NCERT TEXTUAL EXERCISE (SOLVED)

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 the top of a man cycling smoothly on a circular track,

(c) a spinning cricket ball that turns sharply on hitting the ground,

(d) a thumbling beaker that has slipped off the edge of a table.

Sol. (a) The carriage can be considered a point object if the distance between the two stations is very large compared to the size of the railway carriage.

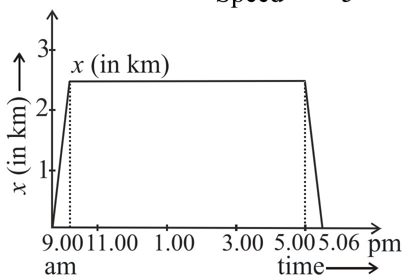
(b) The monkey can be considered as a point object if the cyclist describes a circular track of very large radius because in that case the distance covered by the cyclist is quite large as compared to the size of monkey. The monkey can not be considered as a point object if the cyclist describes a circular track of small radius because in that case the distance covered by the cyclist is not very large as compared to the size of the monkey.

(c) The spinning cricket ball cannot be considered as a point object because the size of the spinning cricket ball is quite appreciable as compared to the distance through which the ball may turn on hitting the ground.

(d) A beaker slipping off the edge of the table can not be considered as a point object because the size of the beaker is not negligible as compared to the height of the table.

2. A woman starts from her home at 9.00 am, walks with a speed 5 km/h on 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. Choose suitable scales and plot the *x*-*t* graph of her motion.

Sol. Time taken in reaching office $= \dfrac{\text{Distance}}{\text{Speed}} = \dfrac{2.5}{5} = 0.5$ h.



Time taken in returning from office = $\frac{2.5}{25}$ = 0.1 h. = 6 min.

It means the woman reaches the office at 9.30 am and returns home at 5.06 pm. The x-t graph of this motion will be as shown.

3. A drunkard walking in a narrow lane takes 5 steps forward and 3 steps backward, followed again 5 steps forward and 3 steps backward, and so on. Each step is 1 m long and requires 1 s. Determine how long the drunkard takes to fall in a pit 13 m away from the start.

Sol. For covering a distance of 8 m in forward direction the drunkard will have to move 32 steps in all.

Now he will have to cover 5 m more to reach the pit, for which he has to take only 5 forward steps.

Therefore, he will have to take = 32 + 5 = 37 steps to move 13 m. Thus, he will fall into the pit after taking 37 steps i.e. after 37 s from the start.

4. A jet airplane travelling at the speed of 500 km/h ejects its products of combustion at the speed of 1500 km/h relative to the jet plane. What is the speed of the later with respect to observer on the ground?

Sol. Let, v_P = velocity of the product w.r.t. ground. Consider the direction of motion of airplane to be positive direction of x-axis. Here

Speed of jet plane, v_A = 500 km h^{-1}

Relative speed of products of combustion w.r.t. jet plane is, v_{PA} = –1500 km/h

Relative speed of products of combustion w.r.t. jet plane is, $v_{PA} = v_P - v_A$ = –1500 km/h

or, $v_P = v_A - 1500 = 500 - 1500$ km/h = –1000 km/h

Here –ve sign shows that the direction of products of combustion is opposite to that of the airplane. Thus the magnitude of relative velocity is 1000 km/h.

5. A car moving along a straight highway with speed 126 km/h 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?

Sol. Here, u = 126 km/h = 126 × 1000/(60 × 60) m/s = 35 m/s

$v = 0$, s = 200 m

We know, $v^2 = u^2 + 2as$

⇒ $0 = (35)^2 + 2\,a \times (200)$

or, $a = -(35)^2/(2 \times 200) = \frac{-49}{16} = -3.06$ m/s^2

As $v = u + at$

$\Rightarrow \quad 0 = 35 + (-49/16)\, t$

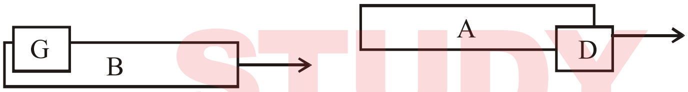
$t = 35 \times 16/49 = 80/7 = 11.43$ s

6. Two trains A and B of length 400 m each are moving on two parallel tracks with a uniform speed of 72 km/h 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 crosses past the driver of A, what was the original distance between them (the guard of B and the driver of A)?

Sol. Originally, both the trains have the same velocities. So the relative velocity of B w.r.t. A is zero.

For train A, u = 72 km/h = (72 × 1000)/(60 × 60) = 20 m/s, t = 50 s, a = 0, $S = S_A$

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



$\therefore \quad S_A = 20 \times 50 + \frac{1}{2} \times 0 \times (50)^2 = 1000$ m

For train B, u = 72 km/h = (72 × 1000)/(60 × 60) = 20 m/s, t = 50 s, a = 1 m/s^2, $S = S_B$

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

$\therefore \quad S_B = 20 \times 50 + \frac{1}{2} \times 1 \times 50^2 = 2250$ m

Taking the guard of the train B in the last compartment of the train B, it comes that original distance between the two trains + length of the train A and B = $S_A - S_B$

or, original distance between the two trains + 400 + 400 = 2250 – 1000 = 1250 m

Original distance between the two trains = 1250 – 800 = 450 m.

7. On a two lane road, car A is travelling with a speed of 36 km/h. Two cars B and C approach car A in opposite directions with a speed of 54 km/h 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?

Sol. Velocity of car A = 36 km/h = 10 m/s; Velocity of car B or C = 54 km/h = 15 m/s

Relative velocity of B w.r.t. A = 15 – 10 = 5 m/s

Relative velocity of C w.r.t. A = 15 + 10 = 25 m/s

Time available to B or C for crossing A = 1000/25 = 40 s.

If car B accelerates with acceleration a, to cross A before car C does, then $u = 5$ m/s, $t = 40$ s,

$s = 1000$ m

Using $s = ut + \frac{1}{2}at^2$ we have, $1000 = 5 \times 40 + \frac{1}{2} \times a \times (40)^2$ or, $a = 1$ m/s^2.

8. Two towns A and B are connected by a regular bus service with a bus leaving in either direction every T min. A man cycling with a speed of 20 km/h 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?

Sol. Let, v km/h = constant speed with which the buses ply between the towns A and B.

Relative velocity of the bus (for motion A to B) w.r.t. the cyclist (i.e. in the direction in which the cyclist is going) = $(v - 20)$ km/h

Relative velocity of the bus (for motion B to A) w.r.t. the cyclist = $(v + 20)$ km/h

The distance travelled by the bus in time T (min) = $v \times T$

As per question, $v \times T/(v - 20) = 18$, or, $v \times T = 18v - 18 \times 20$ ...(i)

and, $v \times T/(v + 20) = 6$, or, $v \times T = 6v + 20 \times 6$ ...(ii)

Solving (i) and (ii), we get, $v = 40$ km/h

Putting this value of v in (i) we get,

$40T = (18 \times 40) - (18 \times 20) = 18 \times 20$ or, $T = 9$ mins.

9. A player throws a ball upwards with an initial speed of 29.4 m/s.

(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 $x = 0$, $t = 0$ be the location and time at its highest point, vertically downward direction to be the positive direction 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 returns to the player's hands (g = 9.8 m/s^2 and air resistance is negligible).

Sol. (a) Since the ball is moving under the effect of gravity, the direction of acceleration due to gravity is always vertically downward.

(b) At the highest point, the vertical velocity of the ball becomes zero and acceleration is equal to the acceleration due to gravity = 9.8 m/s^2 in vertically downward direction.

(c) When the highest point is chosen at the location $x = 0$ and $t = 0$ and vertically downward direction to be the positive direction of x-axis and upward direction as negative direction of x-axis.

During upward motion, sign of position is positive, sign of velocity is negative and sign of acceleration is positive.

During downward motion, sign of position is positive, sign of velocity is positive and sign of acceleration is positive.

(d) Let, t = time taken by the ball to reach the highest point where height from the ground is S.

Taking the vertical motion of the ball, we have, $u = -29.4$ m/s, a = 9.8 m/s^2, $v = 0$,

As $v = u + at$, we get

$0 = 29.4 - gt$

$\therefore \quad t = \dfrac{29.4}{9.8} = 3\ s$

It means time of ascent = 3 s.

When an object moves under the effect of gravity alone, the time of ascent is always equal to the time of descent. Therefore, total time after which the ball returns to the players' hand = 3 + 3 = 6 s.

10. 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

Sol. (a) True: when a body is thrown vertically upwards in the space, then at the highest point, the body has zero speed but has downward acceleration equal to the acceleration due to gravity.

(b) False: because velocity is the speed of body in given direction. When speed is zero, the magnitude of velocity of body is zero, hence velocity is zero.

(c) True: when a particle is moving along a straight line with constant speed, its velocity remains constant with time. Therefore, acceleration (= change in velocity/time) is zero.

(d) The statement depends upon the choice of the instant of time taken as origin. When the body is moving along a straight line with positive acceleration, the velocity of the body at an instant of time t is $v = u + at$.

The given statement is not correct if a is positive and u is negative, at is the instant of time taken as origin. Then for all the times before the time for which v vanishes, there is slowing down of the particle that is the speed of the particle will decrease with time. It happens when body is projected vertically upwards. But the given statement is true if u is positive, and a is positive, at is the instant of time taken as origin. It is so when the body is falling vertically downwards.

11. 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 ($g = 10$ m/s^2).

Sol. $u = 0$, $a = 10$ m/s^2, $s = 90$ m

We get, $t = \sqrt{(2\,s/a)} = \sqrt{(2 \times 90/10)} = 3\sqrt{2}$ s $= 4.24$ s

Now, $v = \sqrt{(2\,sa)} = \sqrt{(2 \times 10 \times 90)} = 30\sqrt{2}$ m/s

Rebound velocity of ball, $u' = (9/10)v = (9/10) \times 30\sqrt{2} = 27\sqrt{2}$ m/s

Time to reach the highest point is, $t' = u'/a = 27\sqrt{2}/\,10 = 2.7\sqrt{2} = 3.81$ s

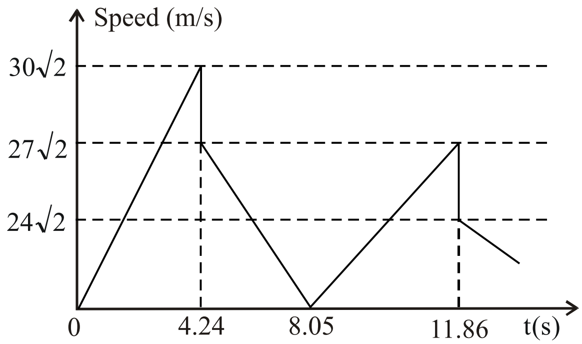
Total time, $t + t' = 4.24 + 3.81 = 8.05$ s

The ball will take further 3.8 s to fall back to floor, where its velocity before striking the floor = $27\sqrt{2}$ m/s

Velocity after striking the floor = $(9/10) \times 27\sqrt{2} = 24.3\sqrt{2}$ m/s

Total time elapsed before upward motion of ball = $8.05 + 3.81 = 11.86$ s

Thus, the speed–time graph of this motion is shown in figure.



12. A man walks on a straight road from his home to a market 2.5 km away with a speed of 5 km/h. Finding the market closed, he instantly turns and walks back with a speed of

(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

Sol. (i) Time taken by the man to go to market from his home,

$t_1 =$ distance/speed = 2.5/5 = $\frac{1}{2}$ h

Time taken by the man to go his home from the market,

$t_2 =$ distance/speed = 2.5/7.5 = 1/3 h

$\therefore$ Total time taken = $t_1 + t_2 = \frac{1}{2} + 1/3 = 5/6$ h = 50 min.

(ii) 0 to 30 min

(a) Average velocity = displacement/time = 2.5/(1/2) = 5 km/h

(b) Average speed = distance/time = 2.5/(1/2) = 5 km/h

(iii) 0 to 50 min

Total distance travelled = 2.5 + 2.5 = 5 km

Total displacement = 0

(a) Average velocity = displacement/time = 0

(b) Average speed = distance/time = 5/(5/6) = 6 km/h

(iv) 0 to 40 min

Distance moved in 30 min (from home to market) = 2.5 km

Distance moved in 10 min (from market to home) with a speed 7.5 km/h

$= 7.5 \times (10/60) = 1.25$ km

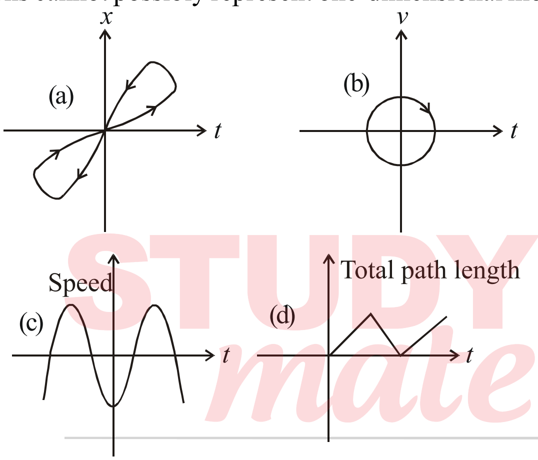
So displacement $= 2.5 - 1.25 = 1.25$ km

Distance travelled $= 2.5 + 1.25 = 3.75$ km

(a) Average velocity $= 1.25/(40/60) = 1.875$ km/h

(b) Average speed $= 3.75/(40/60) = 5.625$ km/h

13. Look at the graphs, given below, carefully and state the reasons which of these graphs cannot possibly represent one-dimensional motion of a particle.



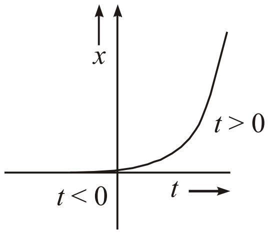
Sol. (a) This graph does not represent one-dimensional motion because at the given instant of time, the particle will have two positions, which is not possible in one-dimensional motion.

(b) This graph does not represent one-dimensional motion because at the given instant of time, the particle will have velocity in positive as well as in negative direction, which is not possible in one-dimensional motion.

(c) It also does not represent one-dimensional motion because this graph tells that the particle will have the negative speed but the speed of the particle can never be negative.

(d) This graph does not represent one-dimensional motion because this graph tells that the total path length decreases after certain time but total path length of a moving particle can never decrease with time.

14. Figure below shows 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.



Sol. No, because the x–t graph does not represent the trajectory of the path followed by a particle.

From the graph, it is noted that at $t = 0$, $x = 0$

Context: The above graph can represent the motion of a body falling freely from a tower under the gravity.

15. A police van moving on a highway with a speed of 30 km/h fires a bullet at a thief's car speeding away in the same direction with a speed of 192 km/h. If the muzzle speed of the bullet is 150 m/s, with what speed does the bullet hit the thief's car? (Note, obtain that speed which is relevant for damaging the thief's car?)

Sol. Muzzle speed of bullet, $v_B = 150$ m/s $= 540$ km/h

Speed of police van, $v_P = 30$ km/h

Speed of thief car, $v_T = 192$ km/h

Since the bullet is sharing the velocity of the police van, its effective velocity is

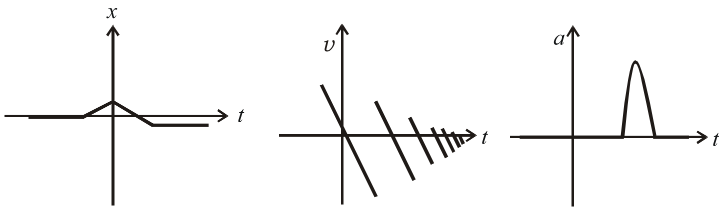
$V_B = v_B + v_P = 540 + 30 = 570$ km/h

The speed of the bullet w.r.t the thief's car moving in the same direction

$$V_{BT} = V_B - V_T = 570 - 192 = 378 \text{ km/h} = \frac{378 \times 1000}{60 \times 60} = 105 \text{ m/s}$$

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

Sol. **Figure (a):** The x–t graph shows that initially x is zero i.e. at rest, then it increases with time, attains a constant value and again reduces to zero with time, then it increases in opposite direction till it again attains a constant value i.e. comes to rest. The similar physical situation arises when a ball resting on a smooth floor is kicked which rebounds from a wall with reduced speed. It then moves to the opposite wall, which stops it.

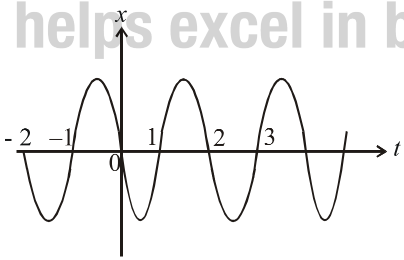


(a) (b) (c)

Figure (b): The velocity changes sign again and again with passage of time and every time some speed is lost. The similar physical situation arises when a ball is thrown up with some velocity, returns back and falls freely. On striking the floor, it rebounds with reduced speed each time it strikes against the floor.

Figure (c): Initially body moves with uniform velocity. Its acceleration increases for a short duration and then falls to zero and there after the body moves with a constant velocity. The similar physical situation arises when a cricket ball moving with a uniform speed is hit with a bat for very short interval of time.

17. Figure below shows x–t plot of a particle executing one-dimensional simple harmonic motion. Give the signs of position, velocity and acceleration variables of the particle at t = 0.3 s, 1.2 s, –1.2 s.



Sol. In the SHM acceleration $a = -\omega^2 x$ where ω is angular frequency (= constant).

(i) At time t = 0.3 s, x is negative, the slope of x–t plot is also negative, hence position and velocity are negative. Since, $a = -\omega^2 x$, acceleration is positive.

(ii) At time t = 1.2 s, x is positive, the slope of x–t plot is also positive, hence position and velocity are positive. Since, $a = -\omega^2 x$, acceleration is negative.

(iii) At time t = – 1.2 s, x is negative, the slope of x–t plot is also negative, But since x and t are negative here, hence velocity is positive. Finally, acceleration is positive.

18. A boy standing on stationary lift (open from above) throws a ball upwards with the maximum initial speed he can, equal to 49 m/s. (a) how much time does the ball take to return to his hands? (b) If the lift starts moving up with a uniform speed of 5 m/s, and the boy again throws the ball up with the maximum speed he can, how long does the ball take to return to his hands?

Sol. (a) Here, $v(0) = 49$ m/s, $a = -9.8$ m/s^2.

We know, $v(t) = v(0) + at$

$\therefore$ $0 = 49 - 9.8\,t$, or, $t = 49/9.8 = 5$ s

This is the time taken by the ball to reach the maximum height. The time of descent is also 5 s. So, the total time after which the ball comes back is 5 s + 5 s = 10 s.

(b) The uniform velocity of the lift does not change the relative motion of ball and lift. So, the ball would take the same total time i.e. it would come back after 10 s.

19. On a long horizontally moving belt, a child runs to-and-fro with a speed of 9 km/h (w.r.t. belt) between his father and mother located 50 m apart on the moving belt. The belt moves with a speed of 4 km/h. For an observer on a stationary platform outside, what is the

(a) speed of the child running in the direction of motion of the belt?

(b) speed of the child running opposite to the direction of the belt? and

(c) time taken by the child in case (a) and (b)?

Which of the answer alter if motion is viewed by one of the parents ?

Sol. Let us consider left to right to be the positive direction of x-axis.

(a) Here, velocity of belt, $v_B = +4$ km/h

Speed of the child w.r.t. belt, $v_C = +9$ km/h

Speed of the child w.r.t. stationary observer,

$v_C' = v_C + v_B = 9 + 4 = 13$ km/h

(b) Here, $v_B = +4$ km/h; $v_C = -9$ km/h

Speed of the child w.r.t. stationary observer,

$v_C' = v_C + v_B = -9 + 4 = -5$ km/h

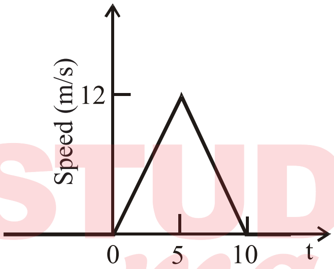
$\therefore$ Velocity of the child in any direction (from father to mother or from mother to father) will be 9 km/h or $\frac{5}{2}$ m/s.

$\therefore$ Time taken by the child in each case (a) and (b) each is $t = 50/(5/2)$ $= 20$ s

If the motion is observed by one of the parents, answer to case (a) or case (b) will get altered. It is so because speed of child w.r.t. either of mother or father is 9 km/h.

But answer (c) remains unaltered due to the fact that parents and child are on the same belt and as such all are equally affected by the motion of belt.

20. The speed–time graph of a particle moving along a fixed direction is as shown in the figure. Obtain the distance travelled by the particle between (a) $t = 0$ to 10 s and (b) $t = 2$ to 6 s. What is the average speed of the particle over the intervals in (a) and (b)?



Sol. Distance travelled by the particle between 0 and 10 s = Area of ΔOAB = $\frac{1}{2} \times 10 \times 12 = 60$ m.

Average speed = 60/10 = 6 m/s

Let s_1 and s_2 be the distances covered by the particle in the time interval 2 s to 5 s and 5 s to 6 s, then the total distance covered in the given time interval is $s_1 + s_2$

To find s_1: Let, u_1 = velocity of particle after 2 s and a_1 = acceleration of the particle during the time interval zero to 5 s.

The $u = 0$, $v = 12$ m/s, $a = a_1$ and $t = 5$ s.

We have, $a_1 = (v - u)/t = (12 - 0)/5 = 2.4$ m/s^2

$\therefore u_1 = u + a_1 t = 0 + 2.4 \times 2 = 4.8$ m/s

Thus for the distance travelled by particle in 3 s (i.e. time interval 2 s to 5 s), we get,

$u_1 = 4.8$ m/s, $t_1 = 3$ s, $a_1 = 2.4$ m/s^2

$$s_1 = u_1 t_1 + \frac{1}{2} a_1 t_1^2 = 4.8 \times 3 + \frac{1}{2} \times 2.4 \times (3)^2 = 25.2 \text{ m}$$

To find s_2: Let, a_2 = acceleration of the particle during the motion, $t = 5$ s to $t = 10$ s.

We have, $a_2 = (0 - 12)/(10 - 5) = -2.4$ m/s^2

Taking motion of the particle during the motion, $t = 5$ s to $t = 10$ s, we get,

$u_2 = 12$ m/s, $t_2 = 1$ s, $a_2 = -2.4$ m/s^2

$s_2 = u_2t_2 + \frac{1}{2} a_2t_2^2 = 12 \times 1 + \frac{1}{2} \times (-2.4) \times (1)^2 = 10.8$ m

$\therefore$ Total distance travelled, s = 25.2 + 10.8 = 36 m

Average speed = 36/(6 – 2) = 36/4 = 9 m/s