Chapter

3

Motion in a Straight Line

BASIC DEFINITIONS

Mechanics : Branch of physics, which deals with the study of objects in rest and in motion.

Statics : Study of objects at rest or in equilibrium.

Kinematics : Study of motion of objects without considering the cause of motion.

Dynamics : Study of motion of objects considering the cause of motion.

Rest : An object is said to be at rest if it does not change its position with time, with respect to its surrounding (a reference point which is generally taken as origin in numerical problems)

Motion : An object is said to be in motion if it changes its position with time, with respect to its surroundings.

Rest and motion are relative terms.

Point mass/Point object : An object is said to be a point mass if during its motion it covers distance much greater than its own size.

One dimensional motion : An object travels in a straight line. It is also called **rectilinear** or **linear motion**. The position change of the object with time in one dimension can be described by only one co-ordinate.

Ex. A stone falling freely under gravity.

Two dimensional motion or motion in a plane : For an object travelling in a plane two coordinates say X and Y are required to describe its motion.

Ex. An insect crawling over the floor.

Three dimensional motion : An object travels in space.To describe motion of objects in three dimension require all three coordinates x, y and z.

Ex. A kite flying in the sky.

DISTANCE AND DISPLACEMENT

Distance or Path length : *The length of the actual path travelled by an object during motion in a given interval of time is called the distance travelled by that object or path length.* It is a scalar quantity.

Displacement : *It is the shortest distance between the initial and final position of an object* and is directed from the initial position to the final position. It is a vector quantity.

Keep in Memory

1. Displacement may be positive, negative or zero but distance is always positive.
2. Displacement is not affected by the shift of the coordinate axes.
3. Displacement of an object is independent of the path followed by the object but distance depends upon path.
4. Displacement and distance both have same unit as that of length i.e. metre.
5. $\dfrac{\text{Distance}}{|\text{Displacement}|} \geq 1$
6. For a moving body distance always increases with time
7. For a body undergoing one dimensional motion, in the same direction distance = | displacement |. For all other motion distance > | displacement |.

SPEED

It is the distance travelled per unit time by an object. It is a scalar quantity. It cannot be negative.

Uniform speed : An object is said to be moving with a uniform speed, if it covers equal distances in equal intervals of time, howsoever small the time intervals may be.

Non-uniform speed : If an object covers unequal distances in equal interval of time or equal distances in unequal interval of time.

Instantaneous speed : The speed of an object at a particular instant of time is called the instantaneous speed.

$$\text{Instantaneous speed, } V_{inst} = \lim_{\Delta t \to 0} \frac{\Delta s}{\Delta t} = \frac{ds}{dt}.$$

Average speed : It is ratio of the total distance travelled by the object to the total time taken.

$$\text{Average speed } V_{av} = \frac{\Delta x}{\Delta t}$$

Dimensions : $[M^0LT^{-1}]$; **Unit:** In SI systems.

VELOCITY

It is the displacement of an object per unit time. It is a vector quantity. It can be positive negative or zero.

Uniform velocity : An object is said to be moving with a uniform velocity, if it covers equal displacements in equal intervals of time, howsoever small the time intervals may be.

Non-uniform velocity : If an object covers unequal displacements in equal interval of time or equal displacements in unequal interval of time.

Instantaneous velocity : The velocity of an object at a particular instant of time is called the instantaneous velocity.

$$\textit{Instantaneous velocity, } \vec{V}_{inst} = \lim_{\Delta t\to 0}\frac{\Delta\vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}.$$

Average Velocity : It is ratio of the total displacement to the total time taken.

$$\textit{Average velocity, } v_{av} = \frac{\Delta\vec{r}}{\Delta t}$$

Dimensions : $[M^0LT^{-1}]$; **Unit:** In SI system, m/s

Keep in Memory

1. | Average velocity | can be zero but average speed cannot be zero for a moving object.
2. $\dfrac{|\text{Average velocity}|}{\text{Average speed}} \le 1$
3. | Instantaneous velocity | = Instantaneous speed.
4. A particle may have constant speed but variable velocity. It happens when particle travels in curvilinear path.
5. If the body covers first half distance with speed v_1 and next half with speed v_2 then

   $$\textit{Average speed } \bar{v} = \frac{2v_1v_2}{v_1+v_2}$$

6. If a body covers first one-third distance at a speed v_1, next one-third at speed v_2 and last one-third at speed v_3, then

   $$\textit{Average speed } \bar{v} = \frac{3v_1\,v_2\,v_3}{v_1\,v_2+v_2\,v_3+v_1\,v_3}$$

7. If a body travels with uniform speed v_1 for time t_1 and with uniform speed v_2 for time t_2, then

   $$\textit{Average speed } \bar{v} = \frac{v_1t_1+v_2t_2}{t_1+t_2}$$

ACCELERATION

The rate of change of velocity with respect to time is called acceleration. It is a vector quantity.

Let velocity changes by $\Delta\vec{v}$ during some interval of time Δt.

Average acceleration $\vec{a}_{av}$ is given by

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

Instantaneous acceleration $\vec{a}$ is given by

$$\vec{a} = \lim_{\Delta t\to 0}\frac{\Delta\vec{v}}{\Delta t} = \frac{d\vec{v}}{dt}$$

Its **SI unit** is meter/sec^2 (ms^{-2}).

A body moving with uniform velocity has zero acceleration. It means that neither its speed nor its direction of motion is changing with time.

Uniform acceleration : If the velocity of the body changes in equal amount during same time interval, then the acceleration of the body is said to be uniform. Acceleration is uniform when neither its direction nor magnitude changes with respect to time.

Variable or non-uniform acceleration : If the velocity of body changes in different amounts during same time interval, then the acceleration of the body is known as variable acceleration. Acceleration is variable if either its direction or magnitude or both changes with respect to time. A good example of variable acceleration is the acceleration in uniform circular motion.

EQUATIONS FOR UNIFORMLY ACCELERATED MOTION

When the motion is uniformly accelerated i.e., when acceleration is constant in magnitude and direction :

(i) $v = u + at$

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

(iii) $v^2 - u^2 = 2as$

where u = initial velocity; v = final velocity;
a = uniform acceleration and
s = distance travelled in time t,

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

(v) Distance travelled in nth second $s_n = u + \frac{a}{2}(2n-1)$;

s_n = distance covered in nth second

Above equations in vector form

$$\vec{v} = \vec{u} + \vec{a}\,t, \quad \vec{s} = \vec{u}\,t + \frac{1}{2}\vec{a}\,t^2,$$

$$\vec{v}^2 - \vec{u}^2 = 2\vec{a}.\vec{s} \quad (\text{or } \vec{v}.\vec{v} + \vec{u}.\vec{u} = 2\vec{a}.\vec{s})$$

$$\vec{s} = \frac{1}{2}(\vec{u}+\vec{v})t$$

When displacement (s) is given as a function of time t [s = f(t)] then

$s \propto t^0$	Body at rest	$v = 0$	$a = 0$
$s \propto t^1$	Uniform velocity; acceleration zero	$v \propto t^0$	$a = 0$
$s \propto t^2$	Uniform acceleration	$v \propto t^1$	$a \propto t^0$
$s \propto t^{3\text{ or more}}$	Non uniform acceleration	$v \propto t^{2\text{ or more}}$	$a \propto t^{1\text{ or more}}$

We use calculus method (integration and differentiation) for displacement, velocity, acceleration as a function of time.

We know that $v = \frac{ds}{dt} \Rightarrow s = \int v\,dt$; $a = \frac{dv}{dt} \Rightarrow v = \int a\,dt$;

when a = f(s)

$$a = v\frac{dv}{ds} \Rightarrow \int a\ ds = \int v\ dv,$$

where s = displacement, v = instantaneous velocity,
a = instantaneous acceleration

VERTICAL MOTION UNDER GRAVITY

(i) For a body thrown downward with initial velocity u from a height h, the equations of motion are

$$v = u + gt \; ; \; v^2 = u^2 + 2gh$$

$$h = ut + \frac{1}{2}gt^2 \; ; \; h_{n^{th}} = u + \frac{g}{2}(2n-1)$$

(ii) If initial velocity is zero, then the equations are

$$v = gt \; ; \; v = \sqrt{2gh}$$

$$h = \frac{1}{2}gt^2 \; ; \; h_{n^{th}} = \frac{g}{2}(2n-1)$$

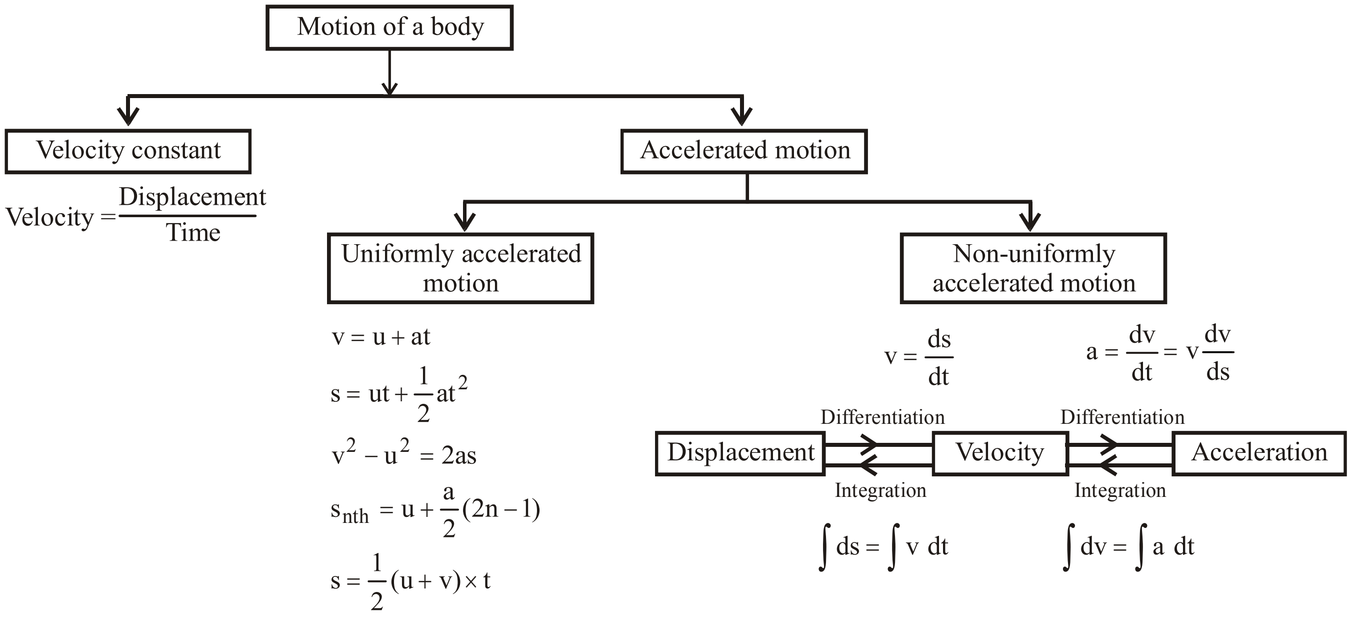
(iii) When a body is thrown upwards with initial velocity u, the equations of motion are

$$v = u - gt$$

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

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

To summarise :



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

$$v = u + at$$

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

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

$$s_{nth} = u + \frac{a}{2}(2n-1)$$

$$s = \frac{1}{2}(u+v) \times t$$

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

$$\int ds = \int v\,dt \qquad \int dv = \int a\,dt$$

NOTE: Calculus method as shown in non-uniformly accelerated motion may also be used for uniformly accelerated motion.

Uniformly Accelerated Motion : A Discussion

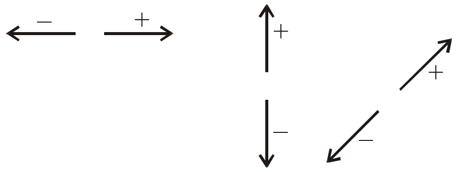
While using equations of motion we can have two approaches.

Approach 1 : Take a = +ve when velocity increases and a = –ve when velocity decreases.

Take rest of physical quantities such as u, v, t and s as positive.

Approach 2 : (Vector method)

Assume one direction to be positive and other negative. Assign sign to all the vectors (u, v, a, s), +ve sign is given to a vector which is directed to the positive direction and vice-versa



Normally the direction taken is as drawn above. But it is important to note that you can take any direction of your choice to be positive and the opposite direction to be negative.

NOTE: The second method (or approach) is useful only when there is reversal of motion during the activity concerned.

Keep in Memory

1. The direction of average acceleration vector is the direction of the change in velocity vector. $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$

   $\vec{a}$ has a direction of $\vec{v}_f - \vec{v}_i = \vec{v}_f + (-\vec{v}_i)$

   i.e., the resultant of $\vec{v}_f$ and $-\vec{v}_i$

2. There is no definite relationship between velocity vector and acceleration vector.

3. For a body starting from rest and moving with uniform acceleration, the ratio of distances covered in t_1 sec., t_2 sec, t_3 sec, etc. are in the ratio $t_1^2 : t_2^2 : t_3^2$ etc.

4. A body moving with a velocity v is stopped by application of brakes after covering a distance *s*. If the same body moves with a velocity nv, it stops after covering a distance n^2s by the application of same retardation.

Example 1.

The displacement of particle is zero at t = 0 and displacement is 'x' at t = t. It starts moving in the positive x-direction with a velocity which varies as $v = k\sqrt{x}$ where k is constant. Show that the velocity varies with time.

Solution :

$$v = k\sqrt{x} \quad \text{or} \quad \frac{dx}{dt} = k\sqrt{x} \quad \text{or} \quad \frac{dx}{\sqrt{x}} = k\ dt$$

Given that when t = 0, x = 0 and when t = t, x = x,

$$\text{Hence} \int_0^x \frac{dx}{\sqrt{x}} = \int_0^t k\ dt\ ;$$

$$\therefore \int_0^x x^{-1/2} dx = k\int_0^t dt \quad \text{or} \quad \left[\frac{x^{-\frac{1}{2}+1}}{-\frac{1}{2}+1}\right]_0^x = k\left[t\right]_0^t$$

$$\text{or } 2\sqrt{x} = kt \quad \text{or} \quad \sqrt{x} = \frac{kt}{2}$$

$$\text{Now, } v = k \times \left[\frac{kt}{2}\right] = \frac{k^2 t}{2}$$

Thus the velocity varies with time.

Example 2.

A particle covers each 1/3 of the total distance with speed v_1, v_2 and v_3 respectively. Find the average speed of the particle.

Solution :

Average speed

$$\bar{v} = \frac{\text{Total distance travelled}}{\text{Total time taken}} = \frac{s}{\frac{s}{3v_1} + \frac{s}{3v_2} + \frac{s}{3v_3}}$$

$$\Rightarrow \quad \bar{v} = \frac{3v_1v_2v_3}{v_1v_2 + v_2v_3 + v_3v_1}$$

Example 3.

A cheetah can accelerate from 0 to 96 km/h in 2 sec., whereas a cat requires 6 sec. Compute the average accelerations for the cheetah and cat.

Solution :

$$\text{For cheetah } |\vec{a}_{av}| = \frac{|\vec{v}_f - \vec{v}_i|}{\Delta t} = \frac{96 km/h - 0}{2 sec}$$

$$= \frac{96 \times \frac{1000 m}{3600 sec}}{2 sec} = 15 \text{ m/s}^2$$

$$\text{For cat } |\vec{a}_{av}| = \frac{96 \times \frac{10}{36}}{6} = 5 \text{ m/s}^2.$$

Example 4.

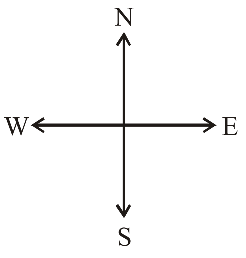
A particle is moving in east direction with speed 5 m/s. After 10 sec it starts moving in north direction with same speed. Find average acceleration.

Solution :

$|\vec{v}_f| = |\vec{v}_i| = 5$ m/s

Acceleration $\neq 0$

(due to change in direction of velocity Av. acceleration,



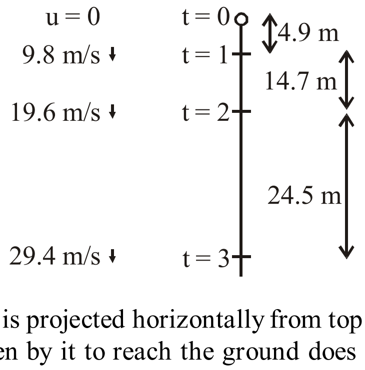
$$\Delta\vec{v} = \vec{v}_f - \vec{v}_i = \vec{v}_f + (-\vec{v}_i)$$

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t} = \frac{5\hat{j} - 5\hat{i}}{10} \Rightarrow \vec{a} = -\frac{1}{2}\hat{i} + \frac{1}{2}\hat{j}$$

$$|\vec{a}| = \sqrt{\left(\frac{1}{2}\right)^2 + \left(\frac{1}{2}\right)^2} = \frac{1}{\sqrt{2}} \text{ m/s}^2.$$

Keep in Memory

1. An object moving under the influence of earth's gravity in which air resistance and small changes in g are neglected is called a freely falling body.
2. In the absence of air resistance, the velocity of projection is equal to the velocity with which the body strikes the ground.
3. Distance travelled by a freely falling body in 1st second is always half of the numerical value of g or 4.9 m, irrespective of height h.
4. For a freely falling body with initial velocity zero
   (i) Velocity $\propto$ time ($v = gt$)
   (ii) Velocity $\propto \sqrt{\text{Distance fallen}}$ ($v^2 = 2gs$)
   (iii) Distance fallen α (time)^2 $\left(s = \frac{1}{2}gt^2\right)$, where g is the acceleration due to gravity.
5. If maximum height attained by a body projected vertically upwards is equal to the magnitude of velocity of projection, then velocity of projection is *2g* ms^{-1} and time of flight is 4 sec.
6. If maximum height attained by a body projected upward is equal to magnitude of acceleration due to gravity i.e., 'g', the time of ascent is $\sqrt{2}$ sec. and velocity of projection is $g\sqrt{2}$.
7. Ratio of maximum heights reached by different bodies projected with velocities u_1, u_2, u_3 etc. are in the ratio of $u_1^2 : u_2^2 : u_3^3$ etc. and ratio of times of ascent are in ratio of $u_1 : u_2 : u_3$ etc.
8. During free fall velocity increases by equal amount every decend and distance covered during 1st, 2nd, 3rd seconds of fall, are 4.9m, 14.7m, 24.5m.



9. If a body is projected horizontally from top of a tower, the time taken by it to reach the ground does not depend on the velocity of projection, but depends on the height of tower and is equal to $t = \sqrt{\frac{2h}{g}}$.

10 If velocity v of a body changes its direction by θ without change in magnitude then the change in velocity will be $2v\sin\frac{\theta}{2}$.

11. From the top of a tower a body is projected upward with a certain speed, 2nd body is thrown downward with same speed and 3rd is let to fall freely from same point then $t_3 = \sqrt{t_1 t_2}$
where t_1 = time taken by the body projected upward, t_2 = time taken by the body thrown downward and t_3 = time taken by the body falling freely.

12. If a body falls freely from a height *h* on a sandy surface and it buries into sand upto a depth of *x*, then the retardation produced by sand is given by $a = g\left(\frac{h+x}{x}\right)$.

13. In case of air resistance, the time of ascent is less than time of descent of a body projected vertically upward i.e. $t_a < t_d$.

14. When atmosphere is effective, then buoyancy force always acts in upward direction whether body is moving in upward or downward direction and it depends on volume of the body. The viscous drag force acts against the motion.

15. If bodies have same volume but different densities, the buoyant force remains the same.

⚠ **CAUTION :** Please note that dropping body gets the velocity of the object but if the object is in acceleration, the body dropped will not acquire the acceleration of the object.

COMMON DEFAULT

✘ ***Incorrect.*** *In the question, if it is given that a body is dropped, taking its initial velocity zero.*

✔ ***Correct.*** The initial velocity is zero if the object dropping the body is also at rest (zero velocity). But if the object dropping the body is having a velocity, then the body being dropped will also have initial velocity which will be same as that of the object.

For example :

(a) When an aeroplane flying horizontally drops a bomb.

(b) An ascending helicopter dropping a food packet.

(c) A stone dropped from a moving train etc.

✘ ***Incorrect.*** *Applying equations of motion in case of non-uniform acceleration of the body.*

✔ ***Correct.*** The equations of motion are for uniformly accelerated motion of the body.

Please note that when the case is of non-uniform acceleration we use calculus (differentiation and integration).

$$a = \frac{dv}{dt} = \frac{vdv}{ds}; \quad v = \frac{ds}{dt}.$$

In fact calculus method is a universal method which can be used both in case of uniform as well as non-uniform acceleration.

✘ ***Incorrect.*** *Taking average velocity same as that of instantaneous velocity.*

✔ ***Correct.*** Average velocity $= \vec{V}_{av} = \frac{\Delta\vec{r}}{\Delta t} = \frac{\vec{r}_f - \vec{r}_i}{t_f - t_i}$

(where $\vec{r}_i$ is position vector at time t_i and $\vec{r}_f$ is position vector at time t_f).

Whereas instantaneous velocity

$$\vec{V}_{inst.} = \lim_{\Delta t \to 0} \frac{\Delta\vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$$

It is important to note that average velocity is equal to instantaneous velocity only when the case is of uniform velocity.

✘ ***Incorrect.*** *Taking acceleration as negative (– a) even when acceleration is an unknown.*

✔ ***Correct.*** Take acceleration as (a) when it is unknown even if we know that the motion is a case of deceleration or retardation. On solving, we will find the value of (a) to be negative .

✘ ***Incorrect.*** *Magnitude of instantaneous velocity is different from instantaneous speed .*

✔ ***Correct.*** Magnitude of instantaneous velocity is equal to the instantaneous speed in any case.

Example 5.

The numerical ratio of average velocity to average speed is

(a) always less than one *(b) always equal to one*

(c) always more than one *(d) equal to or less than one*

Solution : **(d)**

It is equal to or less than one as average velocity depends upon displacement whereas average speed depends upon path length.

Example 6.

The distance travelled by a body is directly proportional to the time taken. Its speed

(a) increases *(b) decreases*

(c) becomes zero *(d) remains constant*

Solution : **(d)**

When $s \propto t$, so $\frac{s}{t} = v =$ constant.

Example 7.

A particle is projected vertically upwards. Prove that it will be at 3/4 of its greatest height at time which are in the ratio 1 : 3.

Solution :

If u is the initial velocity of a particle while going vertically upwards, then the maximum height attained is $h = \frac{u^2}{2g}$.

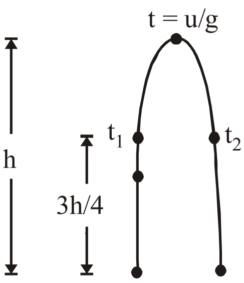
If t is the time when particle reaches at a height $\frac{3}{4}$h, then using the relation

$s = ut + \frac{1}{2}at^2$; we have $\frac{3}{4}h = ut + \frac{1}{2}(-g)\ t^2$

or, $\frac{3}{4}\left(\frac{u^2}{2g}\right) = ut - \frac{1}{2}gt^2$ or $t^2 - \frac{2u}{g}t + \frac{3}{4}\frac{u^2}{g^2} = 0$

Solving it for t, we have

$$t = \frac{\frac{2u}{g} \pm \sqrt{\frac{4u^2}{g^2} - 4 \times 1 \times \frac{3}{4}\frac{u^2}{g^2}}}{2} = \frac{u}{g} \pm \frac{u}{2g}$$



Taking negative sign, $t_1 = \frac{u}{g} - \frac{u}{2g} = \frac{u}{2g}$;

Taking positive sign, $t_2 = \frac{u}{g} + \frac{u}{2g} = 3u/2g.$

$$\frac{t_1}{t_2} = \left(\frac{u/2g}{3u/2g}\right) = \frac{1}{3}.$$

Example 8.

A police party in a jeep is chasing a dacoit on a straight road. The jeep is moving with a maximum uniform speed v. The dacoit rides on a motorcycle of his waiting friend when the jeep is at a distance d from him and the motorcycle starts with constant acceleration a. Show that the dacoit will be caught if $v \geq \sqrt{2ad}$.

Solution :

Suppose the dacoit is caught at a time t sec after the motorcycle starts. The distance travelled by the motorcycle during this interval is

$$s = \frac{1}{2}at^2 \qquad ...(1)$$

During the interval, the jeep travels a distance,

$$s + d = vt \qquad ...(2)$$

By (1) and (2), $\frac{1}{2}at^2 - vt + d = 0$ or $t = \frac{v \pm \sqrt{v^2 - 2ad}}{a}$

The dacoit will be caught if t is real and positive. This will be possible if $v^2 - 2ad > 0$ or $v > \sqrt{2ad}$.

Example 9.

Two trains, each of length 100 m, are running on parallel tracks. One overtakes the other in 20 second and one crosses the other in 10 second. Calculate the velocities of each train.

Solution :

Let u and v be the velocities of the trains.

The relative velocity of overtaking is u – v while the relative velocity of crossing is u + v.

Total distance = 100 + 100 = 200 m.

$$\therefore \quad 20 = \frac{200}{u - v} \quad \text{or} \quad u - v = 10$$

$$\text{and } 10 = \frac{200}{u + v} \quad \text{or} \quad u + v = 20$$

By solving, we get, u = 15 m/sec and v = 5 m/sec.

Example 10.

A body starts from rest and moves with a uniform acceleration. The ratio of the distance covered in the nth sec to the distance covered in n sec is

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

(c) $\frac{2}{n^2} - \frac{1}{n^2}$ (d) $\frac{2}{n} + \frac{1}{n^2}$

Solution : **(a)**

The distance covered in nth second

$$s_n = u + \frac{a}{2}(2n - 1) \quad \text{or} \quad s_n = 0 + \frac{a}{2}(2n - 1) \qquad ...(1)$$

Further distance covered in n second

$$s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}an^2 \qquad ...(2)$$

$$\therefore \quad \frac{s_n}{s} = \frac{\frac{a}{2}(2n-1)}{(an^2/2)} = \frac{2}{n} - \frac{1}{n^2}$$

Example 11.

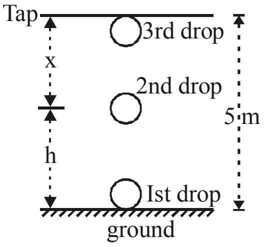
The water drop falls at regular intervals from a tap 5 m above the ground. The third drop is leaving the tap at instant the first drop touches the ground. How far above the ground is the second drop at that instant?

(a) 1.25 m (b) 2.50 m

(c) 3.75 m (d) 4.00 m

Solution : **(c)**

See fig. Let t be the time interval between any two drops.



For third drop $5 = \frac{1}{2}g(2t)^2$ or $gt^2 = 5/2$

For second drop $x = \frac{1}{2}gt^2$ or $x = \frac{1}{2} \times \frac{5}{2} = \frac{5}{4} = 1.25\,m$

Therefore $h = 5 - x = 5 - 1.25 = 3.75$ m

Hence option (c)

Example 12.

The height of a tower is h metre. A body is thrown from the top of tower vertically upward with some speed, it takes t_1, second to reach the ground. Another body thrown from the top of tower with same speed downwards and takes t_2 seconds to reach the ground. If third body, released from same place takes 't' second to reach the ground, then

(a) $t = \frac{t_1 + t_2}{2}$ (b) $t = \frac{t_1}{t_2}$

(c) $\frac{2}{t} = \frac{1}{t_1} + \frac{1}{t_2}$ (d) $t = \sqrt{(t_1 t_2)}$

Solution : **(d)**

Let u be the initial velocity of the body. Then at time t_1

$$h = -u t_1 + \frac{1}{2} g t_1^2 \quad ...(1)$$

and at time t_2, $h = u t_2 + \frac{1}{2} g t_2^2$ ...(2)

From eqs. (1) and (2), we get

$$-u t_1 + \frac{1}{2} g t_1^2 = u t_2 + \frac{1}{2} g t_2^2$$

or $\frac{1}{2} g (t_1^2 - t_2^2) = u\ (t_1 + t_2)$

or $\frac{1}{2} g (t_1 + t_2)\ (t_1 - t_2) = u (t_1 + t_2)$

or $u = \frac{1}{2} g (t_1 - t_2)$ ...(3)

Substituting the value of u in eqn. (2) we get

$$h = \frac{1}{2} g (t_1 - t_2) t_2 + \frac{1}{2} g t_2^2 \quad \text{or} \quad h = \frac{1}{2} g t_1 t_2 \quad ...(4)$$

For third body, $h = \frac{1}{2} g t^2$ ...(5)

From eqs. (4) and (5) we get, $t = \sqrt{t_1 t_2}$

Example 13.

A bullet moving with a speed 10 m/s hits the wooden plank and is stopped when it penetrates the plank 20 cm deep. Calculate retardation of the bullet.

Solution :

$v_0 = 10$ m/s, $v = 0$ and $s = 20$ cm. $= \frac{2}{100} = 0.02$m

Using $v^2 - v_0^2 = 2ax$

$$0 - (10)^2 = 2a\ (0.02) \Rightarrow \frac{-100}{2 \times 0.02} = a$$

or $a = -2500$ m/s^2

Retardation $= 2500$ m/s^2

Example 14.

A body covers a distance of 20m in the 7th second and 24m in the 9th second. How much distance shall it cover in 15th sec?

Solution :

From formula, $S_{n\text{th}} = u + \frac{1}{2} a (2n - 1)$

$S_7\text{th} = u + \frac{a}{2}(2 \times 7 - 1)$ but $S_7\text{th} = 20\text{m}$

$\therefore\ 20 = u + \frac{a}{2} \times 13 \Rightarrow 20 = u + \frac{13a}{2}$ ...(1)

also $s_9\text{th} = 24\text{m}$ $\therefore\ 24 = u + \frac{17a}{2}$ ...(2)

From eq^n. (1) $u = 20 - \frac{13a}{2}$ ...(3)

Substitute this value of in eq^n. (2)

$$24 = 20 - \frac{13a}{2} + \frac{17a}{2}$$

$$24 - 20 = \frac{17a}{2} - \frac{13a}{2}$$

$$4 = \frac{4a}{2} \Rightarrow 4 = 2a \Rightarrow a = \frac{4}{2} = 2\ \text{m/s}^2$$

Substituting this value of a in eqn. (3) $u = 20 - \frac{13a}{2}$

$\Rightarrow u = 20 - \frac{13 \times 2}{2} \Rightarrow u = 20 - 13$

$\therefore\ u = 7$ m/s

Now, $s_{15\text{th}} = u + \frac{a}{2}(2 \times 15 - 1)$

$$= 7 + \frac{2}{2}(29) = 7 + 29 = 36\text{m}$$

Example 15.

A train starts from rest and for the first kilometer moves with constant acceleration, for the next 3 kilometers it has constant velocity and for another 2 kilometers it moves with constant retardation to come to rest after 10 min. Find the maximum velocity and the three time intervals in the three types of motion.

Solution :

Let the three time intervals be t_1 min, t_2 min, and t_3 min. respectively.

Let the maximum velocity attained be v m/min.

For A to B $1000 = \left(\frac{0 + v}{2}\right) t_1 \Rightarrow 2000 = v t_1$ ....(1)

For B to C $3000 = v t_2$ ....(2)

[Using in both equations disp. = mean vel. × time]

and for C to D $2000 = \left(\frac{v + 0}{2}\right) t_3 \Rightarrow 4000 = v t_3$ ...... (3)

Adding eqs. (1), (2) and (3), we get

$$9000 = v\ (t_1 + t_2 + t_3)$$

$$\therefore\ v = \frac{9000}{10} = 900\ \text{m/min.} = \frac{900\times10^{-3}}{1/60\ \text{hr.}}\text{km} = 54\ \text{km/hr.}$$

Now, from eqs. (1), (2) and (3) we get

$$t_1 = \frac{2000}{900} = \frac{20}{9} = 2\frac{2}{9}\text{min.},$$

$$t_2 = \frac{3000}{900} = \frac{10}{9} = 3\frac{1}{3}\text{min.}$$

$$\text{and } t_3 = \frac{4000}{900} = \frac{40}{9} = 4\frac{4}{9}\text{min.}$$

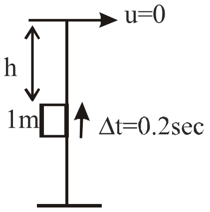
Example 16.

A falling stone takes 0.2 seconds to fall past a window which is 1m high. From how far above the top of the window was the stone dropped ?

Solution :

$$h = \frac{1}{2}gt^2 \quad ; \quad h+1 = \frac{1}{2}g(t+0.2)^2$$

$$\frac{1}{2}gt^2 + 1 = \frac{1}{2}gt^2 + \frac{1}{2}g(0.2)^2 + \frac{1}{2}g\times2\times0.2t$$



$$1 = \frac{1}{5} + 0.2gt \quad ; \quad \frac{4}{5} = 2t \Rightarrow t = \frac{2}{5}$$

$$h = \frac{1}{2}g\frac{4}{25} = \frac{4}{5}m$$

Example 17.

From the top of a multi-storeyed building 40m tall, a boy projects a stone vertically upwards with an initial velocity of 10 ms^{-1} such that it eventually falls to the ground. (i) After how long will the stone strike the ground ? (ii) After how long will it pass through the point from where it was projected ? (iii) What will be its velocity when it strikes the ground ? Take g = 10 ms^{-2}.

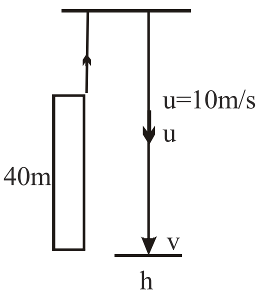
Solution :

Using, $\vec{S} = \vec{u}t + \frac{1}{2}\vec{a}t^2$

(i) $-40 = 10t - \frac{1}{2}gt^2$ or $-40 = 10t - 5t^2$

$[\because \text{ taking } g = 10\text{m/s}^2]$

or $5t^2 - 10t - 40 = 0$



$$\text{or} \quad t = \frac{10+\sqrt{10^2-4\times5(-40)}}{2\times5} = \frac{10+\sqrt{100+800}}{10}$$

$$= \frac{10+30}{10} = 4\text{ sec.}$$

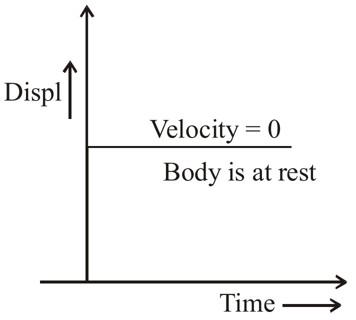
(ii) It will pass from where it was projected after $t = \frac{2\times10}{g} = 2\text{ sec.}$

(iii) Velocity with which stone strikes the ground
$V = 10 + g\times2 = 30\text{ m/s}$

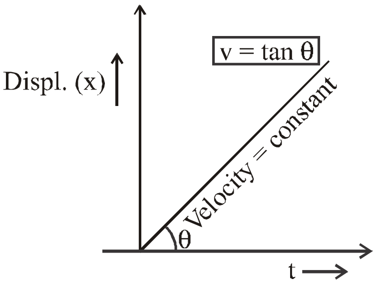
VARIOUS GRAPHS RELATED TO MOTION

(a) **Displacement-time graph -** In this graph time is plotted on x-axis and displacement on y-axis.

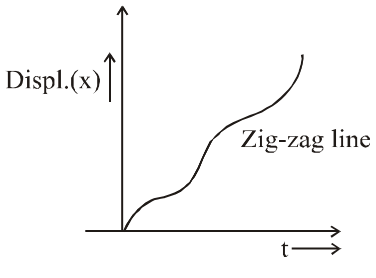
(i) For a stationary body (v = 0) the time-displacement graph is a straight line parallel to time axis.



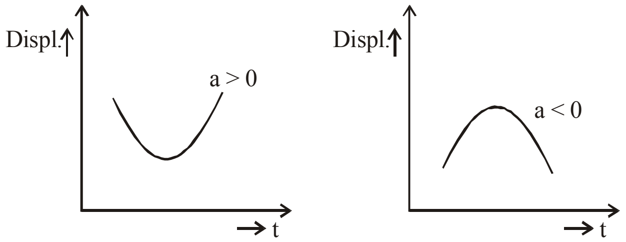
(ii) When the velocity of a body is constant then time-displacement graph will be an oblique straight line. Greater the slope $\left(\frac{dx}{dt} = \tan\theta\right)$ of the straight line, higher will be the velocity.



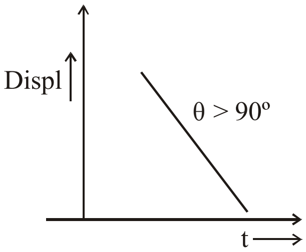
(iii) If the velocity of a body is not constant then the time-displacement curve is a zig-zag curve.



(iv) For an accelerated motion the slope of time-displacement curve increases with time while for decelerated motion it decreases with time.

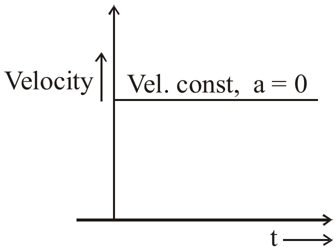


(v) When the particle returns towards the point of reference then the time-displacement line makes an angle $\theta > 90°$ with the time axis.



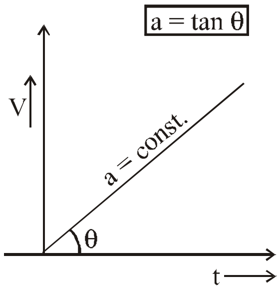
(b) **Velocity-time graph -** In this curve time is plotted along x-axis and velocity is plotted along y-axis.

(i) When the velocity of the particle is constant or acceleration is zero.

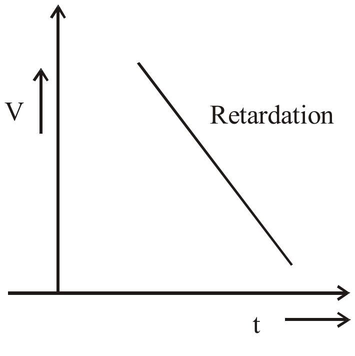


(ii) When the particle is moving with a constant acceleration and its initial velocity is zero.

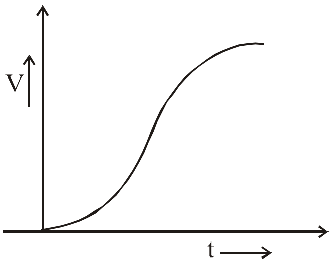
$\boxed{a = \tan\theta}$



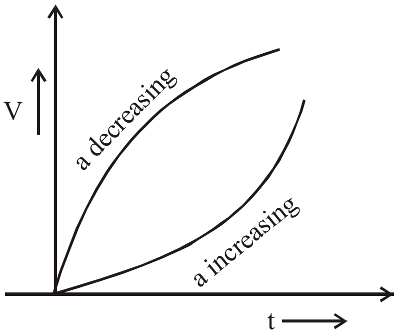
(iii) When the particle is moving with constant retardation.



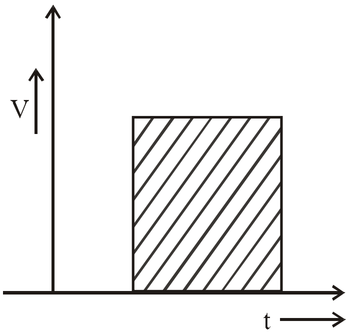
(iv) When the particle moves with non-uniform acceleration and its initial velocity is zero.



(v) When the acceleration decreases and increases.



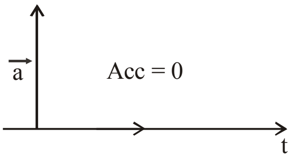
(vi) The total area enclosed by the time - velocity curve represents the distance travelled by a body.



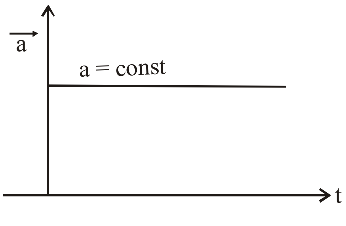
NOTE: While finding displacement through v – t graph, keeping sign under consideration.

(c) **Acceleration-time graph -** In this curve the time is plotted along X-axis and acceleration is plotted along Y-axis.

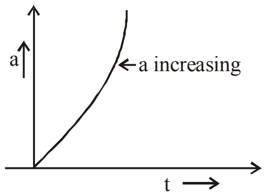
(i) When the acceleration of the particle is zero.



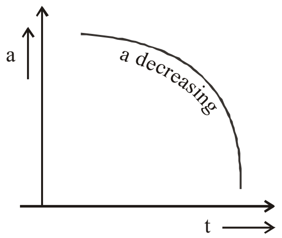
(ii) When acceleration is constant



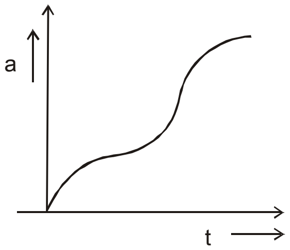
(iii) When acceleration is increasing and is positive.



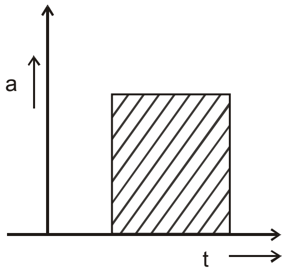
(iv) When acceleration is decreasing and is negative



(v) When initial acceleration is zero and rate of change of acceleration is non-uniform

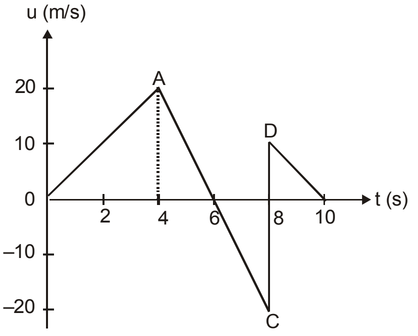


(vi) The change in velocity of the particle = area enclosed by the time-acceleration curve.



Example 18.

The velocity-time graph of a body moving in a straight line is shown in fig. Find the displacement and distance travelled by the body in 10 seconds.



Solution :

The area enclosed by velocity-time graph with time axis measures the distance travelled in a given time. Displacement covered from 0 to 6 seconds is positive; from 6 to 8 seconds is negative and from 8 to 10 seconds is positive; whereas distance covered is always positive.

Total distance covered in 10 s

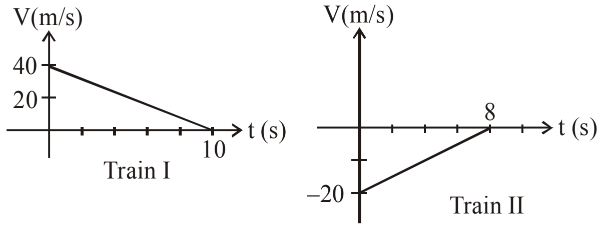
$$=\frac{1}{2}\times 6\times 20+\frac{1}{2}\times 2\times 20+\frac{1}{2}\times 2\times 10=90\,\text{m}$$

Total displacement in 10s

$$=\frac{1}{2}\times 6\times 20-\frac{1}{2}\times 2\times 20+\frac{1}{2}\times 2\times 10=50\,\text{m}$$

Example 19.

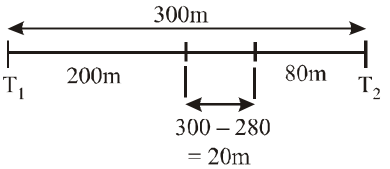
Two trains, which are moving along different tracks in opposite directions, are put on the same track due to a mistake. Their drivers, on noticing the mistake, start slowing down the trains when the trains are 300 m apart. Graphs given below show their velocities as function of time as the trains slow down, The separation, between the trains when both have stopped, is



(a) 120m (b) 280m

(c) 60m (d) 20m.

***Solution :* (d)**



Initial distance between trains is 300m. Displacement of 1st train is calculated by area under v – t.

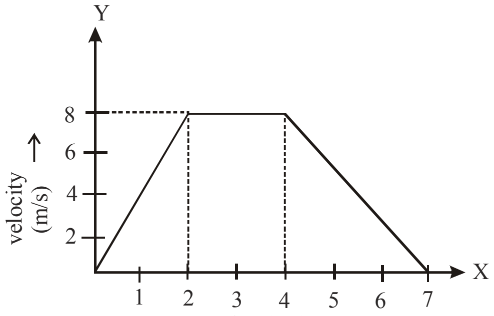
Curve of train I = displacement $=\frac{1}{2}\times 10\times 40=200\text{m}$

Displacement of train II $=\frac{1}{2}\times 8\times(-20)=-80\text{m}$

∴ Distance between the two trains is 20m.

Example 20.

Figure given below shows the variation of velocity of a particle with time.



Find the following :

(i) Displacement during the time intervals

(a) 0 to 2 sec, (b) 2 to 4 sec. and (c) 4 to 7 sec.

(ii) Accelerations at –

(a) t = 1 sec, (b) t = 3 sec. and (c) t = 7 sec.

(iii) Average acceleration –

(a) between t = 0 to t = 4 sec.

(b) between t = 0 to t = 7 sec.

(iv) Average velocity during the motion.

Solution :

(i) **(a)** Displacement between t = 0 sec. to t = 2 sec.

$$\Rightarrow \frac{1}{2} \times 2 \text{ sec} \times 8 \text{ m/s} = 8\text{m}$$

(b) Between t = 2 sec. to t = 4 sec.

$$\Rightarrow 2 \text{ sec} \times 8 \text{ m/s} = 16\text{m}$$

(c) Between t = 4 sec. to t = 7 sec.

$$\Rightarrow \frac{1}{2} \times 3 \text{ sec} \times 8 \text{ m/s} = 12\text{m}$$

(ii) Acceleration = slope of v – t curve

(a) At t = 1 sec,

$$\text{slope} = \frac{8\text{m/sec}}{2\text{sec}} \text{m/sec} = 4 \text{ m/s}^2$$

(b) At t = 3 sec, slope = 0

(c) At t = 7 sec,

$$\text{slope} = -\frac{8}{3} = -2\frac{2}{3}\text{m/s}^2$$

(iii) $\text{Average acceleration} = \dfrac{\text{Total change in velocity}}{\text{Total change in time}}$

(a) Between t = 0 to t = 4 sec.,

$$\text{Average acceleration} = \frac{8\text{m/s}}{4} = 2\text{m/s}^2$$

(b) Between t = 0 to t = 7 sec.,

$$\text{Average acceleration} = \frac{0}{7} = 0$$

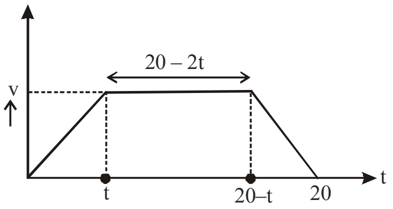
(iv) $\text{Average velocity} = \dfrac{\text{Total displacement}}{\text{Total time}}$

$$= \frac{8+16+12}{7} = \frac{36}{7} = 5\frac{1}{7}\text{m/s}$$

Example 21.

The velocity-time graph of a particle moving along a straight line is shown below.

The acceleration and deceleration are same and it is equal to 4 m/s². If the average velocity during the motion is 15 m/s and total time of motion is 20 second then find



(a) *the value of t* ***(b)*** *the maximum velocity of the particle during the journey.* ***(c)*** *the distance travelled with uniform velocity.*

Solution : v = 0 + at

$$\text{Total displacement} = \frac{1}{2}(20-2t+20) \times 4t = 2t\,(40-2t)$$

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

$$15 = \frac{2t\,(40-2t)}{20}$$

Solving quadratic equation, 150 = 40t – 2t² ⇒ t = 5 sec. (another solution not acceptable think why!)

Maximum velocity = 4t = 4 × 5 = 20 m/s

Distance travelled with uniform velocity

$$= (20-2t)\,V = (20-2\times 5)\times 20 = 200\,\text{m}$$

RELATIVE VELOCITY (In one dimension)

The velocity of A relative to B is the velocity with which A appears to be moving w.r.t.an observer who is moving with the velocity of B

Relative velocity of A w.r.t. B

$$\vec{v}_{AB} = \vec{v}_A - \vec{v}_B$$

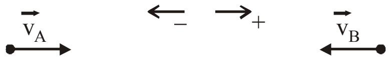
Similarly, relative velocity of B w.r.t. A

$$\vec{v}_{BA} = \vec{v}_B - \vec{v}_A$$

Case 1: Bodies moving in same direction :

$$\vec{v}_{AB} = \vec{v}_A - \vec{v}_B \Rightarrow v_{AB} = v_A - v_B$$

Case 2: Bodies moving in opposite direction :



$$\vec{v}_{AB} = \vec{v}_A - (-\vec{v}_B) \Rightarrow v_{AB} = v_A + v_B$$

Example 22.

Two trains, one travelling at 54kmph and the other at 72kmph, are headed towards each other on a level track. When they are two kilometers apart, both drivers simultaneously apply their brakes. If their brakes produces equal retardation in both the trains at a rate of 0.15 m/s², determine whether there is a collision or not.

Solution :

Speed of first train = 54 kmph = 15m/s.

Speed of second train = 72kmph = 20 m/s

As both the trains are headed towards each other, relative velocity of one train with respect to other is given as

$v_r = 15 + 20 = 35$ m/s

Both trains are retarded by acceleration of 0.15 m/s². Relative retardation $a_r = 0.15 + 0.15 = 0.3$ m/s².

Now, we assume one train is at rest and other is coming at 35m/s retarded by 0.3 m/s² at a distance of two kilometer. The maximum distance travelled by the moving train while retarding is

$$s_{\max} = \frac{v_r^2}{2a_r} = \frac{(35)^2}{2\times 0.3} = 2041.66\text{m}$$

It is more than 2km, which shows that it will hit the second train.

Example 23.

Two cars started simultaneously towards each other from towns A and B which are 480 km apart. It took first car travelling from A to B 8 hours to cover the distance and second car travelling from B to A 12 hours. Determine when the car meet after starting and at what distance from town A. Assuming that both the cars travelled with constant speed.

Solution : $\text{Velocity of car from A} = \dfrac{480}{8} = 60 \text{ km/hour}$

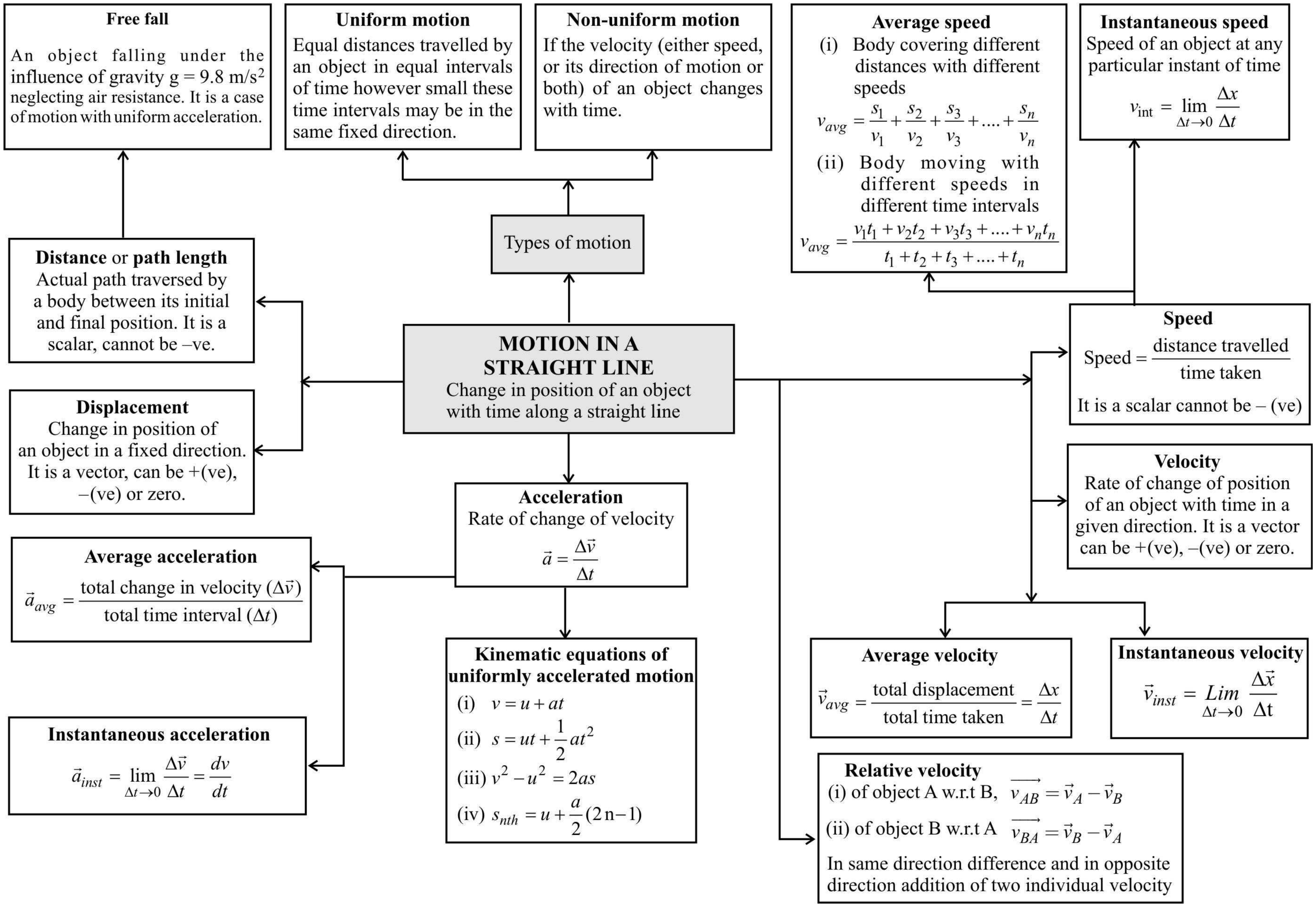
$$\text{velocity of car from B} = \frac{480}{12} = 40 \text{ km/hour}$$

Let the two cars meet at *t* hour

$$\therefore\ t = \frac{\text{total distance}}{\text{relative velocity of meeting}} = \frac{480}{60+40} = 4.8 \text{ hour}$$

The distance $s = v_A \times t = 60 \times 4.8 = 288$ km.

CONCEPT MAP



MOTION IN A STRAIGHT LINE
Change in position of an object with time along a straight line

Types of motion

Uniform motion
Equal distances travelled by an object in equal intervals of time however small these time intervals may be in the same fixed direction.

Non-uniform motion
If the velocity (either speed, or its direction of motion or both) of an object changes with time.

Distance or **path length**
Actual path traversed by a body between its initial and final position. It is a scalar, cannot be –ve.

Free fall
An object falling under the influence of gravity g = 9.8 m/s^2 neglecting air resistance. It is a case of motion with uniform acceleration.

Displacement
Change in position of an object in a fixed direction. It is a vector, can be +(ve), –(ve) or zero.

Acceleration
Rate of change of velocity

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

Average acceleration

$$\vec{a}_{avg} = \frac{\text{total change in velocity } (\Delta\vec{v})}{\text{total time interval } (\Delta t)}$$

Instantaneous acceleration

$$\vec{a}_{inst} = \lim_{\Delta t \to 0} \frac{\Delta\vec{v}}{\Delta t} = \frac{dv}{dt}$$

Kinematic equations of uniformly accelerated motion

(i) $v = u + at$

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

(iii) $v^2 - u^2 = 2as$

(iv) $s_{nth} = u + \frac{a}{2}(2\text{n}-1)$

Speed

$$\text{Speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

It is a scalar cannot be – (ve)

Average speed

(i) Body covering different distances with different speeds

$$v_{avg} = \frac{s_1}{v_1} + \frac{s_2}{v_2} + \frac{s_3}{v_3} + ... + \frac{s_n}{v_n}$$

(ii) Body moving with different speeds in different time intervals

$$v_{avg} = \frac{v_1t_1 + v_2t_2 + v_3t_3 + ... + v_nt_n}{t_1 + t_2 + t_3 + ... + t_n}$$

Instantaneous speed
Speed of an object at any particular instant of time

$$v_{\text{int}} = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$$

Velocity
Rate of change of position of an object with time in a given direction. It is a vector can be +(ve), –(ve) or zero.

Average velocity

$$\vec{v}_{avg} = \frac{\text{total displacement}}{\text{total time taken}} = \frac{\Delta x}{\Delta t}$$

Instantaneous velocity

$$\vec{v}_{inst} = Lim_{\Delta t \to 0} \frac{\Delta\vec{x}}{\Delta \text{t}}$$

Relative velocity

(i) of object A w.r.t B, $\overrightarrow{v_{AB}} = \vec{v}_A - \vec{v}_B$

(ii) of object B w.r.t A $\overrightarrow{v_{BA}} = \vec{v}_B - \vec{v}_A$

In same direction difference and in opposite direction addition of two individual velocity

EXERCISE - 1

Conceptual Questions

1. The study of motion, without consideration of its cause is studied in
(a) statistics (b) kinematics
(c) mechanics (d) modern physics

2. The ratio of the numerical values of the average velocity and average speed of a body is always:
(a) unity (b) unity or less
(c) unity or more (d) less than unity

3. A particle has moved from one position to another position
(a) its distance is zero
(b) its displacement is zero
(c) neither distance nor displacement is zero
(d) average velocity is zero

4. The displacement of a body is zero. The distance covered
(a) is zero
(b) is not zero
(c) may or may not be zero
(d) depends upon the acceleration

5. Which of the following changes when a particle is moving with uniform velocity?
(a) Speed (b) Velocity
(c) Acceleration (d) Position vector

6. The slope of the velocity time graph for retarded motion is
(a) positive (b) negative
(c) zero (d) can be +ve, –ve or zero

7. The area of the acceleration-displacement curve of a body gives
(a) impulse
(b) change in momentum per unit mass
(c) change in KE per unit mass
(d) total change in energy

8. If the displacement of a particle varies with time as $\sqrt{x} = t + 7$, the
(a) velocity of the particle is inversely proportional to t
(b) velocity of the particle is proportional to t
(c) velocity of the particle is proportional to $\sqrt{t}$
(d) the particle moves with a constant acceleration

9. The initial velocity of a particle is u (at t = 0) and the acceleration a is given by f t.
Which of the following relation is valid?
(a) $v = u + ft^2$ (b) $v = u + ft^2/2$
(c) $v = u + ft$ (d) $v = u$

10. The displacement x of a particle moving along a straight line at time t is given by

$$x = a_0 + a_1 t + a_2 t^2$$

What is the acceleration of the particle
(a) a_1 (b) a_2
(c) $2\,a_2$ (d) $3\,a_2$

11. The displacement-time graphs of two particles A and B are straight lines making angles of respectively 30º and 60º with the time axis. If the velocity of A is v_A and that of B is v_B, the value of v_A/v_B is
(a) 1/2 (b) $1/\sqrt{3}$
(c) $\sqrt{3}$ (d) 1/3

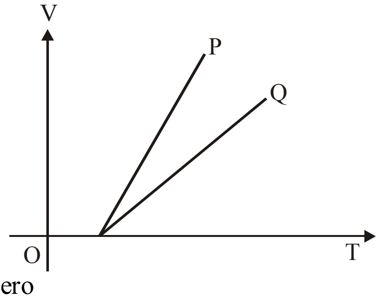
12. A person travels along a straight road for the first half time with a velocity v_1 and the second half time with a velocity v_2. Then the mean velocity $\bar{v}$ is given by
(a) $\bar{v} = \dfrac{v_1 + v_2}{2}$ (b) $\dfrac{2}{v} = \dfrac{1}{v_1} + \dfrac{1}{v_2}$
(c) $\bar{v} = \sqrt{v_1 v_2}$ (d) $\bar{v} = \sqrt{\dfrac{v_2}{v_1}}$

13. A particle covers half of the circle of radius r. Then the displacement and distance of the particle are respectively
(a) $2\pi r, 0$ (b) $2r, \pi r$
(c) $\dfrac{\pi r}{2}, 2r$ (d) $\pi r, r$

14. The distance through which a body falls in the nth second is h. The distance through which it falls in the next second is
(a) h (b) $h + \dfrac{g}{2}$
(c) $h - g$ (d) $h + g$

15. It is given that $t = px^2 + qx$, where x is displacement and t is time. The acceleration of particle at origin is
(a) $-\dfrac{2p}{q^3}$ (b) $-\dfrac{2q}{p^3}$ (c) $\dfrac{2p}{q^3}$ (d) $\dfrac{2q}{p^3}$

16. Figure shows the v-t graph for two particles P and Q. Which of the following statements regarding their relative motion is true ?
Their relative velocity is



(a) is zero
(b) is non-zero but constant
(c) continuously decreases
(d) continuously increases

17. A stone is dropped into a well in which the level of water is h below the top of the well. If v is velocity of sound, the time T after which the splash is heard is given by
(a) $T = 2h/v$ (b) $T = \sqrt{\left(\dfrac{2h}{g}\right)} + \dfrac{h}{v}$
(c) $T = \sqrt{\left(\dfrac{2h}{v}\right)} + \dfrac{h}{g}$ (d) $T = \sqrt{\left(\dfrac{h}{2g}\right)} + \dfrac{2h}{v}$

18. A point traversed half of the distance with a velocity v_0. The half of remaining part of the distance was covered with velocity v_1 & second half of remaining part by v_2 velocity. The mean velocity of the point, averaged over the whole time of motion is

(a) $\frac{v_0 + v_1 + v_2}{3}$ (b) $\frac{2v_0 + v_1 + v_2}{3}$

(c) $\frac{v_0 + .2v_1 + 2v_2}{3}$ (d) $\frac{2v_0(v_1 + v_2)}{(2v_0 + v_1 + v_2)}$

19. The acceleration of a particle is increasing linearly with time t as bt. The particle starts from the origin with an initial velocity v_0. The distance travelled by the particle in time t will be

(a) $v_0 t + \frac{1}{3}bt^2$ (b) $v_0 t + \frac{1}{3}bt^3$

(c) $v_0 t + \frac{1}{6}bt^3$ (d) $v_0 t + \frac{1}{2}bt^2$

20. The deceleration experienced by a moving motorboat after its engine is cut off, is given by $dv/dt = -kv^3$ where k is constant. If v_0 is the magnitude of the velocity at cut-off, the magnitude of the velocity at a time t after the cut-off is

(a) $\frac{v_0}{\sqrt{(2v_0^2 kt + 1)}}$ (c) $v_0 e^{-kt}$

(c) $v_0/2$ (d) v_0

21. The displacement x of a particle varies with time according to the relation $x = \frac{a}{b}(1 - e^{-bt})$. Then select the false alternatives.

(a) At $t = \frac{1}{b}$, the displacement of the particle is nearly $\frac{2}{3}\left(\frac{a}{b}\right)$

(b) the velocity and acceleration of the particle at t = 0 are a and –ab respectively

(c) the particle cannot go beyond $x = \frac{a}{b}$

(d) the particle will not come back to its starting point at $t \to \infty$

22. The displacement of a particle is given by $\sqrt{x} = t + 1$. Which of the following statements about its velocity is true ?

(a) It is zero

(b) It is constant but not zero

(c) It increases with time

(d) It decreases with time

23. Two bodies of masses m_1 and m_2 fall from heights h_1 and h_2 respectively. The ratio of their velocities, when they hit the ground is

(a) $\frac{h_1}{h_2}$ (b) $\sqrt{\frac{h_1}{h_2}}$

(c) $\frac{m_1 h_1}{m_1 h_2}$ (d) $\frac{h_1^2}{h_2^2}$

24. Two cars A and B are travelling in the same direction with velocities v_A and v_B ($v_A > v_B$). When the car A is at a distance d behind the car B the driver of the car A applies brakes producing a uniform retardation a. There will be no collision when

(a) $d < \frac{(v_A - v_B)^2}{2a}$ (b) $d < \frac{v_A^2 - v_B^2}{2a}$

(c) $d > \frac{(v_A - v_B)^2}{2a}$ (d) $d > \frac{v_A^2 - v_B^2}{2a}$

25. A body is thrown upwards and reaches its maximum height. At that position

(a) its acceleration is minimum

(b) its velocity is zero and its acceleration is also zero

(c) its velocity is zero but its acceleration is maximum

(d) its velocity is zero and its acceleration is the acceleration due to gravity.

EXERCISE - 2

Applied Questions

1. The position x of a particle varies with time (t) as $x = At^2 - Bt^3$. The acceleration at time t of the particle will be equal to zero. What is the value of t?

(a) $\frac{2A}{3B}$ (b) $\frac{A}{B}$

(c) $\frac{A}{3B}$ (d) zero

2. The acceleration of a particle, starting from rest, varies with time according to the relation

$$a = -s\omega^2 \sin \omega t$$

The displacement of this particle at a time t will be

(a) s sin ω t (b) s ω cos ω t

(c) s ω sin ω t (d) $-\frac{1}{2}(s\omega^2 \sin \omega t)t^2$

3. The displacement of a particle is given by

$$y = a + bt + ct^2 - dt^4$$

The initial velocity and acceleration are respectively

(a) b, – 4 d (b) – b, 2 c

(c) b, 2 c (d) 2 c, – 4 d

4. A passenger travels along the straight road for half the distance with velocity v_1 and the remaining half distance with velocity v_2. Then average velocity is given by

(a) $v_1 v_2$ (b) v_2^2 / v_1^2

(c) $(v_1 + v_2)/2$ (d) $2v_1 v_2 / (v_1 + v_2)$

5. A point moves with uniform acceleration and v_1, v_2 and v_3 denote the average velocities in t_1, t_2 and t_3 sec. Which of the following relation is correct?

(a) $(v_1 - v_2):(v_2 - v_3) = (t_1 - t_2):(t_2 + t_3)$

(b) $(v_1 - v_2):(v_2 - v_3) = (t_1 + t_2):(t_2 + t_3)$

(c) $(v_1 - v_2):(v_2 - v_3) = (t_1 - t_2):(t_1 - t_3)$

(d) $(v_1 - v_2):(v_2 - v_3) = (t_1 - t_2):(t_2 - t_3)$

6. A bus starts moving with acceleration 2 m/s^2. A cyclist 96 m behind the bus starts simultaneously towards the bus at 20 m/s. After what time will he be able to overtake the bus?

(a) 4 sec (b) 8 sec

(c) 12 sec (d) 16 sec

7. When the speed of a car is v, the minimum distance over which it can be stopped is s. If the speed becomes n v, what will be the minimum distance over which it can be stopped during same retardation

(a) s/n (b) n s

(c) s/n^2 (d) n^2 s

8. The two ends of a train moving with constant acceleration pass a certain point with velocities u and v. The velocity with which the middle point of the train passes the same point is

(a) (u + v)/2 (b) $(u^2 + v^2)/2$

(c) $\sqrt{(u^2 + v\upsilon^2)/2}$ (d) $\sqrt{u^2 + v^2}$

9. A particle accelerates from rest at a constant rate for some time and attains a velocity of 8 m/sec. Afterwards it decelerates with the constant rate and comes to rest. If the total time taken is 4 sec, the distance travelled is

(a) 32m (b) 16m

(c) 4m (d) None of the above

10. The velocity of a particle at an instant is 10 m/s. After 5 sec, the velocity of the particle is 20 m/s. Find the velocity at 3 seconds before from the instant when velocity of a particle is 10m/s.

(a) 8 m/s (b) 4 m/s

(c) 6 m/s (d) 7 m/s

11. A particle experiences constant acceleration for 20 seconds after starting from rest. If it travels a distance s_1 in the first 10 seconds and distance s_2 in the next 10 seconds, then

(a) $s_2 = s_1$ (b) $s_2 = 2\ s_1$

(c) $s_2 = 3\ s_1$ (d) $s_2 = 4\ s_1$

12. A train of 150 m length is going towards north direction at a speed of 10 ms^{-1}. A parrot flies at a speed of 5 ms^{-1} towards south direction parallel to the railway track. The time taken by the parrot to cross the train is equal to

(a) 12 s (b) 8 s

(c) 15 s (d) 10 s

13. A particle is moving along a straight line path according to the relation

$$s^2 = at^2 + 2bt + c$$

s represents the distance travelled in t seconds and a, b, c are constants. Then the acceleration of the particle varies as

(a) s^{-3} (b) $s^{3/2}$

(c) $s^{-2/3}$ (d) s^2

14. A stone thrown vertically upwards with a speed of 5 m/sec attains a height H_1. Another stone thrown upwards from the same point with a speed of 10 m/sec attains a height H_2. The correct relation between H_1 and H_2 is

(a) $H_2 = 4H_1$ (b) $H_2 = 3H_1$

(c) $H_1 = 2H_2$ (d) $H_1 = H_2$

15. A body covers 26, 28, 30, 32 meters in 10th, 11th, 12th and 13th seconds respectively. The body starts

(a) from rest and moves with uniform velocity

(b) from rest and moves with uniform acceleration

(c) with an initial velocity and moves with uniform acceleration

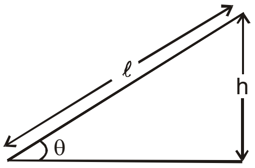
(d) with an initial velocity and moves with uniform velocity

16. A stone thrown upward with a speed u from the top of the tower reaches the ground with a velocity 3u. The height of the tower is

(a) $3u^2/g$ (b) $4u^2/g$

(c) $6u^2/g$ (d) $9u^2/g$

17. A smooth inclined plane is inclined at an angle θ with horizontal. A body starts from rest and slides down the inclined surface.



Then the time taken by it to reach the bottom is

(a) $\sqrt{\left(\frac{2h}{g}\right)}$ (b) $\sqrt{\left(\frac{2\ell}{g}\right)}$

(c) $\frac{1}{\sin\theta}\sqrt{\frac{2h}{g}}$ (d) $\sin\theta\frac{\sqrt{(2h)}}{g}$

18. A ball is dropped downwards, after 1 sec another ball is dropped downwards from the same point. What is the distance between them after 3 sec?

(a) 25m (b) 20m

(c) 50m (d) 9.8m

19. Two trains are each 50 m long moving parallel towards each other at speeds 10 m/s and 15 m/s respectively. After what time will they pass each other?

(a) $5\sqrt{\frac{2}{3}}$ sec (b) 4 sec

(c) 2 sec (d) 6 sec

20. A ball is projected vertically upwards with kinetic energy E. The kinetic energy of the ball at the highest point of its flight will be

(a) E (b) $E/\sqrt{2}$

(c) E/2 (d) zero

21. A particle is moving in a straight line with initial velocity and uniform acceleration a. If the sum of the distance travelled in *t*th and (t + 1)th seconds is 100 cm, then its velocity after *t* seconds, in cm/s, is

(a) 80 (b) 50

(c) 20 (d) 30

22. Similar balls are thrown vertically each with a velocity 20 ms^{-1}, one on the surface of earth and the other on the surface of moon. What will be ratio of the maximum heights attained by them? (Acceleration on moon = 1.7 ms^{-2} approx)

(a) 6 (b) $\frac{1}{6}$

(c) $\frac{1}{5}$ (d) None of these

23. The relative velocity V_{AB} or V_{BA} of two bodies A & B may be

(1) greater than velocity of body A
(2) greater than velocity of body B
(3) less than the velocity of body A
(4) less than the velocity of body B
(a) (1) and (2) only (b) (3) and (4) only
(c) (1), (2) and (3) only (d) (1), (2), (3) and (4)

24. A stone is thrown vertically upwards. When the particle is at a height half of its maximum height, its speed is 10m/sec, then maximum height attained by particle is ($g = 10 m/sec^2$)

(a) 8m (b) 10m
(c) 15m (d) 20m

25. From a 10m high building a stone 'A' is dropped & simultaneously another stone 'B' is thrown horizontally with an initial speed of 5 m/sec^{-1}. Which one of the following statements is true?

(a) It is not possible to calculate which one of two stones will reach ground first
(b) Both stones 'A' & 'B' will reach the ground simultaneously.
(c) 'A' stones reach the ground earlier than 'B'
(d) 'B' stones reach the ground earlier than 'A'

26. An automobile travelling with a speed of 60 km/h, can apply brake to stop within a distance of 20m. If the car is going twice as fast i.e., 120 km/h, the stopping distance will be

(a) 60m (b) 40m
(c) 20m (d) 80m

27. The motion of a particle is described by the equation u = at. The distance travelled by particle in first 4 sec is

(a) 4a (b) 12a
(c) 6a (d) 8a

28. If you were to throw a ball vertically upward with an initial velocity of 50 m/s, approximately how long would it take for the ball to return to your hand? Assume air resistance is negligible.

(a) 2.5 s (b) 5.0 s
(c) 7.5 s (d) 10 s

29. A body travels 2 m in the first two second and 2.20 m in the next 4 second with uniform deceleration. The velocity of the body at the end of 9 second is

(a) $-10\ ms^{-1}$ (b) $-0.20\ ms^{-1}$
(c) $-0.40\ ms^{-1}$ (d) $-0.80\ ms^{-1}$

30. From a 200 m high tower, one ball is thrown upwards with speed of 10 ms^{-1} and another is thrown vertically downwards at the same speeds simultaneously. The time difference of their reaching the ground will be nearest to

(a) 12 s (b) 6 s
(c) 2 s (d) 1 s

31. A rocket is fired upward from the earth's surface such that it creates an acceleration of 19.6 ms^{-2}. If after 5 s, its engine is switched off, the maximum height of the rocket from earth's surface would be

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

32. A particle travels half the distance with a velocity of 6 ms^{-1}. The remaining half distance is covered with a velocity of 4 ms^{-1} for half the time and with a velocity of 8 ms^{-1} for the rest of the half time. What is the velocity of the particle averaged over the whole time of motion ?

(a) 9 ms^{-1} (b) 6 ms^{-1}
(c) 5.35 ms^{-1} (d) 5 ms^{-1}

33. A ball released from a height falls 5 m in one second. In 4 seconds it falls through

(a) 20m (b) 1.25m
(c) 40m (d) 80m

34. A food packet is released from a helicopter rising steadily at the speed of 2 m/sec. After 2 seconds the velocity of the packet is
($g = 10 m/sec^2$)

(a) 22 m/sec (b) 20 m/sec
(c) 18 m/sec (d) none of these

35. The displacement *x* of a particle along a straight line at time t is given by : $x = a_0 + \frac{a_1 t}{2} + \frac{a_2}{3}t^2$. The acceleration of the particle is

(a) $\frac{a_2}{3}$ (b) $\frac{2a_2}{3}$ (c) $\frac{a_1}{2}$ (d) $a_0 + \frac{a_2}{3}$

36. A rubber ball is dropped from a height of 5 metre on a plane where the acceleration due to gravity is same as that onto the surface of the earth. On bouncing, it rises to a height of 1.8 m. On bouncing, the ball loses its velocity by a factor of

(a) $\frac{3}{5}$ (b) $\frac{9}{25}$ (c) $\frac{2}{5}$ (d) $\frac{16}{25}$

37. A boy moving with a velocity of 20 km h^{-1} along a straight line joining two stationary objects. According to him both objects

(a) move in the same direction with the same speed of 20 km h^{-1}
(b) move in different direction with the same speed of 20 km h^{-1}
(c) move towards him
(d) remain stationary

38. A man leaves his house for a cycle ride. He comes back to his house after half-an-hour after covering a distance of one km. What is his average velocity for the ride ?

(a) zero (b) 2 km h^{-1}
(c) 10 km s^{-1} (d) $\frac{1}{2}$ km s^{-1}

39. A car travels from A to B at a speed of 20 km h^{-1} and returns at a speed of 30 km h^{-1}. The average speed of the car for the whole journey is

(a) 5 km h^{-1} (b) 24 km h^{-1}
(c) 25 km h^{-1} (d) 50 km h^{-1}

40. A body dropped from a height ‘h’ with an initial speed zero, strikes the ground with a velocity 3 km/hour. Another body of same mass dropped from the same height ‘h’ with an initial speed u' = 4 km/hour. Find the final velocity of second mass, with which it strikes the ground

(a) 3 km/hr (b) 4 km/hr

(c) 5 km/hr (d) 6 km/hr

41. An electron starting from rest has a velocity that increases linearly with time i.e. v = kt where $k = 2\ \mathrm{m s^{-2}}$. The distance covered in the first 3 second is

(a) 9m (b) 16m

(c) 27m (d) 36m

42. A body released from the top of a tower falls through half the height of the tower in 2 s. In what time shall the body fall through the height of the tower ?

(a) 4 s (b) 3.26 s

(c) 3.48 s (d) 2.828 s

43. The displacement x of a particle at the instant when its velocity is v is given by $v = \sqrt{3x+16}$. Its acceleration and initial velocity are

(a) 1.5 units, 4 units (b) 3 units, 4 units

(b) 16 units, 1.6 units (d) 16 units, 3 units

44. Let A, B, C, D be points on a vertical line such that AB = BC = CD. If a body is released from position A, the times of descent through AB, BC and CD are in the ratio.

(a) $1:\sqrt{3}-\sqrt{2}:\sqrt{3}+\sqrt{2}$ (b) $1:\sqrt{2}-1:\sqrt{3}-\sqrt{2}$

(c) $1:\sqrt{2}-1:\sqrt{3}$ (d) $1:\sqrt{2}:\sqrt{3}-1$

45. A body moves in a straight line along Y-axis. Its distance y (in metre) from the origin is given by $y = 8t - 3t^2$. The average speed in the time interval from t = 0 second to t = 1 second is

(a) $-4\ \mathrm{ms^{-1}}$ (b) zero

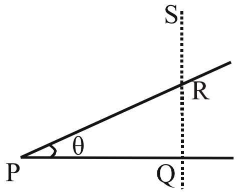
(c) $5\ \mathrm{ms^{-1}}$ (d) $6\ \mathrm{ms^{-1}}$

46. The acceleration due to gravity on planet A is nine times the acceleration due to gravity on planet B. A man jumps to a height 2m on the surface of A. What is height of jump by same person on planet B?

(a) 2/3 m (b) 2/9 m

(c) 18m (d) 6m

47. In the given figure the distance PQ is constant. SQ is a vertical line passing through point R. A particle is kept at R and the plane PR is such that angle θ can be varied such that R lies on line SQ. The time taken by particle to come down varies, as the θ increases



(a) decreases continuously

(b) increases

(c) increases then decreases

(d) decreases then increases

48. The displacement x of a particle varies with time t as $x = ae^{-\alpha t} + be^{\beta t}$, where a, b, α and β are positive constants. The velocity of the particle will

(a) be independent of α and β

(b) drop to zero when $\alpha = \beta$

(c) go on decreasing with time

(d) go on increasing with time

49. Which one of the following equations represents the motion of a body with finite constant acceleration ? In these equations, y denotes the displacement of the body at time t and a, b and c are constants of motion.

(a) $y = at$ (b) $y = at + bt^2$

(c) $y = at + bt^2 + ct^3$ (d) $y = \frac{a}{t} + bt$

50. The dependence of velocity of a body with time is given by the equation $v = 20 + 0.1t^2$. The body is in

(a) uniform retardation

(b) uniform acceleration

(c) non-uniform acceleration

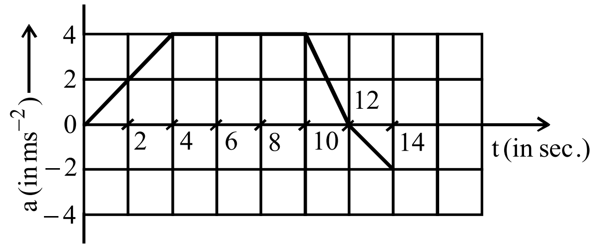
(d) zero acceleration.

51. Two stones are thrown from the top of a tower, one straight down with an initial speed u and the second straight up with the same speed u. When the two stones hit the ground, they will have speeds in the ratio

(a) 2 : 3 (b) 2 : 1

(c) 1 : 2 (d) 1 : 1

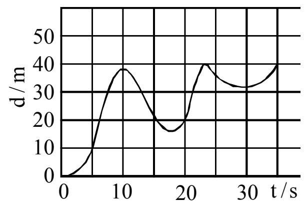
52. A graph of acceleration versus time of a particle starting from rest at t = 0 is as shown in Fig. The speed of the particle at t = 14 second is



(a) $2\ \mathrm{ms^{-1}}$ (b) $34\ \mathrm{ms^{-1}}$

(c) $20\ \mathrm{ms^{-1}}$ (d) $42\ \mathrm{ms^{-1}}$

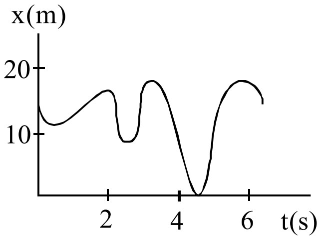
53. In the displacement d versus time t graph given below, the value of average velocity in the time interval 0 to 20 s is (in m/s)



(a) 1.5 (b) 4

(c) 1 (d) 2

54. Figure shows the position of a particle moving along the X-axis as a function of time.



Which of the following is correct?

(a) The particle has come to the rest 6 times

(b) The maximum speed is at t = 6 s.

(c) The velocity remains positive for t = 0 to t = 6 s.

(d) The average velocity for the total period shown is negative.

55. A steel ball is bouncing up and down on a steel plate with a period of oscillation of 1 second. If g = 10 ms^{-2}, then it bounces up to a height of

(a) 5m (b) 10m

(c) 2.5m (d) 1.25m

56. A body starts from rest and travels a distance x with uniform acceleration, then it travels a distance 2x with uniform speed, finally it travels a distance 3x with uniform retardation and comes to rest. If the complete motion of the particle is along a straight line, then the ratio of its average velocity to maximum velocity is

(a) 2/5 (b) 3/5

(c) 4/5 (d) 6/7

57. When two bodies move uniformly towards each other, the distance decreases by 6 ms^{-1}. If both bodies move in the same directions with the same speeds (as above), the distance between them increases by 4 ms^{-1}. Then the speeds of the two bodies are

(a) 3 ms^{-1} and 3 ms^{-1} (b) 4 ms^{-1} and 2 ms^{-1}

(c) 5 ms^{-1} and 1 ms^{-1} (d) 7 ms^{-1} and 3 ms^{-1}

58. A ball is thrown vertically upward with a velocity 'u' from the balloon descending with velocity v. The ball will pass by the balloon after time

(a) $\frac{u-v}{2g}$ (b) $\frac{u+v}{2g}$

(c) $\frac{2(u-v)}{g}$ (d) $\frac{2(u+v)}{g}$

59. Two bodies begin a free fall from the same height at a time interval of N s. If vertical separation between the two bodies is 1 after n second from the start of the first body, then n is equal to

(a) $\sqrt{nN}$ (b) $\frac{1}{gN}$

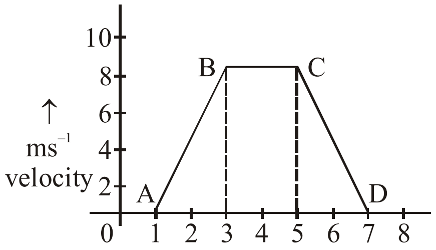
(c) $\frac{1}{gN}+\frac{N}{2}$ (d) $\frac{1}{gN}-\frac{N}{4}$

60. A particle starting from rest falls from a certain height. Assuming that the acceleration due to gravity remain the same throughout the motion, its displacements in three successive half second intervals are S_1, S_2 and S_3 then

(a) $S_1 : S_2 : S_3 = 1 : 5 : 9$ (b) $S_1 : S_2 : S_3 = 1 : 3 : 5$

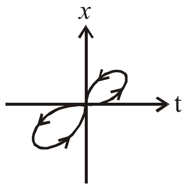
(c) $S_1 : S_2 : S_3 = 9 : 2 : 3$ (d) $S_1 : S_2 : S_3 = 1 : 1 : 1$

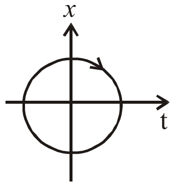
61. For the velocity time graph shown in the figure below the distance covered by the body in the last two seconds of its motion is what fraction of the total distance travelled by it in all the seven seconds?

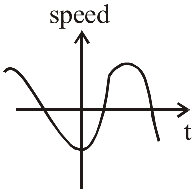


(a) $\frac{1}{2}$ (b) $\frac{1}{4}$ (c) $\frac{2}{3}$ (d) $\frac{1}{3}$

62. Which of the following graph cannot possibly represent one dimensional motion of a particle?

(a)


(b)


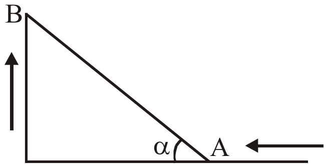
(c)


(d) All of the above

63. The distance time graph of a particle at time t makes angles 45° with the time axis. After one second, it makes angle 60° with the time axis. What is the acceleration of the particle?

(a) $\sqrt{3}-1$ (b) $\sqrt{3}+1$ (c) $\sqrt{3}$ (d) 1

64. Two particles A and B are connected by a rigid rod AB. The rod slides along perpendicular rails as shown here. The velocity of A to the left is 10 m/s. What is the velocity of B when angle α = 60°?



(a) 9.8 m/s (b) 10 m/s (c) 5.8 m/s (d) 17.3 m/s

65. A balloon starts rising from the ground with an acceleration of 1.25 ms^{-2}. After 8 s, a stone is released from the balloon. The stone will (Taking g = 10 m s^{-2})

(a) begin to move down after being released

(b) reach the ground in 4 s

(c) cover a distance of 40 m in reaching the ground

(d) will have a displacement of 50 m.

66. A point initially at rest moves along x-axis. Its acceleration varies with time as $a = (6t + 5)m/s^2$. If it starts from origin, the distance covered in 2 s is

(a) 20m (b) 18m (c) 16m (d) 25m

67. The relation between time t and distance x is $t = \alpha x^2 + \beta x$ where α and β are constants. The retardation is

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

68. A stone is just released from the window of a train moving along a horizontal straight track. The stone will hit the ground following a

(a) straight line path (b) circular path
(c) parabolic path (d) hyperbolic path

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

(a) 182 m (b) 91 m
(c) 111 m (d) 293 m

70. A car accelerates from rest at a constant rate α for some time after which it decelerates at a constant rate β to come to rest. If the total time elapsed is t, the maximum velocity acquired by the car is given by

(a) $\left(\dfrac{\alpha^2+\beta^2}{\alpha\beta}\right)t$ (b) $\left(\dfrac{\alpha^2-\beta^2}{\alpha\beta}\right)t$

(c) $\left(\dfrac{\alpha+\beta}{\alpha\beta}\right)t$ (d) $\left(\dfrac{\alpha\beta}{\alpha+\beta}\right)t$

71. A car moving with a speed of 40 km/hour can be stopped by applying brakes after at least 2m. If the same car is moving with a speed of 80km/hour, what is the minimum stopping distance.

(a) 8m (b) 6m
(c) 4m (d) 2m

72. A man throws balls with same speed vertically upwards one after the other at an interval of 2 sec. What should be the speed of throw so that more than two balls are in air at any time

(a) only with speed 19.6 m/s
(b) more than 19.6 m/s
(c) at least 9.8 m/s
(d) any speed less then 19.6 m/s.

73. A ball is dropped from a high rise platform at t = 0 starting from rest. After 6 seconds another ball is thrown downwards from the same platform with a speed v. The two balls meet at t = 18s. What is the value of v?
(take g = 10 m/s^2)

(a) 75 m/s (b) 55 m/s
(c) 40 m/s (d) 60 m/s

74. A particle moves a distance x in time t according to equation $x = (t + 5)^{-1}$. The acceleration of particle is proportional to

(a) $(\text{velocity})^{3/2}$ (b) $(\text{distance})^2$
(c) $(\text{distance})^{-2}$ (d) $(\text{velocity})^{2/3}$

75. A particle has initial velocity $(2\vec{i}+3\vec{j})$ and acceleration $(0.3\vec{i}+0.2\vec{j})$. The magnitude of velocity after 10 seconds will be

(a) $9\sqrt{2}$ units (b) $5\sqrt{2}$ units
(c) 5 units (d) 9 units

76. 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

(a) $h_1 = \dfrac{h_2}{3} = \dfrac{h_3}{5}$ (b) $h_2 = 3h_1$ and $h_3 = 3h_2$
(c) $h_1 = h_2 = h_3$ (d) $h_1 = 2h_2 = 3h_3$

77. A ball is released from the top of a tower of height h meters. It takes T seconds to reach the ground. What is the position of the ball at $\dfrac{T}{3}$ second

(a) $\dfrac{8h}{9}$ meters from the ground
(b) $\dfrac{7h}{9}$ meters from the ground
(c) $\dfrac{h}{9}$ meters from the ground
(d) $\dfrac{17h}{18}$ meters from the ground

78. The motion of particle is described by the equation x = a + bt^2, where a = 15 cm and b = 3 cm/sec^2. Its instant velocity at time 3 sec will be

(a) 36 cm/sec (b) 9 cm/sec
(c) 4.5 cm/sec (d) 18 cm/sec

79. Which one of the following equation represents the motion of a body moving with constant finite acceleration? In these equation, y denotes the displacement in time t and p, q and r are constant:

(a) y = (p + qt)(t + pt)
(b) y = p + t/r
(c) y = (p + t) (q + t) (r + t)
(d) $y = \dfrac{(p+qt)}{rt}$

80. A ball is thrown up with velocity 19.6 m/s. The maximum height attained by the ball is

(a) 29.2 m (b) 9.8 m
(c) 19.6 m (d) 15.8 m

81. A train *A* which is 120 m long is running with velocity 20 m/s while train *B* which is 130 m long is running in opposite direction with velocity 30 m/s. What is the time taken by train *B* to cross the train *A* ?

(a) 5 sec (b) 25 sec
(c) 10 sec (d) 100 sec

82. A car travelling at a speed of 30 km h^{-1} is brought to a halt in 8 m by applying brakes. If the same car is travelling at 60 km h^{-1}, it can be brought to a halt with the same braking power in

(a) 32 m (b) 24 m
(c) 16 m (d) 8 cm

83. Velocity time curve for a body projected vertically upwards is

(a) parabola (b) ellipse
(c) hyperbola (d) straight line

84. A train is moving towards east and a car is along north, both with same speed. The observed direction of car to the passenger in the train is

(a) east-north direction (b) west-north direction
(c) south-east direction (d) None of the above

85. A metro train starts from rest and in 5 s achieves 108 km/h. After that it moves with constant velocity and comes to rest after travelling 45 m with uniform retardation. If total distance travelled is 395 m, find total time of travelling.

(a) 12.2 s (b) 15.3 s

(c) 9 s (d) 17.2 s

86. A particle moves along a straight line OX. At a time *t* (in second) the distance x (in metre) of the particle from O is given by $x = 40 + 12t - t^3$. How long would the particle travel before coming to rest?

(a) 24m (b) 40m

(c) 56m (d) 16m

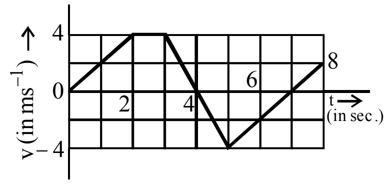
87. The displacement of particle is given by

$x = a_0 + \frac{a_1 t}{2} - \frac{a_2 t^2}{3}$. What is its acceleration?

(a) $\frac{2a_2}{3}$ (b) $-\frac{2a_2}{3}$

(c) a_2 (d) zero

88. Figure here gives the speed-time graph for a body. The displacement travelled between t = 1.0 second and t = 7.0 second is nearest to



(a) 1.5m (b) 2m

(c) 3m (d) 4m

89. A boat takes 2 hours to travel 8 km and back in still water lake. With water velocity of 4 km h^{-1}, the time taken for going upstream of 8 km and coming back is

(a) 160 minutes (b) 80 minutes

(c) 100 minutes (d) 120 minutes

90. A lift in which a man is standing, is moving upwards with a speed of 10 ms^{-1}. The man drops a coin from a height of 4.9 metre and if g = 9.8 ms^{-2}, then the coin reaches the floor of the lift after a time

(a) $\sqrt{2}$ s (b) 1 s

(c) $\frac{1}{2}$ (d) $\frac{1}{\sqrt{2}}$

91. If a ball is thrown vertically upwards with a velocity of 40m/s, then velocity of the ball after two seconds is : (g = 10 m/sec^2)

(a) 15 m/s (b) 20 m/s

(c) 25 m/s (d) 28 m/s

92. If a car at rest accelerates uniformly to a speed of 144 km/h in 20 sec., it covers a distance of

(a) 20 cm (b) 400m

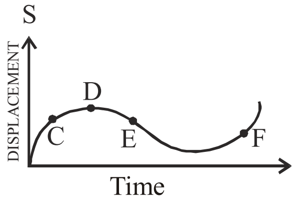
(c) 1440 cm (d) 2980 cm

93. The water drops fall at regular intervals from a tap 5 m above the ground. The third drop is leaving the tap at an instant when the first drop touches the ground. How far above the ground is the second drop at that instant ? (Take g = 10 m/s^2)

(a) 1.25m (b) 2.50m

(c) 3.75m (d) 5.00m

94. The displacement time graph of a moving particle is shown below



The instantaneous velocity of the particle is negative at the point

(a) D (b) F

(c) C (d) E

95. A particle moves along a straight line such that its displacement at any time t is given by

$s = (t^3 - 6t^2 + 3t + 4)$ metres

The velocity when the acceleration is zero is

(a) 3 ms^{-1} (b) – 12 ms^{-1}

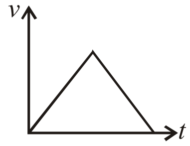
(c) 42 ms^{-2} (d) – 9 ms^{-1}

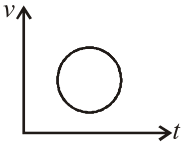
96. A body starts from rest, what is the ratio of the distance travelled by the body during the 4th and 3rd seconds ?

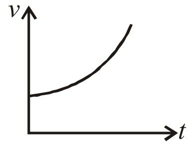
(a) $\frac{7}{5}$ (b) $\frac{5}{7}$

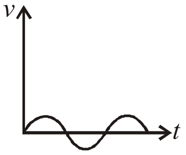
(c) $\frac{7}{3}$ (d) $\frac{3}{7}$

97. Which of the following curve does not represent motion in one dimension?

(a)


(b)


(c)


(d)


DIRECTIONS for Qs. (98 to 100) : Each question contains STATEMENT-1 and STATEMENT-2. Choose the correct answer (ONLY ONE option is correct) from the following.

(a) Statement -1 is false, Statement-2 is true

(b) Statement -1 is true, Statement-2 is true; Statement -2 is a correct explanation for Statement-1

(c) Statement -1 is true, Statement-2 is true; Statement -2 is not a correct explanation for Statement-1

(d) Statement -1 is true, Statement-2 is false

98. **Statement 1 :** Velocity-time graph for an object in uniform motion along a straight path is a straight line parallel to the time axis.

Statement 2 : In uniform motion of an object velocity increases as the square of time elapsed.

99. **Statement 1 :** A positive acceleration can be associated with a 'slowing down' of the body.

Statement 2 : The origin and the positive direction of an axis are a matter of choice.

100. **Statement 1 :**In a free fall, weight of a body becomes effectively zero.

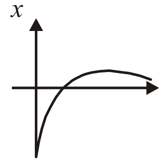
Statement 2 : Acceleration due to gravity acting on a body having free fall is zero.

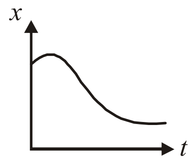
EXERCISE - 3

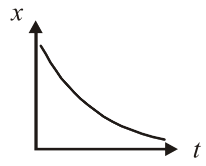
Exemplar & Past Years NEET/AIPMT Questions

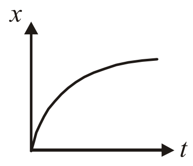
Exemplar Questions

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

(a)


(b)


(c)


(d)


2. 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) $x > 0, v > 0, a < 0$

3. 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 $-v_0T < x < v_0T$

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

(d) The motion has no turning points

4. A vehicle travels half the distance *l* 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) $\frac{2v_1v_2}{v_1 + v_2}$ (d) $\frac{L(v_1 + v_2)}{v_1v_2}$

5. 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) 4m (b) 8m

(c) 12m (d) 16m

6. 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) $t_1 - t_2$

NEET/AIPMT (2013-2017) Questions

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) $h_1 = \frac{h_2}{3} = \frac{h_3}{5}$ (b) $h_2 = 3h_1$ and $h_3 = 3h_2$

(c) $h_1 = h_2 = h_3$ (d) $h_1 = 2h_2 = 3h_3$

8. The displacement '*x*' (in meter) of a particle of mass '*m*' (in kg) moving in one dimension under the action of a force, is related to time '*t*' (in sec) by $t = \sqrt{x} + 3$. The displacement of the particle when its velocity is zero, will be ***[NEET Kar. 2013]***

(a) 2m (b) 4m

(c) zero (d) 6m

9. A particle of unit mass undergoes one-dimensional motion such that its velocity varies according to $v(x) = bx^{-2n}$ where b and n are constants and *x* is the position of the particle. The acceleration of the particle as d function of x, is given by: ***[2015]***

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

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

10. If the velocity of a particle is $v = At + Bt^2$, where A and B are constants, then the distance travelled by it between 1s and 2s is : ***[2016]***

(a) $\frac{3}{2}A + 4B$ (b) $3A + 7B$

(c) $\frac{3}{2}A + \frac{7}{3}B$ (d) $\frac{A}{2} + \frac{B}{3}$

11. 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]***

(a) $\frac{t_1t_2}{t_2 - t_1}$ (b) $\frac{t_1t_2}{t_2 + t_1}$

(c) $t_1 - t_2$ (d) $\frac{t_1 + t_2}{2}$

Hints & Solutions

EXERCISE - 1

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

8. (b) $\sqrt{x} = (t+7)$ or $x = (t+7)^2$

$$\frac{dx}{dt} = 2(t+7), \therefore \text{ velocity } \propto \text{ time}$$

9. (b) $a = ft$, $a = \frac{dv}{dt} = ft$ at $t = 0$, velocity $= u$

$$\int_u^v dv = \int_0^t f\,t\,dt\,,\ v - u = f\frac{t^2}{2} \Rightarrow v = u + f\frac{t^2}{2}$$

NOTE : Do not use v = u + at directly because the acceleration is not constant.

10. (c) $v = \frac{dx}{dt} = a_1 + 2a_2 t \qquad \therefore\ a = \frac{dv}{dt} = 2a_2$

11. (d) $v_A = \tan 30^\circ$ and $v_B = \tan 60^\circ$

$$\therefore\ \frac{v_A}{v_B} = \frac{\tan 30^\circ}{\tan 60^\circ} = \frac{1/\sqrt{3}}{\sqrt{3}} = \frac{1}{3}$$

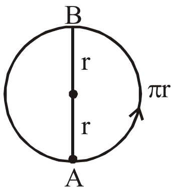
12. (a) Let for the first half time t, the person travels a distance s_1. Hence $v_1 = \frac{s_1}{t}$ or $s_1 = v_1 t$

For second half time, $v_2 = \frac{s_2}{t}$ or $s_2 = v_2 t$

$$\text{Now, } \bar{v} = \frac{\text{Total displacement}}{\text{Total time}} = \frac{s_1 + s_2}{2t}$$

$$= \frac{v_1 t + v_2 t}{2t} = \frac{v_1 + v_2}{2}$$

13. (b) When a particle cover half of circle of radius r, then displacement is AB = 2r
& distance = half of circumference of circle = πr



14. (d) $y = \frac{1}{2}g(n+1)^2 - \frac{1}{2}gn^2$

$$= \frac{g}{2}[(n+1)^2 - n^2] = \frac{g}{2}(2n+1) \qquad ......(i)$$

Also, $h = \frac{g}{2}(2n-1) \qquad ......(ii)$

From (i) and (ii)
$y = h + g$

15. (a) Differentiate two times and put $x = 0$.

16. (d) The difference in velocities is increasing with time as both of them have more constant but different acceleration.

17. (b) Time taken by the stone to reach the water level

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

Time taken by sound to come to the mouth of the well,

$$t_2 = \frac{h}{v}$$

$$\therefore\ \text{Total time } t_1 + t_2 = \sqrt{\frac{2h}{g}} + \frac{h}{v}$$

18. (d) Let the total distance be d. Then for first half distance,

time $= \frac{d}{2v_0}$, next distance. $= v_1 t$ and last half distance $= v_2 t$

$$\therefore\ v_1 t + v_2 t = \frac{d}{2};\ t = \frac{d}{2(v_1 + v_2)}$$

Now average speed

$$t = \frac{d}{\frac{d}{2v_0} + \frac{d}{2(v_1+v_2)} + \frac{d}{2(v_1+v_2)}}$$

$$= \frac{2v_0(v_1+v_2)}{(v_1+v_2) + 2v_0}$$

19. (c) $a = bt$ or $\frac{dv}{dt} = bt$. Integrating, we get

$v = \frac{bt^2}{2} + c$, where c is a constant of integration.
At $t = 0$, $v = v_0$. Thus $v_0 = c$.

$$\text{Now, } v = \frac{ds}{dt} = \frac{bt^2}{2} + v_o \ \therefore\ ds = \left(\frac{bt^2}{2} + v_o\right)dt$$

Integrating we get, $s = \frac{bt^3}{6} + v_o t$

20. (a) $\frac{dv}{dt} = -kv^3$ or $\frac{dv}{v^3} = -k\ dt$

Integrating we get, $-\frac{1}{2v^2} = -kt + c \qquad ...(1)$

At t = 0, $v = v_0$ ∴ $-\frac{1}{2v_o^2} = c$

Putting in (1)

$$-\frac{1}{2v^2} = -kt - \frac{1}{2v_0^2} \text{ or } \frac{1}{2v_0^2} - \frac{1}{2v^2} = -kt$$

$$\text{or } \left[\frac{1}{2v_0^2} + kt\right] = \frac{1}{2v^2} \text{ or } \left[1 + 2v_0^2\, kt\right] = \frac{v_0^2}{v^2}$$

$$\text{or } v^2 = \frac{v_0^2}{1+2v_0^2\, kt} \quad \text{or} \quad v = \frac{v_0}{\sqrt{1+2v_0^2\, kt}}$$

21. (d) $x = \frac{a}{b}(1 - e^{-b\times\frac{1}{b}}) = \frac{a}{b}(1-e^{-1}) = \frac{a}{b}(1-\frac{1}{e})$

$$= \frac{a}{b}\frac{(e-1)}{e} = \frac{a}{b}\frac{(2.718-1)}{2.718} = \frac{a}{b}\frac{(1.718)}{2.718} = 0.637\frac{a}{b} \simeq \frac{2}{3}a/b$$

velocity $v = \frac{dx}{dt} = ae^{-bt}, v_0 = a$

accleration $a = \frac{dv}{dt} = -abe^{-bt}$ & $a_0 = -ab$

At t = 0, $x = \frac{a}{b}(1-1) = 0$ and

At $t = \frac{1}{b}$, $x = \frac{a}{b}(1-e^{-1}) = \frac{a}{b}(1-\frac{1}{e}) = \frac{2}{3}a/b$

At $t = \infty$, $x = \frac{a}{b}$

It cannot go beyond this, so point $x > \frac{a}{b}$ is not reached by the particle.

At t = 0, x = 0, at $t = \infty$, $x = \frac{a}{b}$, therefore the particle does not come back to its starting point at $t = \infty$.

22. (c) $x = t^2 + 2t + 1$

Hence $v = \frac{dx}{dt} = 2t + 2$. It increases with time.

23. (b) When a body falls through a height h, it acquires a velocity $\sqrt{2gh}$.

24. (c) Initial relative velocity $v_A - v_B$, is reduced to 0 in distance d' (<d) with retardation a.

∴ $0^2 - (v_A - v_B)^2 = -2\,ad'$

$$d' = \frac{(v_A - v_B)^2}{2a} \quad \therefore\ d > \frac{(v_A - v_B)^2}{2a}$$

25. (d)

EXERCISE -2

1. (c) Given that $x = At^2 - Bt^3$

∴ velocity $= \frac{dx}{dt} = 2At - 3Bt^2$

and acceleration $= \frac{d}{dt}\left(\frac{dx}{dt}\right) = 2A - 6Bt$

For acceleration to be zero $2A - 6Bt = 0$.

∴ $t = \frac{2A}{6B} = \frac{A}{3B}$

2. (a) $a = \frac{d^2x}{dt^2} = -s\omega^2 \sin \omega t$

On integrating, $\frac{dx}{dt} = s\omega^2 \frac{\cos \omega t}{\omega} = s\omega \cos \omega t$

Again on integrating, we get

$x = s\omega \frac{\sin \omega t}{\omega} = s \sin \omega t$

3. (c) $v = \frac{dy}{dt} = b + 2ct - 4dt^3$

$v_0 = b + 2c(0) - 4d(0)^3 = b$

(∵ for initial velocity, t = 0)

Now $a = \frac{dv}{dt} = 2c - 12dt^2$

∴ $a_0 = 2c - 12d(0)^2 = 2c$, (at t = 0)

4. (d) $\frac{\frac{x}{2}+\frac{x}{2}}{\frac{x}{2v_1}+\frac{x}{2v_2}} = \frac{1}{\left(\frac{v_2+v_1}{2v_1v_2}\right)} = \frac{2v_1v_2}{v_1+v_2}$

5. (b) Let u be the initial velocity

∴ $v_1' = u + at_1$, $v_2' = u + a(t_1 + t_2)$

and $v_3' = u + a(t_1 + t_2 + t_3)$

Now $v_1 = \frac{u + v_1'}{2} = \frac{u + (u + at_1)}{2} = u + \frac{1}{2}at_1$

$v_2 = \frac{v_1' + v_2'}{2} = u + at_1 + \frac{1}{2}at_2$

$v_3 = \frac{v_2' + v_3'}{2} = u + at_1 + at_2 + \frac{1}{2}at_3$

So, $v_1 - v_2 = -\frac{1}{2}a(t_1 + t_2)$

and $v_2 - v_3 = -\frac{1}{2}a(t_2 + t_3)$

∴ $(v_1 - v_2):(v_2 - v_3) = (t_1 + t_2):(t_2 + t_3)$

6. (b) Let after a time t, the cyclist overtake the bus. Then

$$96+\frac{1}{2}\times 2\times t^2 = 20\times t \text{ or } t^2-20t+96=0$$

$$\therefore t=\frac{20\pm\sqrt{400-4\times 96}}{2\times 1}$$

$$=\frac{20\pm 4}{2}=8\,\text{sec. and } 12\,\text{sec.}$$

7. (d) $v^2=u^2+2as$ or $v^2-u^2=2as$
Maximum retardation, $a=v^2/2s$
When the initial velocity is n v, then the distance over which it can be stopped is given by

$$s_n=\frac{u_0^2}{2a}=\frac{(nv)^2}{2(v^2/2s)}=n^2 s$$

8. (c) Let the length of train is s, then by third equation of motion, $v^2=u^2+2a\times s$ ....(1)
Where v is final velocity after travelling a distance s with an acceleration a & u is initial velocity as per question
Let velocity of middle point of train at same point is v', then

$$(v')^2=u^2+2a\times(s/2) \qquad ....(2)$$

By equations (1) and (2), we get $v'=\sqrt{\frac{v^2+u^2}{2}}$

9. (b) $8=at_1$ and $0=8-a(4-t_1)$

or $t_1=\frac{8}{a}$ $\therefore$ $8=a\left(4-\frac{8}{a}\right)$

$8=4a-8$ or $a=4$ and $t_1=8/4=2$ sec

Now, $s_1=0\times 2+\frac{1}{2}\times 4(2)^2$ or $s_1=8\,m$

$s_2=8\times 2-\frac{1}{2}\times 4\times(2)^2$ or $s_2=8\,m$

$\therefore$ $s_1+s_2=16$ m

10. (b) u = 10 m/s, t = 5 sec, v = 20 m/s, a = ?

$$a=\frac{20-10}{5}=2\text{ ms}^{-2}$$

From the formula $v_1=u_1+at$, we have
$10=u_1+2\times 3$ or $u_1=4$ m/sec.

11. (c) Let a be the constant acceleration of the particle. Then

$s=ut+\frac{1}{2}at^2$ or $s_1=0+\frac{1}{2}\times a\times(10)^2=50\,a$

and $s_2=\left[0+\frac{1}{2}a(20)^2\right]-50a=150a$

$\therefore s_2=3s_1$

Alternatively :
Let a be constant acceleration and

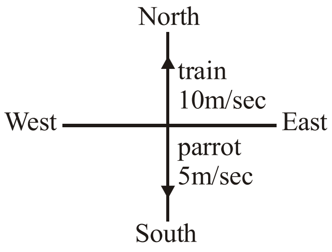
$s=ut+\frac{1}{2}at^2$, then $s_1=0+\frac{1}{2}\times a\times 100=50a$

Velocity after 10 sec. is v = 0 + 10a

So, $s_2=10a\times 10+\frac{1}{2}a\times 100=150a\Rightarrow s_2=3s_1$

12. (d) So by figure the velocity of parrot w.r. t. train is = 5–(–10) = 15m/sec
so time taken to cross the train is

$$=\frac{\text{length of train}}{\text{relative velocity}}=\frac{150}{15}=10\text{ sec}$$



13. (a) $s^2=at^2+2bt+c$ $\therefore$ $2s\frac{ds}{dt}=2at+2b$

or $\frac{ds}{dt}=\frac{at+b}{s}$, again differentiating

$$\frac{d^2s}{dt^2}=\frac{a.s-(at+b)}{s^2}.\frac{ds}{dt}=\frac{as-(at+b)\left(\frac{at+b}{s}\right)}{s^2}$$

$$\therefore \frac{d^2s}{dt^2}=\frac{as^2-(at+b)^2}{s^3}$$

$$\therefore a=\frac{d^2s}{dt^2}\infty s^{-3}.$$

14. (a) From third equation of motion $v^2=u^2+2ah$
In first case initial velocity $u_1=5$ m/sec
final velocity $v_1=0$, $a=-g$

and max. height obtained is H_1, then, $H_1=\frac{25}{2g}$

In second case $u_2=10$ m/sec, $v_2=0$, $a=-g$

and max. height is H_2 then, $H_2=\frac{100}{2g}$.

It implies that $H_2=4H_1$

15. (c) The distance covered in nth second is

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

where u is initial velocity & a is acceleration

then $26=u+\frac{19a}{2}$ ....(1)

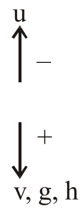
$28=u+\frac{21a}{2}$ ....(2)

$30=u+\frac{23a}{2}$ ....(3)

$32=u+\frac{25a}{2}$ ....(4)

From eqs. (1) and (2) we get u = 7m/sec, a=2m/sec^2
$\therefore$ The body starts with initial velocity u =7m/sec and moves with uniform acceleration a = 2m/sec^2

16. (b) The stone rises up till its vertical velocity is zero and again reached the top of the tower with a speed u (downward). The speed of the stone at the base is 3u.

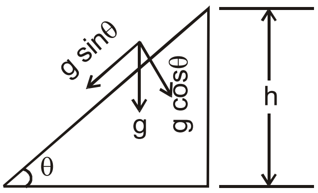


Hence $(3u)^2 = (-u)^2 + 2gh$ or $h = \frac{4u^2}{g}$

17. (c) So by second equation of motion, we get $S = ut + \frac{1}{2}at^2$

here $S = \ell$, $u = 0$, $a = g\sin\theta$

$$t = \sqrt{\frac{2\ell}{a}} = \sqrt{\frac{2h}{g\sin^2\theta}} = \frac{1}{\sin\theta}\sqrt{\frac{2h}{g}} \left(\because \sin\theta = \frac{h}{\ell}\right)$$



18. (a) $S = ut + ½at^2$ here $a = g$

For first body $u_1 = 0 \Rightarrow S_1 = ½g \times 9$

For second body $u_2 = 0 \Rightarrow S_2 = ½g \times 4$

So difference between them after 3 sec. $= S_1 - S_2$
$= ½\, g \times 5$

If $g = 10m/sec^2$ then $S_1 - S_2 = 25$ m.

19. (b) Relative speed of each train with respect to each other be, $v = 10 + 15 = 25$ m/s

Here distance covered by each train = sum of their lengths = 50 + 50 = 100 m

$\therefore$ Required time $= \frac{100}{25} = 4$ sec .

20. (d) At highest point of the trajectory velocity becomes zero and all kinetic energy changes to potential energy so at highest point, K.E. = 0

21. (b) The distance travel in nth second is

$S_n = u + ½(2n-1)a$ ....(1)

so distance travel in tth & (t+1)th second are

$S_t = u + ½(2t-1)a$ ....(2)

$S_{t+1} = u + ½(2t+1)a$ ....(3)

As per question,

$S_t + S_{t+1} = 100 = 2(u + at)$ ....(4)

Now from first equation of motion the velocity, of particle after time t, if it moves with an accleration a is

$v = u + a\,t$ ....(5)

where u is initial velocity

So from eq(4) and (5), we get v = 50cm./sec.

22. (b) Since $v^2 = u^2 + 2as$

For first case u_1=20m/sec, $v_1 = 0$, $a_1 = g = 10$, $s_1 = ?$

So $s_1 = \frac{400}{2 \times 10} = 20m$

For second case (at moon) u_2 =20m/sec, v_2=0,

$a_2 = \frac{g}{6} = 1.7m/sec^2, s_2 = ?$

$s_2 = \frac{400}{2 \times 1.7} = \frac{400}{2 \times 10/6}$ so $\frac{s_1}{s_2} = \frac{1}{6}$

23. (d) All options are correct :

(i) When two bodies A & B move in opposite directions then relative velocity between A & B either V_{AB} or V_{BA} both are greater than V_A & V_B.

(ii) When two bodies A & B move in parallel direction then $V_{AB} = V_A - V_B \Rightarrow V_{AB} < V_A$

$V_{BA} = V_B - V_A \Rightarrow V_{BA} < V_B$

24. (b) From third equation of motion

$v^2 = u^2 - 2gh$ ($\because a = -g$)

Given, v = 10 m/sec at h/2. But v = 0, when particle attained maximum height h.

Therefore $(10)^2 = u^2 - 2gh/2$

or $100 = 2gh - 2gh/2$ ($\because 0 = u^2 - 2gh$)

$\Rightarrow h = 10m$

25. (b) Since in both case the height of building and down ward acceleration 'g' is same. So both stones reach simultaneously i.e., $S = \frac{1}{2}gt^2 \Rightarrow 10 = \frac{1}{2}10 \times t^2$

or $t = \sqrt{2}$ sec, for both stone.

26. (d) Speed $v_1 = 60 \times \frac{5}{18}m/s = \frac{50}{3}m/s$

$d_1 = 20m, v'_1 = 120 \times \frac{5}{18} = \frac{100}{3}$ m/s

Let dceleration be a

$\therefore 0 = v_1^2 - 2ad_1$ ....(1)

or $v_1^2 = 2ad_1$

$(2v_1)^2 = 2ad_2$ ...(2)

(2) divided by (1) gives,

$4 = \frac{d_2}{d_1} \Rightarrow d_2 = 4 \times 20 = 80m$

27. (d) Equation of motion is $u = at$

we know that $u = \frac{ds}{dt} \Rightarrow \frac{ds}{dt} = at$ or $ds = atdt$

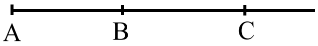
integrating it we get, $\int_0^s ds = a\int_0^4 tdt$

$s = \frac{a}{2}[t^2]_0^4 = 8a$

28. (d) The only force acting on the ball is the force of gravity. The ball will ascend until gravity reduces its velocity to zero and then it will descend. Find the time it takes for the ball to reach its maximum height and then double the time to cover the round trip.

Using $v_{\text{at maximum height}} = v_0 + at = v_0 - gt$, we get:
$0\text{ m/s} = 50\text{ m/s} - (9.8\text{ m/s}^2)\,t$
Therefore,
$t = (50\text{ m/s})/(9.8\text{ m/s}^2) \sim (50\text{ m/s})/(10\text{ m/s}^2) \sim 5\text{s}$
This is the time it takes the ball to reach its maximum height. The total round trip time is 2t ~ 10s.

29. (b)



A to B

$$2 = u \times 2 + \frac{1}{2} \times a \times 2 \times 2 \Rightarrow 1 = u + a,$$

A to C

$$4.20 = u \times 6 + \frac{1}{2} a \times 6 \times 6 \Rightarrow 0.7 = u + 3a\ ,$$

$$2a = -0.3 \text{ or } a = -0.15\,\text{m}\,\text{s}^{-2},$$

$$u = 1 - a = (1 + 0.15)\text{m}\,\text{s}^{-1} = 1.15\text{m}\,\text{s}^{-1}$$

Velocity at t = 9 sec.

$$v = 1.15 - 0.15 \times 9 = 1.15 - 1.35 = -0.2\,\text{m}\,\text{s}^{-1}$$

30. (c) The ball thrown upward will lose velocity in 1s. It return back to thrown point in another 1 s with the same velocity as second. Thus the difference will be 2 s.

31. (b) Velocity when the engine is switched off

$$v = 19.6 \times 5 = 98\,\text{m}\,\text{s}^{-1}$$

$$h_{max} = h_1 + h_2 \text{ where } h_1 = \frac{1}{2} at^2 \ \& \ h_2 = \frac{v^2}{2a}$$

$$h_{max} = \frac{1}{2} \times 19.6 \times 5 \times 5 + \frac{98 \times 98}{2 \times 9.8}$$

$$= 245 + 490 = 735\,\text{m}$$

32. (b) Average velocity for the second half of the distance is

$$= \frac{v_1 + v_2}{2} = \frac{4 + 8}{2} = 6\,\text{m}\,\text{s}^{-1}$$

Given that first half distance is covered with a velocity of $6\,\text{m}\,\text{s}^{-1}$. Therefore, the average velocity for the whole time of motion is $6\,\text{m}\,\text{s}^{-1}$

33. (d) Since $S = ut + ½\, gt^2$
where u is initial velocity & a is acceleration.
In this case u = 0 & a = g
so distance travelled in 4 sec is,
$S = ½ \times 10 \times 16 = 80\text{m}$

34. (c) The food packet has an initial velocity of 2 m/sec in upward direction, therefore
$v = -u + gt$ or $v = -2 + 10 \times 2 = 18$ m /sec.

35. (b) Differentiated twice.

36. (c) Downward motion

$$v^2 - 0^2 = 2 \times 9.8 \times 5$$

$$\Rightarrow \ v = \sqrt{98} = 9.9$$

Also for upward motion

$$0^2 - u^2 = 2 \times (-9.8) \times 1.8$$

$$\Rightarrow \ u = \sqrt{3528} = 5.94$$

Fractional loss $= \dfrac{9.9 - 5.94}{9.9} = 0.4$

37. (a) Use $\vec{v}_{AB} = \vec{v}_A - \vec{v}_B$.

38. (a) Since displacement is zero.

39. (b) Average velocity $= \dfrac{2 \times 20 \times 30}{20 + 30} = 24\,\text{km}\,\text{h}^{-1}$.

40. (c) From third equation of motion, $v^2 = u^2 + 2as$
where v & u are final & initial velocity, a is acceleration, s is distance.
For first case v_1= 3km/hour, u_1= 0, a_1=g & s_1=?

$$s_1 = \frac{9 \times 100}{36 \times 36 \times 20} \text{ metre}$$

For second case v_2=?, u_2=4km/hour ,
a_2= g = 10m/sec

$$\& \ s_1 = s_2 = \frac{9 \times 100}{36 \times 36 \times 20}$$

$$\text{so } v_2^2 = \frac{16 \times 1000 \times 1000}{3600 \times 3600} + \frac{2 \times 10 \times 9 \times 100}{20 \times 36 \times 36}$$

or v_2 = 5 km/hour

41. (a) $\dfrac{ds}{dt} = kt \ \Rightarrow \ s = \dfrac{1}{2} kt^2 = \dfrac{1}{2} \times 2 \times 3 \times 3 \ = 9\,\text{m}.$

42. (d) For constant acceleration and zero initial velocity

$$h \propto t^2$$

$$\frac{h_1}{h_2} = \frac{t_1^2}{t_2^2} \ \Rightarrow t_2 = \sqrt{\frac{h_2}{h_1}} t_1 = \sqrt{2} \times t_1 = \sqrt{2} \times 2s$$

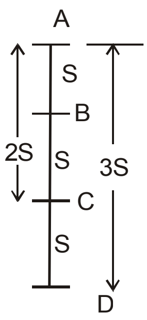
43. (a) $v = \sqrt{3x + 16} \ \Rightarrow \ v^2 = 3x + 16$

$$\Rightarrow \ v^2 - 16 = 3x$$

Comparing with $v^2 - u^2 = 2aS$, we get, u = 4 units, 2a = 3 or a = 1.5 units

44. (b) $S = AB = \dfrac{1}{2} g\, t_1^{\,2} \Rightarrow 2S = AC = \dfrac{1}{2} g\ (t_1 + t_2)^2$

and $3S = AD = \dfrac{1}{2} g\ (t_1 + t_2 + t_3)^2$



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

$$t_1 + t_2 = \sqrt{\frac{4S}{g}},\ t_2 = \sqrt{\frac{4S}{g}} - \sqrt{\frac{2S}{g}}$$

$$t_1 + t_2 + t_3 = \sqrt{\frac{6S}{g}}$$

$$t_3 = \sqrt{\frac{6S}{g}} - \sqrt{\frac{4S}{g}}$$

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

45. (c) $\bar{v} = \frac{(8\times1-3\times1\times1)-0}{1} = 5\,\text{ms}^{-1}$

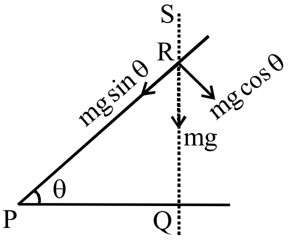
46. (c) Since the initial velocity of jump is same on both planets

So $0 = u^2 - 2g_A h_A$

$0 = u^2 - 2g_B h_B$

or $\frac{g_A \times h_A}{g_B} = h_B \Rightarrow h_B = \frac{9}{1}\times 2 = 18\text{m}$

47. (d)



Let distance (PR) is covered by the particle in time 't'.

$\Rightarrow\ PR = 0 + \frac{1}{2}g\sin\theta . t^2 = \frac{1}{2}gt^2\sin\theta$

Further $PR = \frac{PQ}{\cos\theta}$ (Given PQ = constant)

$\Rightarrow\ PQ = \frac{1}{2}gt^2\sin\theta\cos\theta = \frac{1}{4}gt^2\sin 2\theta$

$\Rightarrow\ t = 2\sqrt{\frac{PQ}{g\sin 2\theta}}\ \therefore\ \ t \propto \frac{1}{\sqrt{\sin 2\theta}}$

So as θ increases, $\sin 2\theta$ first increases and then decreases. Hence 't' first decreases and then increases.

48. (d) Given $x = ae^{-\alpha t} + be^{\beta t}$

Velocity, $v = \frac{dx}{dt} = -a\alpha e^{-\alpha t} + b\beta e^{\beta t} = -\frac{a\alpha}{e^{\alpha t}} + b\beta e^{\beta t}$

i.e., go on increasing with time.

49. (b) $y \propto t^2 ; v\text{-} \propto t' ; a \propto t^{\circ}$

50. (c) On differentiating, acceleration $= 0.2t\ \Rightarrow\ a = f(t)$

51. (d) Use $v^2 - u^2 = 2aS$. In both the cases, (u positive or negative) u^2 is positive.

52. (b) Area under a-t graph is change in velocity.

Area $= \frac{1}{2}(4\times4) + 6\times4 + \frac{1}{2}\times2\times4 - \frac{1}{2}\times2\times2$

$= 36 - 2 = 34\ \text{ms}^{-1}$

As initial velocity is zero therefore, the velocity at 14 second is $34\,\text{ms}^{-1}$.

53. (c) At $t = 20\text{s}$, $d = 20\,\text{m}$

54. (a) At six points in the graph the tangents have zero slope i.e. velocity is zero.

55. (d) Time fall is $\frac{1}{2}$ second.

$h = \frac{1}{2}g\left(\frac{1}{2}\right)^2 = \frac{10}{8} = 1.25\,\text{m}$

56. (b) $v_{av} = \frac{x+2x+3x}{t_1+t_2+t_3}$

$t_1 = \frac{2x}{v_{max}},\ t_2 = \frac{2x}{v_{max}},\ t_3 = \frac{6x}{v_{max}}$

$v_{av} = \frac{6x\ v_{max}}{10x}$

$\frac{v_{av}}{v_{max}} = \frac{3}{5}$

57. (c) Let v_A and v_B are the velocities of two bodies.

In first case, $v_A + v_B = 6\text{m/s}$ ....(1)

In second case, $v_A - v_B = 4\text{m/s}$ ....(2)

From (1) & (2) we get, $v_A = 5$ m/s and $v_B = 1$ m/s.

58. (d) $\vec{v}_{BB}$ = Relative velocity of ball w.r.t. balloon = $\vec{u} + \vec{v}$

$0 = -(u+v) + gt$ of $t = \frac{u+v}{g}$

Total time $= \frac{2(u+v)}{g}$

59. (c) $y_1 = \frac{1}{2}gn^2,\ y_2 = \frac{1}{2}g(n-N)^2$

$\therefore\ y_1 - y_2 = \frac{1}{2}g[n^2 - (n-N)^2]$

$\Rightarrow\ 1 = \frac{g}{2}(2n-N)N$ $[\because y_1 - y_2 = 1]$

$\Rightarrow\ n = \frac{1}{gN} + \frac{N}{2}$

60. (b) $S_1 = \frac{1}{2}\ g\left(\frac{1}{2}\right)^2,\ S_1 + S_2 = \frac{1}{2}\ g(1)^2$

$\frac{1}{2}\ g\left(\frac{3}{2}\right)^2 = S_1 + S_2 + S_3$

By solving we get

$S_1 : S_2 : S_3 = 1 : 3 : 5$

61. (b) Distance in last two second

$= \frac{1}{2} \times 10 \times 2 = 10\,\text{m}.$

Total distance $= \frac{1}{2} \times 10 \times (6+2) = 40\,\text{m}.$

62. (d) In (a), at the same time particle has two positions which is not possible. In (b), particle has two velocities at the same time. In (c), speed is negative which is not possible.

63. (a) Velocity at time t is tan 45° = 1. Velocity at time (t = 1) is $\tan 60^\circ = \sqrt{3}$. Acceleration is change in velocity in one second $= \sqrt{3} - 1$.

64. (c) Here, the particle B moves upwards. Let the upward velocity of B be v then $\frac{v}{10} = \tan 60^\circ$

65. (b) $v = 1.25 \times 8\ ms^{-1} = 10\ ms^{-1}$

$$s = \frac{1}{2} \times 1.25 \times 8 \times 8m = 40m$$

Now, $40 = -10t + \frac{1}{2} \times 10 \times t^2$

or $5t^2 - 10t - 40 = 0$

or $t^2 - 2t - 8 = 0$ or t = 4 s.

66. (b) Given acceleration $a = 6t + 5$

$\therefore\ a = \frac{dv}{dt} = 6t + 5$, $dv = (6t+5)dt$

Integrating it, we have $\int_0^v dv = \int_0^t (6t+5)dt$

$v = 3t^2 + 5t + C,$ where C is constant of integration.

When t = 0 , v = 0 so C = 0

$\therefore\ v = \frac{ds}{dt} = 3t^2 + 5t$ or $ds = (3t^2 + 5t)dt$

Integrating it within the conditions of motion, i.e., as t changes from 0 to 2 s, s changes from 0 to s, we have

$$\int_0^s ds = \int_0^2 (3t^2 + 5t)dt$$

$$\therefore\ s = t^3 + \frac{5}{2}t^2 \Big|_0^2 = 8 + 10 = 18m$$

67. (a) $t = \alpha x^2 + \beta x$

Differentiating w.r.t. time on both sides, we get

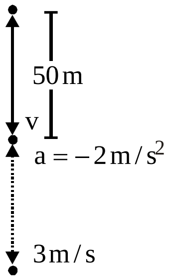
$$1 = 2\alpha \frac{dx}{dt}.x + \beta \frac{dx}{dt}$$

$$\therefore\ v = \frac{dx}{dt} = \frac{1}{\beta + 2\alpha x};\ \frac{dv}{dt} = \frac{-2\alpha v}{(\beta + 2\alpha x)^2} = -2\alpha v^3$$

Negative sign shows retardation.

68. (c) The horizontal velocity of the stone will be the same as that of the train. In this way, the horizontal motion will be uniform motion. The vertical motion will be controlled by the force of gravity, i. e., vertical motion is accelerated motion. Thus the resultant motion will be along a parabolic trajectory.

69. (d) Initial velocity of parachute after bailing out,



$u = \sqrt{2gh}$

$u = \sqrt{2 \times 9.8 \times 50} = 14\sqrt{5}$

The velocity at ground,

v = 3m/s

$$S = \frac{v^2 - u^2}{2 \times 2} = \frac{3^2 - 980}{4} \approx 243\,m$$

Initially he has fallen 50 m.

$\therefore$ Total height from where he bailed out

$= 243 + 50 = 293\,m$

70. (d) As per question,

Let max. velocity is v

then $v = \alpha t_1$ & $v - \beta t_2 = 0$, where $t = t_1 + t_2$

Now $t_1 + t_2 = t$ or $\frac{v}{\alpha} + \frac{v}{\beta} = t$

$$\therefore\ v = \frac{t}{\left(\frac{1}{\alpha} + \frac{1}{\beta}\right)} = \left(\frac{\alpha\beta}{\alpha + \beta}\right)t \text{ and}$$

$$s = s_1 + s_2 = \frac{v^2}{2\alpha} + \frac{v^2}{2\beta} = \frac{v^2}{2}\left(\frac{1}{\alpha} + \frac{1}{\beta}\right)$$

71. (a) From third equation of motion : $v^2 = u^2 + 2as$

for first case $u = \frac{40 \times 10}{36}\ m/sec$,

v =0, a = ?, s = 2 m

so, $a = \left(\frac{40 \times 10}{36}\right)^2 \frac{1}{4}\ m/sec^2$

for second case $u = \frac{80 \times 10}{36}\ m/sec$, v = 0,

$$\text{So } s_2 = \left(\frac{80 \times 10}{36}\right)^2 / 2 \times \frac{1}{4} \times \left(\frac{40 \times 10}{36}\right)^2 = 8\,\text{meter}$$

72. (b) Height attained by balls in 2 sec is

$$= \frac{1}{2} \times 9.8 \times 4 = 19.6m$$

the same distance will be covered in 2 second (for descent)

Time interval of throwing balls, remaining same. So, for two balls remaining in air, the time of ascent or descent must be greater than 2 seconds. Hence speed of balls must be greater than 19.6 m/sec.

73. (a) Clearly distance moved by 1st ball in 18s = distance moved by 2nd ball in 12s.

Now, distance moved in 18 s by 1st ball

$$= \frac{1}{2} \times 10 \times 18^2 = 90 \times 18 = 1620\,m$$

Distance moved in 12 s by 2nd ball

$$= ut + \frac{1}{2}gt^2 \quad \therefore\ 1620 = 12\,v + 5 \times 144$$

$\Rightarrow v = 135 - 60 = 75\ ms^{-1}$

74. (a) $x = \frac{1}{t+5} \quad \therefore\ v = \frac{dx}{dt} = \frac{-1}{(t+5)^2}$

$$\therefore\ a = \frac{d^2x}{dt^2} = \frac{2}{(t+5)^3} = 2x^3$$

$$\text{Now } \frac{1}{(t+5)} \propto v^{\frac{1}{2}} \quad \therefore\ \frac{1}{(t+5)^3} \propto v^{\frac{3}{2}} \propto a$$

75. (b) $\vec{v} = \vec{u} + \vec{a}t$

$$v = (2\hat{i} + 3\hat{j}) + (0.3\hat{i} + 0.2\hat{j}) \times 10 = 5\hat{i} + 5\hat{j}$$

$$|\vec{v}| = \sqrt{5^2 + 5^2}\ ; \ |\vec{v}| = 5\sqrt{2}$$

76. (a) $\because \ h = \frac{1}{2}gt^2$

$$\therefore \ h_1 = \frac{1}{2}g(5)^2 = 125$$

$$h_1 + h_2 = \frac{1}{2}g(10)^2 = 500$$

$$\Rightarrow h_2 = 375$$

$$h_1 + h_2 + h_3 = \frac{1}{2}g(15)^2 = 1125$$

$$\Rightarrow h_3 = 625$$

$$h_2 = 3h_1, h_3 = 5h_1$$

$$\text{or} \quad h_1 = \frac{h_2}{3} = \frac{h_3}{5}$$

77. (a) $h = \frac{1}{2}gT^2$

now for t = T/3 second vertical distance moved is given by

$$h' = \frac{1}{2}g\left(\frac{T}{3}\right)^2 \Rightarrow h' = \frac{1}{2} \times \frac{gT^2}{9} = \frac{h}{9}$$

$\therefore$ position of ball from ground $= h - \frac{h}{9} = \frac{8h}{9}$

78. (d) $x = a + bt^2 = 15 + 3t^2$

$$v = \frac{dx}{dt} = 3 \times 2t = 6t$$

$$\Rightarrow \ v|_{t=3s} = 6 \times 3 = 18 \text{cm/s}$$

79. (a) Motion with constant acceleration is represented by a quadratic equation of t

$Y = (p + qt)(r + pt) = pr + qrt + p^2t + pqt^2$

80. (c) Let the maximum height attained by the ball be h.

At maximum height, velocity of ball, $v = 0$

Given, initial velocity, $u = 19.6$ m/s

Using the equation of motion,

$$v^2 = u^2 + 2gh$$

We get $0 = (19.6)^2 + 2(-9.8) \times h$

$$\Rightarrow h = \frac{(19.6)^2}{2 \times 9.8}$$

$$= 19.6 \text{m}$$

81. (a) Here, length of train A, L_A = 120 m

length of train B, L_B = 130 m

velocity of train A, v_A = 20 m/s

velocity of train B, v_B = 30 m/s

Train B is running in opposite direction to train B,

$\therefore$ velocity of train B relative to train A,

$$v_{BA} = v_B + v_A$$
$$= (30 + 20) \text{ m/s}$$
$$= 50 \text{ m/s}$$

Total distance to be covered by train B

$$= L_A + L_B = (120 + 130) \text{ m}$$
$$= 250 \text{ m}$$

Hence, time required by train B to cross train A

$$t = \frac{250}{50} \text{ sec} = 5 \text{sec}$$

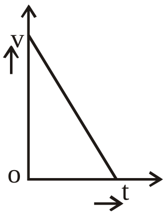
82. (a) Retardation, $a = \frac{v^2 - u^2}{2s} = \frac{0 - (25/3)^2}{2 \times 8}$

$$a = -\left(\frac{25}{3}\right)^2 \times \frac{1}{16}$$

For $u = 60$ km h^{-1} = $\frac{50}{3}$ ms^{-1}

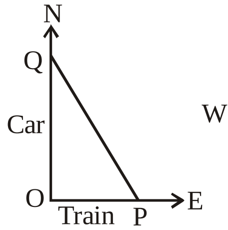
$$s = \frac{0 - (50/3)^2}{2 \times [-(25/3)^2 \times 1/16]} = 32 \text{ m}$$

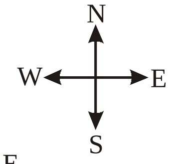
83. (d) Velocity time curve will be a straight line as shown:



At the highest point v = 0.

84. (b) Let O be the origin, then





passenger in the train at P observes the car at Q along the direction PQ; i.e. west north direction.

85. (d) Given : u = 0, t = 5 sec, v = 108 km/hr = 30m/s

By eq^n of motion

v = u + at

or $a = \frac{v}{t} = \frac{30}{5} = 6 \text{ m/s}^2 \quad [\because \ u = 0]$

$$S_1 = \frac{1}{2}at^2$$

$$= \frac{1}{2} \times 6 \times 5^2 = 75 \text{ m}$$

Distance travelled in first 5 sec is 75m.

Distance travelled with uniform speed of 30 m/s is S_2

$395 = S_1 + S_2 + S_3$

$395 = 75 + S_2 + 45$

$\therefore S_2 = 395 - 120 = 275 \text{ m}$

Time taken to travel 275 m = $\frac{275}{30} = 9.2$ sec

For retarding motion, we have

$0^2 - 30^2 = 2(-a) \times 45$

We get, $a = 10\ m/s^2$

Now by, $S = ut + \frac{1}{2}at^2$

$$45 = 30t + \frac{1}{2}(-10)t^2$$

$$45 = 30t - 5t^2$$

Pn solving we get, $t = 3$ sec

Total time taken $= 5 + 9.2 + 3 = 17.2$ sec.

86. (c) When particle comes to rest,

$V = 0 = \frac{dx}{dt} = \frac{d}{dt}(40 + 12t - t^3)$

$\Rightarrow\ 12 - 3t^2 = 0$

$\Rightarrow\ t^2 = \frac{12}{3} = 4\ \therefore t = 2$ sec

Therefore distance travelled by particle before coming to rest,

$x = 40 + 12t - t^3 = 40 + 12 \times 2 - (2)^3 = 56m$

87. (b) We get acceleration by double differentiation of displacement.

$$V = \frac{dx}{dt} = \frac{d}{dt}\left(a_0 + \frac{a_1 t}{2} - \frac{a_2}{3}t^2\right)$$

$$= \frac{a_1}{2} - \frac{2}{3}a_2 t$$

$$a = \frac{dv}{dt} = \frac{d\left(\frac{a_1}{2} - \frac{2}{3}a_2 t\right)}{dt} = \frac{-2}{3}a_2$$

88. (b) $\frac{1}{2}(2+4) \times 2 + \frac{1}{2} \times 1 \times 4 - \frac{1}{2} \times 3 \times 4 = 2\text{m}$

89. (a) Velocity of boat $= \frac{8+8}{2} = 8\,\text{km h}^{-1}$

Velocity of water $= 4\,\text{km h}^{-1}$

$$t = \frac{8}{8-4} + \frac{8}{8+4} = \frac{8}{3}\text{h} = 160 \text{ minute}$$

90. (b) Using relative terms

$u_{\text{rel.}} = 0\ m/s$

$a = 9.8\,\text{m s}^{-2},\ S = 4.9\,\text{m},\ t = ?$

$$4.9 = 0 \times t + \frac{1}{2} \times 9.8 \times t^2$$

$\Rightarrow\ 4.9t^2 = 4.9\ \Rightarrow\ t = 1\ \text{s}$

91. (b) From first equation of motion $v = u + a\,t$

here $u = 40$, $a = g = -10$, $t = 2$

so $v = 40 - 10 \times 2 = 20$ m/sec

92. (b) $v = [144 \times 1000/(60 \times 60)]$ m/sec.

$v = u + at$

or $(144 \times 1000)/(60 \times 60) = 0 + a \times 20$

$$\therefore\ a = \frac{144 \times 1000}{60 \times 60 \times 20} = 2\,\text{m}/\text{sec}^2$$

Now $s = u\,t + \frac{1}{2}at^2\ = 0 + \frac{1}{2} \times 2 \times (20)^2\ = 400\ \ \text{m}$

93. (c) Height of tap = 5m and (g) = 10 m/sec^2.

For the first drop, $5 = ut + \frac{1}{2}gt^2$

$= (0 \times t) + \frac{1}{2} \times 10t^2 = 5t^2$ or $t^2 = 1$ or $t = 1$ sec.

It means that the third drop leaves after one second of the first drop. Or, each drop leaves after every 0.5 sec.

Distance covered by the second drop in 0.5 sec

$= ut + \frac{1}{2}gt^2 = (0 \times 0.5) + \frac{1}{2} \times 10 \times (0.5)^2$

$= 1.25$ m.

Therefore, distance of the second drop above the ground $= 5 - 1.25 = 3.75$ m.

94. (d) At E, the slope of the curve is negative.

95. (d) Velocity, $v = \frac{ds}{dt} = 3t^2 - 12t + 3$

Acceleration, $a = \frac{dv}{dt} = 6t - 12$; For $a = 0$, we have, $0 = 6t - 12$ or $t = 2$s. Hence, at t = 2 s the velocity will be

$v = 3 \times 2^2 - 12 \times 2 + 3 = -9\ \text{ms}^{-1}$

96. (a) $\frac{D_4}{D_3} = \frac{0 + \frac{a}{2}(2 \times 4 - 1)}{0 + \frac{a}{2}(2 \times 3 - 1)} = \frac{7}{5}$

97. (b) In one dimensional motion, the body can have at a time one velocity but not two values of velocities.

98. (d) In uniform motion the object moves with uniform velocity, the magnitude of its velocity at different instane i.e., at $t = 0$, $t = 1$, sec, $t = 2$sec ..... will always be constant. Thus velocity-time graph for an object in uniform motion along a straight path is a straight line parallel to time axis.

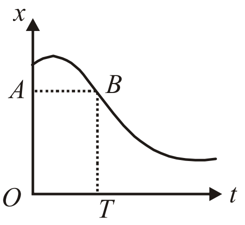
99. (b) 100. (d)

EXERCISE -3

Exemplar Questions

1. (b) If we draw a line parallel to time axis from the point (A) on graph at $t = 0$ sec. This line can intersect graph at B. In graph (b) for one value of displacement there are two different points of time. so, for one time, the average velocity is positive and for other time is equivalent negative.

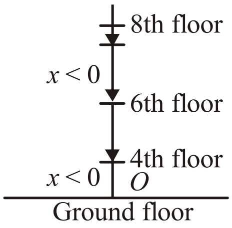
As there are opposite velocities in the inteval 0 to T hence average velocity can vanish in (b). This can be seen in the figure given below.



Here, $OA = BT$ (same displacement) for two different points of time.

2. (a) As the lift is moving downward directions so displacement is negative (zero). We have to see whether the motion is accelerating or retarding.

Due to downward motion displacement is negative the lift reaches 4th floor is about to stop hence, motion is retarding (–a) downward in nature hence, $x < 0$; $a > 0$.



As displacement is in negative direction, $x < 0$ velocity will also be negative i.e., $v < 0$ but net acceleration is +ve $a > 0$, that can be shown in the graph.

3. (b) In one dimensional motion, for the maximum and minimum displacement we must have the magnitude and direction of maximum velocity.

As maximum velocity in positive direction is v_0, hence maximum velocity in opposite direction is also $-v_0$.

Maximum displacement in one direction = v_0T

Maximum displacement in opposite directions = $-v_0T$.

Hence, $-v_0T < x < v_0T$

4. (c) Time taken to travel first half distance,

$$t_1 = \frac{l/2}{v_1} = \frac{l}{2v_1} \qquad (\because L_1 = l/2)$$

Time taken to travel second half distance,

$$t_2 = \frac{l}{2v_2} \qquad (\because L_2 = l/2)$$

So, total time taken to travel full distance

$= t_1 + t_2$

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

$$\text{Total time } = \frac{l}{2}\left[\frac{v_2 + v_1}{v_1 v_2}\right]$$

So, average speed,

$$v_{\text{av.}} = = \frac{\text{Total distance}}{\text{Total time}}$$

$$\Rightarrow v_{\text{av.}} = \frac{l}{\frac{l}{2}\left[\frac{1}{v_1} + \frac{1}{v_2}\right]} = \frac{2v_1v_2}{v_1 + v_2}$$

$$\therefore v_{\text{av.}} = \frac{2v_1v_2}{v_1 + v_2}$$

5. (b) As given that, $x = (t-2)^2$

$$\text{Now, velocity } v = \frac{dx}{dt} = \frac{d}{dt}(t-2)^2$$

$$= 2\,(t-2) \text{ m/s}$$

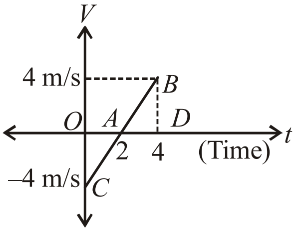
$$\text{Acceleration, } a = \frac{dv}{dt} = \frac{d}{dt}[2(t-2)]$$

$$= 2\,[1-0] = 2 \text{ m/s}^2 = 2 \text{ ms}^{-2}$$

at $t = 0$; $v_0 = 2\,(0-2) = -4$ m/s

$t = 2$ s; $v_2 = 2\,(2-2) = 0$ m/s

$t = 4$ s; $v_4 = 2\,(4-2) = 4$ m/s



v-t graph is shown in diagram.

Distance travelled

= area between time axis of the graph

= area OAC + are ABD

$$= \frac{1}{2}OA \times OC + \frac{1}{2}AD \times BD$$

$$= \frac{4 \times 2}{2} + \frac{1}{2} \times 2 \times 4 = 8 \text{ m}$$

If displacement occurs

$$= \frac{1}{2} \times OA \times OC + \frac{1}{2} \times AD \times BD$$

$$= \frac{1}{2} \times 2(-4) + \frac{1}{2} \times 2 \times 4 = 0$$

6. (c) Let us consider, displacement is L, then velocity of girl with respect to ground,

$$v_g = \frac{L}{t_1}$$

Velocity of escalator with respect to ground,

$$v_e = \frac{L}{t_2}$$

Net velocity of the girl on moving escalator with respect to ground

$$= v_g + v_e = \frac{L}{t_1} + \frac{L}{t_2}$$

$$\Rightarrow \quad v_{ge} = L\left[\frac{t_1 + t_2}{t_1 t_2}\right]$$

Now, if t is total time taken by girl on moving escalator in covering distance L, then

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

$$= \frac{L}{L\left(\frac{t_1 + t_2}{t_1 t_2}\right)} = \frac{t_1 t_2}{t_1 + t_2}$$

NEET/AIPMT (2013-2017) Questions

7. (a) $\because\ h = \frac{1}{2} gt^2$

$\therefore\ h_1 = \frac{1}{2} g(5)^2 = 125$

$h_1 + h_2 = \frac{1}{2} g(10)^2 = 500$

$\Rightarrow\ h_2 = 375$

$h_1 + h_2 + h_3 = \frac{1}{2} g(15)^2 = 1125$

$\Rightarrow\ h_3 = 625$

$h_2 = 3h_1,\ h_3 = 5h_1$

or $h_1 = \frac{h_2}{3} = \frac{h_3}{5}$

8. (c) $\because\ t = \sqrt{x} + 3$

$\Rightarrow\ \sqrt{x} = t - 3 \Rightarrow x = (t-3)^2$

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

$\Rightarrow\ t = 3$

$\therefore\ x = (3-3)^2$

$\Rightarrow\ x = 0.$

9. (a) According to question,

$V(x) = bx^{-2n}$

So, $\frac{dv}{dx} = -2\ nb\ x^{-2n-1}$

Acceleration of the particle as function of x,

$a = v\frac{dv}{dx} = bx^{-2n}\left\{b\,(-2n)\,x^{-2n-1}\right\}$

$= -2nb^2x^{-4n-1}$

10. (c) **Given :** Velocity

$V = At + Bt^2 \quad \Rightarrow \quad \frac{dx}{dt} = At + Bt^2$

By integrating we get distance travelled

$\Rightarrow\ \int_0^x dx = \int_1^2 \left(At + Bt^2\right)dt$

Distance travelled by the particle between 1s and 2s

$x = \frac{A}{2}\left(2^2 - 1^2\right) + \frac{B}{3}\left(2^3 - 1^3\right) = \frac{3A}{2} + \frac{7B}{3}$

11. (b) Velocity of preeti w.r.t. elevator $v_1 = \frac{d}{t_1}$

Velocity of elevator w.r.t. ground $v_2 = \frac{d}{t_2}$ then

velocity of preeti w.r.t. ground

$v = v_1 + v_2$

$\frac{d}{t} = \frac{d}{t_1} + \frac{d}{t_2}$

$\frac{1}{t} = \frac{1}{t_1} + \frac{1}{t_2}$

$\therefore\ t = \frac{t_1 t_2}{(t_1 + t_2)}$ (time taken by preeti to walk up on the moving escalator)