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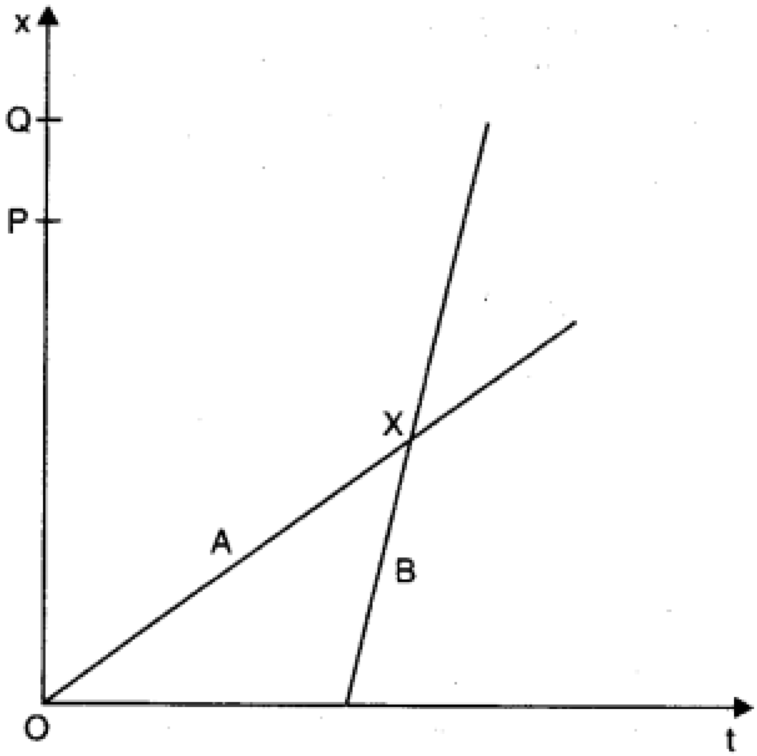
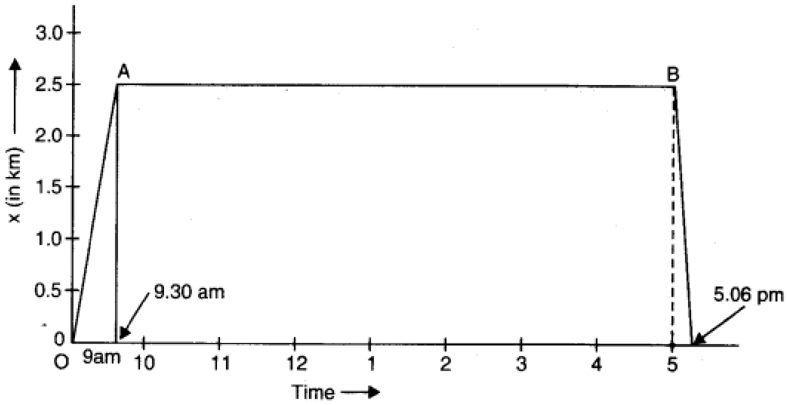
Question 3. 1. In which of the following examples of motion, can the body be considered approximately a point object.
(a) A railway carriage moving without jerks between two stations.
(b) A monkey sitting on top of a man cycling smoothly on a circular track.
(c) A spinning cricket ball that turns sharply on hitting the ground.
(d) A tumbling beaker that has slipped off the edge of 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 3. 2. The position-time (x -1) 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).



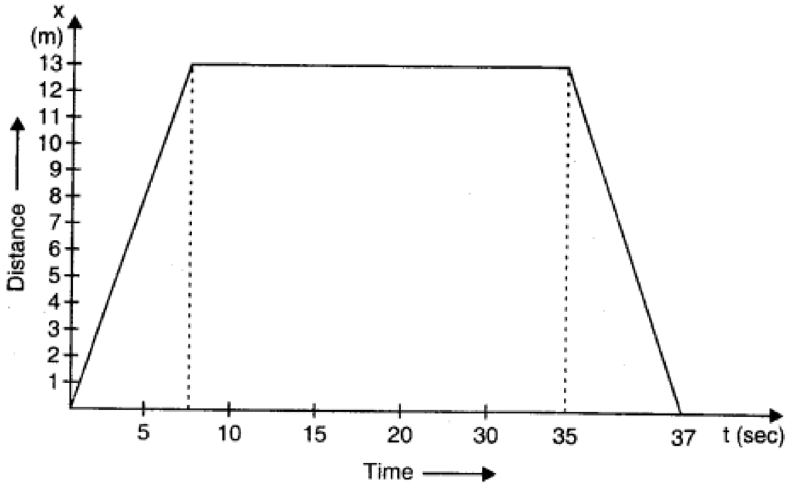
Answer:
(a) A lives closer to school than B, because B has to cover higher distances [OP < OQ],
(b) A starts earlier for school than B, because t = 0 for A but for B, t has some finite time.
(c) As slope of B is greater than that of A, thus B walks faster than A.
(d) A and B reach home at the same time.
(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 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 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) h=1/2 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 3. 4. A drunkard walking in a narrow lane takes 5 steps forward and 3 steps backward, followed again by 5 steps forward and 3 steps backward, and so on. Each step is 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 3. 5. A jet airplane travelling at the speed of 500 km h-1 ejects its products of combustion at the speed of 1500 km h^{-1} relative to the jet plane. What is the speed of the latter with respect to an observer on the ground?
Answer: Velocity of jet airplane w.r.t observer on ground = 500 km/h.
If vj and v0 represent the velocities of jet and observer respectively, then vj - v0 = 500 km h^{-1}
Similarly, if vc represents the velocity of the combustion products w.r.t jet plane, then vc - vg = -1500 km/h
The negative sign indicates that the combustion products move in a direction opposite to that of jet.
Speed of combustion products w.r.t. observer
= vc - u0 = (vc - vj) + (vj - v0) = (-1500 + 500) km h^{-1} = -1000 km h^{-1}.

Question 3. 6. 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?
Answer:

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

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

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

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

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

Also, $\quad v = u + at$

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

Question 3. 7. Two trains A and B of length 400 m each are moving on two parallel tracks with a uniform speed of 71 km h^{-1} in the same direction, with A ahead of B. The driver of B decides to overtake A and accelerates by 1 ms^{-1}. If after 50 s, the guard of B just brushes past the driver of A, what was the original distance between them?
Answer: Here length of train A = length of train B = l = 400 m. As speed of both trains u = 72 km h^{-1} = 20 ms^{-1} in same direction, hence their relative velocity u_{BA} = 0.
Let initial distance between the two trains be 'S' then train B covers the distance (S + 11) = (S + 800) m in time t = 50 s when accelerated with a uniform acceleration a = 1 m/s^2.

$$\therefore \quad (S + 800) = u_{AB} \times t + \frac{1}{2}at^2$$

$$= 0 + \frac{1}{2} \times 1 \times (50)^2 = 1250 \text{ m}$$

$$\Rightarrow \quad S = 1250 - 800 = 450 \text{ m}$$

and initial distance between guard of train B from driver of train A = 450 + 800 = 1250 m.

Question 3. 8. On a two-lane road, car A is travelling with a speed of 36 km h^{-1}. Two cars B and C approach car A in opposite directions with a speed of 54 km h^{-1} each. At a certain instant, when the distance AB is equal to AC, both being 1 km, B decides to overtake A before C does. What minimum acceleration of car B is required to avoid an accident?

Answer:

Speed of car A, $\quad v_A = 36 \text{ km/h} = 36 \times \frac{5}{18} = 10 \text{ m/s}$

Speed of car B, $\quad v_B = 54 \text{ km/h} = 54 \times \frac{5}{18} = 15 \text{ m/s}$

Relative speed of car A w.r.t car C = v_{AC} = (10 + 15) ms^{-1} = 25 ms^{-1}

Relative speed of car B w.r.t car A = v_{BA} = (15 − 10) ms^{-1} = 5 m/s

Time taken by car C to cover distance AC,

$$t = \frac{1000}{v_{AC}} = \frac{1000}{25} = 40\text{s}$$

If a is the acceleration, then

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

$$\Rightarrow \quad 1000 = 5 \times 40 + \frac{1}{2}a \times (40)^2$$

$$\Rightarrow \quad a = \frac{1000 - 200}{800} = 1 \text{ m/s}^2.$$

Question 3. 9. Two towns A and B are connected by a regular bus service with a bus leaving in either direction every T minute. 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?

Answer: Let vb be the speed of each bus. Let vc be the speed of cyclist.

Relative velocity of the buses plying in the direction of motion of cyclist is vb - vc.

The buses playing in the direction of motion of the cyclist go past him after every 18 minute i.e.18/20 h.

$\therefore$ Distance covered is $(v_b - v_c) \times \frac{18}{60}$.

Since a bus leaves after every T minute therefore distance is also equal to $v_b \times \frac{T}{60}$.

$$\therefore \quad (v_b - v_c) \times \frac{18}{60} = v_b \times \frac{T}{60}. \quad \text{...(1)}$$

Relative velocity of the buses plying opposite to the direction of motion of the cyclist is $v_b + v_c$. In this case, the buses go past the cyclist after every 6 minute.

$$\therefore \quad (v_b + v_c) \times \frac{6}{60} = v_b \times \frac{T}{60} \quad \text{...(2)}$$

Dividing (1) by (2), we get $\frac{(v_b - v_c)18}{(v_b + v_c)6} = 1$

On simplification $v_b = 2v_c$

But $v_c = 20$ km h^{-1}

$\therefore$ $v_b = 40$ km h^{-1}

From equation (1),

$$(40 - 20) \times \frac{18}{60} = 40 \times \frac{T}{60}$$

On simplification, T = **9 minutes.**

Question 3. 10. 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).
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 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

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

As $v^2 - u^2 = 2aS \Rightarrow 0 - (29.4)^2 = 2 \times 9.8 \times S$

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

Also $v = u + at \Rightarrow v - u = at$

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

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

Total time $= 3 + 3 = 6$ s [$\because$ time of ascent = time of descent]

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