

## CHAPTER 2 :MOTION IN A STRAIGHT LINE

### EXERCISES

PAGE:24

**Question 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 table.

**Answer:** (a) The railway carriage moving without jerks between two stations, so the distance

between two stations is considered to be large as compared to the size of the train. Therefore the train is considered as a point object.

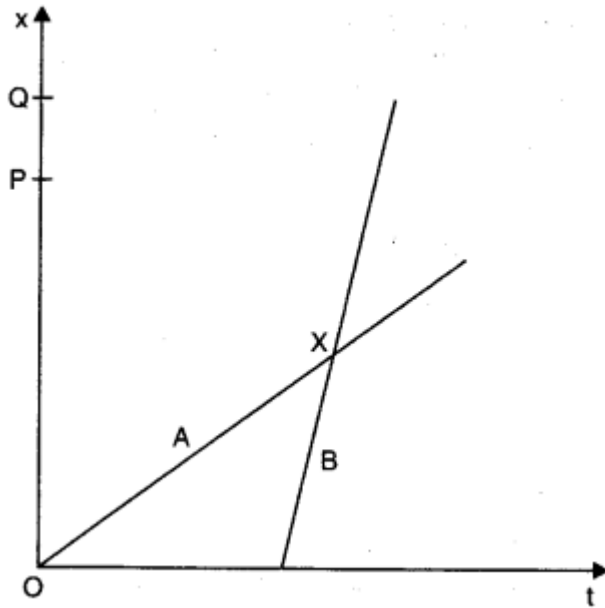
(b) The monkey may be considered as point object because value of distance covered on a circular track is much greater.

(c) As turning of ball is not smooth, thus the distance covered by ball is not large in the reasonable time. Therefore ball cannot be considered as point object.

(d) Again a tumbling beaker slipped off the edge of a table cannot be considered as a point object because distance covered is not much larger.

**Question 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).



**Answer:** (a) A lives closer to school than B, because B has to cover higher distances [OP < OQ],

(b) A starts earlier for school than B, because  $t = 0$  for A but for B,  $t$  has some finite time.

(c) As slope of B is greater than that of A, thus B walks faster than A.

(d) A and B reach home at the same time.

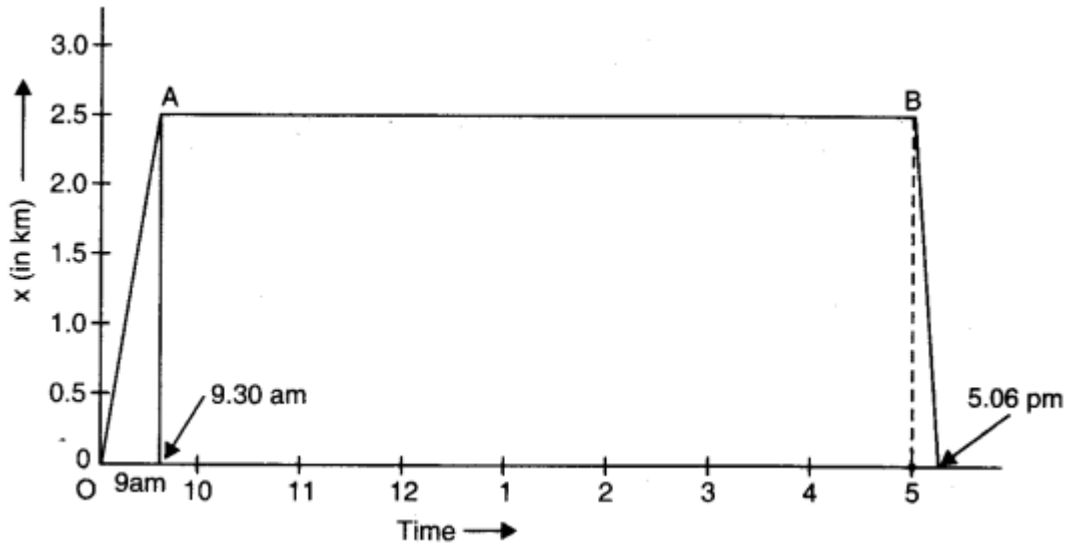
(e) At the point of intersection (i.e., X), B overtakes A on the roads once.

**Question 3. 3. A woman starts from her home at 9.00 am, walks with a speed of  $5 \text{ km h}^{-1}$  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  $2.5 \text{ km h}^{-1}$ . Choose suitable scales and plot the x-t graph of her motion.**

**Answer:** Distance covered while walking = 2.5 km.

Speed while walking = 5 km/h

Time taken to reach office while walking =  $(2.5/5) \text{ h} = 1/2 \text{ h}$



If O is regarded as the origin for both time and distance, then at  $t = 9.00$  am,  $x = 0$  and at  $t = 9.30$  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 =  $2.5/5$  h =  $1/10$  h = 6 minute

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:

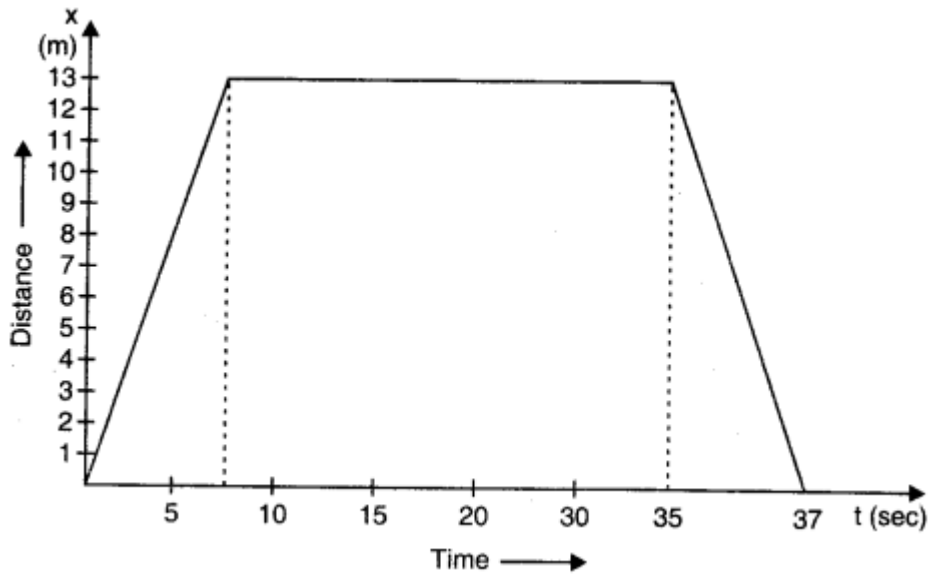
Along time-axis, one division equals 1 hour.

Along positive-axis, one division equals 0.5 km.

**Question 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.

**Answer:** Since the man steadily moves forward as the time progresses so the following graph will represent his motion till he covers 13 m. In 5 s he moves through a distance of 5 m and then in next 3 s comes back by 3 m.

Thus in 8 s he covers only 2 m, as shown in the graph he would fall in the pit in 37 s.



As pointed out earlier, the man covers 2 m in 8 s so, he will cover 8 m in 32 s. But at the end in 5 s he would cover another 5 m i.e., 32 s + 5 s = 37 s, he would cover 8 m + 5 m = 13 m. Thus, he would fall in the pit in 37th second.

**Question 5.** A car moving along a straight highway with speed of  $126 \text{ km h}^{-1}$  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?

**Answer:**

Given  $u = 126 \text{ km/h} = 126 \times \frac{5}{18} \text{ m/s} = 35 \text{ m/s}$

$S = 200 \text{ m}$  and  $v = 0$

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

$\therefore 0 - (35)^2 = 2a \times 200$

$\Rightarrow a = \frac{-(35)^2}{400} = -3.06 \text{ m/s}^2$

Also,  $v = u + at$

$\Rightarrow t = \frac{v-u}{a} = \frac{0-35}{-3.06} = 11.4 \text{ s.}$

**Question 6.** A player throws a ball upwards with an initial speed of  $29.4 \text{ ms}^{-1}$ .

(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  $x = 0 \text{ m}$  and  $t = 0 \text{ s}$  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  $g = 9.8 \text{ m s}^{-2}$  and neglect air resistance).

**Answer:** (a) The direction of acceleration during the upward motion of the ball is vertically downward.

(b) At the highest point, velocity of ball is zero but acceleration ( $g = 9.8 \text{ ms}^{-2}$ ) in vertically downward direction.

(c) If we consider highest point of ball motion as  $x = 0$ ,  $t = 0$  and vertically downward direction to be +ve direction of x-axis, then

(i) during upward motion of ball before reaching the highest point position (as well as displacement)  $x = +ve$ , velocity  $v = -ve$  and acceleration  $a = g = +ve$ .

(ii) during the downward motion of ball after reaching the highest point,  $x$ ,  $v$  and  $a = g$  all the three quantities are positive.

(d) During upward motion

$$\text{As } \quad u = -29.4 \text{ ms}^{-1}, a = 9.8 \text{ ms}^{-2}, v = 0$$
$$v^2 - u^2 = 2 a S \Rightarrow 0 - (29.4)^2 = 2 \times 9.8 \times S$$

$$\Rightarrow \quad S = \frac{-(29.4)^2}{2 \times 9.8} = -44.1 \text{ m}$$

$$\text{Also } \quad v = u + at \Rightarrow v - u = at$$

$$\Rightarrow \quad 0 - (-29.4) = 9.8 t$$

$$\text{or } \quad t = \frac{29.4}{9.8} = 3 \text{ s}$$

$$\text{Total time} = 3 + 3 = 6 \text{ s} \quad [\because \text{time of ascent} = \text{time of descent}]$$

**Question 7** 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.

**Answer:** (a) True. Consider a ball thrown up. At the highest point, speed is zero but the acceleration is non-zero.

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

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

(d) False. True only when the chosen position direction is along the direction of motion.

**Question 8.** 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.

Answer:

$$u = 0, a = 10 \text{ ms}^{-2}, S = 90 \text{ m}, t = ?, v = ?$$

$$\text{Using } v^2 - u^2 = 2as, v^2 - (0)^2 = 2 \times 10 \times 90$$

$$\Rightarrow v = 30\sqrt{2} \text{ m/s}$$

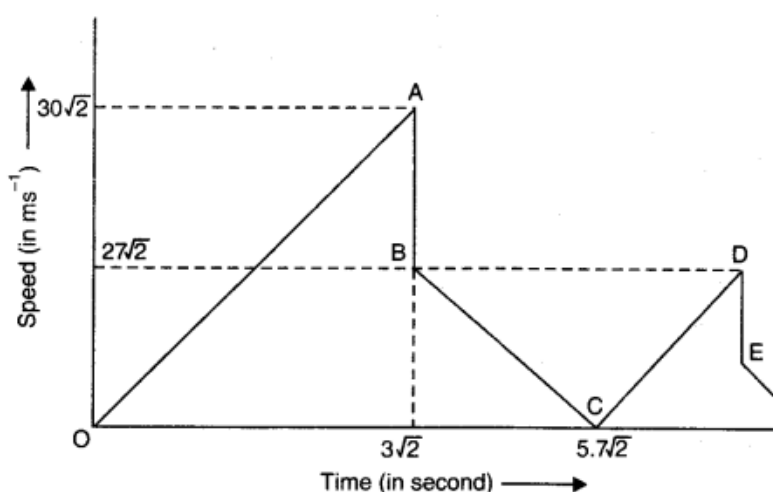
$$\text{Again, using } S = ut + \frac{1}{2}at^2, 90 = 0 \times t + \frac{1}{2} \times 10t^2$$

$$\Rightarrow t = \sqrt{18} \text{ s} = 3\sqrt{2} \text{ s}$$

$$\text{Rebound velocity} = \frac{9}{10} \times 30\sqrt{2} \text{ ms}^{-1} = \sqrt{2} \text{ ms}^{-1}$$

$$\text{Time taken to reach highest point} = \frac{27\sqrt{2}}{10} \text{ s} = 2.7\sqrt{2} \text{ s}$$

$$\text{Total time} = (3\sqrt{2} + 2.7\sqrt{2}) \text{ s} = 5.7\sqrt{2} \text{ s}$$



OA represents the vertically downward motion after the ball has been dropped from a height of 90 m. The ball reaches the floor with a velocity of  $30\sqrt{2} \text{ ms}^{-1}$  after having been

in motion for  $3\sqrt{2}$  s. The vertical straight portion AB represents the loss of  $\frac{1}{10}$  th of speed. BC represents the vertically upward motion after first rebound. The ball reaches the highest point in  $2.7\sqrt{2}$  s. The total time from the beginning is  $3\sqrt{2} + 2.7\sqrt{2}$  i.e.,  $5.7\sqrt{2}$  s. C represents the highest point reached after first rebound. CD represents the vertically downward motion. D represents the situation when the ball again reaches the floor. DE represents the loss of speed.

Question 9 Explain clearly, with examples, the distinction between:

- 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;
- 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],**

**Answer:** (a) Suppose a particle goes from point A to B along a straight path and returns to A along the same path. The magnitude of the displacement of the particle is zero, because the particle has returned to its initial position. The total length of path covered by the particle is  $AB + BA = AB + AB = 2 AB$ . Thus, the second quantity is greater than the first,

(b) Suppose, in the above example, the particle takes time  $t$  to cover the whole journey. Then, the magnitude of the average velocity of the particle over time-interval  $t$  is = Magnitude of displacement / Time-interval =  $0/t = 0$

While the average speed of the particle over the same time-interval is = Total path length / Time-interval =  $2 AB / t$

Again, the second quantity (average speed) is greater than the first (magnitude of average velocity).

**Note:** In both the above cases, the two quantities are equal if the particle moves from one point to another along a straight path in the same direction only.

**Question 10. A man walks on a straight road from his home to a market 2.5 km away with a speed of  $5 \text{ km h}^{-1}$ . Finding the market closed, he instantly turns and walks back home with a speed of  $7.5 \text{ km h}^{-1}$ . 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!]**

**Answer:**

Since  $v = \frac{S}{t} \Rightarrow t = \frac{S}{v}$

Time taken by the man to reach market,

$$t = \frac{S}{v} = \frac{2.5}{5} = 0.5 \text{ h}$$

Time taken by the man to come back,

$$t_1 = \frac{S}{v_1} = \frac{2.5}{7.5} = 0.333 \text{ h}$$

(i) Average velocity (0 – 30 min) =  $\frac{\Delta x}{\Delta t} = \frac{2.5}{0.5} = 5 \text{ kmh}^{-1}$

[ $\because$  In 0.5 h, distance covered by man = 2.5 km]

(ii) Average velocity (0 – 50 min)

$$= \frac{(2.5 + 2.5) \text{ km}}{(0.5 + 0.333) \text{ h}} = \frac{5}{0.833} \text{ kmh}^{-1} = 8 \text{ kmh}^{-1}$$

(iii) Average velocity (0 – 40 min) =  $\frac{\Delta x}{\Delta t} = \frac{\left(2.5 - \frac{2.5}{2}\right) \text{ km}}{\frac{40}{60} \text{ h}} = 1.875 \text{ kmh}^{-1}$

[ $\because$  during 1st 30 min, distance covered = 2.5 km, in next 10 min, distance covered =  $\frac{2.5}{2}$  km in return journey]

(iv) Average speed (0 – 40 min) =  $\frac{\text{Total distance}}{\text{Total time}}$

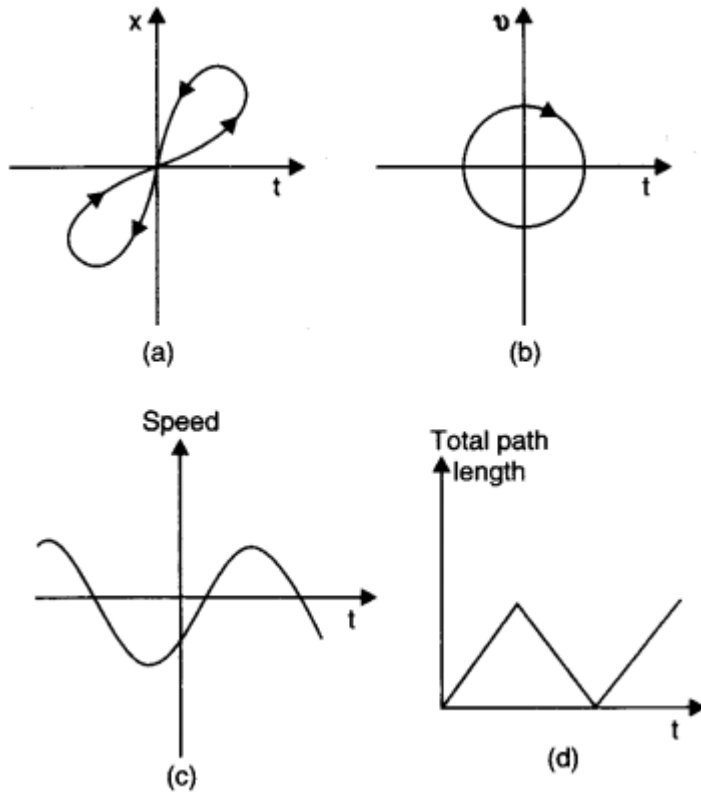
$$= \frac{2.5 + \frac{2.5}{2}}{\frac{40}{60}} = 5.625 \text{ km h}^{-1}$$

**Question 11.** In Exercises 9 and 10, 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?

**Answer:** Instantaneous velocity is the velocity of a particle at a particular instant of time. In this case of small interval of time, the magnitude of the displacement is effectively equal to the distance travelled by the particle in the same interval of time. Therefore, there is no distinction between instantaneous velocity and speed.



**Question 12** 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.



**Answer:** None of the four graphs represent a possible one-dimensional motion. In graphs (a) and (b) motions are definitely two dimensional. Graph (a) represents two positions at the same time which is not possible.

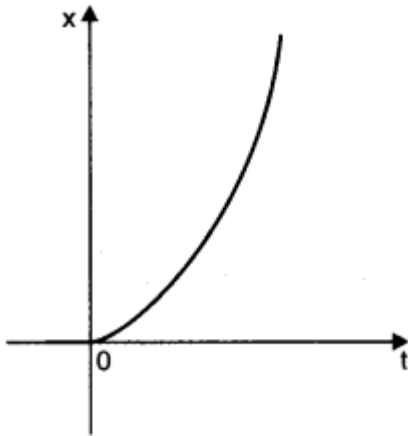
In graph (b) opposite motion is visible at the same time.

The graph (c) is not correct since it shows that the particle has negative speed at a certain instant. Speed is always positive.

In graph (d) path length is shown as increasing as well as decreasing. Path length never decreases.

**Question 13.** 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.



**Answer:** It is not correct to say that the particle moves in a straight line for  $t < 0$  (i.e., -ve) and on a parabolic path for  $t > 0$  (i.e., +ve) because the  $x$ - $t$  graph can not show the path of the particle. For the graph, a suitable physical context can be the particle thrown from the top of a tower at the instant  $t = 0$ .

**Question 14.** A police van moving on a highway with a speed of  $30 \text{ km h}^{-1}$  fires a bullet at a thief's car speeding away in the same direction with a speed of  $192 \text{ km h}^{-1}$ . If the muzzle speed of the bullet is  $150 \text{ ms}^{-1}$ , with what speed does the bullet hit the thief's car? (Note: Obtain that speed which is relevant for damaging the thief's car).

**Answer:**

$$\text{Speed of police van} = v_p = 30 \text{ kmh}^{-1} = 30 \times \frac{1000}{3600} \text{ ms}^{-1} = \frac{25}{3} \text{ ms}^{-1}$$

$$\begin{aligned} \text{Speed of thief's car} &= v_t = 192 \text{ km h}^{-1} \\ &= 192 \times \frac{5}{18} \text{ ms}^{-1} = \frac{160}{3} \text{ ms}^{-1} \end{aligned}$$

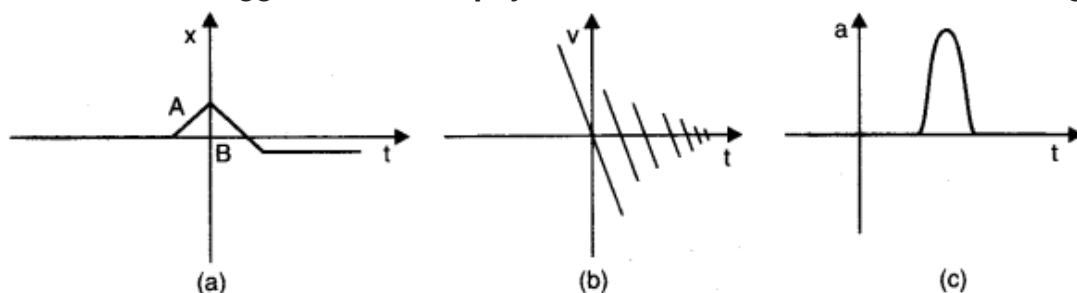
Speed of bullet,  $v_b$  = Speed of police van + speed with which bullet is actually fired

$$\therefore v_b = \left( \frac{25}{3} + 150 \right) \text{ ms}^{-1} = \frac{475}{3} \text{ ms}^{-1}$$

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

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

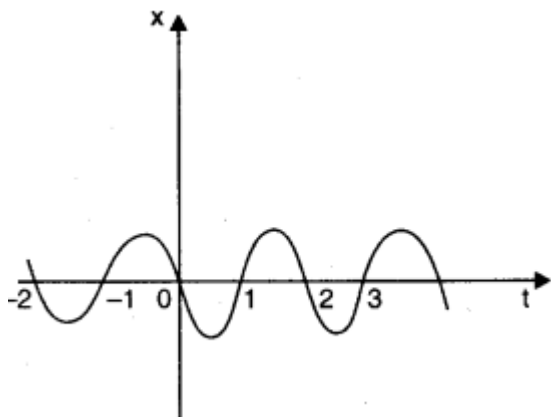
**Question 15. Suggest a suitable physical situation for each of the following graphs:**



**Answer:** (a) A ball at rest on a smooth floor is kicked. It rebounds from a wall with reduced speed and moves to the opposite wall which stops it.  
 (b) The graph shows that velocity changes again and again with the passage of time and every time losing some speed. Therefore, it may represent a physical situation such as a ball falling freely (after thrown up), on striking the ground rebounds with reduced speed after each hit against the ground.  
 (c) A uniformly moving cricket ball turned back by hitting it with a bat for a very short time-interval.

**Question 16 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 Chapter 13). Give the signs of position, velocity and acceleration variables of the particle at  $t = 0.3 \text{ s}$ ,  $1.2 \text{ s}$ ,  $-1.2 \text{ s}$ .**

**Answer:** In x-t graph of Fig. showing simple harmonic motion of a particle, the signs of position, velocity and acceleration are as given below.



In S.H.M., acceleration,  $a = -x$  or  $a = -kx$ .

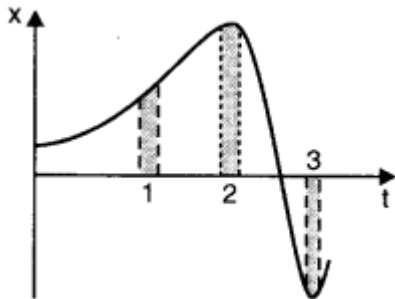
(i) At  $t = 0.3 \text{ s}$ ,  $x < 0$  i.e.,  $x$  is in -ve direction. Moreover, as  $x$  is becoming more negative with time, it shows that  $v$  is also -ve (i.e.,  $v < 0$ ). However,  $a = -kx$  will be +ve ( $a > 0$ ).

(ii) At  $t = 1.2 \text{ s}$ ,  $x > 0$ ,  $v > 0$  and  $a < 0$ .

(iii) At  $t = -1.2 \text{ s}$ ,  $x < 0$ , but here on increasing the time  $t$ , value of  $x$  becomes less negative.

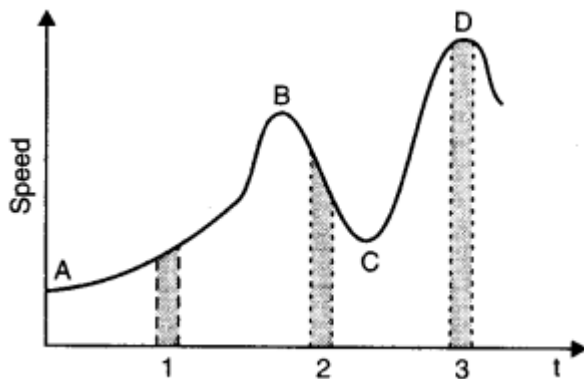
It means that  $v$  is +ve (i.e.,  $v > 0$ ). Again  $a = -kx$  will be positive (i.e.,  $a > 0$ ).

**Question 17.** 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.



**Answer:** Greater in 3, least in 2;  $v > 0$  in 1 and 2,  $v < 0$  in interval 3.

**Question 18.** 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 points A, B, C and D?



**Answer:** The acceleration is greatest in magnitude in interval 2 as the change in speed in the same time is maximum in this interval.

The average speed is greatest in interval 3 (peak D is at maximum on speed axis).

The sign of  $v$  and  $a$  in the three intervals are:

$v > 0$  in 1, 2 and 3;  $a > 0$  in 1

$a < 0$  in 2,  $a=0$  in 3.

acceleration is zero at A,B,C and D.

