NCERT Solutions for Class-XI Physics

Chapter-3
NCERT Physics Class 11

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.

1. (a), (b)

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.

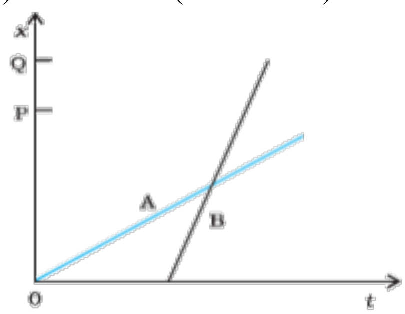
The size of a monkey is very small as compared to the size of a circular track. Therefore, the monkey can be considered as a point sized object on the track.

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.

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.

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. 3.19. 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).



2. From the given Figure

(a) Distance OP < OQ. So, A lives closer to the school than B.
(b) From School, starting time for A is Zero whereas B has some finite value t. So, A starts from the school earlier than B.
(c) Slope represents the velocity in uniform motion.
Slope of B > Slope of A

So, B walks faster than A.

(d) Since, the end point of time for B has less value than A. A and B reaches their homes at different times. B reach home before A.

(e) Only one point of intersection occurs in graph and we know that B is faster than A. So, B overtakes A once in whole journey.

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.

3. Speed of the woman = 5 km/h

Distance between her office and home = 2.5 km

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

$$= \frac{2.5}{5} = 0.5\,\text{h} = 30\text{ min}$$

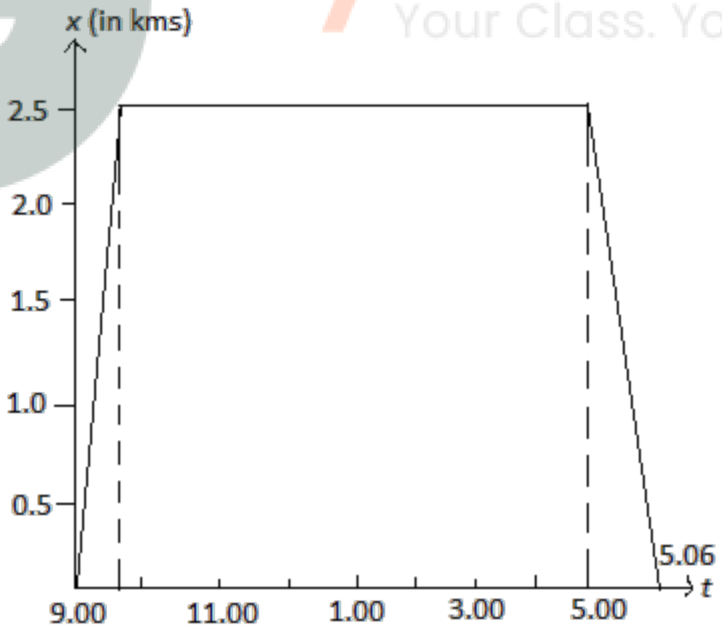
It is given that she covers the same distance in the evening by an auto.

Now, speed of the auto = 25 km/h

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

$$= \frac{2.5}{25} = \frac{1}{10} = 0.1\text{h} = 6\,\text{min}$$

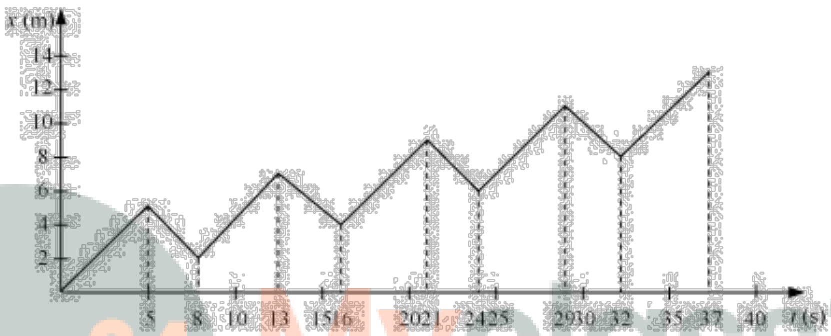
The suitable x-t graph of the motion of the woman is shown in the given figure.



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 1 m long and requires 1 s. 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.

4. Given,

Distance covered in one step = 1 m
Time required for one step = 1 s
Distance for pit from initial position = 13 m
Time taken to move 5m forward = 5 s
Time taken to move 3m backward = 3 s
Speed of the drunkard = 1 m/s (∵from above two observations)
Net distance covered = 5-3 = 2 m
Net time required to cover 2m = 8 s
Total 6 complete forward-backward cycles possible.
Time taken for 6 cycles = 36 s
Distance covered in 6 cycles = 12 m
∴ Total time required to cover 13 m = 36 + 1 =37 s
The graph obtained from above data is,



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?

5. Speed of the jet airplane, v_{jet} = 500 km/h
Relative speed of its products of combustion with respect to the plane,
v_{smoke} = – 1500 km/h
Speed of its products of combustion with respect to the ground = v_{smoke}
Relative speed of its products of combustion with respect to the airplane,
$v_{smoke} = v'_{smoke} - vjet$
$1500 = v'_{smoke} - 500$
$v'_{smoke} = -1000$ km/h
The negative sign indicates that the direction of its products of combustion is opposite to the direction of motion of the jet airplane.

6. A car moving along a straight highway with a speed of 126 km 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?

6. Given,
Initial velocity of the car, u = 126 km/h

$$= \frac{126\times1000}{60\times60} = 35 \text{ m/s}$$

Distance covered before stop, s = 200 m

Final velocity of the car, v = 0 m/s
Let, the retardation be 'a'.
From the 3rd equation of motion,
$v^2 - u^2 = 2as$
where,
v = Final velocity
u = Initial velocity
a = Acceleration / Deceleration
s = Distance covered

$$\therefore a = \frac{v^2 - u^2}{2s} = \frac{0^2 - 35^2}{2 \times 200} ms^{-2} = -3.06 ms^{-2}$$

From the 1st equation of motion, v = u + at
where,
v = Final velocity
u = Initial velocity
a = Acceleration
t = Time

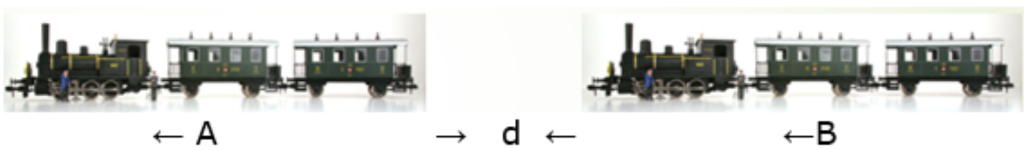
$$\therefore t = \frac{v - u}{a} = \frac{0 - 35}{-3.06} s = 11.44 s$$

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 m/s^2. If after 50 s, the guard of B just brushes past the driver of A, what was the original distance between them?

7. Given,
Initial velocity of both train A and train B, u = 72 km/h

$$= \frac{72 \times 1000}{60 \times 60} = 20 m/s$$

Length of each train, l = 400 m
Acceleration of train A = 0 ms^{-2}
Acceleration of train B = 1 ms^{-2}
Time to overtake, t = 50 s
Distance to be covered to overtake,
Let, Distance travelled by train B in t, s_B
Distance travelled by train A in t, s_A



We have,
$s_B + s_A$= initial distance between trains (d) + (2×length of the train)
= d + (2×400) m
From 1st equation of motion,
v = u + at
where,

v = Final velocity
u = Initial velocity
a = Acceleration/Deceleration
t = Time
Final velocity of train A, $v_A = 20 + 0 = 20$ m/s
Final velocity of train B, $v_B = 20 + (1\times50) = 70$ m/s
From 2nd equation of motion,
$s = ut + 0.5at^2$
where,
u = Initial velocity
a = Acceleration/Deceleration
s = Distance covered
t = Time
$\therefore s_A = (20\times50) + (0.5\times0\times50^2) = 1000$ m
$s_B = (20\times50) + (0.5\times1\times50^2) = 2250$ m
∴ Initial distance between trains, d = 2250 – (2×400)-1000
= 450 m

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?

8. Velocity of car A, v_A = 36 km/h = 10 m/s
Velocity of car B, v_B = 54 km/h = 15 m/s
Velocity of car C, v_C = 54 km/h = 15 m/s
Relative velocity of car B with respect to car A,
$v_{BA} = v_B - v_A = 15 - 10 = 5$ m/s
Relative velocity of car C with respect to car A,
$v_{CA} = v_C - (-v_A) = 15 + 10 = 25$ m/s
At a certain instance, both cars B and C are at the same distance from car A i.e.,
s = 1 km = 1000 m

Time taken (t) by car C to cover 1000 m = $\frac{1000}{25} = 40s$

Hence, to avoid an accident, car B must cover the same distance in a maximum of 40 s. From second equation of motion, minimum acceleration (a) produced by car B can be obtained as:

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

$1000 = 5\times40 + \frac{1}{2}\times a\times(40)^2 \quad a = \frac{1600}{1600} = 1 m/s^2$

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–1 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 period T of the bus service and with what speed (assumed constant) do the buses ply on the road?

9. Given,
Speed of the cyclist, v = 20 km/h = 5.55 m/s
Time period for same direction bus pass by cyclist = 18 min = 1080 s
Time period for opposite direction bus pass by cyclist = 6 min = 360 s
Let, The velocity if the busses be V.
Thus,
Relative velocity of bus moving in the direction cyclist = (V − 5.55) m/s
Relative velocity of bus moving in opposite direction to the cyclist,
= (V+5.55) m/s
Distance covered by same direction bus = (V – 5.55) × 1080 m ……. (1)
Distance covered by opposite direction bus = (V+5.55) × 360 m …..(2)
Since both buses cover same distance (VT), equations (1) and (2) are equal.
⇒ (V–5.55) × 1080 m = (V + 5.55) × 360 m
∴ V = 11.11 m/s
Thus,
Equating, equation (1) = VT
(11.11-5.55) × 1080 = 11.11 × T
We get, T = 540 s

10. A player throws a ball upwards with an initial speed of 29.4 m s^{-1}. What is the direction of acceleration during the upward motion of the ball? What are the velocity and acceleration of the ball at the highest point of its motion? 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. 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).

10 (a) Irrespective of the direction of the motion of the ball, acceleration due to gravity always acts in the downward direction towards the center of the Earth.
(b) At highest point ball comes to rest. So, velocity of the ball at maximum height is Zero.
(c) During upward motion, Position is negative, Velocity is negative and Acceleration is positive. During downward motion, Position, velocity and acceleration all are positive.
(d) Initial velocity of the ball, u = 29.4 m/s
Final velocity of the ball, v = 0 m/s
Acceleration due to gravity, g = 9.8 ms^{-2}
For freely falling body, 3rd equation of motion becomes,
$v^2 - u^2 = -2gs$
where,
v = Final velocity
u = Initial velocity
g = Acceleration due to gravity

s = Distance covered

$$\therefore s = \frac{v^2 - u^2}{-2g} m = \frac{0^2 - 29.4^2}{-2 \times 9.81} m = 44.05m$$

and, from 1st equation of motion for freely falling body,

v = u - gt

Where,

v = Final velocity

u = Initial velocity

g = Acceleration due to gravity

t = Time

thus, time of ascent $= \frac{29.4}{9.81} s = 3s$

For freely falling body, time of ascent = time decent

∴ Total time = 2t = 6 s

Hence, the total time taken by the ball to reach players hands = 6 s.

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.

11. (a) True

(b) False

(c) True

(d) False

Explanation:

When an object is thrown vertically up in the air, its speed becomes zero at maximum height. However, it has acceleration equal to the acceleration due to gravity (g) that acts in the downward direction at that point.

Speed is the magnitude of velocity. When speed is zero, the magnitude of velocity along with the velocity is zero.

A car moving on a straight highway with constant speed will have constant velocity.

Since acceleration is defined as the rate of change of velocity, acceleration of the car is also zero.

This statement is false in the situation when acceleration is positive and velocity is negative at the instant time taken as origin. Then, for all the time before velocity becomes zero, there is slowing down of the particle. Such a case happens when a particle is projected upwards.

This statement is true when both velocity and acceleration are positive, at the instant time taken as origin. Such a case happens when a particle is moving with positive acceleration or falling vertically downwards from a height.

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 12 s.

12. Given,

Ball is dropped from a height = 90 m

Time interval, $0 \leq t \leq 12$

Initial velocity of the ball =0 m/s

Final velocity of the ball = v m/s

Acceleration due to gravity, $g = 9.81\ ms^{-2}$

From 2^{nd} equation of motion for freely falling body,

$s = ut + 0.5gt^2$

where,

u = Initial velocity

g = Acceleration due to gravity

s = Distance covered

t = Time

$\Rightarrow 90 = 0 + (0.5\times9.81)t^2$

$\therefore t = 4.29$ s

From 1^{st} equation of motion for freely falling body,

$v = u + gt$

where,

v = Final velocity

u = Initial velocity

g = Acceleration due to gravity

t = Time

$\Rightarrow v = 0 + (9.81\times4.29) = 42.04$ m/s

Bounce velocity of the ball, $v_b = 0.9v = 37.84$ m/s

Time (t') by the bouncing ball to reach maximum is given by,

$v = v_b - gt'$

where,

v = Final velocity

v_b = Bounce velocity

g = Acceleration due to gravity

t' = Bouncing time

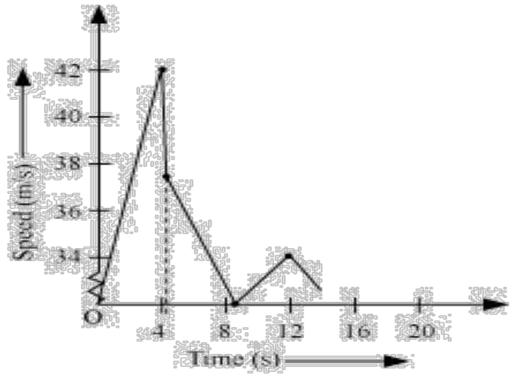
$\Rightarrow 0 = 37.84 - (9.81\times t')$

$\therefore t' = 3.86$ s

Total time taken by the ball = t + t' = 4.29 + 3.86 = 8.15 s

The iterations goes on like this up to ball reach a static condition.

The graph obtained by the data is,



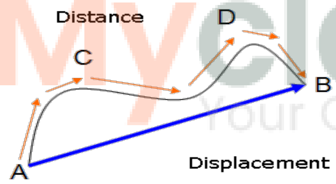
13. Explain clearly, with examples, the distinction between:

(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].

13. (a) The shortest path between two points in a travel is defined as Displacement and the actual path traveled is called Distance (or) Total length of the path in same interval.



In above figure, AB is Displacement and AC-CD-DB is distance or Total length of the path in the same time interval T.

(b) $\text{Average velocity, } v = \frac{\text{Magnitude of displacement}}{\text{time taken}} \, m/s$

$\text{Average speed, } s = \frac{\text{Magnitude of total length of the path}}{\text{time taken}} \, m/s$

From the figure,

$v = \frac{AB}{T} \, m/s$ $\qquad$ $s = \frac{ACDB}{T} \, m/s$

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? [Note: You will appreciate from this exercise why it is better to define average speed as total path length divided by time, and not as magnitude of average velocity. You would not like to tell the tired man on his return home that his average speed was zero!]

14. Time taken by the man to reach the market from home, $t_1 = \frac{2.5}{5} = \frac{1}{2} h = 30 \min$

Time taken by the man to reach home from the market, $t_2 = \frac{2.5}{7.5} = \frac{1}{3} h = 20 \min$

Total time taken in the whole journey = 30 + 20 = 50 min

Average velocity = $\frac{\text{Displacement}}{\text{Time}} = \frac{2.5}{\frac{1}{2}} = 5 \text{km/h}$ …(a)(i))

Average speed = $= \frac{\text{Distnace}}{\text{Time}} = \frac{2.5}{\frac{1}{2}} = 5 \text{km/h}$ …(b)(i))

Time = 50 min = $\frac{5}{6}$ h

Net displacement = 0

Total distance = 2.5 + 2.5 = 5 km

Average velocity = $\frac{\text{Displacement}}{\text{Time}} = 0$ …(a)(ii))

Average velocity = $\frac{\text{Displacement}}{\text{Time}} = \frac{5}{\left(\frac{5}{6}\right)} = 6 \text{km/h}$ …(b)(ii))

Speed of the man = 7.5 km

Distance travelled in first 30 min = 2.5 km

Distance travelled by the man (from market to home) in the next 10 min

$= 7.5 \times \frac{10}{60} = 1.25 \text{km}$

Net displacement = 2.5 – 1.25 = 1.25 km

Total distance travelled = 2.5 + 1.25 = 3.75 km

Average velocity = $\frac{1.25}{\left(\frac{40}{60}\right)} = \frac{1.25 \times 3}{2} = 1.875$ km/h …(a)(iii))

Average speed =

$\frac{3.75}{\left(\frac{40}{60}\right)} = 5.625 \text{km/h}$ …(b)(iii))

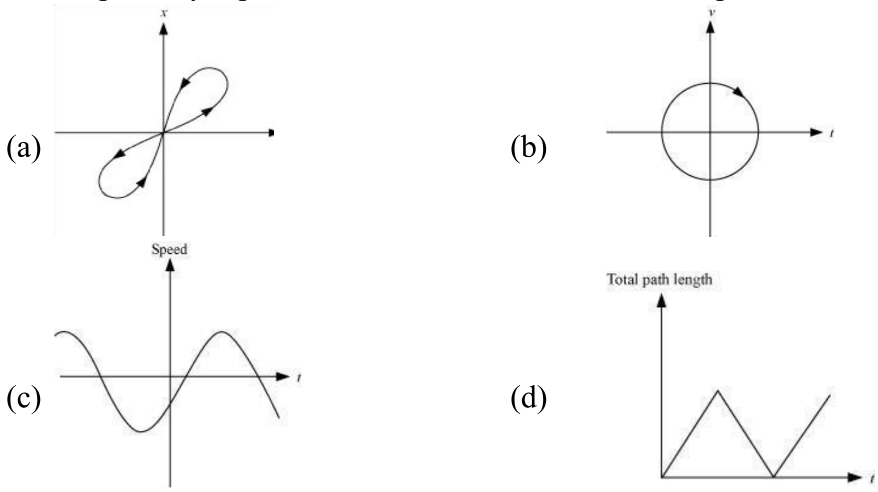
15. In Exercises 3.13 and 3.14, we have carefully distinguished between average speed and magnitude of average velocity. No such distinction is necessary when we consider instantaneous speed and magnitude of velocity. The instantaneous speed is always equal to the magnitude of instantaneous velocity.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

15. Instantaneous velocity is defined as first derivative of distance with respect to time, $v_{in} = \frac{dx}{dt} m/s$. The time interval dt is very small such that direction particle doesn't change. Since, velocity and speed differ in direction only.

Thus,

Instantaneous velocity = Instantaneous speed ……always

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



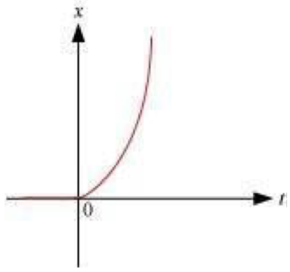
16. The given x-t graph, shown in (a), does not represent one-dimensional motion of the particle. This is because a particle cannot have two positions at the same instant of time.

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.

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.

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.

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.



17. No. x-t graph doesn't represent the trajectory followed by the particle. It is formed by the points consist of both time and space coordinates.

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? (Note: Obtain that speed which is relevant for damaging the thief's car).

18. Speed of the police van, v_p = 30 km/h = 8.33 m/s

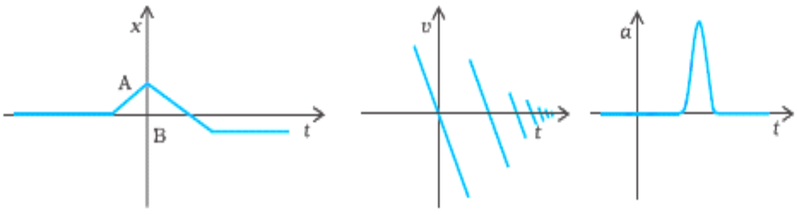
Muzzle speed of the bullet, v_b = 150 m/s

Speed of the thief's car, v_t = 192 km/h = 53.33 m/s

Since the bullet is fired from a moving van, its resultant speed can be obtained as:

= 150 + 8.33 = 158.33 m/s
Since both the vehicles are moving in the same direction, the velocity with which the bullet hits the thief's car can be obtained as:
$v_{bt} = v_b - v_t = 158.33 - 53.33 = 105$ m/s

19. Suggest a suitable physical situation for each of the following graphs.



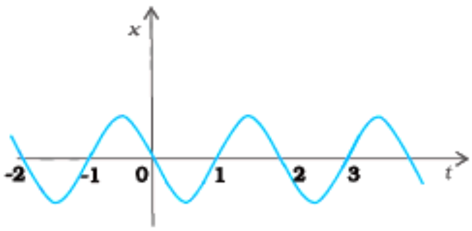
(a) (b) (c)

19. (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.

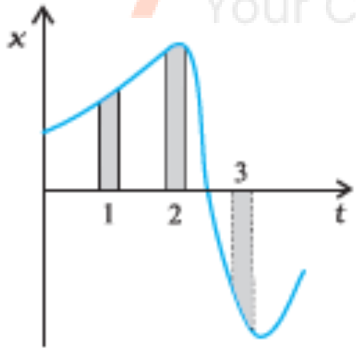
20. Figure gives the x-t plot of a particle executing one-dimensional simple harmonic motion. (You will learn about this motion in more detail in Chapter14). Give the signs of position, velocity and acceleration variables of the particle at t = 0.3 s, 1.2 s, – 1.2 s.



20. The given figure represents simple harmonic motion (SHM).
Acceleration of a particle in simple harmonic motion is given by,
$a = -\omega^2 x$ ………….. (1)
Where,
a = acceleration/deceleration

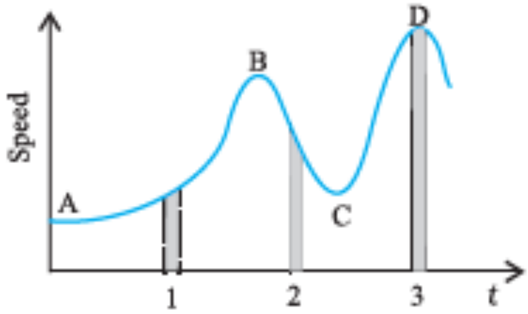
ω = angular frequency
x = path distance
And v = r ω
Where,
v = velocity
r = radial distance
From above graph,
At t = 0.3 s (lies between t=0 and t=1),
Position, x is Negative,
Velocity, v is Negative (negative slope), and
Acceleration, a is Negative (from equation 1)
At t = 1.2 s (lies between t=1 and t=2),
Position, x is Positive,
Velocity, v is Positive (negative slope), and
Acceleration, a is Negative (from equation 1)
At t = -1.2 s (lies between t=1 and t=2),
Position, x is Negative,
Velocity, v is Positive (negative slope), and
Acceleration, a is Positive (from equation 1)]

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.



21. From the graph,
It is clear that slope of x-t graph is maximum in interval 2 and minimum in interval 3. The interval which covers more lengthy line will have maximum average speed. Thus, average speed is maximum in interval 3. If slope in x-t graph is positive average speed is positive and slope in x-t graph is negative average speed is also negative.
∴ In interval 1 average speed is positive.
In interval 2 average speed is positive.
In interval 3 average speed is negative.

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?



22. 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.