CHAPTER 2

MOTION IN A STRAIGHT LINE

CLASS 11TH

NCERT EXERCISE AND SOLUTIONS - PHYSICS

2.1 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.

SOLUTION:

(a) **Can be considered a point object:** The railway carriage moves smoothly, and its size is relatively large compared to its motion (it doesn't change shape or orientation in a noticeable way during the motion). However, the entire body can still be treated as a point object for simple analysis because we are usually interested in its position and motion as a whole, not its details.

(b) **Can be considered a point object:** Both the man and the monkey are part of the motion, and their combined size and shape can affect the motion. However, if we focus on the overall motion of the man and the monkey as a single system, we can consider the body of the man and the monkey as a point object for simplicity.

(c) **Cannot be considered a point object:** The cricket ball is rotating and spinning, and its shape and orientation significantly affect its motion. Since the ball's spin and the effects of hitting the ground are important, it cannot be treated as a point object in this scenario.

(d) **Cannot be considered a point object:** The beaker is tumbling and rotating as it falls, and its shape and orientation play a crucial role in its motion. Hence, it cannot be treated as a point object in this case.

2.2 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. 2.9. Choose the correct entries in the brackets below;

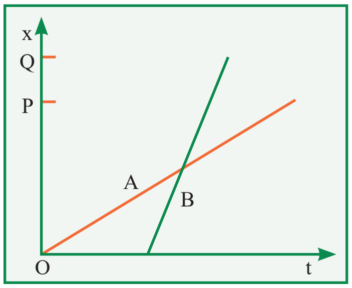
(a) (A/B) lives closer to the school than (B/A)

(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).



SOLUTION:

(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.

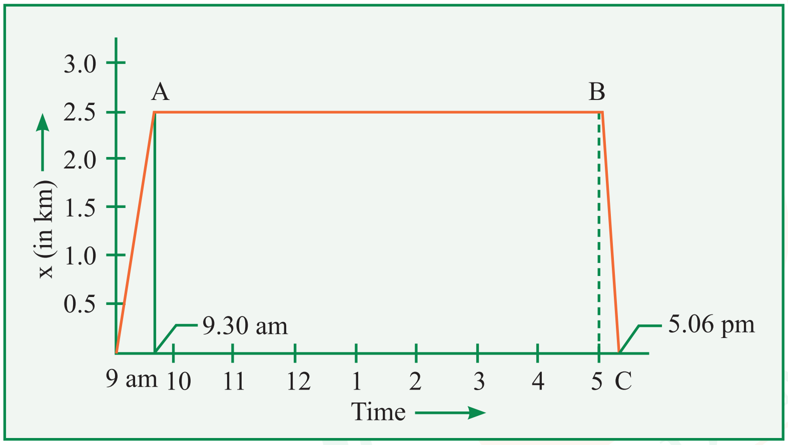
(c) As slope of B is greater than that of A, thus B walks faster than A.

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

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

2.3 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.

SOLUTION:



Given - Distance to her office (d), = 2.5 km, Walking speed the woman (s) = 5 km/h,
Time taken to reach office while walking = (2.5/5)h = (1/2)h = 30 minutes, Speed of auto = 25 km/h

Time taken to reach home in auto (t) = $\dfrac{\text{distance (d)}}{\text{speed (s)}}$

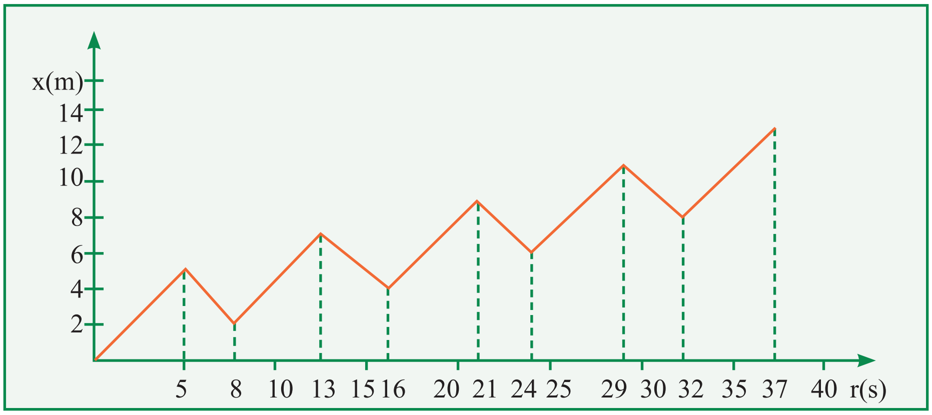
t = 2.5/25 = (1/10)h = 0.1 h = 6 minutes

In the graph, O is taken as the origin of the distance and the time, then at and at t = 9.00 am, x = 0 and at t = 9.30 am, x = 2.5 km

OA is the portion on the x –t graph that represents her walk from home to the office. AB represents her time of stay in the office from 9.30 to 5. Her return journey is represented by BC.

2.4 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.

SOLUTION:



The time taken to go one step is 1 second. In 5 s, he moves forward through a distance of 5 m, and then in the next 3 s, he comes back by 3 m. Therefore, in 8 s, he covers 2 m. So, to cover a distance of 8 m, he takes 32 s. He must take another 5 steps forward to fall into the pit.

So, the total time taken is 32 s + 5 s = 37 s to fall into a pit 13 m away.

2.5 **A car moving along a straight highway with 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?**

SOLUTION:

Given – speed of the car $(u) = \dfrac{126\text{km}}{\text{h}} = 126 \times \dfrac{\frac{5}{18}\text{m}}{\text{s}} = \dfrac{35\text{m}}{\text{s}}$,

distance (s) = 200 m and final velocity (v) = 0

Need to find – Retardation of the car (a) and time taken by car to stop (t)

Using equation of motion $v^2 - u^2 = 2as$

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

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

$v = u + at$

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

Hence retardation is 3.06 m/s^2 and time taken will be 11.4s.

2.6 A player throws a ball upwards with an initial speed of 29.4 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 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).

SOLUTION:

Given- initial speed (u) = 29.4 ms^{-1}

(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 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 -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 .

(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

Given: $u = -29.4$ ms^{-1}, a= 9.8 ms^{-2}, $v = 0$

$$v^2 - u^2 = 2aS \Rightarrow 0 - (29.4)^2 = 2\times9.8\times S$$

$$\Rightarrow \quad S = \frac{-(29.4)^2}{2\times9.8} = -44.1\text{m}$$

Also

$$v = u + at$$

$$v - u = at$$

$$0 - (-29.4) = 9.8t$$

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

Total time = 3 + 3 = 6 s [∵ time of ascent = time of descent]

Hence time taken = 6 s.

2.7 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.

SOLUTION:

(a) **True.** A particle can have zero speed at a specific moment but still experience acceleration. For example, when an object momentarily stops at the highest point of its trajectory (like a ball thrown vertically upwards), its speed is zero at that instant, but the acceleration due to gravity is non-zero (approximately 9.8 m/s^2 downward).

(b) **False.** Velocity is a vector quantity, and when the speed is zero, the magnitude of velocity is also zero. However, the direction of motion can change. For instance, at the highest point of a vertically thrown object, the speed is zero, but the object still has a direction of motion, which means its velocity is zero in magnitude, not non-zero.

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

(d) **False.** Whether a particle is speeding up or slowing down depends on the direction of acceleration relative to the velocity. If the acceleration is in the same direction as the velocity, the particle will speed up. However, if the acceleration is in the opposite direction to the velocity, the particle will slow down. For instance, a particle moving in the positive direction with a negative acceleration (deceleration) will slow down, even though the acceleration is positive in magnitude.

2.8 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.

SOLUTION:

Given: Height from which the ball is dropped(s) = 90 m, The initial velocity of the ball (u) = 0

Let v be the final velocity of the ball

Using the equation

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

$v^2_1 - 0 = 2 \times 10 \times 90$

$v_1 = 42.43$ m/s

Time taken for the first collision can be given by the equation

$v = u + at$

$42.43 = 0 + (10)t$

$t_1 = 4.24$ s

The ball losses one-tenth of the velocity at collision. So, the rebound velocity of the ball is

$v_2 = v - (1/10)v$

$v_2 = (9/10)v$

$v_2 = (9/10)(42.43)$

$= 38.19$m/s

Time taken to reach maximum height after the first collision is

$v = u + at$

$38.19 = 0 + (10)t_2$

$t_2 = 3.819$ s

The total time taken by the ball to reach the maximum height is

$T = t_1 + t_2$

$T = 4.24 + 3.819 = 8.05$ s

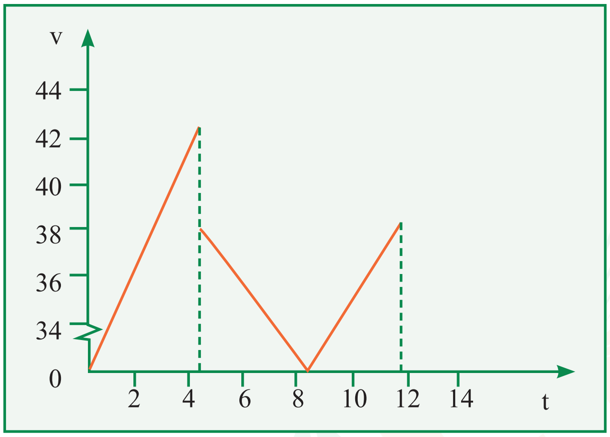
Now the ball will travel back to the ground in the same time as it took to reach the maximum height = 3.918 s

Total time taken will be, T = 4.24 + 3.819 + 3.819 = 11.86

Velocity after the second collision

$v_3 = (9/10)(38.19)$

$v_3 = 34.37$ m/s



2.9 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].

SOLUTION:

(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 = 2AB. 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).

2.10 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!]

SOLUTION:

Given – distance (S) = 2.5 km, speed while going = 5 km/hr, speed while returning back = 7.5 km/hr

Need to find – magnitude of average velocity(v), average speed

Using-

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

Time taken while going,

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

Time taken while returning,

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

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

[∵ In 0.5 h,distance covered by man = 2.5 km]

(ii) Average velocity (0 – 50 min)

$$= \frac{(2.5+2.5)\text{km}}{(0.5+0.333)\text{h}} = \frac{5}{0.833}\text{kmh}^{-1} = 6\text{kmh}^{-1}$$

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

[∵ 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) $= \frac{\text{Total distance}}{\text{Total time}}$

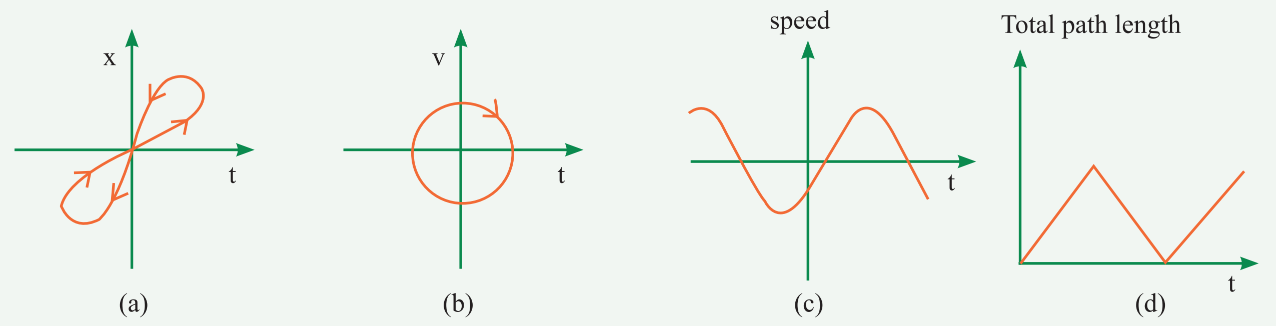
$$= \frac{2.5 + \frac{2.5}{2}}{\frac{40}{60}} = 5.625\text{kmh}^{-1}$$

2.11 In Exercises 2.9 and 2.10, 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?

SOLUTION:

Instantaneous velocity refers to the velocity of a particle at a specific moment in time. During a very small-time interval, the displacement is nearly equal to the distance travelled by the particle. As a result, there is no significant difference between instantaneous velocity and speed in such cases.

2.12 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.



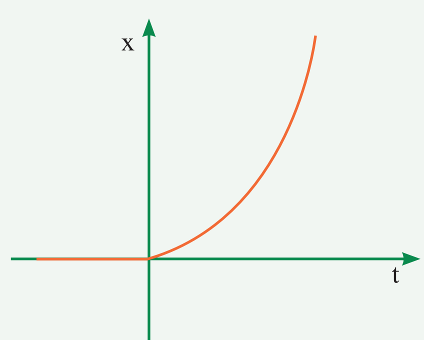
Figure

SOLUTION:

None of the four graphs represent a valid one-dimensional motion.

- In graphs (a) and (b), the motions are clearly two-dimensional. Graph (a) shows two positions at the same time, which is not possible in one-dimensional motion. Graph (b) shows opposite motions occurring simultaneously, which is also not possible.
- Graph (c) is incorrect because it suggests that the particle has a negative speed at a certain instant, but speed is always a positive quantity.
- Graph (d) is invalid because it shows the path length increasing and decreasing, which contradicts the fact that path length can only increase or remain constant, never decrease.

2.13 Figure shows the x – t plot of onedimensional 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.



Figure

SOLUTION:

It is incorrect to say that the particle moves in a straight line for $t < 0$ (negative time) and on a parabolic path for $t > 0$ (positive time), because an $x - t$ graph (position vs. time) cannot depict the actual path of the particle. The x – t graph only shows the position of the particle over time, not the trajectory or path it follows.

A more appropriate physical context for such a graph would be a particle thrown from the top of a tower at t = 0. For t < 0, the graph would represent the position of the particle before it was thrown (perhaps at rest or in a different state), and for t > 0, the graph could represent the particle's downward motion under the influence of gravity, which follows a parabolic trajectory.

2.14 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 km h^{-1} , with what speed does the bullet hit the thiefs car? (Note: Obtain that speed which is relevant for damaging the thief's car).

SOLUTION:

Given- Speed of police van $\left(v_p\right) = 30\text{kmh}^{-1} = 30\times\frac{1000}{3600}\text{ms}^{-1} = \frac{25}{3}\text{ms}^{-1}$,

speed of thief's car $\left(v_t\right) = 192\text{kmh}^{-1} = 192\times\frac{5}{18}\text{ms}^{-1} = \frac{160}{3}\text{ms}^{-1}$,

muzzle speed of the bullet (v_m) = 150 m s^{-1}

Need to find- speed of the bullet when it hits the car(v_b)

Speed of bullet, v_b = Speed of police van(v_p) + speed with which bullet is fired(v_m)

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

$$v_b = \frac{475}{3}\text{ms}^{-1}$$

Relative velocity of bullet with respect to thief's car,

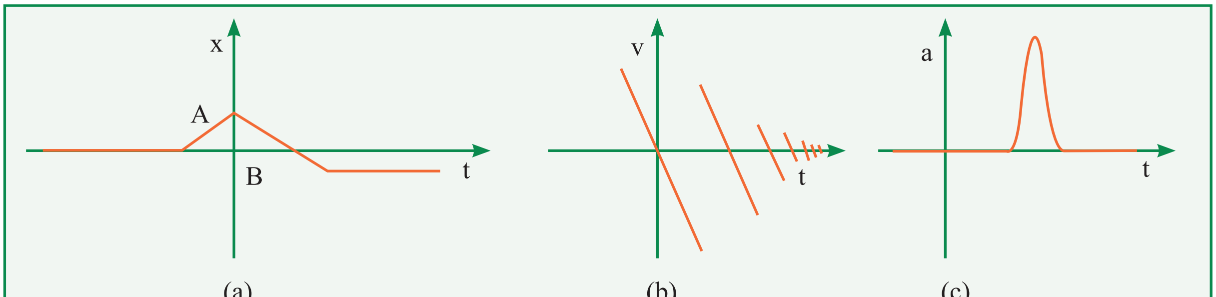
$$v_{bt} = v_b - v_t$$

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

$$v_{bt} = 105\ \text{ms}^{-1}$$

Hence speed of bullet while hitting thief's car is 105 ms^{-1}.

2.15 Suggest a suitable physical situation for each of the following graphs (Fig.):



Figure

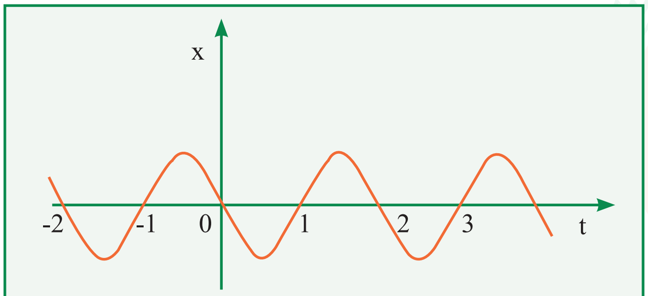
SOLUTION:

(a) A ball at rest on a smooth floor is kicked, causing it to rebound from a wall with reduced speed and move towards the opposite wall, which eventually stops it. In this scenario, the ball's speed decreases after each collision due to energy loss in the form of sound and heat.

(b) The graph shows that the velocity of the ball changes repeatedly with time, and the speed decreases each time. This could represent a ball falling freely (after being thrown upwards), where it rebounds with reduced speed after each impact with the ground. The ball loses energy after each bounce, which results in a decrease in speed.

(c) A uniformly moving cricket ball is struck by a bat for a very short time interval. This sudden change in direction and velocity occurs due to the force applied by the bat, causing the ball to turn back abruptly, which is typical in short-duration interactions like a cricket shot.

2.16 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 s, 1.2 s,-1.2 s.



Figure

SOLUTION:

In S.H.M., acceleration, $a = -\omega^2 x$.

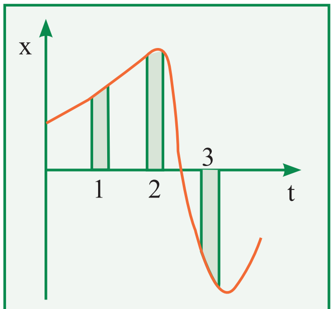
(i) At t = 0.3 s, x < 0 i.e., x is in -ve direction. Moreover, as x is becoming more negative with time, it shows that v is also - ve (i.e., v < 0). However, a = – kx will be +ve (a > 0).

(ii) At t = 1.2 s, x > 0,v > 0 and a < 0.

(iii) At t = –1.2 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).

2.17 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.



Figure

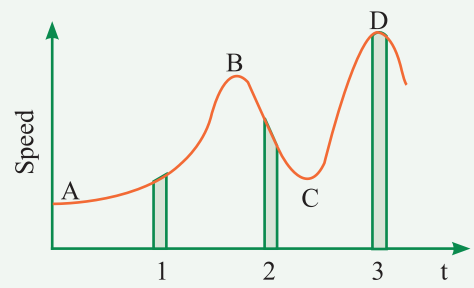
SOLUTION:

Greater in 3, least in 2;v > 0 in 1 and 2,v < 0 in interval 3 .

The average speed of a particle shown in the x -t graph is given by the slope of the graph in a particular interval of time.

From the graph it is clear that the slope is maximum and minimum restively in intervals 3 and 2 respectively. Thus, 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.

2.18 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 and in the three intervals. What are the accelerations at the points A, B, C and D?



Figure

SOLUTION:

Acceleration is determined as slope of the speed time graph.

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. {slope at all these points is zero}