distance of:

(*a*) 60 cm (*b*) 30 cm
(*c*) 20 cm (*d*) 10 cm

Sol. (*c*) S = 60 cm

$S = 0.6\text{ m}, V = \frac{u}{2}, u = u$

$2\times(-a)\times 0.6 = \left(\frac{u}{2}\right)^2 - u^2,\ a = \frac{3}{4}\times\frac{u^2}{1.2} = \frac{u^2}{1.6}$

Now, $S' = ?\ u' = \frac{u}{2}\ V = 0$

$\left(2\times\frac{u^2}{1.6}\right)S' = \frac{-u^2}{4}$

$S' = \frac{1.2}{6} = 0.2\text{ m} = 20\text{ cm}$

16. A particle has an initial velocity $3\hat{i}+7\hat{j}$ on acceleration of $0.4\hat{i}+3\hat{j}$. Its speed after 10s is:

(*a*) 10 units (*b*) $7\sqrt{2}$ units
(*c*) 7 units (*d*) 8.5 units

Sol. (*b*) $V = u + at = 3\hat{i}+7\hat{j}+\left(0.4\hat{i}+0.3\hat{j}\right)\times 10$

$V = 7\hat{i}+7\hat{j}, |V| = 7\sqrt{2}$ units

17. A particle located at x = 0 at time t = 0, starts moving along the positive x direction with a velocity V that varies as $V \propto \sqrt{x}$. The displacement of the particle varies with time as:

(*a*) $t^{1/2}$ (*b*) t^3
(*c*) t^2 (*d*) t

Sol. (*c*) $V \propto \sqrt{x}$

$\frac{dx}{dt} \propto \sqrt{x} \Rightarrow \int\frac{dx}{\sqrt{x}} = \int \alpha dt$

$2\sqrt{x} = \alpha t + c$

$\therefore x \propto t^2$

18. The velocity of a body depends on time according to the equation $V = 20 + 0.1\ t^2$. The body is undergoing:

(*a*) Uniform acceleration
(*b*) Non-uniform acceleration
(*c*) Retardation
(*d*) Zero acceleration

Sol. (*b*) $V = 20 + 0.1\ t^2$

$acc = \frac{dV}{dt} = 2(0.1)t = 0.2\ t$

Since $acc \propto t$

$\therefore$ Non-uniform acceleration

19. A particle moving along X-axis has acceleration f, at time t, given by $f_0\left(1-\frac{t}{T}\right)$, where f_0 and t are constants between t = 0 and the instant when f = 0, the particle's velocity (v_x) is:

(*a*) f_0T (*b*) f_0T^2
(*c*) f_0T^3 (*d*) $\frac{1}{2}f_0T$

Sol. (*d*) $f = f_0 - \frac{f_0 t}{T}$

For $t = 0 \Rightarrow f = f_0$

$S = \frac{1}{2}f_0t^2\quad V = \frac{S}{t} = \frac{1}{2}f_0 t$

for t = T

$V = \frac{1}{2}f_0T$

20. At a metro station, a girl walks up a stationary escalator in time t_1. If she remains stationary on the escalator, then the escalator take her up in time t_2. The time taken by her to walk up on the moving escalator will be:

(*a*) $\frac{(t_1+t_2)}{2}$ (*b*) $\frac{t_1t_2}{(t_2-t_1)}$
(*c*) $\frac{t_1t_2}{(t_2+t_1)}$ (*d*) $t_1 - t_2$

Sol. (*c*) For walking: $S = V_1 t_1$, $\therefore V_1 = \frac{S}{t_1}$

For standing: $S = V_2 t_2$, $V_2 = \frac{S}{t_2}$

If she would walk on moving escalator.

$S = (V_1+V_2)T'$

$S = \left(\frac{1}{t_1}+\frac{1}{t_2}\right)ST'$

$\frac{1}{T'} = \frac{1}{t_1}+\frac{1}{t_2}$

T' – time taken by girl to reach on top on moving escalator while walking on it.

$T' = \frac{t_1t_2}{t_1+t_2}$

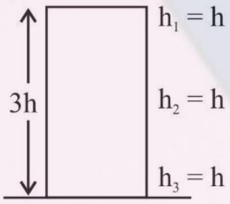
21. A particle is released from rest from a tower of height 3h. The ratio of the intervals of time to cover three equal heights h is:

(*a*) $t_1 : t_2 : t_3 = 3 : 2 : 1$
(*b*) $t_1 : t_2 : t_3 = 1 : (\sqrt{3}-2)$
(*c*) $t_1 : t_2 : t_3 = \sqrt{3} : \sqrt{2} : 1$
(*d*) $t_1 : t_2 : t_3 = 1 : (\sqrt{2}-1) : (\sqrt{3}-\sqrt{2})$

Sol. (*d*) t_1 – Cover h_1 distance

t_2 – Cover h_2 distance

t_3 – Cover h_3 distance



Now, for S = 2h, g = g, u = 0 ...(i)

$$t_1 = \sqrt{\frac{2h}{g}}$$

$$\therefore 2h = \frac{1}{2}(t_2')^2$$

$$t_2' = 2\sqrt{\frac{h}{g}}$$

$$\therefore t_2 = t_2' - t_1$$

$$= 2\sqrt{\frac{h}{g}} - \sqrt{\frac{2h}{g}} = \sqrt{\frac{2h}{g}}\left(\sqrt{2}-1\right)$$

$$t_2 = \sqrt{\frac{2h}{g}}\left(\sqrt{2}-1\right) \quad ...(ii)$$

For S = 3h, u = 0, g = g

$$t_3' = \sqrt{\frac{6h}{g}},\ t_3 = t_3' - t_2 - t_1$$

$$= \sqrt{\frac{2h}{g}}\left(\sqrt{3}-\sqrt{2}+1-1\right)$$

$$t_3 = \sqrt{\frac{2h}{g}}\left(\sqrt{3}-\sqrt{2}\right)$$

$$t_1 : t_2 : t_3 = 1 : \left(\sqrt{2}-1\right) : \left(\sqrt{3}-\sqrt{2}\right)$$

22. From a building two balls A and B are thrown such that A is thrown upwards and B downwards with same velocity. V_A & V_B are the velocities on reaching the ground than:

(*a*) $V_B > V_A$

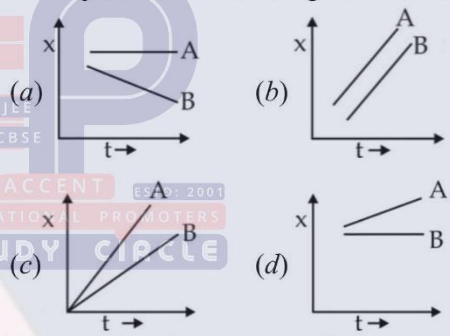
(*b*) $V_A = V_B$

(*c*) $V_A > V_B$

(*d*) Velocity depends upon mass

Sol. (*b*) $V_A = V_B$. Since, the motion is uniform. The velocity at each point is same so this velocity of A after coming back is also V_A, just the defection is reversed. Thus, $V_A = V_B$.

23. Which one of the following represents the x-t graph of two object A and B moving with zero relative speed:



Sol. (*b*) $V_{Rel} = 0$ as lines are parallel.

Topicwise Questions

DISTANCE AND DISPLACEMENT

1. A man goes 20 m towards north, then 30 m towards east then his displacement is:

(*a*) 37 m (*b*) 36 m
(*c*) 40 m (*d*) 38 m

2. An aeroplane flies 400 m north and 300 m south and then flies 1200 m upwards, then net displacement is:

(*a*) 1200 m (*b*) 1300 m
(*c*) 1400 m (*d*) 1500 m

3. An athlete completes one round of a circular track of radius R in 80 sec. What will be his displacement at the end of 4 min 60 second?

(*a*) $2\pi R$ (*b*) $3\pi R$
(*c*) $\sqrt{2}R$ (*d*) Zero

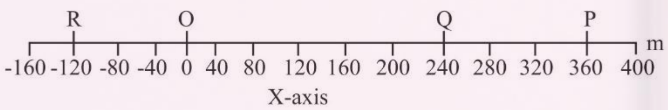
4. An aeroplane flies from (–4m, –5m, +8m) to (7m, –2m, –3m) in the xyz coordinates. The aeroplanes displacement in co-ordinate form is given by:

(*a*) (3m, -4m, 5m) (*b*) (4m, –5m, 11m)
(*c*) (11m, 3m, –11m) (*d*) (11m, –6m, 7m)

5. Let x_1 and x_2 be the positions of an object at time t_1 and t_2. Then, its displacement, denoted by A, in time Δt = B, is given by the difference between the C and D position. Here A, B, C and D refer to

(*a*) $A \to \Delta x$, $B \to t_1 - t_2$, $C \to$ final, $D \to$ initial
(*b*) $A \to \Delta x$, $B \to t_2 - t_1$, $C \to$ final, $D \to$ initial
(*c*) $A \to x$, $B \to t_2 - t_1$, $C \to$ initial, $D \to$ final
(*d*) $A \to \Delta x$, $B \to t_2 - t_1$, $C \to$ initial, $D \to$ final

Directions: (Q. No. 6 to 8) Answer the following questions based on given figure.



6. The displacement of car in moving from O to P and its displacement in moving from P to Q are

(*a*) + 360 m and –120 m (*b*) – 120 m and + 360 m
(*c*) + 360 m and +120 m (*d*) + 360 m and – 600 m

7. Which of the following statements is/are false?

I. For motion of the car from O to P, the magnitude of displacement is equal to the path length.

II. For motion of car from O to P and back to Q, magnitude of displacement is equal to + 240 m.

III. For motion of car from O to P and back to Q, magnitude of displacement is not equal to the path length.

(*a*) Only I (*b*) Only II
(*c*) Only III (*d*) None of these

8. If the car goes from O to P and returns back to O, the displacement and path length of the journey are:

(*a*) 0, 720 m (*b*) 720 m, 720 m
(*c*) 0, 0 (*d*) 720 m, 0

9. The displacement of a particle is given by $x = (t - 2)^2$ where x is in metre and t in second. The distance covered by the particle in first 4 seconds is:

(*a*) 4 m (*b*) 8 m
(*c*) 12 m (*d*) 16 m

SPEED, VELOCITY, ACCELERATION

10. A truck travels a distance A to B at a speed of 40 km/h and returns to A at a speed of 50 km/h, then what is the average velocity of the whole journey?

(*a*) 34.5 km/h (*b*) Zero
(*c*) 35 km/hr (*d*) 40 km/hr

11. Which of the following changes when a particle is moving with uniform velocity?

(*a*) Velocity (*b*) Speed
(*c*) Position (*d*) Acceleration

12. An athlete participates in a race now he is moving on a circular track of radius 80 m completes half a revolution in 20s. Its average velocity is:

(*a*) 8 m/s (*b*) 16 m/s
(*c*) 10 m/s (*d*) 12 m/s

13. The motion of a particle is described by the equation $x = a + bt^2$, where a = 10 cm , b = 15 cms^{-2}. Its instantaneous velocity at t = 3 second will be?

(*a*) 10 cms^{-1} (*b*) 20 cms^{-1}
(*c*) 60 cms^{-1} (*d*) 90 cms^{-1}

14. One car moving on a straight road covers one third of distance with a speed of 20 m/s, other one third with speed of 40 m/s and next one third with speed 60 m/s, then the average speed of the car is:

(*a*) 32.7 m/s (*b*) 40 m/s
(*c*) 31 m/s (*d*) 33 m/s

15. A car travel half the distance with constant velocity of 40 kmph and the remaining half with a constant velocity of 80 kmph. The average velocity of the car in kmph is:

(*a*) 32 km/hr (*b*) 53.3 km/hr
(*c*) 43.2 km/hr (*d*) 42 km/hr

16. An α-particle in a cyclotron changes its velocity from 30 km/s south to 40 km/s west in 10 second what is the magnitude of average acceleration during this time:

(*a*) 5 Km/s^2 (*b*) 7 Km/s^2
(*c*) 9 Km/s^2 (*d*) 11 Km/s^2

17. A particle is moving eastward with a velocity of 5 m/s. In 10 seconds, the velocity changes to 5 m/s northward. The average acceleration in this time is:

(*a*) Zero

(*b*) $\frac{1}{2}$ m/ s^2 (towards north – east)

(*c*) $\frac{1}{\sqrt{2}}$ m/ s^2 (towards north – east)

(*d*) $\frac{1}{\sqrt{2}}$ ms^{-2} (towards north – west)

18. In one dimensional motion, instantaneous speed v satisfies $0 \le v < v_0$.

(*a*) The displacement in time T must always take non-negative values

(*b*) The displacement *x* in time T satisfies $-v_0 T < x < v_0 T$

(*c*) The acceleration is always a non-negative number

(*d*) The motion has no turning points

19. A vehicle travels half the distance with speed v_1 and the other half with speed v_2, then its average speed is:

(*a*) $\frac{v_1 + v_2}{2}$

(*b*) $\frac{2v_1 + v_2}{v_1 + v_2}$

(*c*) $\frac{2v_1 v_2}{v_1 + v_2}$

(*d*) $\frac{(v_1 + v_2)}{v_1 v_2}$

MOTION WITH UNIFORM ACCELERATION IN STRAIGHT LINE PATH, MOTION UNDER GRAVITY

20. A bullet emerges from a barrel of length 1.2 m with a speed of 640 ms^{-1}. Assuming constant acceleration the approximate time that it spends in the barrel after the bullet fired is:

(*a*) 40 ms (*b*) 4 ms

(*c*) 4 second (*d*) 0.4 second

21. A particle having initial velocity 10 m/s moves with a constant acceleration 5ms^{-2}, for a time 15 second along a straight line, what is the displacement of the particle in the last 2 second?

(*a*) 160 m (*b*) 200 m

(*c*) 210 m (*d*) 230 m

22. A ball thrown vertically upward with a speed of 19.6 m/s from the top of a tower returns to the earth in 6 second. What is the height of the tower?

(*a*) 40 m (*b*) 58.8 m

(*c*) 50 m (*d*) 70 m

23. On turning a corner, a motorist rushing at 40 m/s, finds a child on the road 108 m ahead. He instantly stops the engine and applies the brakes so as to stop it within 1 m of the child, what time is required to stop it?

(*a*) 5.4 second (*b*) 6.4 second

(*c*) 3.9 second (*d*) 2 second

24. A ball is thrown vertically upwards with a velocity of 40 ms^{-1} from the top of a multistory building of 25 m high. How high will the ball rise from building?

(*a*) 20 m (*b*) 80 m

(*c*) 40 m (*d*) 10 m

25. A body starting from rest moves with constant acceleration. The ratio of distance covered by the body during 8^{th} second to that covered in 8 second is:

(*a*) $\frac{15}{60}$ (*b*) $\frac{15}{64}$

(*c*) $\frac{12}{15}$ (*d*) 1

26. A car moving with a velocity of 10 m/s can be stopped by the application of a constant force F in a distance of 20 m. If the velocity of the car is 30 m/s it can be stopped by this force in:

(*a*) 100 m (*b*) 90 m

(*c*) 180 m (*d*) 160 m

27. A particle moves for 50 seconds if first accelerates from rest and then retard or deaccelerates to rest. If the retardation be 5 times the acceleration then the time for retardation is:

(*a*) 25/3 second (*b*) 50/3 second

(*c*) 25 second (*d*) 100/3 second

28. A truck travelling with uniform acceleration crosses two points A & B with velocities 60 m/s and 40 m/s respectively. The speed of the body at the mid point of A and B is nearest to:

(*a*) 17 m/s (*b*) 20 m/s

(*c*) 19.49 m/s (*d*) 50.9 m/s

29. An object of mass 10 Kg moves at a constant speed of 20 m/s. A constant force, that acts for 5 second on the object gives it a speed 2 m/s in opposite direction. The force acting on the object is:

(*a*) 44 N (*b*) –44 N

(*c*) –20 N (*d*) 20 N

30. A body thrown vertically upwards with a speed of 19.6 ms^{-1} from the top of a tower returns to the earth in 10 seconds. What will be the height of tower?

(*a*) 304 m (*b*) 308 m

(*c*) 310 m (*d*) 312 m

31. A splash is heard after 3 second after the stone is dropped into a well of depth 20 m. The velocity of sound is:

(*a*) 18 m/s (*b*) 28 m/s
(*c*) 20 m/s (*d*) 19 m/s

32. From a balloon rising vertically upward at 6m/s a stone is thrown up at 16 m/s relative to the balloon. Its velocity with respect to the ground after 2 second is:

(*a*) 10 m/s (*b*) 4 m/s
(*c*) 6 m/s (*d*) 2 m/s

33. Water drops falls at regular intervals from a tap which is 8 m above the ground. The third drop is leaving the tap at the instant the first drop touches the ground the second drop at that instant, is at height:

(*a*) 2 m (*b*) 6 m
(*c*) 4 m (*d*) 6.05 m

34. Two balls A & B, mass of A is 'm' and that of B is '5m' are dropped from the towers of height 36 m and 64 m respectively. The ratio of the time taken by them to reach the ground is:

(*a*) 0.75 (*b*) 3/4
(*c*) Both (a) and (b) (*d*) 5/2

35. A man throws a ball vertically upward and it rises through 40 m and returns to his hands, what was the ascent initial velocity of the ball and for how much time (T) it remained in the air?

(*a*) $T = 5$ sec, $u = 20\sqrt{3}$ m/s
(*b*) $T = 5.64$ sec, $u = 10\sqrt{2}$ m/s
(*c*) $T = 5.64$ sec, $u = 20\sqrt{2}$ m/s
(*d*) None of these

36. A lift is coming from 8th floor and is just about to reach 4th floor. Taking ground floor as origin and positive direction upwards for all quantities, which one of the following is correct?

(*a*) $x < 0, v < 0, a > 0$ (*b*) $x > 0, v < 0, a < 0$
(*c*) $x > 0, v < 0, a > 0$ (*d*) $x > 0, v > 0, a < 0$

MOTION WITH NON-UNIFORM ACCELERATION, APPLICATION OF CALCULUS

37. The velocity of the particle at any time t is given by $V = 2t(3 - t)$ ms^{-1}. At what time is its velocity maximum?

(*a*) 2 second (*b*) 1.5 seconds
(*c*) 1 second (*d*) 5 second

38. The acceleration a of the body starting from rest varies with time following the equation $a = 8t + 5$. The velocity of the body at time t = 2 sec will be:

(*a*) 22 m/s (*b*) 26 m/s
(*c*) 28 m/s (*d*) 30 m/s

Paragraph for Q. 39 to 42

Given questions are based on following passage. Choose the correct option from those given below.

The position of an object moving along X-axis is given by $x = a + bt^2$, where a = 8.5 m, b = 2.5 ms^{-2} and t is measured in seconds.

39. The velocity at t = 0 s is:

(*a*) 0 m s^{-1} (*b*) 10 m s^{-1}
(*c*) 8.5 m s^{-1} (*d*) 2.5 m s^{-1}

40. The velocity at t = 2.0 s is:

(*a*) 10 m s^{-1} (*b*) 0 m s^{-1}
(*c*) 5 m s^{-1} (*d*) 2.5 m s^{-1}

41. The average velocity between t = 2.0 s and t = 4.0 s is:

(*a*) 30
(*b*) 15 m s^{-1}
(*c*) 10 m s^{-1}
(*d*) None of these

42. The position of an object moving along X-axis is given by $x = a - bt^2$, where a = 8.5 m, b = 2.5 ms^{-2} and t is measured in seconds. For the given situation, match the terms in Column I with the values of Column II and choose the correct option from the codes given below:

	Column I		Column II
A.	Velocity of object at t = 2.0 s	1.	– 15 ms^{-1}
B.	Velocity of object at t = 0s	2.	– 10 ms^{-1}
C.	Instantaneous speed of object at t = 2.0 s	3.	0 ms^{-1}
D.	Average velocity between t = 2.0 s and t = 4.0 s	4.	10 ms^{-1}

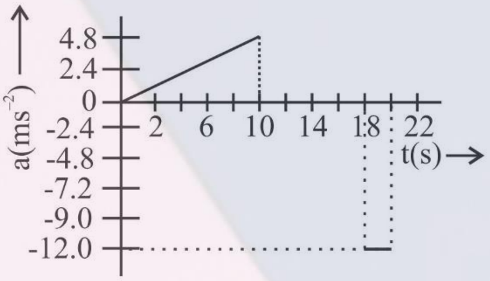
Codes:

(*a*) A-1 B-2 C-3 D-4
(*b*) A-2 B-3 C-4 D-1
(*c*) A-4 B-3 C-2 D-1
(*d*) A-3 B-2 C-1 D-4

GRAPHICAL REPRESENTATION OF MOTION

43. The slope of the tangent to the v - t curve gives the value of:

(*a*) Instantaneous acceleration
(*b*) Instantaneous velocity
(*c*) Average acceleration
(*d*) Centripetal acceleration

44. 

With reference to the above graph there are three statements given below. Which of the statement(s) is/are correct?

I. The acceleration is non-uniform over, the period 0 s to 10 s

II. The acceleration is zero between 10 s to 18 s

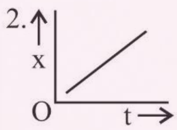
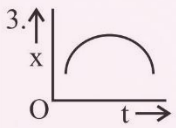
III. The acceleration is constant with value –12 ms^{-2} between 18 s to 20 s

Choose the correct option from those given below.

(*a*) Only I (*b*) I and II

(*c*) II and III (*d*) I, II and III

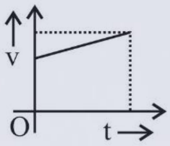
45. Match the terms in Column I with items (position-time graph) in Column II and choose the correct option from the codes given below:

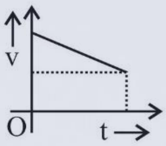
Column I	Column II
A. Positive acceleration	1. 
B. Negative acceleration	2. 
C. Zero acceleration	3. 

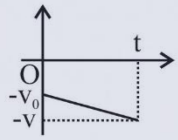
Codes:

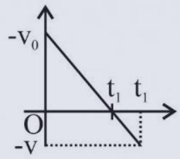
(*a*) A-1 B-2 C-3
(*b*) A-1 B-3 C-2
(*c*) A-2 B-1 C-3
(*d*) A-3 B-2 C-1

46. An object is moving in a positive direction with a positive acceleration. The velocity-time graph with constant acceleration which represents the above situation is:

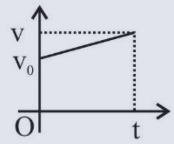
(*a*) 

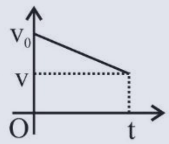
(*b*) 

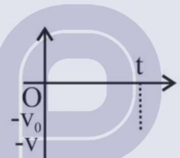
(*c*) 

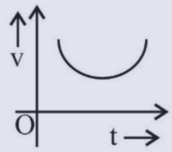
(*d*) 

47. The velocity-time graph for motion with constant acceleration for an object moving in positive direction with a negative acceleration is:

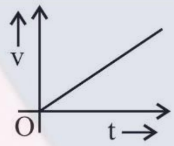
(*a*) 

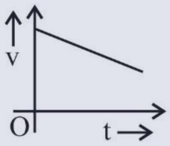
(*b*) 

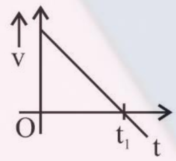
(*c*) 

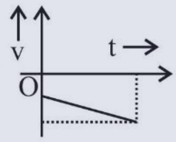
(*d*) 

48. An object is moving in negative direction with a negative acceleration. The velocity-time graph with constant acceleration which represents the above situation is:

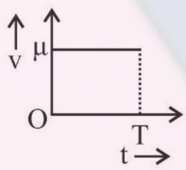
(*a*) 

(*b*) 

(*c*) 

(*d*) 

49. The v-t curve shown above is a straight line parallel to time-axis. The displacement in the time interval t = 0 and t = T is equal to



(*a*) μT

(*b*) Area of the rectangle of height μ and base T

(*c*) Both (*a*) and (*b*)

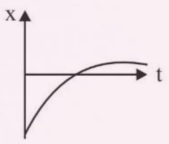
(*d*) Slope of the curve

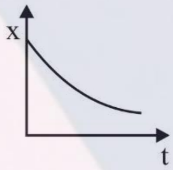
50. The displacement time graph for two particles A & B are straight line inclined at the angles of 30° & 45° with the time axis. The ratio of velocities of $V_A : V_B$ is:

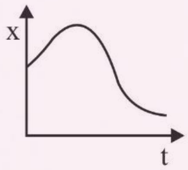
(*a*) $\frac{1}{\sqrt{3}}$ (*b*) $2\sqrt{3}$

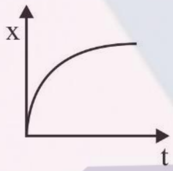
(*c*) $\frac{2}{\sqrt{3}}$ (*d*) $\sqrt{3}$

51. Among the four graph shown in the figure there is only one graph for which average velocity over the time interval (0, T) can vanish for a suitably chosen T. Which one is it?

(*a*)


(*b*)


(*c*)


(*d*)


RELATIVE MOTION IN 1 D

52. A bus begins to move with an acceleration of 1 ms^{-2}. A man who is 48 m behind the bus starts running at 10 ms^{-1} to catch the bus. The man will be able to catch the bus after:

(*a*) 6 s (*b*) 12 s

(*c*) 3 s (*d*) 8 s

53. An elevator car whose floor to ceiling distance is equal to 3.8m, starts ascending with constant acceleration of 2.2 m/s^2, 4 second after the start a bolt begins falling from the ceiling of the car. The free fall time of the bolt is:

(*a*) 0.132 second

(*b*) 0.931 second

(*c*) 1 second

(*d*) 0.795 second

54. Two trains one 60 m long and other is 80 m long are travelling in opposite direction with velocity 10 m/s and 25 m/s. The time of crossing is:

(*a*) 4 second (*b*) 5 second

(*c*) 6 second (*d*) 3 second

55. Two trains are moving with equal speed in opposite directions along two parallel railway tracks. If the wind is blowing with speed u along the track so that the relative velocities of the trains with respect to the wind are in the ratio 1 : 2, then the speed of each train must be:

(*a*) 3u (*b*) 2u

(*c*) 5u (*d*) 4u

56. Two balls are dropped from same height at 1 second interval of time. The separation between the two balls after 4 second of the drop of the 1st ball is:

(*a*) 30 m (*b*) 35 m

(*c*) 40 m (*d*) 48 m

Learning Plus

1. The numerical ratio of distance to displacement is:

(*a*) Always equal to one

(*b*) Always less than one

(*c*) Always greater than one

(*d*) Equal to or more than one

2. A wheel of radius 3 m rolls forward half a revolution on a horizontal ground. The magnitude of the displacement of the point of the wheel initially in contact with the ground is:

(*a*) 2π m (*b*) $\sqrt{2\pi}$ m

(*c*) $\sqrt{\pi^2+4}$ m (*d*) $3\sqrt{\pi^2+4}$

3. The displacement of a body along *x*-axis depends on time as $\sqrt{x} = 3t + 5$. Then the velocity of body:

(*a*) Increase with time (*b*) Independent of time

(*c*) Decrease with time (*d*) None of these

4. A particle is moving with a constant speed V in a circle. What is the magnitude of average velocity after one-fourth rotation?

(*a*) $\frac{\pi V}{\sqrt{2}}$ (*b*) $\frac{\sqrt{2}V}{\pi}$

(*c*) $\frac{2\sqrt{2}V}{\pi}$ (*d*) $\frac{\pi R}{2V}$

5. A bullet fired into a fixed target loses half of its velocity after penetrating 4 cm. How much further it will penetrate before coming to rest assuming that it faces constant resistance to motion?

(*a*) 0.2 cm (*b*) 5 cm

(*c*) 3 cm (*d*) 1.33 cm

6. A juggler maintains four balls in motion making each of them to rise of height of 40m from his hand, what time interval should be maintain for the proper distance between them?

(*a*) 1.71 seconds (*b*) 2.14 seconds
(*c*) 1.41 seconds (*d*) 4 seconds

7. A particle start from rest with a velocity of 10 m/s and moves with a constant acceleration till the velocity increases to 100 m/s. At an instant the acceleration is simultaneously reversed, what will be the velocity of the particle when it comes back to the starting point?

(*a*) 10 m/s (*b*) 20 m/s
(*c*) 30 m/s (*d*) 40 m/s

8. Two balls of different masses m_a & m_b are dropped from two different heights a and b. The ratio of the time taken by balls to cover these distances are:

(*a*) 1 (*b*) $\sqrt{a/b}$
(*c*) b : a (*d*) a : b

9. A stone is dropped from a bridge at a height of 180 m over a river. After 3 second, a second ball is thrown straight downwards. What should be the initial velocity of the second ball so that both hit the water simultaneously?

(*a*) 45 m/s (*b*) 46 m/s
(*c*) 50 m/s (*d*) 55 m/s

10. When a ball is thrown up vertically with velocity V_0, it reaches a maximum height of h. If one wishes to triple the maximum height then the ball should be thrown with velocity:

(*a*) $\sqrt{3}V_0$ (*b*) $3\ V_0$
(*c*) $9\ V_0$ (*d*) $3/2\ V_0$

11. A body thrown upwards with some velocity reaches the maximum height of 50 m. Another body with double the mass thrown up with four times the initial velocity will reach a maximum height of:

(*a*) 600 m (*b*) 200 m
(*c*) 800 m (*d*) 100 m

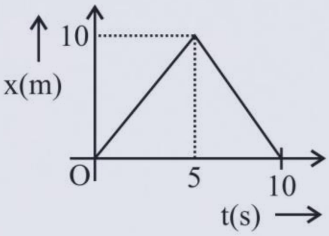
12. A ball is projected vertically upwards, the time corresponding to height *h* while ascending and while descending are t_1 and t_2 respectively. Then the velocity of projection is:

(*a*) $\frac{g(t_1+t_2)}{2}$ (*b*) $t_1 + t_2$
(*c*) $2g(t_1 + t_2)$ (*d*) $\frac{3}{2}g(t_1 + t_2)$

13. If the velocity of a car is given by $v = (150 - 10x)^{1/2}$ m/s. If car retards their motion by applying brakes then what will be the acceleration?

(*a*) 1 m/s^2 (*b*) 2 m/s^2
(*c*) 5 m/s^2 (*d*) –5 m/s^2

14. The x-t graph for motion of a car is given below. With reference to the graph which of the given statement (s) is/are correct?



A. The instantaneous speed during the interval t = 5 s to t = 10 s is negative at all time instants during the interval.

B. The velocity and the average velocity for the interval t = 0 s to t = 5 is equal and positive.

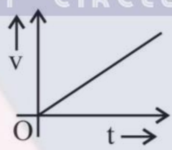
C. The car changes its direction of motion at t = 5 s

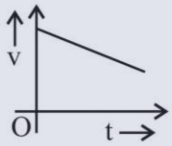
D. The instantaneous speed and the instantaneous velocity is positive at all time instants during the interval t = 0 s to t = 5 s

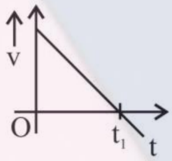
Choose the correct option:

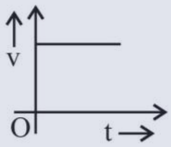
(*a*) A, B and C (*b*) B and C
(*c*) B, C and D (*d*) A, B, C and D

15. An object is moving in positive direction till time t and then turns back with the same negative acceleration. The velocity time graph which best describes the situation is:

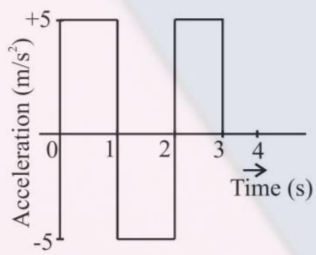
(*a*) 

(*b*) 

(*c*) 

(*d*) 

16. A particle starts from rest at t = 0 and moves in a straight line with an acceleration shown below. The velocity of the particle at t = 3 s is:



(*a*) 5 m/s (*b*) 6 m/s
(*c*) 10 m/s (*d*) 15 m/s

17. A train of 200 m long travelling at 50 m/s overtakes another train 130 m long travelling at 30 m/s. The time taken by the first train to pass the second train is:

(*a*) 15 second (*b*) 17 second
(*c*) 16.5 second (*d*) 18 second

18. The distance between two trucks moving towards each other is decreasing at the rate of 10 m/s. If these trucks travel with same speeds in same direction the separation increases at the rate of 5 m/s. The velocity of the trucks are:

(*a*) $V_1 = 8.5$ m/s , $V_2 = 1.5$ m/s
(*b*) $V_1 = 7.5$ m/s , $V_2 = 2.5$ m/s
(*c*) $V_1 = 5$ m/s , $V_2 = 5$ m/s
(*d*) None of these

19. A bus is moving with a speed of 10 m/s on the straight road. A scooterist wishes to overtake the bus in 50 seconds. If the bus is at a distance of 1 km from the scooterist, with what speed should the scooterist chase the bus?

(*a*) 50 m/s (*b*) 60 m/s
(*c*) 80 m/s (*d*) 30 m/s

20. A rocket travelling at a speed of 200 m/s ejects its products of combustion at the speed of 1200 m/s relative to the rocket, then the speed of escaping vapours with respect to the person on the ground is:

(*a*) 1000 ms^{-1} (*b*) 1200 m/s
(*c*) 1400 m/s (*d*) 200 m/s

21. Two sphere of same size, one of mass 2kg and another of mass 4 kg, are dropped simultaneously from the top of Qutab Minar (height = 72 m). When they are 1 m above the ground, the two spheres have the same:

(*a*) Momentum (*b*) Kinetic energy
(*c*) Potential energy (*d*) Acceleration

22. On a long horizontally moving belt, a child runs to and fro with a speed 9 km h^{-1} (with respect to the belt) between his father and mother located 50 m apart on the moving belt. The belt moves with a speed of 4 km h^{-1}. For an observer on a stationary platform, the speed of the child running in the direction of motion of the belt is:

(*a*) 4 km h^{-1} (*b*) 5 km h^{-1}
(*c*) 9 km h^{-1} (*d*) 13 km h^{-1}

23. From a building two balls A and B are thrown such that A is thrown upwards and B downwards with same velocity. V_A & V_B are the velocities on reaching the ground then:

(*a*) $V_B > V_A$
(*b*) $V_A = V_B$
(*c*) $V_A > V_B$
(*d*) Velocity depends upon mass

24. An object falling through a fluid is observed to have acceleration given by a = g – bv where g = gravitational acceleration and b is constant. After a long time of release, it is observed to fall with constant speed. The value of constant speed is

(*a*) $\frac{g}{b}$ (*b*) $\frac{b}{g}$
(*c*) bg (*d*) b

25. The velocity υ and displacement r of a body are related as $\upsilon^2 = kr$, where k is a constant. What will be the velocity after 1 second? (Given that the displacement is zero at t = 0).

(*a*) $\sqrt{kr}$ (*b*) $kr^{3/2}$
(*c*) $\frac{k}{2}r^0$ (*d*) Data is not sufficient

Multiconcept MCQs

1. A ball is dropped on the floor from a height of 10 m. It rebounds to a height of 2.5 m. If the ball is in contact with the floor for 0.01 second, the average acceleration during contact is:

(*a*) 2121 m/s^2 downward (*b*) 2121 m/s^2 upward
(*c*) 1400 m/s^2 (*d*) 700 m/s^2

2. A shuttle cork hitted upward from badminton racket with a velocity of 50 m/s and it reaches 3 m from the hitting point in last seconds of its upward journey. If the same shuttle cork is hitted upward with a velocity of 200 m/s, then what will be the distance travelled in last second of its upward journey?

(*a*) 111 m
(*b*) 170 m
(*c*) 153 m
(*d*) 120 m

3. A balloon is rising vertically up with a velocity of 30 m/s. A stone is dropped from it reaches the ground in 8 seconds. The height of the balloon when the stone was dropped from it is:

(*a*) 80 m
(*b*) 100 m
(*c*) 85 m
(*d*) 95 m

4. A bird is tossing (flying to and fro) between two cars moving towards each other on a straight road. One car has speed of 27 km h^{-1} while the other has the speed of 18 km h^{-1}. The bird starts moving from first car towards the other and is moving with the speed of 36 km h^{-1} when the two cars were separated by 36 km. The total distance covered by the bird is:

(*a*) 28.8 km (*b*) 38.8 km
(*c*) 48.8 km (*d*) 58.8 km

5. A stone is dropped from the top of tall cliff and n seconds later another stone is thrown vertically downwards with a velocity u. Then the second stone overtakes the first, below the top of the cliff at a distance given by:

(*a*) $\frac{g}{2}\left[\frac{n\left(u-\frac{gn}{2}\right)}{(u-gn)}\right]^2$ (*b*) $\frac{g}{2}\left[\frac{n\left(\frac{u}{2}-gn\right)}{(u-gn)}\right]^2$

(*c*) $\frac{g}{2}\left[\frac{n\left(\frac{u}{2}-gn\right)}{\left(\frac{u}{2}-gn\right)}\right]^2$ (*d*) $\frac{g}{5}\left[\frac{(u-gn)}{\left(\frac{u}{2}-gn\right)}\right]^2$

6. A ball is released from the top of a tower of height h. It taken T seconds to reach the ground. What is the position of the ball at T/3 seconds?

(*a*) h/9 from ground (*b*) 7h/9 form ground
(*c*) 8h/9 from ground (*d*) 17h/18 from ground

7. A particle traveling along a straight line traverse one third of the total distance with a velocity V_0. The remaining part of the distance was covered with a velocity V_1 for half the time and velocity V_2 for the other half of the time. Find the mean velocity of the point averaged over the whole motion of time:

(*a*) $\frac{3V_0(V_1+V_2)}{V_1+V_2+12V_0}$ (*b*) $\frac{V_0(V_1+V_2)}{V_1+V_2+12V_0}$

(*c*) $\frac{V_0}{V_1+V_2+V_0}$ (*d*) $\frac{V_1+V_2+V_0}{V_0}$

8. Two bikes A and B are moving in the same direction with velocities u_A and u_B ($u_A > u_B$). When the bike A is at a distance s behind the bike B, the driver of the bike A applies breaks producing a uniform retardation α. There collision in the two bikes is avoided only when:

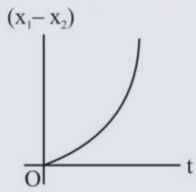
(*a*) $s < \frac{(u_A-u_B)^2}{2\alpha}$

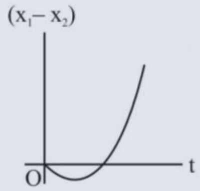
(*b*) $s = \frac{(u_A-u_B)^2}{2\alpha}$ only

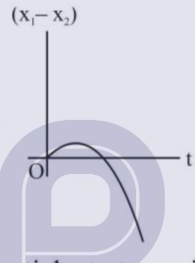
(*c*) $s \geq \frac{(u_A-u_B)^2}{2\alpha}$

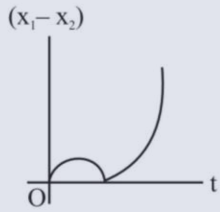
(*d*) $s \leq \frac{(u_A-u_B)^2}{2\alpha}$

9. A body is at rest at x = 0. At t = 0, it starts moving in the positive x-direction with a constant acceleration. At the same instant another body passes through *x* = 0 moving in the positive x-direction with a constant speed. The position of the first body is given by x_1 (t) after '*t*' and that of the second body by x_2 (t) after the same time interval. Which of the following graphs correctly describes $(x_1 - x_2)$ as a function of time '*t*' ?

(*a*) 

(*b*) 

(*c*) 

(*d*) 

10. A particle starts moving rectilinearly at time t = 0 such that its velocity 'v' changes with time 't' according to the equation $v = t^2 - t$ where t is in seconds and v is in m/s. The time interval for which the particle retards is:

(*a*) t < 1/2
(*b*) 1/2 < t < 1
(*c*) t > 1
(*d*) t < 1/2 and t > 1

11. A particle moving with uniform acceleration has average velocities V_1, V_2 and V_3 over the successive intervals of time t_1, t_2 and t_3 respectively. The value of $\frac{(V_1 - V_2)}{V_2 - V_3}$ will be:

(*a*) $\frac{t_1-t_2}{t_2-t_3}$ (*b*) $\frac{t_1-t_2}{t_2+t_3}$

(*c*) $\frac{t_1+t_2}{t_2-t_3}$ (*d*) $\frac{t_1+t_2}{t_2+t_3}$

12. The relation between time and displacement is $t = \alpha x^2 + \beta x$, where α, β are constants. The retardation is:

(*a*) $2\alpha v^3$ (*b*) $2\beta v^3$
(*c*) $2\alpha\beta v^3$ (*d*) $2\beta^2 v^3$

13. A stone is dropped from the top of a tower of height *h*. After 1 second another stone is dropped from the balcony 20 m below the top, both reach the bottom simultaneously. What is the value of *h*?

(*a*) 31.25 m (*b*) 100 m
(*c*) 120 m (*d*) 130 m

14. A crazy ball is dropped on to the floor from the hand of the children from the height of 2 m. It rebounds to the height of 1.5 m. If the ball was in contact with the floor for 0.02 second, what was the average acceleration during contact?
(a) 544.5 ms^{-2} (b) 600 ms^{-2}
(c) 589.5 ms^{-2} (d) 400 ms^{-2}

15. A particle moves along a straight line OX. At a time t (in seconds) the distance x (in metres) of the particle from O is given by $x = 20 + 14t - t^3$. How long would the particle travel before coming to rest:
(a) $(3)^{1/2}$ (b) $(5)^{1/2}$
(c) $(8)^{1/2}$ (d) $(18)^{1/2}$

NEET Past 10 Years Questions

1. A toy car with charge q moves on a frictionless horizontal plane surface under the influence of a uniform electric field $\vec{E}$. Due to the force $q\vec{E}$, its velocity increases from 0 to 6 m/s in one second duration. At that instant the direction of the field is reversed. The car continues to move for two more seconds under the influence of this field. The average velocity and the average speed of the toy car between 0 to 3 second are respectively *(2018)*
(a) 1 m/s, 3.5 m/s (b) 1 m/s, 3 m/s
(c) 2 m/s, 4 m/s (d) 1·5 m/s, 3 m/s

2. Preeti reached the metro station and found that the escalator was not working. She walked up the stationary escalator in time t_1. On other days, if she remains stationary on the moving escalator, then the escalator takes her up in time t_2. The time taken by her to walk up on the moving escalator will be: *(2017-Delhi)*
(a) $\frac{t_1 t_2}{t_2 - t_1}$ (b) $\frac{t_1 t_2}{t_2 + t_1}$
(c) $t_2 - t_1$ (d) $\frac{t_1 + t_2}{2}$

3. The 'x' and 'y' coordinates of the particle at any time are 'x' = $5t - 2t^2$ and 'y' = 10t, respectively, where 'x' and 'y' are in metres and 't' in seconds. The acceleration of the particle at t = 2 s is: *(2017-Delhi)*
(a) 5 m/s^2 (b) –4 m/s^2
(c) –8 m/s^2 (d) 0

4. Two cars P and Q start from a point at the same time in a straight line and their positions are represented by $X_P(t) = at + bt^2$ and $X_Q(t) = ft - t^2$. At what time do the cars have the same velocity? *(2016 - II)*
(a) $\frac{a+f}{2(1+b)}$ (b) $\frac{f-a}{2(1+b)}$
(c) $\frac{a-f}{1+b}$ (d) $\frac{a+f}{2(b-1)}$

5. If the velocity of a particle is $v = At + Bt^2$, where A and B are constants, then the distance travelled by it between 1 s and 2 s is: *(2016 - I)*
(a) $\frac{3}{2}A + 4B$ (b) 3A + 7B
(c) $\frac{3}{2}A + \frac{7}{3}B$ (d) $\frac{A}{2} + \frac{B}{3}$

6. A particle of unit mass undergoes one dimensional motion such that its velocity varies according to $v(x) = \beta x^{-2n}$ where β and n are constants and x is the position of the particle. The acceleration of the particle as a function of x, is given by: *(2015)*
(a) $-2n\beta^2 x^{-4n-1}$ (b) $-2\beta^2 x^{-2n+1}$
(c) $-2n\beta^2 e^{-4n+1}$ (d) $-2n\beta^2 x^{-2n-1}$

7. A stone falls freely under gravity. It covers distances h_1, h_2 and h_3 in the first 5 seconds, the next 5 seconds and the next 5 seconds respectively. The relation between h_1, h_2 and h_3 is: *(2013)*
(a) $h_1 = h_2 = h_3$
(b) $h_1 = 2h_2 = 3h_3$
(c) $h_1 = \frac{h_2}{3} = \frac{h_3}{5}$
(d) $h_2 = 3h_1$ and $h_3 = 3h_2$

8. The motion of a particle along a straight line is described by equation : $x = 8 + 12t - t^3$ where x is in metre and t in second. The retardation of the particle when its velocity becomes zero, is: *(2012 Pre)*
(a) 24 ms^{-2} (b) Zero
(c) 6 ms^{-2} (d) 12 ms^{-2}

ANSWER KEY

Topicwise Questions

1. (b)	2. (a)	3. (c)	4. (c)	5. (b)	6. (a)	7. (d)	8. (a)	9. (b)	10. (b)
11. (c)	12. (a)	13. (d)	14. (a)	15. (b)	16. (a)	17. (d)	18. (b)	19. (c)	20. (b)
21. (a)	22. (b)	23. (a)	24. (b)	25. (b)	26. (c)	27. (a)	28. (d)	29. (b)	30. (a)
31. (c)	32. (d)	33. (b)	34. (c)	35. (c)	36. (a)	37. (b)	38. (b)	39. (a)	40. (a)
41. (b)	42. (b)	43. (a)	44. (d)	45. (b)	46. (a)	47. (b)	48. (d)	49. (c)	50. (a)
51. (c)	52. (d)	53. (a)	54. (a)	55. (a)	56. (b)				

Learning Plus

1. (d)	2. (d)	3. (a)	4. (c)	5. (d)	6. (c)	7. (a)	8. (b)	9. (a)	10. (a)
11. (c)	12. (a)	13. (d)	14. (b)	15. (c)	16. (a)	17. (c)	18. (b)	19. (d)	20. (a)
21. (d)	22. (d)	23. (b)	24. (a)	25. (c)					

Multiconcept MCQs

1. (b)	2. (c)	3. (a)	4. (a)	5. (a)	6. (c)	7. (a)	8. (c)	9. (b)	10. (b)
11. (d)	12. (a)	13. (a)	14. (c)	15. (b)					

NEET Past 10 Years Questions

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

Topicwise Questions

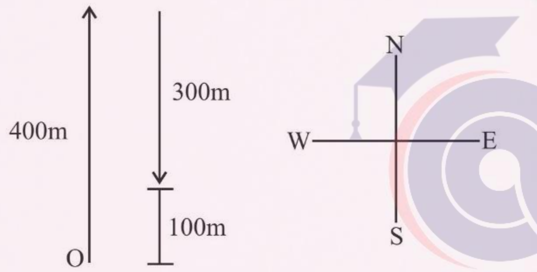
1. (*b*) Position of the man $\vec{r} = 30\hat{i} + 20\hat{j}$; initial position $\vec{r}_0 = 0\hat{i} + 0\hat{j}$

Displacement = change in position $= \vec{r} - \vec{r}_0 = 20\hat{i} + 30\hat{j}$

Magnitude of displacement is $= \sqrt{(20)^2 + (30)^2}$

$r = \sqrt{400 + 900} \qquad = \sqrt{1300} = 36.05\,\text{m}$

2. (*a*) An aeroplane flies 400 m north and 300 m south so let aeroplane starts there journey from point O



Net displacement of the plane is 100 m, after it flies 1200 m upward; so the displacement or position is-

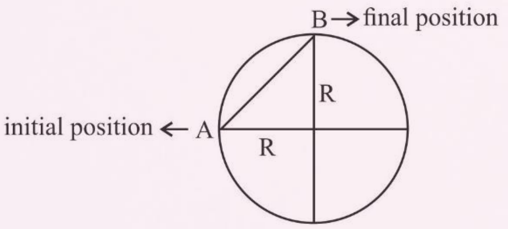
$\vec{r} = 100\hat{i} + 1200\hat{j}$

Magnitude of displacement $= r = \sqrt{(100)^2 + (1200)^2}$

$r = \sqrt{10000 + 1440000}$

$= 1204 \text{ m} \quad \simeq 1200$

3. (*c*)



∴ Displacement is line segment AB

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

4. (*c*) Displacement = (7m, –2m, –3m) – (–4m, –5m, +8m)

= (11m, 3m, –11m)

5. (*b*) Displacement is denoted by Δx, in time $\Delta t = t_2 - t_1$ is given by the difference between final position (t_2) and initial position (t_1).

6. (*a*) Displacement $= \Delta x = x_2 - x_1$

For journey, displacement of car moving from O to P,

$x_2 = +360$ m $\qquad x_1 = 0$ m

$\Rightarrow \quad \Delta x = x_2 - x_1 = 360 - 0 = +360$ m

For journey, displacement in moving from P to Q

$x_2 = +240$ m $\qquad x_1 = +360$ m

$\Rightarrow \quad \Delta x = x_2 - x_1 = 240 - 360 = -120$ m

Here, –ve sign implies that the displacement is in –ve direction i.e., towards left.

7. (*d*) For motion of the car from O to P

Displacement $= \Delta x = x_2 - x_1 = +360\text{ m} - 0\text{ m} = +360$ m

Path length = Distance OP = 360

So, displacement and path length are same.

For motion of the car from O to P and back to Q

Displacement $= \Delta x = x_2 - x_1 \ = +240\text{ m} - 0\text{ m} \ = +240$ m

Path length = OP + PQ $\quad$ = + 360 m + (+ 120 m)

= + 480 m = 480 m

So, displacement and path length are not equal.

8. (*a*) Displacement $= \Delta x = x_2 - x_1 = 0 - 0 = 0$ m

Path length of the journey

= OP + PO = + 360 m + (+ 360)m $\quad$ = 720 m

9. (*b*) Given, $x = (t-2)^2$

Velocity, $v = \frac{dx}{dt} = \frac{d}{dt}(t-2)^2 = 2(t-2)\,\text{m/s}$

Acceleration, $a = \frac{dv}{dt} = \frac{d}{dt}[2(t-2)] = 2[1-0] = 2\ \text{m/s}^2$

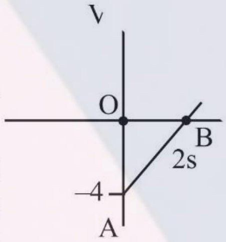
When,

$t = 0,\ v = -4$ m/s

$t = 2s;\ v = 0$ m/s

$t = 4s;\ v = 4$ m/s

v – t graph is shown in adjacent diagram.



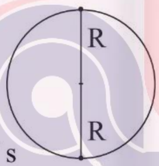
Distance traveled = area of the graph = area OAB + area CBD

$\Rightarrow 4 + 4 = 8\text{m}$

10. (*b*) Displacement is zero

11. (*c*) When particle is moving with uniform velocity then acceleration is always zero. Under uniform motion speed also remains constant.

12. (*a*) Displacement = 2R



Time = 20 sec.

Average velocity $= \frac{2R}{20} = \frac{2\times 80}{20} = 8\ \text{m/s}$

13. (*d*) $x = a + bt^2$

Differentiating both side

$$\frac{dx}{dt} = \frac{d(a+bt^2)}{dt} \Rightarrow V = 0 + 2bt$$

$V = 0 + 2 \times 15 \times 3 \Rightarrow V = 90\ \text{cms}^{-1}$

14. (*a*) Average speed $= \frac{\text{Total distance}}{\text{Total time}}$

Total time is $t_1 + t_2 + t_3$

$$t_1 = \frac{x}{3\times 20},\ t_2 = \frac{x}{3\times 40},\ t_3 = \frac{x}{3\times 60}$$

$$\therefore \text{Average speed} = \frac{x}{\frac{x}{3\times 20}+\frac{x}{3\times 40}+\frac{x}{3\times 60}}$$

$$= \frac{x}{\frac{x}{3}\left(\frac{1}{20}+\frac{1}{40}+\frac{1}{60}\right)} = \frac{3}{\frac{9+4.5+3}{180}} = \frac{3\times 180}{16.5}$$

Average speed = 32.7 m/s

Short trick: $\text{Av.speed} = \frac{3\times 20\times 40\times 60}{20\times 40 + 40\times 60 + 60\times 20}$

$$= \frac{144000}{800+2400+1200} = \frac{144000}{4400} = 32.7\ \text{m/s}$$

15. (*b*) Average velocity $= \frac{\text{Total distance / displacement}}{\text{Total time}}$

Total time $= t_1 + t_2$

Now, $t_1 = \frac{x}{2\times 40},\ t_2 = \frac{x}{2\times 80}$

$$\therefore \text{Average velocity} = \frac{x}{\frac{x}{2\times 40}+\frac{x}{2\times 80}}$$

$$= \frac{x}{\frac{x}{2}\left(\frac{1}{40}+\frac{1}{80}\right)} = \frac{1}{\frac{1}{80}\left(1+\frac{1}{2}\right)}$$

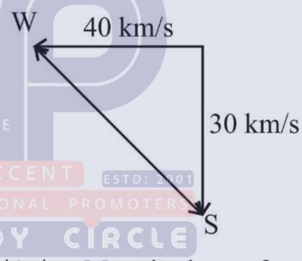
$$= \frac{80}{3/2} = \frac{160}{3} = 53.3\ \text{km/hr}$$

Short Trick:

$$\text{av. velocity} = \frac{2\times V_1 \times V_2}{V_1 + V_2} = \frac{2\times 40\times 80}{40+80} = \frac{6400}{120}$$

$= 53.3$ km / hr

16. (*a*)



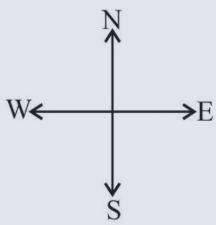
$\Delta v = -40\hat{i} + 30\hat{j}$

$|\Delta v|$ Magnitude of change in velocity

$= \sqrt{(30)^2 + (40)^2} = \sqrt{900+1600}$

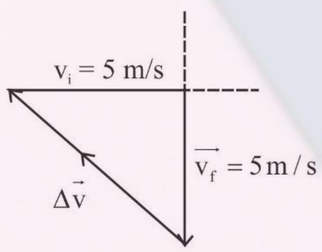
$|\Delta v| = \sqrt{2500} = 50\ \text{km/s}$ $\quad |a| = \frac{50}{10}\text{km/s}^2 = 5\ \text{km/s}^2$

17. (*d*) $v_i = 5$ m/s $\quad v_f = 5$ m/s



$\therefore \Delta v = v_f - (v_i)$

$= v_f + (-v_i)$



$|\Delta v| = \sqrt{(v_f)^2 + (v_i)^2}$ $\quad |\Delta v| = 5\sqrt{2}\ \text{m/s}$

$\Delta t = 10$ seconds

av. acceleration $= \frac{5\sqrt{2}}{10} = \frac{1}{\sqrt{2}}\text{m/s}^2$ (towards north-west)

18. (*b*) For maximum and minimum displacement we have to keep in mind the magnitude and direction of maximum velocity.

As maximum velocity in positive direction is v_0.

Maximum velocity in opposite direction is also v_0.

Maximum displacement in one direction = v_0T

Maximum displacement in opposite directions = $-v_0T$

Hence, $-v_0T < x < v_0T$.

19. (*c*) Time taken to travel first half distance $t_1 = \frac{l/2}{v_1} = \frac{l}{2v_1}$

Time taken to travel second half distance $t_2 = \frac{l}{2v_2}$

Total time = $t_1 + t_2$ $\quad = \frac{l}{2v_1} + \frac{1}{2v_2} = \frac{l}{2}\left[\frac{1}{v_1} + \frac{1}{v_2}\right]$

We know that,

$$V_{av} = \text{Average speed} = \frac{\text{total distance}}{\text{total time}}$$

$$= \frac{l}{\frac{l}{2}\left[\frac{1}{v_1} + \frac{1}{v_2}\right]} = \frac{2v_1v_2}{v_1 + v_2}$$

20. (*b*) Length of the barrel = 1.2 m

Speed of the bullet = 640 ms^{-1}

According to the third equation of motion

$v^2 = u^2 + 2as \qquad v^2 = 0 + 2as$

$640 \times 640 = 2 \times a \times 1.2 \qquad \frac{320 \times 640}{1.2} = a$

$640 = 0 + \frac{640 \times 320}{1.2} \times t \quad \Rightarrow \quad t = \frac{1.2 \times 640}{640 \times 320}$

$t = 0.0037 = t = 3.7 \times 10^{-3} \quad \Rightarrow \quad t \approx 4\text{ms}$

21. (*a*) Displacement in last 2 seconds is

$= S_{15} - S_{13} \quad = a(15-13) + \frac{1}{2}a(15^2 - 13^2)$

$= 10 \times 2 + \frac{1}{2} \times 5 \times (225 - 169) \quad = 20 + 140 \quad = 160\,\text{m}$

22. (*b*) $u = -19.6\ ms^{-1} \qquad a = 9.8\ ms^{-2} \qquad t = 6s$

$S = ut + \frac{1}{2}at^2 \qquad S = -19.6 \times 6 + \frac{1}{2} \times 9.8 \times 6^2$

$\qquad = -19.6 \times 6 + 4.9 \times 36$

$S = 58.8$ m

23. (*a*) $2as = v^2 - u^2 \qquad a = \frac{v^2 - u^2}{2s} = \frac{0 - (40)^2}{2 \times 108} = \frac{-1600}{216}$

$a = -7.4\ m/s^2$

And,

$v = u + at \qquad v - u = at$

$\therefore t = \frac{v - u}{a} = \frac{0 - (40)}{-7.4} = \frac{-40}{-7.4} = 5.4\,s$

24. (*b*) In vertically upward motion V = 0

$v^2 - u^2 = 2as \qquad 0 - (40)^2 = 2 \times -10 \times s$

$-1600 = -20 \times s \quad \Rightarrow +80\ m = s$

25. (*b*) Distance covered in 8[th] second

$$S_{8^{th}} = u + \frac{a}{2}(2n - 1) = 0 + \frac{a}{2}(2 \times 8 - 1)$$

$$S_{8^{th}} = \frac{a}{2}(15)$$

Distance covered in 8 second-

$$S = ut + \frac{1}{2}at^2 \Rightarrow 0 + \frac{1}{2}a \times 64 = 64\left(\frac{a}{2}\right)$$

$$\text{Ratio, } \frac{S_{8^{th}}}{S_8} = \frac{\frac{a}{2}(15)}{\frac{a}{2}(64)} = \frac{15}{64}$$

26. (*c*) $v^2 - u^2 = 2as$

After applying the brakes car will come to rest v = 0

$u^2 \propto s$

$$\therefore \frac{s_1}{s_2} = \frac{u_1^2}{u_2^2} \Rightarrow s_2 = \left(\frac{u_2}{u_1}\right)^2 \times s_1$$

$$s_2 = \left(\frac{30}{10}\right)^2 \times 20 = 9 \times 20 = 180\,\text{m}$$

27. (*a*) Let particle accelerates with acceleration α for time t_1, and retard with retardation $-\beta$ for t_2.

$t_1 + t_2 = 50$

CASE -1	CASE -2
$v = u + \alpha t_1$	$v = u - \beta t_2$
$v = 0 + \alpha t_1$	$0 = u - \beta t_2$
$v = \alpha t_1$	$u = \beta t_2$

Initial velocity is equal to the final velocity of Case I.

$\alpha t_1 = \beta t_2 \qquad \alpha t_1 = 5\alpha t_2$

$\alpha t_1 = 5\alpha t_2 \Rightarrow 5t_2 + t_2 = 50 \qquad 6t_2 = 50 \Rightarrow t_2 = 25/3$ sec.

28. (*d*) As we know the relation $V_{mid} = \sqrt{\frac{V_A^2 + V_B^2}{2}}$

$$V_{mid} = \sqrt{\frac{(60)^2 + (40)^2}{2}} = \sqrt{\frac{3600 + 1600}{2}}$$

$$V_{mid} = \sqrt{\frac{5200}{2}} = \sqrt{2600} = 50.9\,\text{m/s}$$

29. (*b*) As we know that,

$v = u + at$, $v = -2$ m/s, $u = 20$ m/s

(–ve sign) = opposite direction

$\frac{v - u}{t} = a \qquad \frac{-2 - 20}{5} = a \Rightarrow \frac{-22}{5} = a$

Force = ma = $10 \times \frac{-22}{5} = -44\text{N}$

30. (*a*) Body covers equal distance in ascending or descending

$$h = ut + \frac{1}{2}gt^2 \qquad (u = -ve)$$

(g = +ve because after passing highest position motion is under gravity)

$$h = -19.6 \times 10 + \frac{1}{2} \times 10 \times 100 \qquad (g = +ve)$$

$= -196 + 5 \times 100 = 500 - 196 \qquad h = 304$ m

31. (*c*) Stone is dropped, $u = 0$

Let t is the time taken by the stone to cover depth of 20 m.

$$20 = ut + \frac{1}{2}gt^2 \Rightarrow 20 = \frac{1}{2} \times 10 \times t^2 \qquad t = 2$$

Splash heard after 3 second but time taken by stone is 2 second

$\therefore \Delta t = 3 - 2 = 1$ second

or velocity of sound = 20/1 = 20 m/s

32. (*d*) Initial velocity of the balloon w.r.t the ground

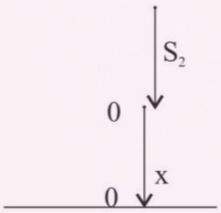
$u = 6 + 16 = 22$ m/s

because thrown velocity of stone and balloon is opposite in direction w.r.t the ground

Velocity after 2 second $\Rightarrow v = u - gt$

$v = 22 - 10 \times 2 \qquad v = 22 - 20 = 2$ m/s

33. (*b*) Time taken by first drop to reach the ground $t = \sqrt{\frac{2h}{g}}$



$$t = \sqrt{\frac{2 \times 8}{10}} = \sqrt{1.6} \Rightarrow t = 1.26\,\text{sec}.$$

As the water drops falls at regular intervals of time. Let it be approx second drop is halfway between third and first drop, so time difference between any two drops = t/2 sec = 1.26/2 = 0.63 sec.

Distance of 2nd drop $S_2 = \frac{1}{2}gt^2 \qquad (u = 0)$

From the tap

$$S_2 = \frac{1}{2} \times 10 \times (0.63)^2 = 2 \text{ m}$$

Distance of drop from ground (x) = 8 – 2 = 6 m

34. (*c*) Time period is independent of mass of body.

$$t = \sqrt{\frac{2h}{g}} \qquad \therefore \frac{t_A}{t_B} = \frac{3}{4}$$

35. (*c*) Velocity of descent or ascent always equal.

$$u = \sqrt{2 \times g \times h} = \sqrt{2 \times 10 \times 40} = \sqrt{800} = 20\sqrt{2} \text{ m/s}$$

Time of ascent and descent always equal.

T = time of ascent + time of descent

$T = t_1 + t_2$

Let t_1 is the time of ascent and t_2 be that of descent

$v = u - gt$

$0 = u - gt_1 \qquad v = u + gt_2$

$u = gt_1 \qquad u = 0 + gt_2$

$t_1 = \frac{u}{g} \qquad \frac{u}{g} = t_2$

$T = t_1 + t_2 \qquad T = \frac{u}{g} + \frac{u}{g} = \frac{2u}{g} = \frac{2 \times \sqrt{800}}{10}$

$T = 4 \times \sqrt{2}$ sec $\qquad T = 4 \times 1.41 = 5.64$ seconds

36. (**a**) As the lift is coming in downward direction, displacement will be negative. We have to see whether the motion is accelerating or retarding.

We know that due to downward motion displacement will be negative. When the lift reaches 4th floor is about to stop hence, motion is retarding in nature. Hence, $x < 0$; $a > 0$.

As displacement is in negative direction, velocity will also be negative i.e., $v < 0$.

37. (*b*) At the time of maximum velocity, acceleration is zero.

$V = 2t(3 - t) \qquad V = 6t - 2t^2$

Differentiating both side

$$\frac{dV}{dt} = \frac{d(6t - 2t^2)}{dt} \qquad 0 = 6 - 4t \qquad t = 1.5$$

38. (*b*) $a = 8t + 5 \Rightarrow \frac{dv}{dt} = 8t + 5 \Rightarrow dv = (8t + 5)dt$

$$\int_0^v dv = \int_0^t (8t + 5)dt \Rightarrow v = \frac{8t^2}{2} + 5t$$

$v = 4t^2 + 5t = 4 \times 4 + 10 = 16 + 10 = 26$ m/s

39. (*a*) Given, $x(t) = a + bt^2$; $\quad (a = 8.5 \text{ m and } b = 2.5 \text{ ms}^{-2})$

In notation of differential calculus, the velocity is

$$v = \frac{dx}{dt} = \frac{d}{dt}(a + bt^2) = 2bt$$

At $t = 0$, $\quad v = 2\,b \times 0 = 0 \text{ ms}^{-1}$

40. (*a*) Since, $\quad v = 2bt$

$\Rightarrow$ At $t = 2$, velocity $= 2 \times 2.5 \times 2 = 10 \text{ ms}^{-1}$

41. (*b*) $$\text{Average velocity} = \frac{x(t_2) - x(t_1)}{t_2 - t_1} = \frac{x(4.0) - x(2.0)}{4.0 - 2.0}$$

Given, $(t) = a + bt^2 \qquad = \frac{(a + 16b) - (a + 4b)}{2.0} = 6.0\,b$

$= 6.0 \times 2.5 = 15 \text{ ms}^{-1}$

42. (*b*) Given, $x(t) = a - bt^2$, $a = 8.5m$ and $b = 2.5m/s^2$ $= 8.5 - 2.5t^2$

Velocity of object $= \frac{dx}{dt} = -2bt$

(A) velocity at $t = 2.0\,s = \left.\frac{dx}{dt}\right|_{t=2} = -4b$

$= -4 \times 2.5 = -10\ ms^{-1}$

(B) velocity at $t = 0 = \left.\frac{dx}{dt}\right|_{t=0} = 0\,ms^{-1}$

(C) Instantaneous speed = Magnitude of velocity

$= |-10\ ms^{-1}| = 10\ ms^{-1}$

(D) Average velocity $= \frac{x(t_2) - x(t_1)}{t_2 - t_1}$

$= \frac{x(4) - x(2)}{4 - 2}$

$= \frac{\left[a - b(4)^2\right] - \left[a - b(2)^2\right]}{2}$

$= \frac{4b - 16b}{2} = -\frac{12b}{2} = -6b$

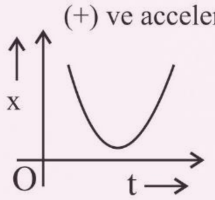
$= -6 \times 2.5\ ms^{-1} = -15\ ms^{-1}$

43. (*a*) The acceleration at an instant is the slope of the tangent to the v - t curve at that instant.

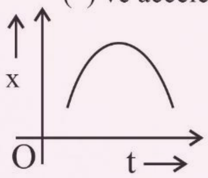
44. (*d*) In graph, non-uniform acceleration during 0s to 10s and acceleration is zero between 10s to 18s and it becomes constant between 18s to 20s.

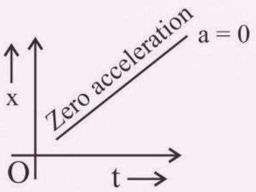
45. (*b*) In position-time curve, upward direction for positive acceleration and downward for negative acceleration and it is straight line for zero acceleration as shown in figure.

(+) ve acceleration

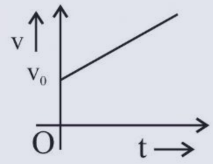


(–) ve acceleration



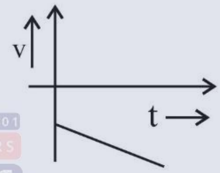


46. (*a*) The velocity-time graph formation with uniform acceleration (constant acceleration) is a straight line inclined to time axis. The above graph is for motion in positive direction as velocity is positive throughout the time interval and is also increasing, so the acceleration is positive. For positive acceleration, the slope of the graph must be positive.



47. (*b*) For object moving in positive direction, the velocity must be positive.
For negative acceleration,the velocity must be decreasing with time or the slope of the straight line must be negative.

48. (*d*) For negative direction, the velocity must be negative throughout the journey.



For negative acceleration,the velocity must be decreasing and hence the slope of the straight line representing the motion must be negative.

49. (*c*) For the graph shown, area under the v-t curve represents area of the rectangle of height μ and base T.

$\because$ Area under the v-t curve

= Displacement during $t = 0$ and $t = T$

$= \mu \times T = \mu T$

50. (*a*) As we know that, $\frac{V_A}{V_B} = \frac{\tan\theta_1}{\tan\theta_2}$

$\therefore \frac{V_A}{V_B} = \frac{\tan 30^0}{\tan 45^0} = \frac{1}{\sqrt{3} \times 1} = \frac{1}{\sqrt{3}}$

51. (*c*) In graph (c) for one value of displacement there are two different points of time. Hence, for one time, the average velocity is positive and for other time it is equally negative.
As there are opposite velocities in the interval 0 to T.
Hence average velocity can vanish.

52. (*d*) We are considering that the man will catch the bus after time t sec. Then, according to the second equation of motion

$$10t = 48 + \frac{1}{2} \times 1 \times t^2$$

$t^2 = 20t + 90 = 0$ $\qquad$ $t^2 - 20t - 90 = 0$

$\Rightarrow (t - 12)(t - 8) = 0$

t = 8 sec. and t = 12 sec.

Minimum time will be considered.

53. (*a*) Effective acceleration is $g + a = 9.8 + 2.2 = 12\ m/s^2$

As we know, $s = ut + \frac{1}{2}a_{eff}t^2$, at the time of free fall

$$u = 0, \text{ then } t = \sqrt{\frac{2s}{g+a}} = \sqrt{\frac{2 \times 3.8}{12}} = \sqrt{\frac{3.8}{6}} = \sqrt{0.633}$$

$t = 0.132$ sec

54. (*a*) Total length of distance that has to be crosses = 60 + 80 = 140 m

Relative speed = 10 + 25 = 35 m/s

$$\text{Time} = \frac{140}{35} = \frac{20}{5} = 4\text{ seconds} \left(\text{Time} = \frac{\text{Displacement}}{\text{Velocity}}\right)$$

55. (*a*) Let the speed of each train be x

Relative velocities of trains are

Train 1, $V_r = x - u$ (wind is along the direction of track)

Train 2, $V_r = x + u$ (Wind is in opposite direction)

According to the question

$$\frac{x-u}{x+u} = \frac{1}{2} \Rightarrow 2x - 2u = x + u \Rightarrow x = 3u$$

56. (*b*) Motion of first ball u = 0 , a = g , t = 4 sec.

We are consider that the s_1 is the distance covered by the first ball in 4 seconds.

$$s_1 = ut + \frac{1}{2}gt^2$$

$$0 + \frac{1}{2} \times 10 \times (4)^2 = 80\,m$$

Let s_2 be the distance covered by the second ball in 2 seconds. t = 3 sec.

$$s_2 = 0 + \frac{1}{2} \times 10 \times (3)^2 = 45\,m$$

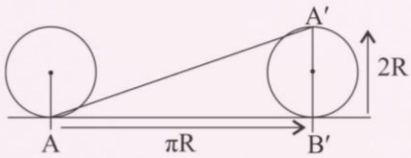
Separation between the two balls

$S_1 - S_2 = 80\ m - 45\ m = 35\ m$

Learning Plus

1. (*d*) $\frac{\text{Distance}}{\text{Displacement}} \geq 1$

2. (*d*) Horizontal distance covered by the wheel in half revolution = $\pi R = 3\pi$



Net displacement of the point which was initially in contact with ground.

$$\text{Displacement} = AA' = \sqrt{(\pi R)^2 + (2R)^2}$$

$$= \sqrt{(3\pi)^2 + (2 \times 3)^2} = \sqrt{9\pi^2 + 36} = 3\sqrt{\pi^2 + 4}$$

3. (*a*) $\sqrt{x} = 3t + 5$

Squaring both side

$(\sqrt{x})^2 = (3t + 5)^2$ $\qquad$ $x = 9t^2 + 25 + 30t$

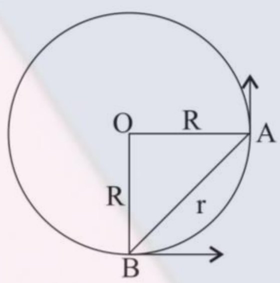
Differentiate both side

$$\frac{dx}{dt} = \frac{d(9t^2 + 30t + 25)}{dt} \qquad V = 18t + 30$$

Velocity will increase with time.

4. (*c*) Let R be the radius of the circle

Displacement of particle = r



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

$$\text{Time} = \frac{\pi R}{2V} \quad (V = \text{velocity})$$

$$r = \sqrt{R^2 + R^2} = \sqrt{2}R$$

$$\text{Average velocity} = \frac{\sqrt{2}R}{\frac{\pi R}{2V}} = \frac{2\sqrt{2}V}{\pi}$$

5. (*d*) **Case I:** Let the initial velocity of the bullet = u

After penetrating its final velocity $=\frac{u}{2}$

From $v^2 - u^2 = 2as$ $\quad \left(\frac{u}{2}\right)^2 - u^2 = 2\times a\times 4$

$\frac{u^2}{4} - u^2 = 2\times a\times 4$

$\frac{-3u^2}{4} = 8\times a \Rightarrow a = \frac{-3u^2}{32}$

Bullet will further penetrate after penetrate 4 cm.

Case II:

Initial velocity $=\frac{u}{2}$ $\quad$ Final velocity = 0

From $v^2 - u^2 = 2as$ $\quad 0^2 - \left(\frac{u}{2}\right)^2 = 2\times\frac{-3u^2}{32}\times s$

$\frac{-u^2}{4} = \frac{-3u^2}{16}\times s \quad \Rightarrow s = \frac{4}{3} = 1.33$ cm

6. (*c*) If t is the total time of flight of ball in going up and coming back, then total displacement in time t is zero because ball comes back in hand of juggler.

When ball is going at the highest point then v = 0

$v^2 - u^2 = 2as \quad 0 - u^2 = 2\times -g\times 40 \quad -u^2 = -80\times 10$

$u = \sqrt{800} \quad u = 2\sqrt{2}\times 10 = 20\sqrt{2}$

Displacement of the ball is zero.

So, $S = ut + \frac{1}{2}(-g)t^2$

(g is negative because acts in opposite direction)

$0 = 20\sqrt{2}t - \frac{1}{2}\times 10t^2 \quad 20\sqrt{2}t = 5t^2$

$\frac{20\sqrt{2}}{5} = t \quad 4\sqrt{2} = t$

$\therefore$ Time interval of each ball

$\frac{4\sqrt{2}}{4} = \sqrt{2} = 1.414\,\text{sec}.$

7. (*a*) According to relation = $v^2 - u^2 = 2as$

$(100)^2 - (10)^2 = 2as$

$10000 - 100 = 2as \quad 9900 = 2as$

Now acceleration just reversed = a = –a

Particle comes back to original position v = ?

$v^2 - u^2 = 2as \quad (v)^2 - (100)^2 = 2(-a)s$

$v^2 = 10000 - 2as \quad v^2 = 10000 - 2as$

Put 2as = 9900 $\quad v^2 = 100 \Rightarrow v = \sqrt{100} = 10\,m/s$

8. (*b*) According to the relation $h = ut + \frac{1}{2}gt^2$

$h = \frac{1}{2}gt^2 \quad (u = 0)$

$h \propto t^2 \quad \therefore t \propto \sqrt{h} \quad$ Hence, $\frac{t_a}{t_b} = \sqrt{\frac{a}{b}}$

9. (*a*) When stone is dropped $S = \frac{1}{2}gt^2 \quad 180 = \frac{1}{2}\times 10\times t^2$

t = 6 seconds

Second ball is taking 3 second to reach the river

$180 = u\times 3 + \frac{1}{2}\times 10\times 9 \Rightarrow 180 = u\times 3 + 5\times 9$

$u = \frac{180-45}{3} = 45\,m/s$

10. (*a*) As we know that $v^2 = u^2 - 2gs$ (for upward motion g = –g)

V = 0 at maximum height

$-u^2 = -2gs \quad u^2 \propto s$

$\frac{V_0^2}{V^2} = \frac{h}{3h} \Rightarrow V = \sqrt{3}V_0$

11. (*c*) $v^2 = u^2 - 2gs \Rightarrow 0 = u^2 - 2gs$

$u^2 = 2gs \Rightarrow u^2 \propto S$

Motion under gravity is independent of mass

$\frac{u^2}{16u^2} = \frac{50}{h} \quad h = 16\times 50 \Rightarrow h = 800$ m

12. (*a*) **Case I:** Ascending

$u = u, \quad V = 0, \quad g = -g, \quad t = t_1$

$V = u + gt \quad 0 = u - gt_1 \quad u = gt_1$

$t_1 = \frac{u}{g}$

Case II: Descending

Similarly

$v = u\ ,\ u = 0\ ,\ g = g\ ,\ t = t_2$

$V = u + gt \quad u = 0 + gt_2 \quad t_2 = \frac{u}{g}$

Total time of journey

$t_1 + t_2 = \frac{u}{g} + \frac{u}{g} \quad t_1 + t_2 = \frac{2u}{g} \Rightarrow u = \frac{g(t_1+t_2)}{2}$

13. (*d*) $v = (150 - 10x)^{1/2} \Rightarrow \frac{dv}{dt} = \frac{d(150-10x)^{1/2}}{dt}\times\frac{dx}{dx}$

$\frac{dv}{dt} = \frac{d(150-10x)^{1/2}}{dx}\times\frac{dx}{dt} \Rightarrow a = \frac{d(150-10x)^{1/2}}{dx}v$

$a = \frac{1}{2}\times(150-10x)^{-1/2}(-10)\times(150-10x)^{1/2}$

$\Rightarrow a = -5\,m/s^2$

14. (*b*) I. The instantaneous speed is always positive as it is the magnitude of the velocity at an instant.

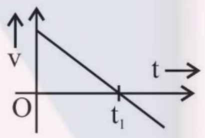
II. For t = 0s to t = 5s, the motion is uniform. So, the average velocity and the instantaneous velocity are equal.

III. During t = 0s to t = 5s. The slope of the graph is positive, hence the average velocity and the velocity both are positive. During t = 5s to t = 10s. The slope of the graph is negative, hence the velocity is negative.

Since, there is change in sign of velocity at t = 5s the car changes its direction at that instant.

IV. In figure, instantaneous speed during t = 5s to t = 10s is negative at all time instants during the interval.

15. (*c*) Here, we observe that the object is moving in positive direction till time $t = 0$ to $t = t_1$ and at $t = t_1$ we find that the velocity become negative i.e., the object changes its direction at $t = t_1$ and continues in negative direction hence forth.



For acceleration we can observe that throughout the journey the slope of the v-t curve is negative and hence, acceleration is negative. Thus, the area under the v-t curve gives displacement.

16. (*a*) Velocity = area under acceleration time graph

Velocity = (5 × 1) – (5 × 1) + (5 × 1)

Velocity = 5 – 5 + 5 = 5 m/s

17. (*c*) Relative velocity of 1st train w.r.t 2nd = 50 – 30 = 20 m/s

Total distance = 130 + 200 = 330

$$\text{Time taken} = \frac{330}{20} = 16.5\,\text{seconds}$$

18. (*b*) According to the given equation

First case: Separation between the trucks decreases at the rate of 10 m/s. Due to the opposite relative motion of trucks towards each other-

$V_1 + V_2 = 10$ (condition given)......(1)

Second case: Separation between the trucks increases due to the opposite relative motion of trucks away from each other-

$V_1 - V_2 = 5$......(2) (condition given)

From equation (1) and (2), we get

$V_1 + V_2 = 10$

$V_1 - V_2 = 5$

$2V_1 = 15$

$V_1 = 7.5$ m/s

By putting the value of V_1 in equation (1)

$7.5 + V_2 = 10 \qquad V_2 = 2.5$ m/s

19. (*d*) Let the velocity of the scooter is V_S

Distance between the bus and scooter is 1 km

Velocity of bus = 10 m/s

Relative velocity of scooter w.r.t the bus = $V_S - 10$

$$\text{Time taken to overtake, } t = \frac{1000}{V_S - 10}$$

$$50 = \frac{1000}{V_S - 10}$$

$50\,V_S - 500 = 1000$

$50V_s = 1500 \quad \Rightarrow V_s = 30$ m/s

20. (*a*) Relative velocity of combustion product of rocket w.r.t the motion of rocket

$\vec{V_c} = +1200\,\text{m/s} \quad \vec{V_r} = -200\,\text{m/s}$

Velocity of vapours is V_V

$\vec{V_c} = \vec{V_v} - (\vec{V_r})$

$1200 = \vec{V_v} - (-200) \quad \vec{V_v} = 1000\,\text{m/s}$

21. (*d*) $P = mV, \quad K = \frac{1}{2}mV^2$

F = Mgh, All are mass dependent. So they would be different. But g = 9.8 m/s^2, which is constant on earth surface.

22. (*d*) Speed of child w.r.t. belt = 9 km/hr

Speed of belt = 4 km/hr

From ground frame

Speed = (9 + 4) = 13 km/hr

23. (*b*) $V_A = V_B$. Since, the motion is uniform. The velocity at each point is same so this velocity of A after coming back is also V_A, just the direction is reversed. Thus $V_A = V_B$.

24. (*a*) Here, a = g – bv

When an object falls with constant speed v_c, its acceleration becomes zero.

$$\therefore\ g - bv_c = 0 \text{ or } v_c = \frac{g}{b}$$

25. (*c*) $v^2 = kr$ or $v = \sqrt{kr}$

$$\frac{dv}{dt} = \sqrt{k}\frac{1}{2}r^{-1/2}\frac{dr}{dt} = \sqrt{k}\frac{1}{2}r^{-1/2}.v$$

$$= \sqrt{k}\frac{1}{2}r^{-1/2}.\sqrt{k}r^{1/2} = \frac{k}{2}r^0$$

$$\text{Velocity after 1 sec} = 0 + \frac{k}{2}r^0 \times 1 = \frac{k}{2}r^0$$

Multiconcept MCQs

1. (*b*) Velocity when ball strikes the ground $V_1 = \sqrt{2gh_1}$

$$V_1 = \sqrt{2\times10\times10} = \sqrt{200}$$

Velocity of ball after rebound $V_2 = \sqrt{2gh_2}$

$$V_2 = \sqrt{2\times10\times2.5} = \sqrt{50}$$

Change in velocity / time

$$= \frac{\sqrt{50}-\left(-\sqrt{200}\right)}{0.01} = \frac{7.07+14.114}{0.01} = 2121.2\,m/s^2$$

2. (*c*) $S = u - \frac{a}{2}(2n-1)$ $\quad 3 = 50 - \frac{10}{2}(2n-1)$

$3 = 50 - \left(\frac{20n}{2} - 5\right)$ $\quad \Rightarrow 3 = 50 - 10n + 5$

$\Rightarrow 10n = 52$ $\quad \Rightarrow n = 5.2$

$S = 200 - \frac{10}{2}(2\times5.2-1) \Rightarrow 200 - 47 = 153$

3. (*a*) u = –30 m/s, t = 8 seconds

$h = ut + \frac{1}{2}gt^2$ $\quad h = -30\times8 + \frac{1}{2}\times10\times64$

$= -240 + 64\times5$ $\quad \Rightarrow h = 80$ m

4. (*a*) Total time taken by bird

$$\Rightarrow t = \frac{D}{V} = \frac{36}{(27+18)} = \frac{36}{45}hr$$

Distance travelled by bird

$S = V\,t$ $\quad S = 36\times\frac{36}{45} = \frac{1296}{45} = 28.8\ km$

5. (*a*) Distance traveled by stone in n time

$u = 0, t = n$ $\quad \therefore S = \frac{1}{2}gn^2$ $\quad = ut + \frac{1}{2}gt^2$

Equating the distance traveled by both stones when one stone is overtaking the other.

$$ut + \frac{1}{2}gt^2 = \frac{1}{2}g(n+t)^2$$

$t(u-gn) = \frac{1}{2}gn^2$ $\quad t = \frac{1/2gn^2}{u-gn}\,...(i)$

t – time at which second stone is thrown down

$\therefore$ Distance traveled S = ut + ½ gt² by second stone

$$S = t\left[u + \frac{1}{g}t\right]$$

$$S = \frac{1}{2}gn^2 + gnt + 1/2gt^2$$

$$= \frac{g}{2}\left[n^2 + 2nt + t^2\right] = \frac{g}{2}[n+t]^2$$

$$= \frac{g}{2}\left[n + \frac{1/2gn^2}{u-gn}\right]^2$$

$$= \frac{g}{2}\left[\frac{nu - gn^2 + \frac{gn^2}{2}}{4-gn}\right]^2$$

$$S = \frac{g}{2}\left[\frac{nu - \frac{gn^2}{2}}{(u-gn)}\right]^2 = \frac{g}{2}\left[\frac{n\left(u - g\frac{n}{2}\right)}{(u-gn)}\right]^2$$

6. (*c*) Distance traveled in T/3 seconds

$$S = \frac{1}{2}\times g\times\left(\frac{T}{3}\right)^2,\ S = \frac{T^2}{9\times2}g$$

Now $T = \sqrt{\frac{2h}{g}}$ $\quad S = \frac{1}{18}\times\frac{2h}{g}\times g = \frac{h}{9}$

Distance from ground $= h - \frac{h}{9} = \frac{8h}{9}$

7. (*a*) Let the time taken for one third distance be t_1, then $t_1 = \frac{d}{3V_0}$, where d is the total length of the journey.

Let the time taken for next 2d/3 distance be t_2,

$$\frac{2d}{3} = \frac{V_1t_2}{2} + \frac{V_2t_2}{2} = \frac{(V_1+V_2)t_2}{2}$$

$t_2 = \frac{4d}{3(V_1+V_2)}$. Thus, the total time taken for the journey is $\frac{d}{3V_0} + \frac{4d}{3(V_1+V_2)} = \frac{d(V_1+V_2+12V_0)}{3V_0(V_1+V_2)}$

Thus the average velocity $= \frac{\text{Total distance}}{\text{Total time}}$

$$V = \frac{d}{\frac{d(V_1+V_2+12V_0)}{3V_0(V_1+V_2)}} = \frac{3V_0(V_1+V_2)}{(V_1+V_2+12V_0)}$$

8. (*c*) Just to avoid collision, the speed of bike A should be equal or lesser than B, i.e., $u_A \le u_B$.

Now initial relative velocity of bike A with respect to $B = u_A - u_B$

And final relative velocity of A with respect to $B \le$ zero. Also the relative acceleration of A w.r.t. B = – a – 0 = – a

Then, using $u^2 + 2as = v^2$ $(u_A - u_B)^2 - 2\alpha s \le 0$

or $(u_A - u_B)^2 \le 2\alpha s$ or $s \ge \frac{(u_A - u_B)^2}{2\alpha}$

9. (*b*) At t = 0 the first body starts moving with constant acceleration while the second body is already moving with certain constant speed. So the distance covered by the first body x_1 is smaller that covered by the second body x_2 i.e., $x_1 < x_2$ or $x_1 - x_2$ = negative till the first body attains the speed equal to that of second body. At that instant $x_1 = x_2$ or $x_1 - x_2 = 0$ and after that $x_1 > x_2$ i.e. $x_1 - x_2$ = positive and goes on increasing with increasing t.

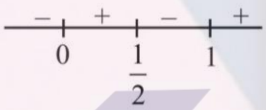
10. (*b*) $\vec{a}.\vec{v} < 0$ (condition of retardation)

$a = 2t - 1;$ $v = t^2 - t$

$av < 0$

$(2t - 1)\ (t^2 - t) < 0$

$(2t - 1)\ t(t - 1) < 0$



$\frac{1}{2} < t < 1$

11. (*d*) Let u be initial velocity and a be the uniform acceleration Average velocities in the intervals from-

0 to t_1, t_1 to t_2, t_2 to t_3 are

$$V_1 = \frac{u + u + at_1}{2} = u + \frac{at_1}{2} \quad ......(1)$$

$$V_2 = \frac{u + at_1 + u + a(t_1 + t_2)}{2} = u + at_1 + \frac{a}{2}t_2 \quad ......(2)$$

$$V_3 = \frac{u + a(t_1 + t_2 + t_3) + u + a(t_1 + t_2)}{2}$$

$$V_3 = u + at_1 + at_2 + \frac{a}{2}t_3 \quad .....(3)$$

Subtracting (1) from (2), we get

$$V_2 - V_1 = u + at_1 + \frac{a}{2}t_2 - \left(u + \frac{a}{2}t_1\right)$$

$$= u + at_1 + \frac{a}{2}t_2 - u - \frac{a}{2}t_1$$

$$V_2 - V_1 = \frac{a}{2}t_1 + \frac{a}{2}t_2 \Rightarrow \frac{a}{2}(t_1 + t_2) \quad ......(4)$$

Similarly (2) from (3), we get

$$(V_3 - V_2) = \frac{a}{2}t_2 + \frac{a}{2}t_3 \Rightarrow \frac{a}{2}(t_2 + t_3) \quad ......(5)$$

Divide (4) by (5) we get

$$\frac{V_2 - V_1}{V_3 - V_2} = \frac{\frac{a}{2}(t_1 + t_2)}{\frac{a}{2}(t_2 + t_3)} = \frac{(t_1 + t_2)}{(t_2 + t_3)}$$

12. (*a*) Given relation is $t = \alpha x^2 + \beta x$

Differentiating w.r.t x

$$\frac{dt}{dx} = \frac{d(\alpha x^2 + \beta x)}{dx}$$

$$\frac{1}{v} = 2\alpha x + \beta \Rightarrow v = \frac{1}{2\alpha x + \beta}$$

Acceleration is $a = \frac{dv}{dt}$ (multiplying and divide by dx)

$$a = \frac{dv}{dt} \times \frac{dx}{dx} \Rightarrow \frac{dv}{dx}.\frac{dx}{dt}$$

$$a = v.\frac{dv}{dx} \Rightarrow a = \frac{-v.2\alpha}{(2\alpha x + \beta)^2} = -2\alpha.v.v^2$$

$$\Rightarrow a = -2\alpha v^3$$

13. (*a*) According to the equation

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

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

$$(h - 20) = 0 + \frac{1}{2}g(t - 1)^2$$

$$(h - 20) = \frac{1}{2}g(t - 1)^2 \quad ....(2)$$

u = 0 in both case because stone s dropped from rest. From the equation (1) and (2) we get

$$h = \frac{1}{2}gt^2 \qquad (h - 20) = \frac{1}{2}g(t - 1)^2$$

$$h - (h - 20) = \frac{1}{2}gt^2 - \frac{1}{2}g(t - 1)^2$$

$$h - h + 20 = \frac{1}{2}gt^2 - \frac{1}{2}gt^2 - \frac{1}{2}g + gt$$

$$\Rightarrow 20 = gt - \frac{g}{2}$$

$$\Rightarrow gt = 25 \qquad (\because g = 10\ m/s^2)$$

$$\Rightarrow t = 2.5 \text{ second}$$

$$h = \frac{1}{2} \times 10 \times (2.5)^2$$

$$= 31.25\,m$$

14. (*c*) Average Acceleration $= \frac{\vec{v}_2 - \vec{v}_1}{\Delta t} = \frac{\text{Change in velocity}}{\text{Change in time}}$

When ball falls from height h_1 we get,

$$v_1^2 = u_1^2 + 2gh_1$$

$$v_1 = \sqrt{2gh_1} \quad ......(1) \qquad (u = 0 \text{ under free fall})$$

Similarly, when ball falls from height h_2 after striking the floor

But g = –g because after striking ball goes upward against the gravity.

$v_2^2 = u_2^2 + 2(-g)h_2$

(After contact $v_2 = 0$ at rest highest point, $u_2 = v_2$)

$0 = v_2^2 - 2gh_2$

$v_2^2 = 2gh \Rightarrow v_2 = \sqrt{2gh_2}$ .....(2)

$$\text{Average acceleration} = \frac{v_2 - v_1}{\Delta t}$$

$$= \frac{v_2 + v_1}{\Delta t} \quad (v_1 = -ve)$$

$$\text{Average acceleration} = \frac{\sqrt{2gh_2} + \sqrt{2gh_1}}{\Delta t}$$

$$= \frac{\sqrt{2\times10\times2} + \sqrt{2\times10\times1.5}}{0.020}$$

$$\text{Average acceleration} = \frac{\sqrt{40}+\sqrt{30}}{0.020} = \frac{6.32+5.47}{0.020}$$

$$\text{Average acceleration} = \frac{11.79\times100}{2} = \frac{1179}{2}$$

$a_{av} = 589.5\ m/s^2$

15. (*b*) Given condition is $x = 20 + 14t - t^3$

Differentiating both side

$$\frac{dx}{dt} = \frac{d(20+14t-t^3)}{dt}$$

$V = 0 + 14 - 3t^2 \Rightarrow 0 = 0 + 14 - 3t^2$ (body comes to rest)

$-14 = -3t^2$

$$\left(\frac{14}{3}\right)^{1/2} = t \Rightarrow t = (4.66)^{1/2} \approx (5)^{1/2}$$

NEET Past 10 Years Questions

1. (*b*) Between t = 0 to t = 1 s

$v = u + at \Rightarrow 6 = 0 + a \times 1$

$a = 6\ m/s^2$

$$\text{Average speed} = \frac{\text{Total distance}}{\text{Total time}}$$

$$= \frac{3X}{3} = X\ m/s$$

$$\text{where } X = 0 + \frac{1}{2}\times6\times(1)^2 = 3m$$

∴ Average speed = 3m/s

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

$$= \frac{X}{3} = \frac{3}{3} = 1\ m/s$$

2. (*b*) V_1 = Preeti's velocity

V_2 = Escalator's velocity

$$t = \frac{\text{distance}}{\text{speed}} \Rightarrow t = \frac{\ell}{V_1 + V_2}$$

$$= \frac{\ell}{\frac{\ell}{t_1} + \frac{\ell}{t_2}} = \frac{t_1 t_2}{t_2 + t}$$

3. (*b*) $x = 5t - 2t^2$ $\quad y = 10t$

$$v = \frac{dx}{dt} = 5 - 4t \qquad v = \frac{dy}{dt} = 10$$

$$a_x = \frac{dv}{dt} = -4\ ms^{-2} \qquad a_y = 0$$

$a = -4 m/s^2$

4. (*b*) $X_p(t) = at + bt^2$ $\quad X_Q(t) = ft - t^2$

$V_p = a + 2bt$ $\quad V_Q = f - 2t$

as $V_p = V_Q$

$a + 2bt = f - 2t$

$$\Rightarrow t = \frac{f-a}{2(1+b)}$$

5. (*c*) $v = At + Bt^2$

$$\frac{dx}{dt} = At + Bt^2$$

$$\int_0^x dx = \int_1^2 (At + Bt^2)dt$$

$$x = \frac{A}{2}(2^2 - 1^2) + \frac{B}{3}(2^3 - 1^3) = \frac{3A}{2} + \frac{7B}{3}$$

6. (*a*) $v = \beta x^{-2n}$

So, $\dfrac{dv}{dx} = -2n\beta x^{-2n-1}$

Now $a = v\dfrac{dv}{dx} = \left(\beta x^{-2n}\right)\left(-2n\beta x^{-2n-1}\right)$

$\Rightarrow a = -2n\beta^2 x^{-4n-1}$

7. (*c*) $AB = h_1 = \dfrac{1}{2}g(5)^2 \quad \Rightarrow \quad h_1 = 125 \text{ m} \qquad (\because \mu = 0)$

$h_2 = BC = \dfrac{1}{2}g\,[10^2 - 5^2] \quad \Rightarrow \quad h_2 = 375 \text{ m}$

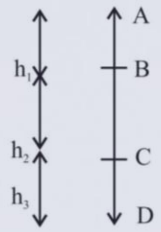
$h_3 = CD = \dfrac{1}{2}g\left[15^2 - 10^2\right]$

$h_3 = 625 \text{ m}$

$h_1 \;:\; h_2 \;:\; h_3$

$125 : 375 : 625 = 1 : 3 : 5$

$\Rightarrow h_1 = \dfrac{h_2}{3} = \dfrac{h_3}{5}$



8. (*d*) $v = \dfrac{dx}{dt} = 0 + 12 - 3t^2 = 0$

$\Rightarrow t = 2\text{s}$

At $t = 2$ s

Retardation

$= -\dfrac{dv}{dt} = -(-6t) = 12 \text{ ms}^{-2}$