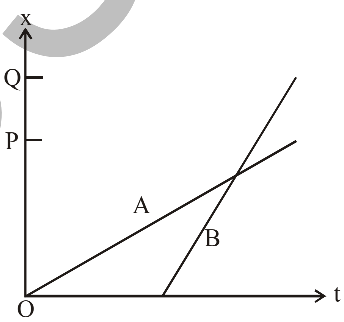
NCERT SOLUTIONS
PHYSICS XI CLASS
CHAPTER - 3
MOTION IN A STRAIGHT LINE

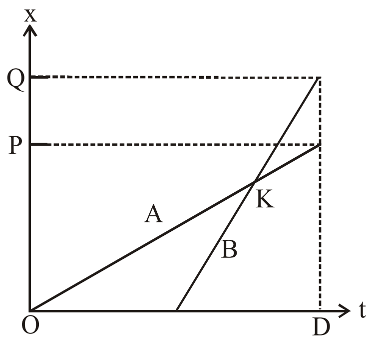
3.1 In which of the following examples of motion, can the body be considered approximately a point object:
(a) a railway carriage moving without jerks between two stations.
(b) a monkey sitting on top of a man cycling smoothly on a circular track.
(c) a spinning cricket ball that turns sharply on hitting the ground.
(d) a tumbling beaker that has slipped off the edge of a table.

Sol. (a) The size of a carriage is very small as compared to the distance between two stations. Therefore, the carriage can be treated as a point sized object.
(b) The size of a monkey is very small as compared to the size of a circular track. Therefore, the monkey can be considered as a point sized object on the track.
(c) The size of a spinning cricket ball is comparable to the distance through which it turns sharply on hitting the ground. Hence, the cricket ball cannot be considered as a point object.
(d) The size of a beaker is comparable to the height of the table from which it slipped. Hence, the beaker cannot be considered as a point object.

3.2 The position-time (x-t) graphs for two children A and B returning from their school O to their homes P and Q respectively are shown in Fig.
Choose the correct entries in the brackets below ;
(a) (A/B) lives closer to the school than (B/A)
(b) (A/B) starts from the school earlier than (B/A)
(c) (A/B) walks faster than (B/A)
(d) A and B reach home at the (same/different) time
(e) (A/B) overtakes (B/A) on the road (once/twice).



Sol. (a) It is clear from the graph that OQ > OP. So, A lives closes to the school than B.
(b) The position-time graph of A starts from the origin (t = 0) while the position-time graph of B starts from C which indicates that B started later than A after a time interval OC. So, A started earlier than B.
(c) The speed is represented by the steepness (or slope) of the position-time graph. Since the position-time graph of B is steeper than the position-time of graph A, therefore, we conclude that B is faster than A.



(d) Corresponding to both P and Q, the time interval is the same, i.e., OD. This indicates that both A and B reach their homes at the same time.
(e) The position-time graphs intersect at the point K. This indicates that B crosses A. Since there is only one point of intersection, therefore, they cross each other only once.

3.3 A woman starts from her home at 9.00 am, walks with a speed of 5 km h^{-1} on a straight road up to her office 2.5 km away, stays at the office up to 5.00 pm, and returns home by an auto with a speed of 25 km h^{-1}. Choose suitable scales and plot the x-t graph of her motion.

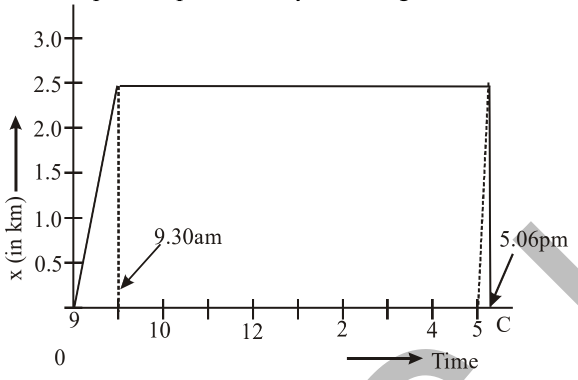
Sol. Distance covered while walking = 2.5 km.

Speed while walking = 5 kmh^{-1}.

Time taken to reach office while walking $= \frac{2.5}{5} h = \frac{1}{2} h$

If O is regarded as the origin for both time and distance, then at t = 9.00 am, x = 0 and t = 9.30 am, x = 2.5 km.

OA is the x-t graph of the motion when the woman walks from her home to office. Her stay in the office from 9.30 am to 5.00 pm is represented by the straight line AB in the graph.



Now, time taken to return home by an auto = $\frac{2.5}{5} h = \frac{1}{10} h$ = 6 minutes . So, at t = 5.06 pm, x = 0

This motion is represented by the straight line BC in the graph. While drawing the x-t graph, the scales chosen are as under.

Along time-axis: One division equals 1 hour.

Along position axis: One division equals 0.5 km.

3.4 A drunkard walking in a narrow lane takes 5 steps forward and 3 steps backward, followed again by 5 steps forward and 3 steps backward, and so on. Each step is 1m long and requires 1s. Plot the x-t graph of his motion. Determine graphically and otherwise how long the drunkard takes to fall in a pit 13 m away from the start.

Sol. Distance covered with 1 step = 1 m

Time taken = 1 s

Time taken to move first 5 m forward = 5s

Time taken to move 3 m backward = 3s

Net distance covered = 5 – 3 = 2m

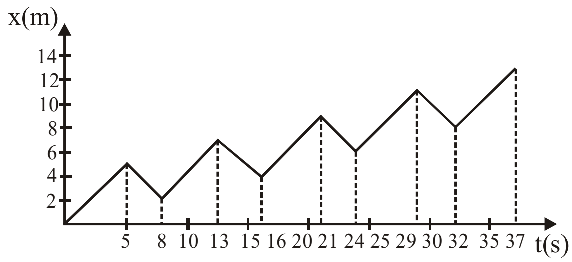
Net time taken to cover 2 m = 8s ; Drunkard covers 2 m in 8 s.

Drunkard covered 4 m in 16 s. ; Drunkard covered 6 m in 24 s.

Drunkard covered 8 m in 32 s.

In the next 5 s, the drunkard will cover a distance of 5 m and a total distance of 13 m and falls into the pit. Net time taken by the drunkard to cover 13 m = 32 + 5 = 37s

The x-t graph of the drunkard's motion can be shown as:



3.5 A jet airplane travelling at the speed of 500 km h^{-1} ejects its products of combustion at the speed of 1500 km h^{-1} relative to the jet plane. What is the speed of the latter with respect to an observer on the ground?

Sol. Speed of combustion products w.r.t. observer on the ground =?
Velocity of jet air plane w.r.t. observer on ground = 500 kmh^{-1}

If $\vec{v}_j$ and $\vec{v}_0$ represent the velocities of jet and observer respectively, then $v_j - v_0 = 500\ kmh^{-1}$

Similarly, if $\vec{v}_c$ represents the velocity of the combustion products w.r.t. jet plane, then $v_c - v_j = -1500\ km\ h^{-1}$.

The negative sign indicates that the combustion products move in a direction opposite to that of jet.
Speed of combustion products w.r.t. observer

$$= v_c - v_0 = (v_c - v_j) + (v_j - v_0) = (-1500 + 500)\ km\ h^{-1} = -1000\ km\ h^{-1}.$$

3.6 A car moving along a straight highway with speed of 126km h^{-1} is brought to a stop within a distance of 200 m. What is the retardation of the car (assumed uniform), and how long does it take for the car to stop?

Sol. Initial velocity, $u = 126\ km\ h^{-1} = 126 \times \frac{5}{18} ms^{-1} = 35\ ms^{-1}$

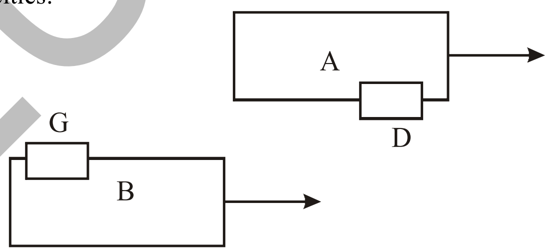
Final velocity, v = 0, Distance, S = 200m

Using $v^2 - u^2 = 2as$, $0^2 - 35 \times 35 = 2a \times 200$ or $a = -\frac{35 \times 35}{400} ms^{-2} = -3.06 ms^{-2}$

Using $v = u + at$, $0 = 35 - 3.06\ t$ or $3.06\ t = 35$ or $t = \frac{35}{3.06} s = 11.4s$

3.7 Two trains A and B of length 400 m each are moving on two parallel tracks with a uniform speed of 72 km h^{-1} in the same direction, with A ahead of B. The driver of B decides to overtake A and accelerates by 1 ms^{-2}. If after 50s, the guard of B just brushes past the driver of A, what was the original distance between them ?

Sol. Originally, both the trains have the same velocities.
So, the relative velocity of B w.r.t. A is zero.
Now, for train B



$v(0)$, $a = 1\ ms^{-2}$, $t = 50s$, $x(t) - x(0) = ?$

$x(t) = x(0) + v(0) + \frac{1}{2}at^2$

or $x(t) - x(0) = v(0) + \frac{1}{2}at^2$

$= 0 \times 50 + \frac{1}{2} \times 1 \times 50 \times 50 = 1250$ m.

3.8 On a two-lane road, car A is travelling with a speed of 36 km h^{-1}. Two cars B and C approach car A in opposite directions with a speed of 54 km h^{-1} each. At a certain instant, when the distance AB is equal to AC, both being 1 km, B decides to overtake A before C does. What minimum acceleration of car B is required to avoid an accident?

Sol. $v_A = 36\ km\ h^{-1} = 36 \times \frac{5}{18} ms^{-1} = 10 ms^{-1}$

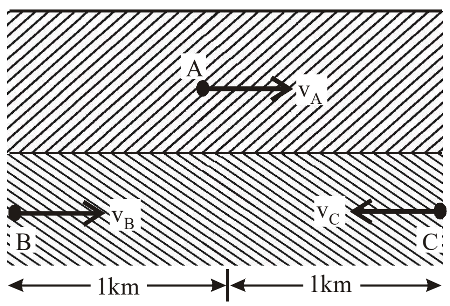
$v_B = v_C = 54\ km\ h^{-1} = 54 \times \frac{5}{18} ms^{-1} = 15 ms^{-1}$

Relative velocity of B w.r.t. A, $v_{BA} = 5\ ms^{-1}$

Relative velocity of C w.r.t. A, $v_{CA} = 5\ ms^{-1}$

Time taken by C to cover distance AC = $\frac{1000m}{25ms^{-1}} = 40s$

Now, for B, $1000 = 5 \times 40 + \frac{1}{2} a \times 40 \times 40$



On simplification, $a = 1\ ms^{-2}$.

3.9 Two towns A and B are connected by a regular bus service with a bus leaving in either direction every T minutes. A man cycling with a speed of 20 km/h in the direction A to B notices that a bus goes past him every 18 min in the direction of his motion and every 6 min. in the opposite direction. What is the time period T of the bus service and with what speed (assumed constant) do the buses ply on the road.

Sol. Let Bus A leaves town A and bus B leaves town B at regular intervals. Let C represents the cyclist and V_A, V_B and V_C are velocities of bus A, bus B and the cyclist respectively.

Let V_{AC} = Relative velocity of A w.r.t. C = $V_A - V_C$ (by defn.)

Similarly, $V_{BC} = V_B - V_C$

Let T = Time interval at which buses are leaving from town A and B.

Now, the funda to remember in this:

"The distance between two buses plying in the same direction at the same constant speed will remain the same whether measured by an observer moving at some constant speed or by a standing observer".

The distance between two consecutive buses A for an observer standing on ground = $V_A T$ ....(1)

This distance as measured by the cyclist = $V_{AC}\ T'$.

where, T' = Time interval between two consecutive buses for the cyclist = 18 minutes

Distance between two consecutive A-buses for the cyclist = $18\ V_{AC} = 18\ (V_A - V_C)$ .... (2)

$V_A T = 18\ (V_A - V_C)$ .... (3)

Similarly, $V_B T = 6\ (V_B + V_C)$ .... (4)

[$V_{BC} = |V_A| + |V_C|$, because B and C are moving in opposite directions]

Given, $|V_A| = |V_B| = V$, say and $|V_C| = 20$ km/hr

Equation (3) and (4) become

$V.T = 18\ (V - 20)$ .... (5)

$V.T = 6\ (V + 20)$ .... (6)

$18\ (V - 20) = 6\ (V + 20)$

$18V - 360 = 6V + 120$

$12V = 480 \Rightarrow V = 40$ km/hr

Putting it in equation (5) we get, T = 9 mins.

3.10 A player throws a ball upwards with an initial speed of $29.4\ m\ s^{-1}$.

(a) What is the direction of acceleration during the upward motion of the ball?

(b) What are the velocity and acceleration of the ball at the highest point of its motion?

(c) Choose the x = 0 m and t = 0 s to be the location and time of the ball at its highest point, vertically downward direction to be the positive direction of x-axis, and give the signs of position, velocity and acceleration of the ball during its upward, and downward motion.

(d) To what height does the ball rise and after how long does the ball return to the player's hands? (Take $g = 9.8\ m\ s^{-2}$ and neglect air resistance).

Sol. (a) The ball moves under gravity. The direction of acceleration due to gravity is vertically downwards.

(b) At the highest point, the velocity of the ball is zero. The acceleration is $9.8\ ms^{-2}$ vertically downwards.

(c) For upward motion, position is positive, velocity is negative and acceleration is positive.
For downward motion, position is positive, velocity is positive and acceleration is positive.

(d) Initial velocity of the ball, u = 29.4 m/s
Final velocity of the ball, v = 0 (At maximum height, the velocity of the ball becomes zero)
Acceleration, $a = -g = -9.8\ m/s^2$

From third equation of motion, height (s) can be calculated as: $v^2 - u^2 - 2gs$

$$s = \frac{v^2 - u^2}{2g} = \frac{(0)^2 - (29.4)^2}{2 \times (-9.8)} = 44.1\text{m}$$

From first equation of motion, time of ascent (t) is given as: $v = u + at$

$$t = \frac{v - u}{a} = \frac{-29.4}{-9.8} = 3\text{s}$$

Time of ascent = Time of descent

Hence, the total time taken by the ball to return to the player's hands = 3 + 3 = 6s.

3.11 Read each statement below carefully and state with reasons and examples, if it is true or false;

A particle in one-dimensional motion

(a) with zero speed at an instant may have non-zero acceleration at that instant

(b) with zero speed may have non-zero velocity,

(c) with constant speed must have zero acceleration,

(d) with positive value of acceleration must be speeding up.

Sol. (a) True (b) False (c) True (d) False

For (a), consider a ball thrown up. At the highest point, speed is zero but the acceleration is non-zero.

For (b), if a particle has non-zero velocity, it must have speed.

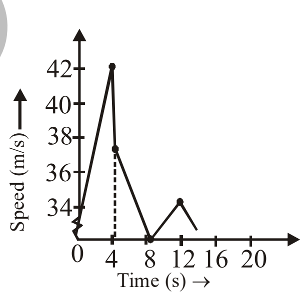
For (c), if the particle rebounds instantly with the same speed, it implies infinite acceleration which is physically impossible.

For (d), true only when the chose positive direction is along the direction of motion.

3.12 A ball is dropped from a height of 90 m on a floor. At each collision with the floor, the ball loses one tenth of its speed. Plot the speed-time graph of its motion between t=0 to 12s.

Sol. Here u = 0, g = 10 ms^2, h = 90m

From relation, $t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2 \times 90}{10}} = 4.24$ s



Also, $v = \sqrt{2gh} = \sqrt{2 \times 10 \times 90} = 30\sqrt{2}\ ms^{-1}$

Rebound velocity of ball

$$u' = \frac{9}{10}v = \frac{9}{10} \times 30\sqrt{2} = 27\sqrt{2}\ ms^{-1}$$

Time taken to reach the point of maximum height t'.

$v = u + gt$

$$0 = 27\sqrt{2} - 10t' \text{ or } t' = \frac{27\sqrt{2}}{10} = 3.81 \text{ s}$$

Total time = t + t' = 4.24 + 3.81 = 8.05s

The ball takes further same time 3.81 to fall back to floor.

Also it will strike with velocity $27\sqrt{2}\ ms^{-1}$.

Velocity of ball after striking the floor = $\frac{9}{10}v = \frac{9}{10} \times 27\sqrt{2} = 24.3\sqrt{2}\ ms^{-1}$

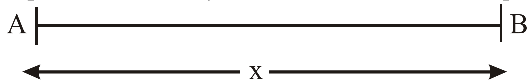
Total time elapsed before upward motion of ball = 8.05 + 3.81 = 11.86s

3.13 Explain clearly, with examples, the distinction between:

(a) Magnitude of displacement (sometimes called distance) over an interval of time, and the total length of path covered by a particle over the same interval;

(b) Magnitude of average velocity over an interval of time, and the average speed over the same interval. [Average speed of a particle over an interval of time is defined as the total path length divided by the time interval]. Show in both (a) and (b) that the second quantity is either greater than or equal to the first. When is the equality sign true? [For simplicity, consider one-dimensional motion only].

Sol. (a) Consider a particle which moves from A to B and then back to A. In this case, the magnitude of displacement is zero. This is because the magnitude of displacement is equal to the shortest distance between initial and final positions of the particle.
If B is separated from A by a distance x, then the total path length travelled by the particle is 2x.



(b) $|\text{Average velocity}| = \dfrac{|\text{displacement}|}{\text{time}} = \dfrac{0}{t} = 0$

Average speed $= \dfrac{\text{Total path length}}{\text{Corresponding time interval}} = \dfrac{2x}{t}$

3.14 A man walks on a straight road from his home to a market 2.5 km away with a speed of 5 km h^{-1}. Finding the market closed, he instantly turns and walks back home with a speed of 7.5 km h^{-1}. What is the
(a) Magnitude of average velocity, and
(b) Average speed of the man over the interval of time
(i) 0 to 30 min, (ii) 0 to 50 min, (iii) 0 to 40 min ?

Sol. (a) (i) Magnitude of average velocity over the interval of tome from 0 to 30 min is 5 km h^{-1}.
This is because the 'distance travelled' and the 'magnitude of displacement' over the interval of time from 0 to 30 min are equal.
(ii) The displacement over the interval of time from 0 to 50 min is zero. So, the magnitude of average velocity is zero.
(iii) The 'magnitude of displacement' is (2.5 – 1.25)km, i.e. 1.25 km.

Time interval $= \dfrac{2}{3}$h

The magnitude of average velocity is $\dfrac{1.25\text{km}}{(2/3)\text{h}}$

i.e., $\dfrac{1.25 \times 3}{2}$km h^{-1} i.e., 1.875 km h^{-1}

(b) (i) Average speed over the interval of time from 0 to 30 min $= \dfrac{2.5\text{km}}{30\,\text{min}} = \dfrac{2.5\text{km}}{(1/2)\text{h}} = 5\text{km h}^{-1}$

(ii) Distance covered from 30 to 50 minutes = 7 km h^{-1} × $\dfrac{20}{60}$h = 2.5 km

Total distance covered from 0 to 50 minute = 2.5 km + 2.5 km = 5 km.

Total time = 50 min = $\dfrac{50}{60}\text{h} = \dfrac{5}{6}\text{h}$

∴ Average speed over the interval of time from 0 to 50 min $= \dfrac{5\text{km}}{5/6\text{ h}}$ = 6 km h^{-1}.

(iii) Distance covered from 30 to 40 min = 7.5 km h^{-1} × $\dfrac{1}{6}$h = 1.25 km

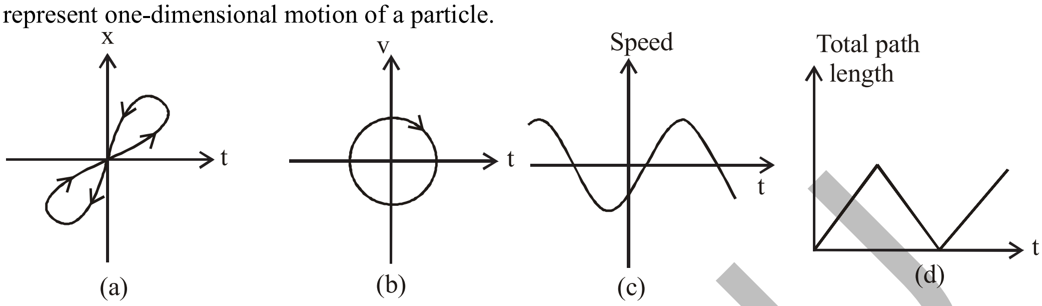
Total distance covered from 0 to 40 min = 2.5 km + 1.25 km = 3.75 km

Average speed over the interval of time from 0 to 40 min $= \dfrac{3.75\text{km}}{(40/60)\text{h}}$ = 5.625 km h^{-1}

3.15 In Q.3.13 and 3.14, we have carefully distinguished between average speed and magnitude of average velocity. No such distinction is necessary when we consider instantaneous speed and magnitude of velocity. The instantaneous speed is always equal to the magnitude of instantaneous velocity. Why?

Sol. When we define instantaneous speed, we take only a small interval of time, during which direction of motion is not supposed to change. Thus there is no difference between total path covered and magnitude of displacement. Hence instantaneous speed is always equal to magnitude of instantaneous velocity.

3.16 Look at the graphs (a) to (d) (Fig.) carefully and state, with reasons, which of these cannot possibly represent one-dimensional motion of a particle.



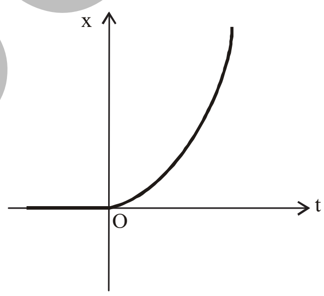
Sol. (a) The given x-t graph, shown in (a), does not represent one-dimensional motion of the particle. This is because a particle cannot have two positions at the same instant of time.

(b) The given v-t graph, shown in (b), does not represent one-dimensional motion of the particle. This is because a particle can never have two values of velocity at the same instant of time.

(c) The given v-t graph, shown in (c), does not represent one-dimensional motion of the particle. This is because speed being a scalar quantity cannot be negative.

(d) The given v-t graph, shown in (d), does not represent one-dimensional motion of the particle. This is because the total path length travelled by the particle cannot decrease with time.

3.17 Figure shows the x-t plot of one-dimensional motion of a particle. Is it correct to say from the graph that the particle moves in a straight line for $t < 0$ and on a parabolic path for $t > 0$? If not, suggest a suitable physical context for this graph.



Sol. No, wrong. x-t graph plot does not show the trajectory of a particle. Context : A body is dropped from a tower ($x=0$) at $t = 0$.

3.18 A police van moving on a highway with a speed of 30 km h^{-1} fires a bullet at a thief's car speeding away in the same direction with a speed of 192 km h^{-1}. If the muzzle speed of the bullet is 150 m s^{-1}, with what speed does the bullet hit the thief's car ? (Obtain that speed which is relevant for damaging the thief's car).

Sol. Speed of police van, $v_p = 30 \text{ km h}^{-1} = \dfrac{30 \times 1000}{3600} \text{ms}^{-1} = \dfrac{25}{3} \text{ms}^{-1}$

Speed of thief's car, $v_t = 192 \text{ km h}^{-1} = \dfrac{192 \times 1000}{3600} \text{ms}^{-1} = \dfrac{160}{3} \text{ms}^{-1}$

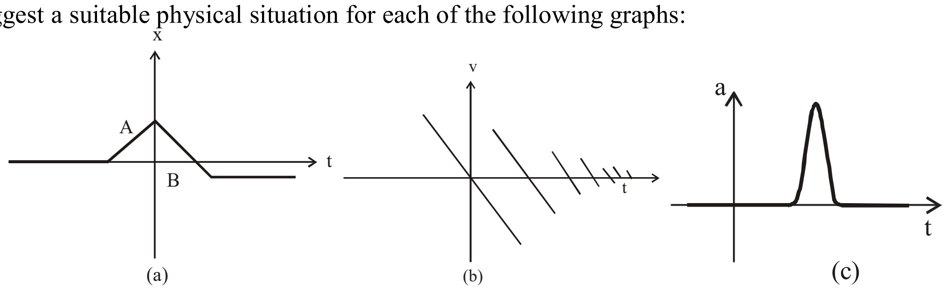
Speed of bullet, v_b = speed of police van + speed with which bullet is actually fired

$$\therefore \quad v_b = \left(\frac{125}{3} + 150\right) \text{ms}^{-1} = \frac{475}{3} \text{ms}^{-1}$$

Relative velocity of bullet w.r.t. thief's car,

$$v_{bt} = v_b - v_t = \left(\frac{475}{3} - \frac{160}{3}\right) \text{ms}^{-1} = 105 \text{ ms}^{-1}$$

3.19 Suggest a suitable physical situation for each of the following graphs:

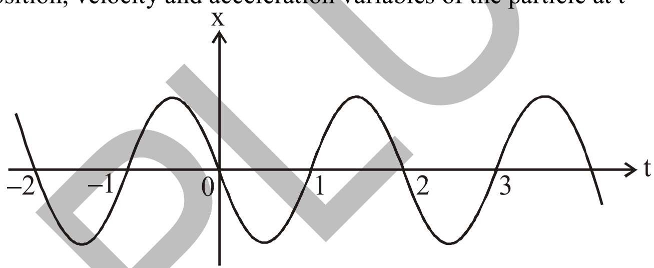


Sol. (a) The given x-t graph shows that initially a body was at rest. Then, its velocity increases with time and attains an instantaneous constant value. The velocity then reduces to zero with an increase in time. Then, its velocity increases with time in the opposite direction and acquires a constant value. A similar physical situation arises when a football (initially kept at rest) is kicked and gets rebound from a rigid wall so that its speed gets reduced. Then, it passes from the player who has kicked it and ultimately gets stopped after sometime.

(b) In the given v-t graph, the sign of velocity changes and its magnitude decreases with a passage of time. A similar situation arises when a ball is dropped on the hard floor from a height. It strikes the floor with some velocity and upon rebound, its velocity decreases by a factor. This continues till the velocity of the ball eventually becomes zero.

(c) The given a-t graph reveals that initially the body is moving with a certain uniform velocity. Its acceleration increases for a short interval of time, which again drops to zero. This indicates that the body again starts moving with the same constant velocity. A similar physical situation arises when a hammer moving with a uniform velocity strikes a nail.

3.20 Figure gives the x-t plot of a particle executing one-dimensional simple harmonic motion. Give the signs of position, velocity and acceleration variables of the particle at t = 0.3 s, 1.2 s, – 1.2 s.



Sol. At t = 0.3s:

$x < 0$ i.e., x is negative.

$v < 0$ i.e., v is negative.

but $a > 0$ i.e., a is positive

(In S.H.M. acceleration $a = -\omega^2 x$ since x is negative so a is positive.)

At t = 1.2 s:

$x > 0$ i.e., x is positive

$v > 0$ i.e., v is positive

$a < 0$ i.e., a is negative

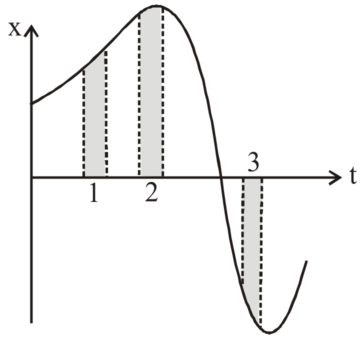
At t = –1.2 s:

$x < 0$ i.e., x is negative

$v > 0$ i.e., v is positive

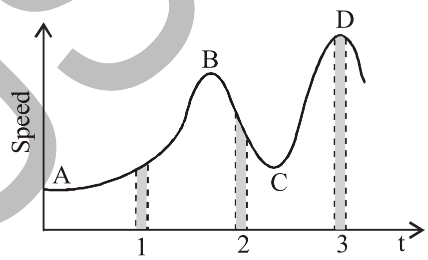
$a > 0$ i.e., a is positive

3.21 Figure gives the x-t plot of a particle in one-dimensional motion. Three different equal intervals of time are shown. In which interval is the average speed greatest, and in which is it the least ? Give the sign of average velocity for each interval.



Sol. Interval 3 (Greatest), Interval 2 (Least)
Positive (Intervals 1 & 2), Negative (Interval 3)
The average speed of a particle shown in the x-t graph is obtained from the slope of the graph in a particular interval of time.
It is clear from the graph that the slope is maximum and minimum in intervals 3 and 2 respectively. Therefore, the average speed of the particle is the greatest in interval 3 and is the least in interval 2. The sign of average velocity is positive in both intervals 1 and 2 as the slope is positive in these intervals. However, it is negative in interval 3 because the slope is negative in this interval.

3.22 Figure gives a speed-time graph of a particle in motion along a constant direction. Three equal intervals of time are shown. In which interval is the average acceleration greatest in magnitude? In which interval is the average speed greatest? Choosing the positive direction as the constant direction of motion, give the signs of v and a in the three intervals. What are the accelerations at the points A, B, C and D?



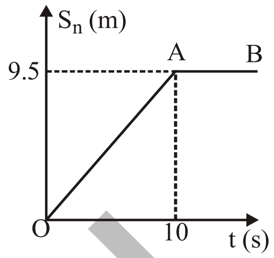
Sol. Average acceleration is greatest in interval 2
Average speed is greatest in interval 3
v is positive in intervals 1, 2, and 3
a is positive in intervals 1 and 3 and negative in interval 2
a = 0 at A, B, C, D
Acceleration is given by the slope of the speed-time graph. In the given case, it is given by the slope of the speed-time graph within the given interval of time.
Since the slope of the given speed-time graph is maximum in interval 2, average acceleration will be the greatest in this interval.
Height of the curve from the time-axis gives the average speed of the particle. It is clear that the height is the greatest in interval 3. Hence, average speed of the particle is the greatest in interval 3.
In interval 1: The slope of the speed-time graph is positive. Hence, acceleration is positive. Similarly, the speed of the particle is positive in this interval.
In interval 2: The slope of the speed-time graph is negative. Hence, acceleration is negative in this interval. However, speed is positive because it is a scalar quantity.
In interval 3: The slope of the speed-time graph is zero. Hence, acceleration is zero in this interval. However, here the particle acquires some uniform speed. It is positive in this interval.
Points A, B, C, and D are all parallel to the time-axis. Hence, the slope is zero at these points. Therefore, at points A, B, C, and D, acceleration of the particle is zero.

3.23 A three-wheeler starts from rest, accelerates uniformly with 1 m s^{-2} on a straight road for 10 s, and then moves with uniform velocity. Plot the distance covered by the vehicle during the nth second (n = 1, 2, 3….) versus n. What do you expect this plot to be during accelerated motion: a straight line or a parabola?

Sol. Here u = 0, a = 1 ms^{-2}.

$$\therefore\ S_n = u + \frac{a}{2}(2n-1) = \frac{1}{2}(2n-1) = (2n-1)\ 0.5$$

n	1	2	3	4	5	6	7	8	9	10
S_n	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5



On plotting a graph between S_n and n we get a straight line OA. After 10 sec the graph is a straight line parallel to time axis.

3.24 A boy standing on a stationary lift (open from above) throws a ball upwards with the maximum initial speed he can, equal to 49ms^{-1}. How much time does the ball take to return to his hands? If the lift starts moving up with a uniform speed of 5 m s^{-1} and the boy again throws the ball up with the maximum speed he can, how long does the ball take to return to his hands ?

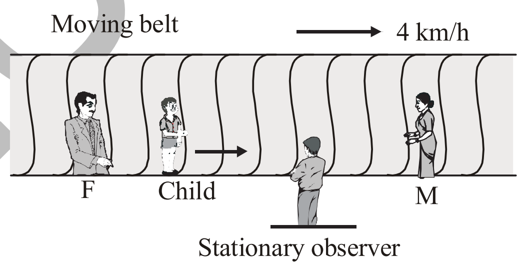
Sol. v (0) = 49 m s^{-1}, a = 9.8 ms^{-2}, t = ?, v (t) = 0,

v (t) = v (0) + at

$$0 = 49 - 9.8\ t \quad \text{or} \quad 9.8t = 49 \quad \text{or} \quad t = \frac{49}{9.8}s = 5s$$

This is time taken by the ball to reach the maximum height. The time of descent is also 5s.
So, the total time after which the ball comes back is 5s + 5s i.e., 10s.
The uniform velocity of the lift does not change the relative motion of ball and lift. So, the ball would take the same total time i.e., it would come back after 10 second.

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



(a) Speed of the child running in the direction of motion of the belt?.
(b) Speed of the child running opposite to the direction of motion of the belt?
(c) Time taken by the child in (a) and (b)?
Which of the answers alter if motion is viewed by one of the parents?

Sol. Speed of child with respect to belt = 9 km h^{-1}.
Speed of belt = 4 km h^{-1}.

(a) When the child runs in the direction of motion of the belt, then speed of child w.r.t. stationary observer = (9 + 4) km h^{-1} = 13 km h^{-1}.

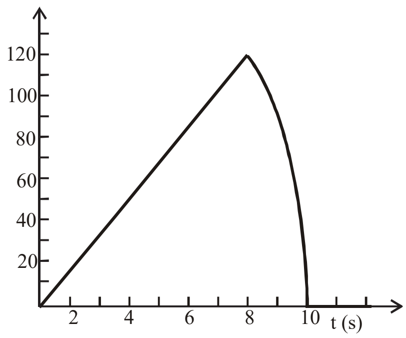
(b) When the child runs opposite to the direction of motion of the belt, then speed of child w.r.t. stationary observer = (9 – 4) km h^{-1} = 5 km h^{-1}.

(c) Speed of child w.r.t. either parent = 9 km h^{-1}.
Distance to be covered = 50m = 0.05 km

$$\text{Time} = \frac{0.05\text{km}}{9\text{kmh}^{-1}} = 0.0056\text{h} \approx 20\text{s}$$

If the motion is viewed by one of the parents, then the answers to (a) and (b) are altered but answer to (c) remains unaltered.

3.26 Two stones are thrown up simultaneously from the edge of a cliff 200 m high with initial speeds of 15 m s^{-1} and 30 ms^{-1}. Verify that the graph shown in figure correctly represents the time variation of the relative position of the second stone with respect to the first. Neglect air resistance and assume that the stones do not rebound after hitting the ground. Take g = 10 ms^{-2}. Give the equations for the linear and curved parts of the plot.



Sol. Let x_1 and x_2 be the position of first stone (u = 15 m/s) and second stone (u = 30 m/s) at any time t, relative to the top of the cliff.

$a = g = -10\ m/^2$

Using second equation of motion

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

$x_1 = 15t - 5t^2$ .... (1)

$x_2 = 30t - 5t^2$ .... (2)

Subtracting eq. (1) from eq. (2)

$x_2 - x_1 = 15t$

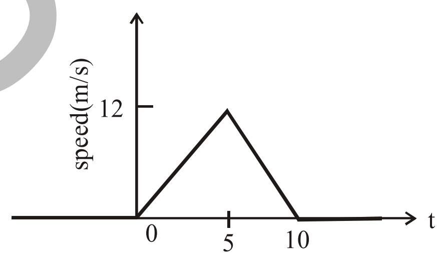
This is the equation of the linear part since the cliff is 200m high.

For second stone reaching the ground x_2 = 200m.

From eq. (2), $200 = 30t - 5t^2$

This is the equation of the curved path i.e., for time interval 8s to 10s.

3.27 The speed-time graph of a particle moving along a fixed direction is shown in figure. Obtain the distance traversed by the particle between (a) t = 0s to 10s, (b) t = 2s to 6s.



Sol. (a) Distance travelled for t = 0 to t = 10sec is the area enclosed by the speed time graph i.e,

$$S = \text{Area OBA} = \frac{1}{2}\times 10\times 12 = 60\text{m}$$

(b) Acceleration for t = 0 to t = 5s $\qquad a_1 = \frac{12}{5} = 2.4\ ms^{-2}$

Acceleration from t = 5s to 10s $\qquad a_2 = -\frac{12}{5} = -2.4\ ms^{-2}$

At t = 2s, the speed is given by $v = u + at = 0 + 2.4 \times 2 = 4.8$ m/s

During the time t = 2s to 5s the distance travelled

$$S_1 = ut + \frac{1}{2}at^2 = 4.8\times 3 + \frac{1}{2}\times 2.4\ (3)^2 = 25.2\text{m.}$$

At t = 5s speed of particle = 12 m/s

$\therefore$ The distance travelled from t = 5 to t = 6 sec.

$$S_2 = 12\times 1 - \frac{1}{2}\times 2.4\ (1)^2 = 12 - 1.2 = 10.8\text{m}$$

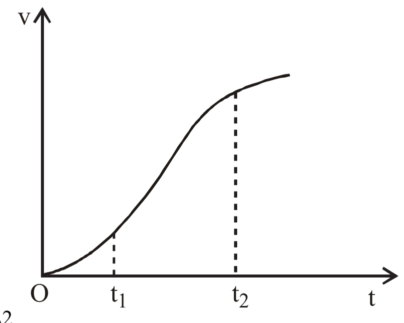
$\therefore$ Total distance travelled = 25.2 + 10.8 = 36m

Average speed from t = 0 to t = 10s

$$= \frac{\text{Distance travelled}}{\text{time taken}} = \frac{60}{10} = 6\text{ m/s.}$$ Average speed for t = 2 to t = 6s = 36/4 = 9 m/s

3.28 The velocity-time graph of a particle in one-dimensional motion is shown in figure :

Which of the following formulae are correct for describing the motion of the particle over the time-interval t_1 to t_2:



(a) $x(t_2) = x(t_1) + v(t_1)(t_2 - t_1) + (½)\, a\, (t_2 - t_1)2$

(b) $v(t_2) = v(t_1) + a(t_2 - t_1)$

(c) $v_{average} = (x(t_2) - x(t_1))/(t_2 - t_1)$

(d) $a_{average} = (v(t_2) - v(t_1))/(t_2 - t_1)$

(e) $x(t_2) = x(t_1) + v_{average}(t_2 - t_1) + (½)\, a_{average}(t_2 - t_1)^2$

(f) $x(t_2) - x(t_1)$ = area under the v-t curve bounded by the t-axis and the dotted line shown.

Sol. The velocity time graph is not a straight line, the acceleration is not uniform. Hence relation (a), (b) and (e) are not correct, but relation, (c), (d) and (f) are correct.