Class XI : Physics
Chapter 2 : Motion And Straight Line

Questions and Solutions | Exercises - NCERT Books

Question 1:

In which of the following examples of motion, can the body be considered approximately a point object:

a railway carriage moving without jerks between two stations.

a monkey sitting on top of a man cycling smoothly on a circular track.

a spinning cricket ball that turns sharply on hitting the ground.

a tumbling beaker that has slipped off the edge of a table.

Answer

Answer: (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.

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. 3.19. Choose the correct entries in the brackets below;

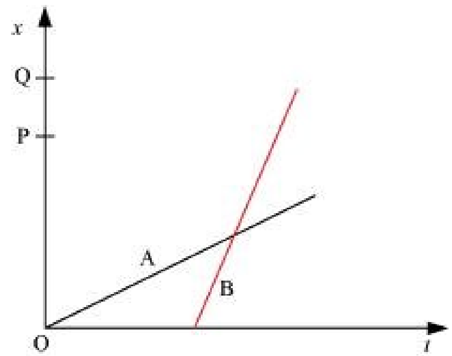
(A/B) lives closer to the school than (B/A)

(A/B) starts from the school earlier than (B/A)

(A/B) walks faster than (B/A)

A and B reach home at the (same/different) time

(A/B) overtakes (B/A) on the road (once/twice).



Answer

Answer:

A lives closer to school than **B.**

A starts from school earlier than **B.**

B walks faster than **A.**

A and **B** reach home at the same time.

B overtakes **A** once on the road.

Explanation:

In the given x–t graph, it can be observed that distance OP < OQ. Hence, the distance of school from the **A's** home is less than that from **B's** home.

In the given graph, it can be observed that for $x = 0$, $t = 0$ for **A**, whereas for $x = 0$, t has some finite value for **B**. Thus, **A** starts his journey from school earlier than **B**.

In the given x–t graph, it can be observed that the slope of **B** is greater than that of **A**. Since the slope of the x–t graph gives the speed, a greater slope means that the speed of **B** is greater than the speed **A**.

It is clear from the given graph that both **A** and **B** reach their respective homes at the same time.

B moves later than **A** and his/her speed is greater than that of **A.** From the graph, it is clear that **B** overtakes **A** only once on the road.

Question 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.

Answer

Speed of the woman = 5 km/h

Distance between her office and home = 2.5 km

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

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

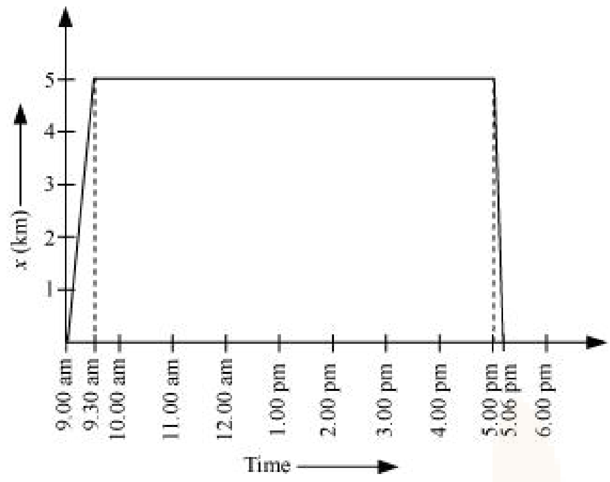
It is given that she covers the same distance in the evening by an auto.

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.



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

Distance covered with 1 step = 1 m

Time taken = 1 s

Time taken to move first 5 m forward = 5 s

Time taken to move 3 m backward = 3 s

Net distance covered = 5 – 3 = 2 m

Net time taken to cover 2 m = 8 s

Drunkard covers 2 m in 8 s.

Drunkard covered 4 m in 16 s.

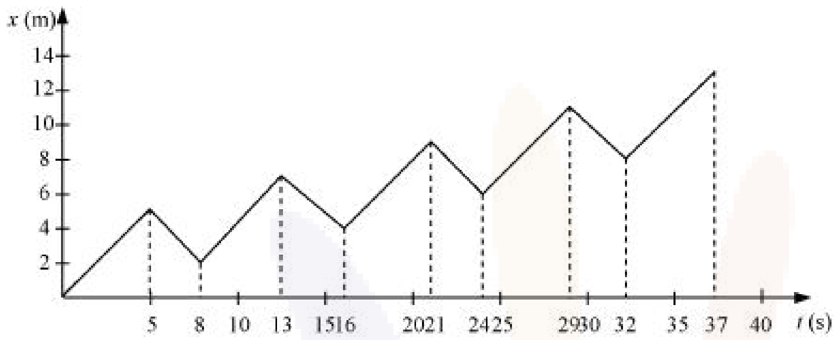
Drunkard covered 6 m in 24 s.

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 = 37 s

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



Question 5:

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

Answer

Initial velocity of the car, u = 126 km/h = 35 m/s

Final velocity of the car, v = 0

Distance covered by the car before coming to rest, s = 200 m

Retardation produced in the car = a

From third equation of motion, a can be calculated as:

From first equation of motion, time (t) taken by the car to stop can be obtained as:

$$v = u + at$$

$$t = \frac{v-u}{a} = \frac{-35}{-3.06} = 11.44\,\text{s}$$

Question 6:

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).

Answer

Answer:

Downward

Velocity = 0, acceleration = 9.8 m/s^2

$x > 0$ for both up and down motions, $v < 0$ for up and $v > 0$ for down motion, $a > 0$ throughout the motion

44.1 m, 6 s

Explanation:

Irrespective of the direction of the motion of the ball, acceleration (which is actually acceleration due to gravity) always acts in the downward direction towards the centre of the Earth.

At maximum height, velocity of the ball becomes zero. Acceleration due to gravity at a given place is constant and acts on the ball at all points (including the highest point) with a constant value i.e., 9.8 m/s^2.

During upward motion, the sign of position is positive, sign of velocity is negative, and sign of acceleration is positive. During downward motion, the signs of position, velocity, and acceleration are all positive.

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:

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

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

with zero speed may have non-zero velocity,

with constant speed must have zero acceleration,

with positive value of acceleration mustbe speeding up.

Answer

Answer:

True

False

True

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.

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

Ball is dropped from a height, $s = 90$ m

Initial velocity of the ball, $u = 0$

Acceleration, $a = g = 9.8 \text{ m/s}^2$

Final velocity of the ball = v

From second equation of motion, time (t) taken by the ball to hit the ground can be obtained as:

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

$$90 = 0 + \frac{1}{2} \times 9.8 t^2$$

$$t = \sqrt{18.38} = 4.29 \text{ s}$$

From first equation of motion, final velocity is given as:

$v = u + at$

$= 0 + 9.8 \times 4.29 = 42.04$ m/s

Rebound velocity of the ball, $u_r = \frac{9}{10}v = \frac{9}{10} \times 42.04 = 37.84\,\text{m/s}$

Time (t) taken by the ball to reach maximum height is obtained with the help of first equation of motion as:

$v = u_r + at'$

$0 = 37.84 + (-9.8)\,t'$

$$t' = \frac{-37.84}{-9.8} = 3.86\text{ s}$$

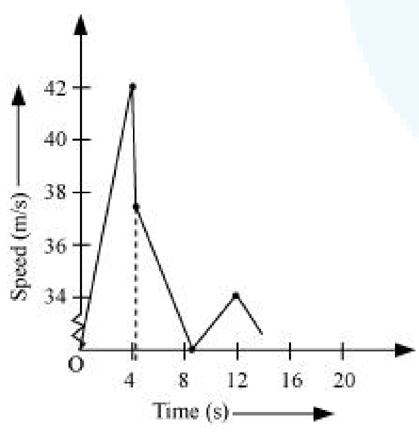
Total time taken by the ball $= t + t' = 4.29 + 3.86 = 8.15$ s

As the time of ascent is equal to the time of descent, the ball takes 3.86 s to strike back on the floor for the second time.

The velocity with which the ball rebounds from the floor $= \frac{9}{10} \times 37.84 = 34.05$ m/s

Total time taken by the ball for second rebound $= 8.15 + 3.86 = 12.01$ s

The speed-time graph of the ball is represented in the given figure as:



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].

<u>Answer</u>

The magnitude of displacement over an interval of time is the shortest distance (which is a straight line) between the initial and final positions of the particle.

The total path length of a particle is the actual path length covered by the particle in a given interval of time.

For example, suppose a particle moves from point A to point B and then, comes back to a point, C taking a total time *t*, as shown below. Then, the magnitude of displacement of the particle = AC.

Whereas, total path length = AB + BC

It is also important to note that the magnitude of displacement can never be greater than the total path length. However, in some cases, both quantities are equal to each other.

(b)

$$\text{Magnitude of average velocity} = \frac{\text{Magnitude of displacement}}{\text{Time interval}}$$

For the given particle,

$$\text{Average velocity} = \frac{AC}{t}$$

$$\text{Average speed} = \frac{\text{Total path length}}{\text{Time interval}}$$
$$= \frac{AB+BC}{t}$$

Since (AB + BC) > AC, average speed is greater than the magnitude of average velocity. The two quantities will be equal if the particle continuentities will be equal if the particle continues to move along a straight line.ong a straight line.

Question 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 iFinding the market closed, he instantly turns and walks back home wihe instantly turns and walks back home with a speed of 7.5 km h^{-1}. What is the

magnitude of average velocity, andverage velocity, and

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 exercwill appreciate from this exercise why it is better to define average speed as total path length divided by td 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

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

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

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

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

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

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

Net displacement = 0

Total distance = 2.5 + 2.5 = 5 km

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

$$\text{Average speed} = \frac{\text{Distance}}{\text{Time}} = \frac{5}{\left(\frac{5}{6}\right)} = 6 \text{ km/h} \qquad \ldots (b(ii))$$

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

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

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

Question 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?

Answer

Instantaneous velocity is given by the first derivative of distance with respect to time i.e.,

$$v_{In} = \frac{dx}{dt}$$

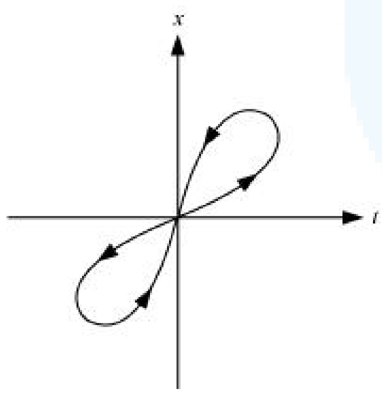
Here, the time interval *dt* is so small that it is assumed that the particle does not change its direction of motion. As a result, both the total path length and magnitude of displacement become equal is this interval of time.

Therefore, instantaneous speed is always equal to instantaneous velocity.

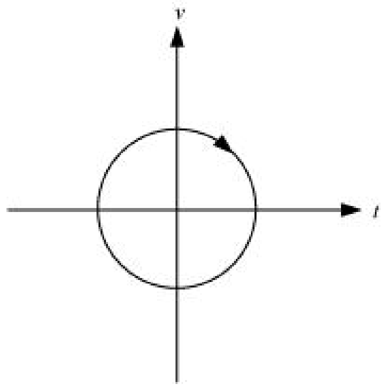
Question 12:

Look at the graphs (a) to (d) (Fig. 2.10) carefully and state, with reasons, which of these *cannot* possibly represent one-dimensional motion of a particle.

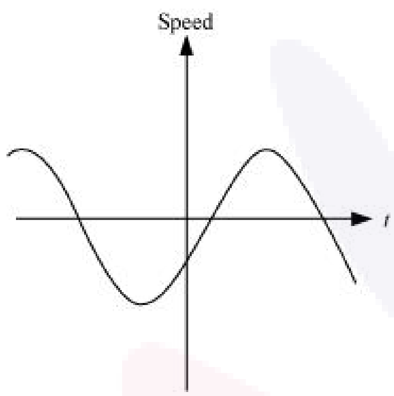
(a)



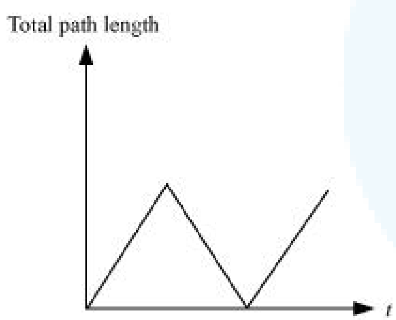
(b)



(c)



(d)



Answer

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.

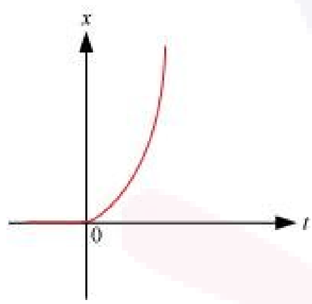
The given *v*-*t* graph, shown in (b), does not represent one-dimensional motion of the particle. This is because a particle can never have two values of velocity at the same instant of time.

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.

Question 13:

Figure 2.11 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.



(Fig 3.21)

<u>Answer</u>

Answer: No

The *x-t* graph of a particle moving in a straight line for $t < 0$ and on a parabolic path for $t > 0$ cannot be shown as the given graph. This is because, the given particle does not follow the trajectory of path followed by the particle as $t = 0$, $x = 0$. A physical situation that resembles the above graph is of a freely falling body held for sometime at a height

Question 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 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).

Answer

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:

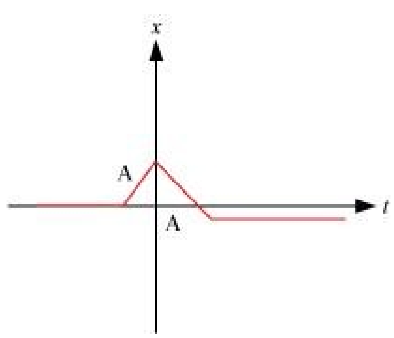
$v_{bt} = v_b - v_t$

= 158.33 – 53.33 = 105 m/s

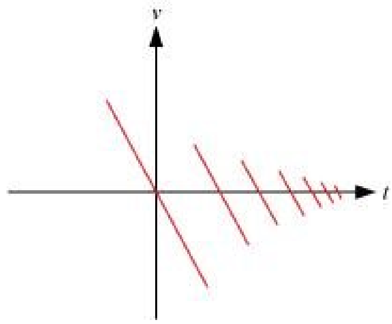
Question 15:

Suggest a suitable physical situation for each of the following graphs (Fig 3.22):

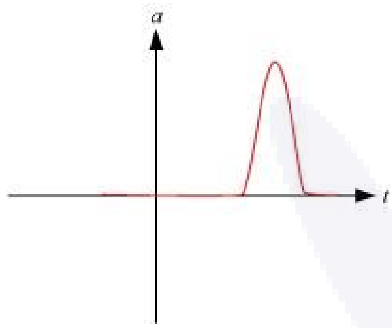
(a)



(b)



(c)



(Fig: 3.22)

Answer

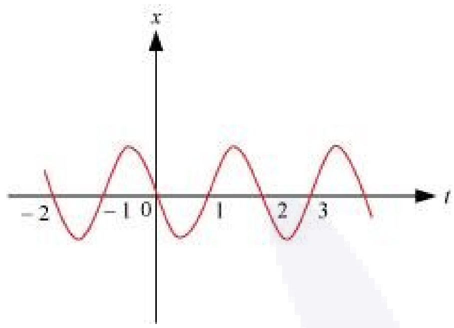
(a)The given *x-t* graph shows that initially a body was at rest. Then, its velocity increases with time and attains an instantaneous constant value. The velocity then reduces to zero with an increase in time. Then, its velocity increases with time in the opposite direction and acquires a constant value. 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*-tgraph, 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.

Question 16:

Figure 2.13 gives the x-tplot of a particle executing one-dimensional simple harmonic motion. (You will learn about this motion in more detail in Chapter13). Give the signs of position, velocity and acceleration variables of the particle at t = 0.3 s, 1.2 s, -1.2s.



(Fig: 2.13)

Answer

Negative, Negative, Positive (at t = 0.3 s)

Positive, Positive, Negative (at t = 1.2 s)

Negative, Positive, Positive (at t = –1.2 s)

For simple harmonic motion (SHM) of a particle, acceleration (a) is given by the relation:

$a = -\omega^2 x$ $\omega \rightarrow$ angular frequency … (i)

t = 0.3 s

In this time interval, x is negative. Thus, the slope of the x-t plot will also be negative. Therefore, both position and velocity are negative. However, using equation (i), acceleration of the particle will be positive.

t = 1.2 s

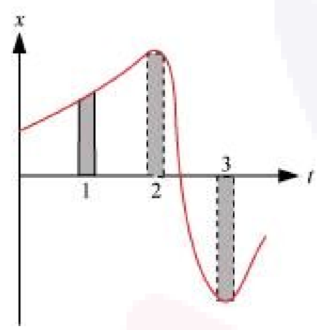
In this time interval, x is positive. Thus, the slope of the x-t plot will also be positive. Therefore, both position and velocity are positive. However, using equation (i), acceleration of the particle comes to be negative.

$t = -1.2$ s

In this time interval, x is negative. Thus, the slope of the x-t plot will also be negative. Since both x and t are negative, the velocity comes to be positive. From equation (i), it can be inferred that the acceleration of the particle will be positive.

Question 17:

Figure 2.14 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.



(Fig: 2.14)

Answer

Interval 3 (Greatest), Interval 2 (Least)

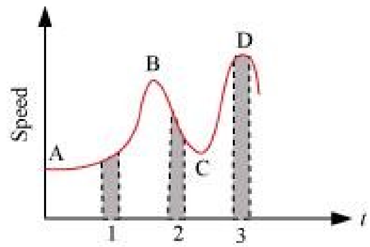
Positive (Intervals 1 & 2), Negative (Interval 3)

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 restively 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.

Question 18:

Figure 2.15 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?



(Fig: 2.15)

Answer

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.