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NCERT Solutions for 11th Class Physics:Chapter 3-Motion In A Straight Line

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Exercises

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 a table.

Answer

(a) 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.

(b) 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.

(c) 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.

(d) 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.

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3.2. 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) (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).

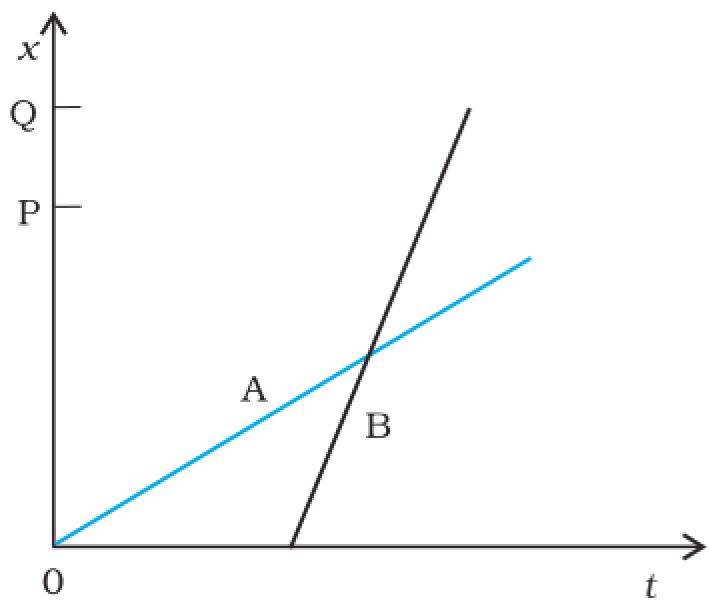


Fig. 3.19

Answer

(a) As $OP < OQ$, A lives closer to the school than B.

(b) For $x = 0$, $t = 0$ for A; while t has some finite value for B. Therefore, A starts from the school earlier than B.

(c) Since the velocity is equal to slope of *x*-*t* graph in case of uniform motion and slope of *x*-*t* graph for *B* is greater that that for *A* =, hence *B* walks faster than *A*.

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

(e) *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.

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 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

Time taken = Distance / Speed

= 2.5 / 5 = 0.5 h = 30 min

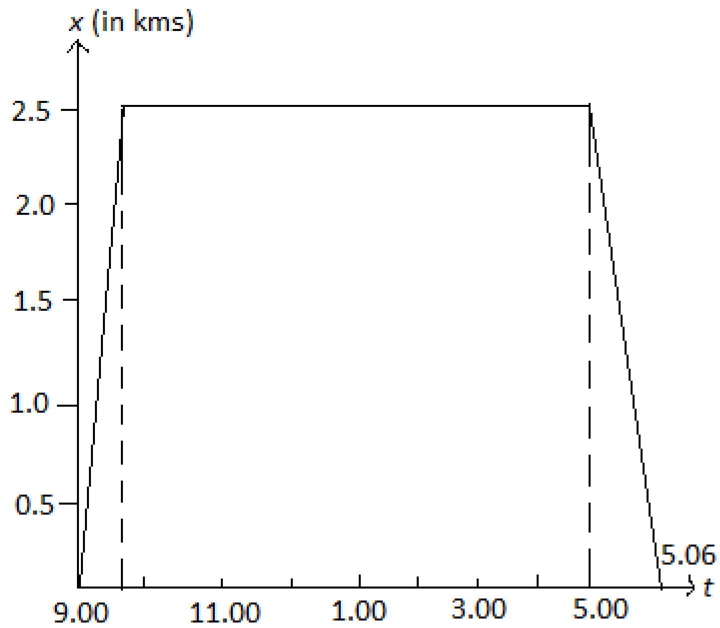
It is given that she covers the same distance in the evening by an auto.

Now, speed of the auto = 25 km/h

Time taken = Distance / Speed

= 2.5 / 25 = 1 / 10 = 0.1 h = 6 min

The suitable *x*-*t* graph of the motion of the woman is shown in the given figure.



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

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.

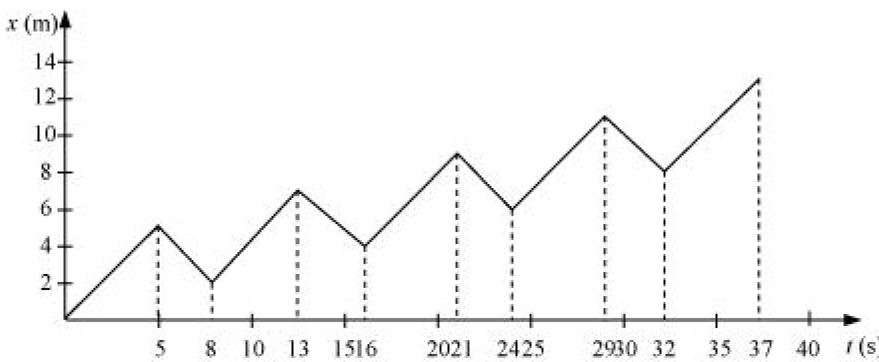
Drunkard covered 6 m in 24 s.

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:



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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

Speed of the jet airplane, v_{jet} = 500 km/h

Relative speed of its products of combustion with respect to the plane,

v_{smoke} = – 1500 km/h

Speed of its products of combustion with respect to the ground = v'_{smoke}

Relative speed of its products of combustion with respect to the airplane,

$v_{smoke} = v'_{smoke} - v_{jet}$

$-1500 = v'_{smoke} - 500$

v'_{smoke} = – 1000 km/h

The negative sign indicates that the direction of its products of combustion is opposite to the direction of motion of the jet airplane.

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

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:

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

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

$a = -35 \times 35 / 2 \times 200 = -3.06\ ms^{-2}$

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

$v = u + at$

$t = (v - u) / a = (- 35) / (-3.06) = 11.44$ s

3.7. Two trains A and B of length 400 m each are moving on two parallel tracks with a uniform speed of 72 km h^{-1} 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 brushes past the driver of A, what was the original distance between them ?

Answer

For train A:

Initial velocity, u = 72 km/h = 20 m/s

Time, t = 50 s

Acceleration, a_I = 0 (Since it is moving with a uniform velocity)

From second equation of motion, distance (s_I)covered by train A can be obtained as:

$s = ut + (1/2)a_1t^2$

$= 20 \times 50 + 0 = 1000$ m

For train B:

Initial velocity, u = 72 km/h = 20 m/s

Acceleration, a = 1 m/s^2

Time, t = 50 s

From second equation of motion, distance (s_{II}) covered by train A can be obtained as:

$s_{II} = ut + (1/2)at^2$

$= 20 \text{ X } 50 + (1/2) \times 1 \times (50)^2 = 2250$ m

Length of both trains = 2 × 400 m = 800 m

Hence, the original distance between the driver of train A and the guard of train B is 2250 - 1000 - 800 = 450m.

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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

Velocity of car A, v_A = 36 km/h = 10 m/s

Velocity of car B, v_B = 54 km/h = 15 m/s

Velocity of car C, v_C = 54 km/h = 15 m/s

Relative velocity of car B with respect to car A,

$v_{BA} = v_B - v_A$

$= 15 - 10 = 5$ m/s

Relative velocity of car C with respect to car A,

$v_{CA} = v_C - (-v_A)$

= 15 + 10 = 25 m/s

At a certain instance, both cars B and C are at the same distance from car A i.e.,

s = 1 km = 1000 m

Time taken (t) by car C to cover 1000 m = 1000 / 25 = 40 s

Hence, to avoid an accident, car B must cover the same distance in a maximum of 40 s.

From second equation of motion, minimum acceleration (a) produced by car B can be obtained as:

$s = ut + (1/2)at^2$

$1000 = 5 \times 40 + (1/2) \times a \times (40)^2$

$a = 1600 / 1600 = 1 \text{ ms}^{-2}$

3.9. Two towns A and B are connected by a regular bus service with a bus leaving in either direction every T minutes. 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 V be the speed of the bus running between towns A and B.

Speed of the cyclist, v = 20 km/h

Relative speed of the bus moving in the direction of the cyclist

$= V - v = (V - 20)$ km/h

The bus went past the cyclist every 18 min i.e., 18 / 60 h (when he moves in the direction of the bus).

Distance covered by the bus = $(V - 20) \times 18 / 60$ km .... (i)

Since one bus leaves after every T minutes, the distance travelled by the bus will be equal to

$V \times T / 60$ ....(ii)

Both equations (i) and (ii) are equal.

$(V - 20) \times 18 / 60 = VT / 60$ ......(iii)

Relative speed of the bus moving in the opposite direction of the cyclist

$= (V + 20)$ km/h

Time taken by the bus to go past the cyclist = 6 min = 6 / 60 h

$\therefore (V + 20) \times 6 / 60 = VT / 60$ ....(iv)

From equations (iii) and (iv), we get

$(V + 20) \times 6 / 60 = (V - 20) \times 18 / 60$

$V + 20 = 3V - 60$

$2V = 80$

$V = 40$ km/h

Substituting the value of V in equation (iv), we get

$(40 + 20) \times 6 / 60 = 40T / 60$

$T = 360 / 40 = 9$ min

3.10. A player throws a ball upwards with an initial speed of 29.4 m s^{-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)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.

(b)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.

(c) 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.

(d)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:

$v^2 - u^2 = 2gs$

$s = (v^2 - u^2) / 2g$

$= ((0)^2 - (29.4)^2) / 2 \times (-9.8) = 3\ s$

Time of ascent = Time of descent

Hence, the total time taken by the ball to return to the player's hands = 3 + 3 = 6 s.

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3.11. 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 mustbe speeding up.

Answer

(a) True, 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.

(b) Speed is the magnitude of velocity. When speed is zero, the magnitude of velocity along with the velocity is zero.

(c) 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.

(d) 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.

3.12. 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 m/s²

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:

$s = ut + (1/2)at^2$

$90 = 0 + (1/2) \times 9.8\ t^2$

$t = \sqrt{18.38} = 4.29$ 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, $u_r = 9v / 10 = 9 \times 42.04 / 10 = 37.84$ m/s

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

$v = u_r + at'$

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

$t' = -37.84 / -9.8 = 3.86$ s

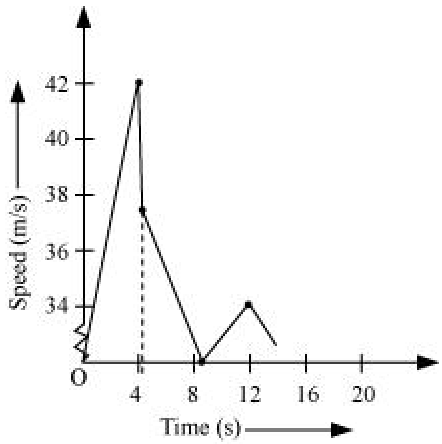
Total time taken by the ball $= t + t' = 4.29 + 3.86 = 8.15$ s

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 $= 9 \times 37.84 / 10 =$ 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:



3.13. 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.

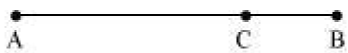
When is the equality sign true? [For simplicity, consider one-dimensional motion only].

Answer

(a) 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) Magnitude of average velocity = Magnitude of displacement / Time interval

For the given particle,

Average velocity = AC / t

Average speed = Total path length / Time interval

= (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 continues to move along a straight line.

3.14. 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 !]

Answer

Time taken by the man to reach the market from home, t_1 = 2.5/5 = 1/2 h = 30 min

Time taken by the man to reach home from the market, t_2 = 2.5/7.5 = 1/3 h = 20 min

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

(i) 0 to 30 min

Average velocity = Displacement/Time = 2.5/(1/2) = 5 km/h

Average speed = Distance/Time = 2.5/(1/2) = 5 km/h

(ii) 0 to 50 min

Time = 50 min = 50/60 = 5/6 h

Net displacement = 0

Total distance = 2.5 + 2.5 = 5 km

Average velocity = Displacement / Time = 0

Average speed = Distance / Time = 5/(5/6) = 6 km/h

(iii) 0 to 40 min

Speed of the man = 7.5 km/h

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 × 10/60 = 1.25 km

Net displacement = 2.5 – 1.25 = 1.25 km

Total distance travelled = 2.5 + 1.25 = 3.75 km

Average velocity = Displacement / Time = 1.25 / (40/60) = 1.875 km/h

Average speed = Distance / Time = 3.75 / (40/60) = 5.625 km/h

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Chapterwise NCERT Solutions for Class 11 Physics:

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