Chapter – 3: Motion in a Straight Line

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.

Ans. a) When compared to the distance between two stations, the size of a carriage is quite modest.As a result, the carriage can be considered a point-sized object.

b) When compared to the size of a circular track, a monkey is quite little.As a result, the monkey can be thought of as a pointy object on the track.

c) A spinning cricket ball's size corresponds to the distance it travels before quickly turning on impact with the ground. As a result, the cricket ball isn't considered a point object.

d) The height of the table from which it slipped is comparable to the size of a beaker. As a result, the beaker isn't a point object.

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;

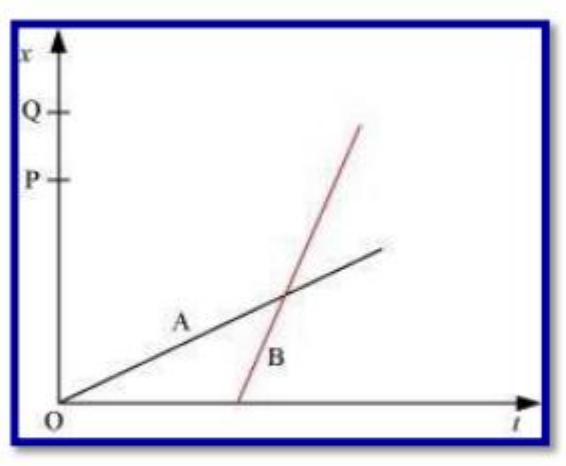
a) (A/B) lives closer to the school than (B/A)

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).



Ans. B lives further away from school than A.

A begins school one day earlier than B.

A is a faster walker than A.

A and B arrive at their respective homes at the same moment.

A gets the upper hand. Once upon a time, I was on the road.

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.

Ans: Speed of the woman on a straight Road = 5 km/h

Distance between office and home = 2.5 km

time taken=distance/time

$\frac{2.5}{5} = 0.5h = 30mins$

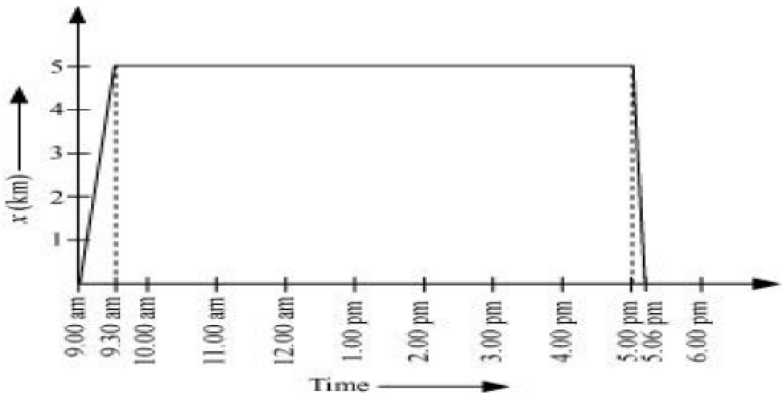
It's assumed that she drives the same distance in the evening.

now, let's talk about auto speed. 25 km/h

time taken=distance/time

$\frac{2.5}{25} = 0.1h = 6mins$

The appropriate x-t graph of the woman's movements is depicted in the diagram.



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.

Ans: 1 m is the distance traveled by 1 step.

1 second is the amount of time it takes to complete the task.

The time it takes to move the first 5 meters ahead is 5 seconds.

The time it takes to move 3 meters backward is 3 seconds.

$5 - 3 = 2$ m is the net distance travelled

Time taken to cover 2 m in net time = 8 s

Drunkard travels 2 meters in 8 seconds.

Drunkard ran 4 meters in 16 seconds.

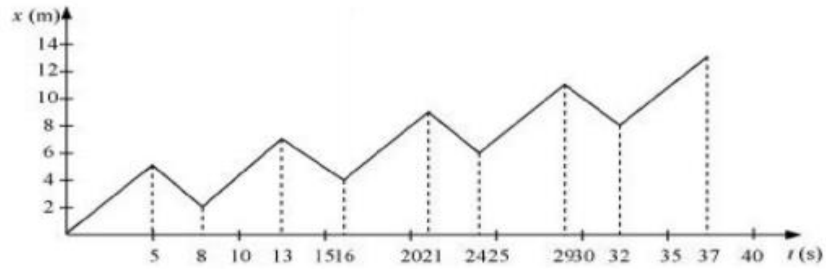
Drunkard ran 6 meters in 24 seconds.

Drunkard ran 8 meters in 32 seconds.

The drunkard will traverse a distance of 5 m and a total distance of 13 m in the following 5 seconds before falling into the abyss.

The drunkard's net time to cover 13 meters is $32 + 5 = 37$ seconds.

The x-t graph of the drunkard's movement looks like this:



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 ground?

Ans: Vjet = 500 km/h is the speed of a jet plane.

Vsmoke = – 1500 km/h

V′smoke is the speed of its combustion products relative to the ground.

In relation to the aeroplane, the relative speed of its combustion products,

Vsmoke= V′smoke+ Vjet

1500= V′,smoke-500

= V′smoke

The negative sign shows that the direction of its combustion products is opposite that of the jet plane's velocity.

6.A car moving along a straight highway with a 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?

Ans: The car's initial velocity is u = 126 km/h = 35 m/s.

v = 0 is the car's final velocity.

s = 200 m is the distance travelled by the car before it comes to a stop.

Retardation caused by driving = a'from equation 3,v^2 $=$ u^2 $+$ $2as$

$(0^2) - (35)^2$ =$22 \times a \times 200$

$a = \frac{35\times35}{200\times22} = -3.06 m/s^2$

now,from first equation,

$v = u + at$

$t = \frac{v-u}{a}$

$= \frac{-35}{-3.06} = 11.44s$

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/s2. If after 50 s, the guard of B just brushes past the driver of A, what was the original distance between them?

Ans: For train A:

u = 72 km/h = 20 m/s

Time, t = 50 s

Acceleration = 0

The distance (sI) travelled by train A can be calculated using the second equation of motion:

$s_{1=ut+\frac{1}{2}a_1t^2}$

$20 \times 50 + \frac{1}{2}at^2$

As a result, the initial distance between train A's driver and train B's guard was $2250 - 1000 = 1250$ m.

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? On a two-lane road, car A is travelling with a speed of 36 km h–1

Ans: Car A's speed, vA = $36\ km/h = 10\ m/s$

Car B's speed, vB = $54\ km/h = 15\ m/s$

Car C's speed, vC = $54\ km/h = 15\ m/s$

Relative velocity of car B wrt A,

vBA = vB – vA = $15 - 10 = 5\ m/s$

Relative velocity of car C wrt A,

vCA = vC – (– vA) = $15 + 10 = 25\ m/s$

Both cars B and C are at the same distance from car A at one point, i.e.

s = 1 $km = 1000\ m$

Time taken by car C to cover 1000 m is $=\frac{1000}{25} = 40s$

As a result, car B must go the same distance in less than 40 seconds to prevent an accident.

Car B's minimal acceleration (a) can be calculated using the second equation of motion as follows:

$s_{1=ut+\frac{1}{2}a_1t^2}$

$1000 = 5 \times 40 + \frac{1}{2}at^2$

$a = \frac{1600}{1600} = 1m/s^2$

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?

Ans: Let V represent the bus's speed between towns A and B.

The cyclist's speed, v =20 km/h, was calculated as follows:

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

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

The cyclist was passed by the bus every 18 minutes, or when he moved in the direction of the bus.

distance travelled by bus= $(v - 20)\frac{18}{60}km$ …………………………..(1)

Because one bus leaves every T minutes, the bus's distance travelled will be equal to:

$v \times \frac{t}{60}$ ………………………………………………………………….(2)

from equation 1 and 2,

$(v - 20)\frac{18}{60}km = v \times \frac{t}{60}$ ……………………………………………………….(3)

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

$= (V + 20)\ km/h$

time taken by the bus is= $6min = 6/60\ hrs$

$\frac{(V+20)6}{60} hrs = v \times \frac{t}{60}$ ....(4)

from eqation 3 and 4 ,

$(v-20)\frac{18}{60}km = \frac{(V+20)6}{60}$

$v + 20 = 3v - 60$

$2v = 80$

$v = 40 km/h$

putting value of v in equation 4,

$\frac{(40+20)6}{60} = 40 \times \frac{t}{60}$

$t = 360/40 = \ min$

A player throws a ball upwards with an initial speed of 29.4 m s–1

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10.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).

Ans: During the upward motion of the ball, the direction of acceleration is downward.

Velocity is 0, acceleration is 9.8 m/s2

$x > 0$ is for both up and down motions,

$v < 0$ is for up and $v > 0$ for down motion,

$a > 0$ is throughout the motion

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 must be speeding up.

Ans: a) True

b) False

c) True

d) False

explanation:

a) At maximum height, the speed of an object thrown vertically up in the air becomes zero. It does, however, have an acceleration equal to the downward acceleration owing to gravity (g) at that point.
b) The magnitude of velocity is called speed. When the velocity is zero, the magnitude of the velocity is also zero.
c) A car travelling at constant speed on a straight highway will have constant velocity.The car's acceleration is zero because acceleration is defined as the rate of change of velocity.
d) When the acceleration is positive and the velocity is negative at the time selected as origin, this assertion is untrue. The particle then slows down for the duration of time before its velocity reaches zero. When a particle is propelled upwards, this happens.

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 $t = 0\ to 12\ s$.

Ans: The ball is thrown from a height of 90 metres.

The ball's initial velocity is u = 0 and its acceleration is $a = g = 9.8$ m/s2.

The ball's final velocity is equal to v.

The time (t) it takes for the ball to strike the ground can be calculated using the second equation of motion.

$s_{1=ut+\frac{1}{2}a_1t^2}$

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

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

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=$\frac{9}{10}v$=$\frac{9}{10} \times 42.04 = 37.84m/s$

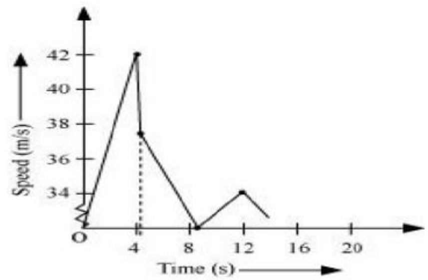
Time (t) taken by the ball to reach maximum height is obtained from the first equation of motion as: $v = ur + at'$

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

$t' = 3.86s$

The ball's total time for the second rebound is $8.15 + 3.86 = 12.01$ seconds.

The following is a representation of the ball's speed-time graph:



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

(c) 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].

Ans: a) The shortest distance (which is a straight line) between the particle's starting and final positions is the magnitude of displacement over a time interval.

The actual path length covered by a particle in a given span of time is its total path length.

Consider the case when a particle travels from point A to point B and then returns to point C in the time t indicated below. The magnitude of the particle's displacement is then equal to AC.

Total path length = AB + BC, on the other hand.

It's also worth noting that the amount of the displacement must never exceed the overall path length. However, in other circumstances, the two quantities are the same.

b)magnitude of average velocity is magnitude of displacement by time taken.

average velocity=$\frac{AC}{t}$

Because (AB + BC) > AC, average speed is greater than average velocity magnitude.

If the particle continues to move in a straight path, the two values will be equal.

AB + BC = length

It's also worth noting that the amount of the displacement must never exceed the overall path length. However, in other circumstances, the two quantities are the same.

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!]

Ans: The time it took the man to go from his house to the market,=$t_1 = \frac{2.5}{5} = \frac{1}{2} hr = 30 mins$

The time it took the man to go from his market to the house,=t_1=$\frac{2.5}{7.5} = \frac{1}{3} hr = 20 mins$

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

average velocity = $\frac{displacement}{time}$=$\frac{2.5}{\frac{1}{2}} = 5 km/h$

average speed = $\frac{displacement}{time}$=$\frac{2.5}{\frac{1}{2}} = 5 km/h$

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

The net displacement is zero.

$2.5 + 2.5 = 5$ km total distance.

average velocity = $\frac{displacement}{time}$=0

average speed = $\frac{displacement}{time}$=$\frac{5}{\frac{5}{6}} = 6 km/h$

Speed of the man is 7.5 km

Distance travelled in first 30 min is 2.5 km

Distance travelled by the man (from market to home) in the next 10 min

$7.5 \times \frac{10}{60} = 1.25km$

Net displacement is $2.5 - 1.25 = 1.25\ km$

Total distance travelled is $2.5 + 1.25 = 3.75\ km$

average velocity = $\frac{displacement}{time} = \frac{1.25}{\frac{40}{60}} = \frac{1.25\times 3}{2} = 1.875\ km/h$

average velocity = $\frac{displacement}{time} = \frac{3.75}{\frac{40}{60}} = \frac{1.25\times 3}{2} = 5.625km/h$

15. In Exercises 3.13 and 3.14, 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?

Ans: The first derivative of distance with respect to time, i.e., the instantaneous velocity, is given by the first derivative of distance with respect to time.

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

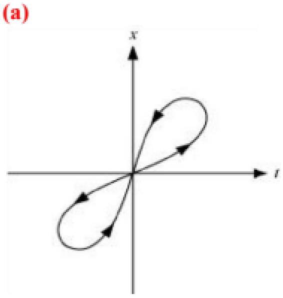
The time interval dt is so short in this case that it is presumed that the particle does not change its motion direction. As a result, in this time frame, the total path length and magnitude of displacement are equal.

As a result, instantaneous velocity is always equal to instantaneous speed.

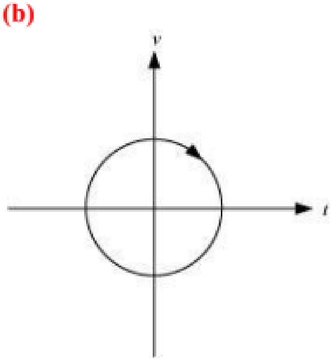
The first derivative of distance with respect to time, i.e., the instantaneous velocity, is given by the first derivative of distance with respect to time.

16.Look at the graphs (a) to (d) (Fig. 3.20) carefully and state, with reasons, which of these cannot possibly represent one-dimensional motion of a particle.

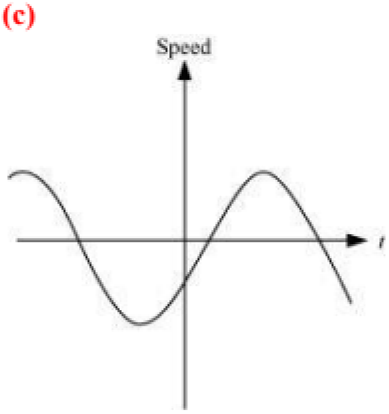
(a)



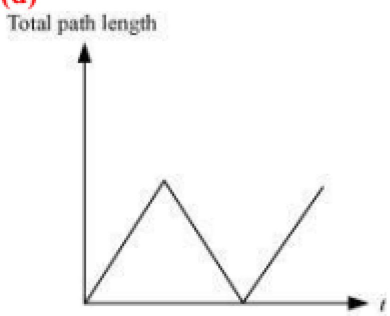
(b)



(c)



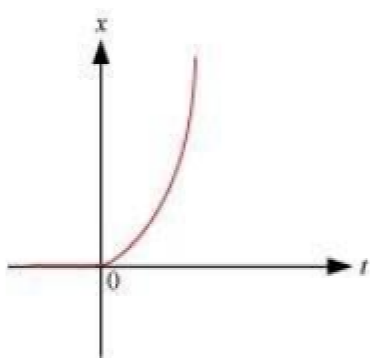
(d)



Ans:

a. The presented x-t graph (a) does not depict the particle's one-dimensional motion. This is due to the fact that a particle cannot be in two places at the same time.
b. The presented v-t graph (b) does not depict the particle's one-dimensional motion. This is due to the fact that a particle can never have two velocity values at the same time.
c. The presented v-t graph (c) does not depict the particle's one-dimensional motion. This is due to the fact that speed is a scalar quantity that cannot be negative.
d. The presented v-t graph (d) does not depict the particle's one-dimensional motion. This is due to the fact that the particle's total route length cannot decrease with time.

17. Figure 3.21 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)

Ans: No, the x-t graph of a particle travelling in a straight line for time t 0 and on a parabolic path for time t > 0 cannot be represented as the provided graph. This is due to the fact that the provided particle does not follow the trajectory of the particle's route at t = 0, x = 0. A freely falling body kept for a period of time at a height is a physical scenario that resembles the following graph.

18.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).

Ans:The police van's speed is vp = 30 $km/h = 8.33\, m/s$.

vb = 150 m/s is the bullet's muzzle speed.

vt = 192 $km/h = 53.33\, m/s$ is Speed of the thief's car.

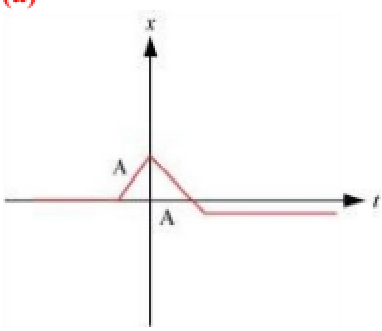
Because the bullet is shot from a moving truck, its speed is calculated as follows: =

$150 + 8.33 = 158.33\, m/s$

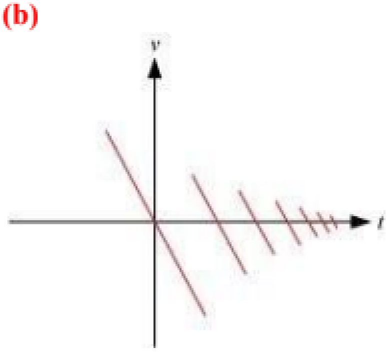
Because both vehicles are going in the same direction, the bullet's velocity when it impacts the thief's car is $vbt = vb - vt = 158.33 - 53.33 = 105\, m/s$.

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

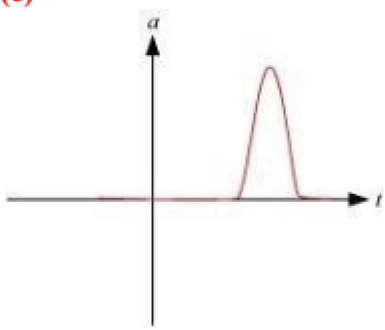
(a)



(b)



(c)



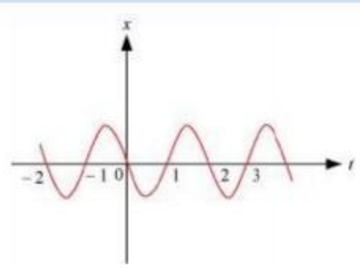
Ans: (a) According to the x-t graph, a body was initially at rest. The velocity of the object then increases with time until it reaches an instantaneous constant value. With the passage of time, the velocity falls to zero. The velocity of the object then rises in the opposite direction with time until it reaches a constant value. A comparable physical scenario occurs when a football (which was initially at rest) is booted and bounces off a stiff wall, slowing it down. The ball then moves from the guy who kicked it to the next player, who eventually stops it.

(b) With the passage of time, the sign of velocity changes and its magnitude decreases in the given v-t graph. When a ball is dropped from a height onto a hard floor, a similar phenomenon occurs. It has some velocity when it hits the floor, but that velocity lowers by a factor when it rebounded. This continues until the velocity reaches a certain point.

(c) The presented a-t graph demonstrates that the body moves with a uniform velocity at first. Its acceleration increases for a brief period before returning to zero.

This implies that the body has resumed its constant velocity movement. When a hammer strikes a nail at a constant speed, a comparable physical state occurs.

20. Figure 3.23 gives the x-t plot of a particle executing one-dimensional simple harmonic motion. (You will learn about this motion in more detail in Chapter14). Give the signs of position, velocity and acceleration variables of the particle at $t = 0.3\ s, 1.2\ s, -1.2\ s$.



(Fig: 3.23)

Ans: (at t = 0.3 s),Negative, Negative, Positive (at t = 1.2 s)Positive, Positive, Negative

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

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

$a = -\omega^2 \times \omega \rightarrow \ angular\ frequency \ldots\ldots\ldots\ldots\ldots\ldots (i)$

$t\ =\ 0.3\ s$

x is negative during this time span. As a result, the x-t plot's slope will similarly be negative.

As a result, location and velocity are both negative.

The particle's acceleration will be positive if equation I is used.

$t\ =\ 1.2$ seconds

x is positive in this time span. As a result, the x-t plot's slope will also be positive.

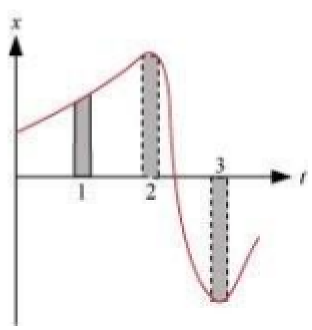
As a result, location and velocity are both positive.

However, when employing equation I the particle's acceleration becomes negative.

$t\ = -1.2\ s$

x is negative during this time span. As a result, the x-t plot's slope will similarly be negative. Because x and t are both negative, the velocity becomes positive. It may be deduced from equation I that the particle's acceleration will be positive.

21. Figure 3.24 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.



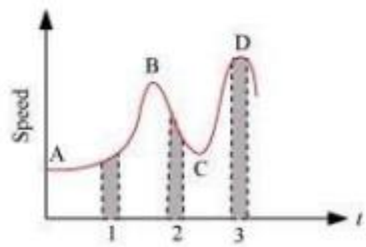
(Fig: 3.24)

Ans: Interval 3 (Greatest), Interval 2 (Least)

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

The slope is highest and minimum restively in intervals 3 and 2, as can be seen in the graph. As a result, the particle's average speed is greatest in interval 3 and lowest in interval 2. In both intervals 1 *and* 2, the sign of average velocity is positive since the slope is positive. In interval 3, however, it is negative because the slope is negative in this interval.

22.Figure 3.25 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: 3.25)

Ans: Interval 2 has the fastest average acceleration. Average speed is greatest in interval 3 v is positive in intervals 1, 2, and 3 an is positive in intervals 1 and 3 and negative in interval 2 $a = 0$ at A, B, C, and D v is positive in intervals 1, 2, and 3 an is positive in intervals 1 and 3 and negative in interval 2 a = 0 at A, B, C, and D

The slope of the speed-time graph determines acceleration. It is given in the given situation by the slope of the speed-time graph inside the given time interval.

Because the slope of the provided speed-time graph is greatest in interval 2, this interval will have the greatest average acceleration.

The average particle speed is determined by the height of the curve from the time axis. It is obvious that interval 3 has the highest height. As a result, the particle's average speed is greatest in interval 3.

The slope of the speed-time graph is positive in interval 1. As a result, the acceleration is positive. Similarly, in this interval, the particle's speed is positive.

The slope of the speed-time graph is negative in interval 2. As a result, acceleration in this interval is negative. Speed, on the other hand, is a positive quantity because it is a scalar quantity.

The slope of the speed-time graph is 0 at interval 3. As a result, acceleration in this interval is zero.

The particle, on the other hand, acquires a uniform speed here. In this interval, it is positive.

The time-axis is parallel to points A, B, C, and D. As a result, the slope at these places is zero. As a result, the particle's acceleration is zero at sites A, B, C, and D.

23.A three-wheeler starts from rest, accelerates uniformly with 1 m s–2 on a straight road for 10 s, and then moves with uniform velocity. Plot the distance covered by the vehicle during the nth second $(n = 1, 2, 3....)$ versus n. What do you expect this plot to be during accelerated motion: a straight line or a parabola?

Ans: In n, the distance travelled by a body is:

The related points determine the second. As a result, the particle's acceleration is zero at sites A, B, C, and D.

$D_n = \frac{1}{2}(2n - 1)$

Where,

u = Initial velocity

a = Acceleration

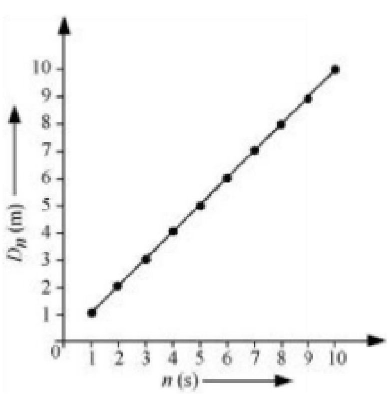
n = Time = $1, 2, 3, \ldots.., n$

In the given case, u = 0 and a = 1 m/s^2

We now get the following table by substituting several values of n in equation (iii):

n	1	2	3	4	5	6	7	8	9	10
D_n	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5

The plot between n and D_n will be a straight line as shown:



The line will be parallel to the time-axis after n = 10 seconds since the three-wheeler gets uniform velocity after 10 seconds.

24. A boy standing on a stationary lift (open from above) throws a ball upwards with the maximum initial speed he can, equal to 49 m/s. How much time does the ball take to return to his hands? 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?

Ans: Initial velocity of the ball, u is 49 m/s

Acceleration is a = – g = – 9.8 m/s2

case1:

The boy throws the ball as the lift is stationary.

Taking the ball's upward motion into account, the ball's final velocity, v, reaches zero at the highest point.

The time of ascent (t) is calculated using the first equation of motion:

$$v = u + at$$

$$t = \frac{v-u}{a} = \frac{-49}{-9.8} = 5s$$

However, the time spent ascending and descending is the same.

As a result, the total time the ball takes to return to the boy's hand is $5 + 5 = 10\ seconds.$

case-2

However, the time for ascension has passed.

The lift was ascending at a constant speed of 5 m/s.

The ball's relative velocity with respect to the youngster remains the same in this scenario, i.e. 49 m/s.

As a result, the ball will return to the boy's hand after 10 seconds in this situation as well.

On a long horizontally moving belt (Fig. 3.26), a child runs to and fro with a speed 9

km h–1 (with respect to the belt) between his father and mother located 50 m apart on

the moving belt. The belt moves with a speed of 4 km h–1

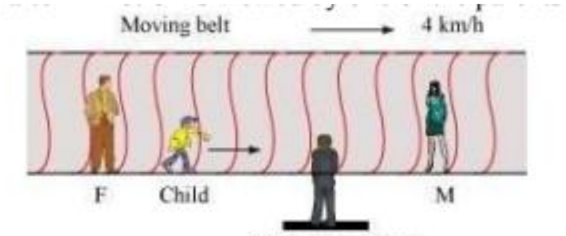
25. For an observer on a stationary platform outside, what is the

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 motion of the belt?

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

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



(Fig: 3.26)

Ans: Speed of the belt, vB = 4 km/h

Speed of the boy, vb = 9 km/h

a) Because the youngster is sprinting in the same direction as the belt's motion, his speed (as measured by the stationary observer) is: $vbB = vb + vB = 9 + 4 = 13\ km/h$

b) Because the youngster is sprinting in the opposite direction of the belt's motion, his speed (as measured by the stationary observer) can be calculated as follows:

$vbB = vb + (-vB) = 9 - 4$ = 5 km/h

c) 50 m between the parents of the kid

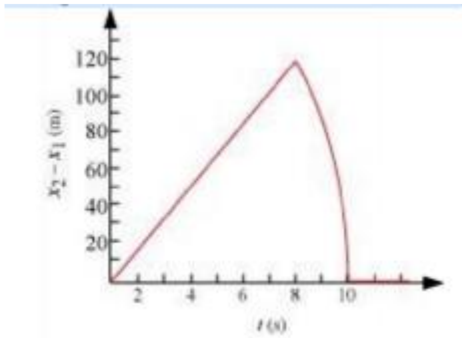
As long as both parents are standing on the moving belt, the child's speed in either direction will remain the same, i.e. 9 $km/h = 2.5\ m/s$.

As a result, the child will take $50/2.5 = 20$ seconds to move near one of his parents.

When one of the parents watches the movie, the answers in (a) and (b) are changed. This is due to the fact that the child and his parents are both standing on the same belt and are thus equally influenced by the belt's motion. As a result, the child's speed remains the same for both parents (regardless of motion direction), i.e. 9 km/h.

As a result, it is reasonable to conclude that the child's time to reach any of his parents has not changed.

26. Two stones are thrown up simultaneously from the edge of a cliff $200\ m$ high with initialspeeds of 15 m/s and 30 m/s. Verify that the graph shown in Fig. 3.27 correctly represents the time variation of the relative position of the second stone with respect to the first. Neglect air resistance and assume that the stones do not rebound after hitting the ground. Take g = 10 $m/s2$. Give the equations for the linear and curved parts of the plot.



Ans:For first stone:

Initial velocity, u = 15 m/s

Acceleration, $a = -g = -10\ m/s2$

Using the relation,$x_{0=}$ut+$\frac{1}{2}at^2$

When this stone hits the ground, x1 = 0

$=-5t^2 + 15t + 200 = 0$

$=t^2 - 3t - 40 = 0$

$= 8t^2 + 5t - 40 = 0$

$= t\ (t - 8) + 5\ (t - 8) = 0$

$t = 8\ s\ or\ t = -5\ s$

The negative sign before time has no meaning because the stone was projected at time t = 0.

$t = 8$ seconds

For second stone:

Initial velocity, uII = 30 m/s

Acceleration, a = –g = – 10 m/s2

Using the relation,

Using the relation,$x_{0=}$ut+$\frac{1}{2}at^2$

When this stone hits the ground, x1 = 0

$=-5t^2 + 15t + 200 = 0$

$=t^2 - 6t - 40 = 0$

$= t\,(t - 10) + 4\,(t - 10) = 0$

$= t = 10\,s \text{ or } t = -4\,s$

Here again, the negative sign is meaningless.

$t = 10\,s$

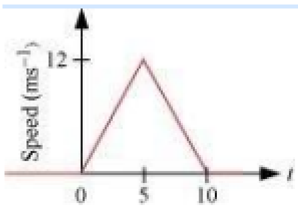
As a result, the equation for a linear and curved path is

$x^2 - x^1 = 15t$ (Linear path)

$x^2 - x^1 = 200 + 30t - 5t$ (Curved path).

27.The speed-time graph of a particle moving along a fixed direction is shown in Fig. 3. 28. Obtain the distance traversed by the particle between $(a)\ t = 0\ s\ to\ 10\ s, (b)\ t = 2\ s\ to\ 6\ s$.

What is the average speed of the particle over the intervals in (a) and (b)?



Ans: Distance travelled by the particle = Area under the given graph

$\frac{1}{2} \times (10 - 0)(12 = 0) = 60$

$Average\ speed\ = \frac{distance}{time} = \frac{60}{10} = 6$

Let s1 and s2 be the distances covered by the particle between time

$t = 2$ s to 5 s and t = 5 s to 6 s respectively.

Total distance (s) covered by the particle in time t = 2 $s\ to\ 6s$

s = s1 + s2 ... (i)

For distance s1:

Let u′ be the velocity of the particle after 2 s and a′ is the acceleration of the particle in t

$= 0\ to\ t = 5\ s.$

Since the particle goes in uniform acceleration in the interval $t = 0\ to\ t = 5\ s$, from first equation of motion, acceleration can be obtained as:

$v = u + at$

We get $v = u + at = 0 + 2.4\,2 = 4.8\,m/s$ from the first equation of motion.

The particle's distance travelled between 2 and 5 seconds, or in 3 seconds.

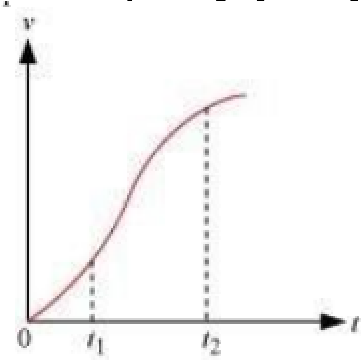
For distance s2:

Let a″ be the acceleration of the particle between time $t = 5\,s$ and $t = 10\,s$. From first equation of motion, v = u + at (where v = 0 as the particle finally comes to rest) $0 = 12 + a'' \times 5$

From equations (i), (ii), and (iii), we get

$s = 25.2 + 10.8 = 36\,m$ 28.

28.The velocity-time graph of a particle in one-dimensional motion is shown in Fig.



28.Which of the following formulae are correct for describing the motion of the particle over the time-interval t2 to t1?

a) x(t2) = x(t1) + v(t1)(t2–t1) + (1/2)a(t2–t1)

b) v(t2)= v(t1) + a(t2–t1)

c) vAverage = (x(t2) – x(t1)) / (t2 – t1)

d) aAverage = (v(t2) – v(t1)) / (t2 – t1)

e) x(t2) = x(t1) + vAverage(t2 – t1) + (1/2)aAverage(t2 – t1)2

f) x(t2) – x(t1) = area under the v–t curve bounded by the t-axis and the dotted line shown.

Ans: (c), (d), and (e) are the correct formulae for characterising the particle's motion (f)

The slope of the graph is not uniform.

As a result, the formulas in (a), (b), and (e) are unable to characterise the particle's velocity.

Only the equations of motion given in (c), (d), and (f) are accurate.

EXAMPLES:

1.A car is moving along a straight line, say OP in Fig. 3. 1. It moves from O to P in 18 s and returns from P to Q in 6. 0 s. What are the average velocity and average speed of the car in going (a) from O to P ? and (b) from O to P and back to Q ?

Ans: Average velocity = $\frac{\text{Displacement}}{time\ taken}$

$\bar{v}=\frac{+\,360\text{ m}}{18\text{ s}} = 20\text{m/s}$

Average speed $= Path\ length\ /\ Time\ interval$

$= \frac{+\,360\text{ m}}{18\text{ s}} = 20$

As a result, the average speed is equal to the average velocity's magnitude in this scenario.

Average velocity = $\frac{\text{Displacement}}{time\ taken}$

$=\frac{240\text{ m}}{18\ +6.0} = 10\text{m/s}$

Average speed $= Path\ length\ /\ Time\ interval = \frac{\text{OP + PQ}}{\text{t}\,\Delta}$

$$= \frac{(\ 360 + 120\text{ m } - 1)}{24\text{ s}} = 20\text{ m/s}$$

As a result, the average speed is not equal to the average velocity's magnitude in this scenario. This occurs when the motion involves a change in direction, resulting in a route length that exceeds the magnitude of displacement.

This demonstrates that speed is generally greater than velocity magnitude.

2 .The position of an object moving along x-axis is given by x = a + bt2 where a = 8. 5 m, b = 2. 5 m s–2 and t is measured in seconds. What is its velocity at t = 0 s and t = 2. 0 s. What is the average velocity between t = 2. 0 s and t = 4. 0 s ?

Ans: The velocity is written in differential calculus notation as

$$\frac{dx}{dt} = \frac{d(\text{a } + \text{bt}^2)}{dt} = 2bt = 5.0\text{ t m/s}$$

At t = 0 s, v = 0 m s–1 and at t = 2.0 s, v = 10 m s-1

Average velocity $=\frac{(4.0\,)\,x-(2.0)x}{4.0\,-2.0} = a + 16b - a - 4b = \ 6.0 \times \ 2.5 \ = 15 \text{ m }/s$

We can see from Fig. 3.7 that the velocity is constant from t =10 to 18 seconds. It is evenly decreasing between periods t =18 s and t = 20 s, and increasing between periods t = 0 s and t = 10 s. It's worth noting that with uniform motion, velocity is equal to the average velocity at all times.

The magnitude of velocity is known as instantaneous speed or simply speed. A speed of 24.0 m s-1 is related with both a velocity of + 24.0 m s−1 and a velocity of – 24.0 m s–1. It's worth noting that, while average speed during a finite period of time is more or equal to the average velocity's magnitude,

3. Obtain equations of motion for constant acceleration using method of calculus.

Ans: By definition, $a = \frac{dv}{dt}$

dv = adt

Integrating both side,

$\int_{vo}^{v} dv = \int_{0}^{t} a\, dt$

$= a\int_{0}^{t} dt$ (a is constant)

$= \boldsymbol{v} - vo = at$

$\boldsymbol{v} = \frac{\boldsymbol{dx}}{\boldsymbol{dt}}$

dx = v dt

Integrating both sides,

$\int_{xo}^{x} dx = \int_{0}^{t} v\, dt$

$x \ = xo + vo\ t + \frac{1}{2}at^2$

$a = \frac{dv}{dt} = \frac{dv}{dx}\frac{dx}{dt} = v\frac{dv}{dx}$

Integrating both sides,

$\int_{v0}^{v} v\, dv = \int_{xo}^{x} adx$

$\frac{\boldsymbol{v-vo^2}}{\boldsymbol{2}} = \text{a} - (\text{x} - \text{xo})\text{s}$

$v^2 = vo^2 + 2(\text{x} - \text{xo})$

This approach has the advantage of being able to handle motions with non-uniform acceleration.

4. A ball is thrown vertically upwards with a velocity of 20 m s–1 from the top of a multistorey building. The height of the point from where the ball is thrown is 25. 0 m from the ground. (a) How high will the ball rise ? and (b) how long will it be before the ball hits the ground? Take g = 10 m s–2 .

Ans:(a) Assume that the y-axis is vertically upward, with zero at the bottom, as shown in Fig. 3.13.

Now , $v_o = +20\, m\ s^{-1}$,

$a = -\ g = -10\, m\ s^{-2}$,

$v = 0\, m\, s^{-1}$

Using the equation 1.3, if the ball rises to a height of y from the point of launch,

$v^2 = {v_o}^2 + 2a(y - y_0)$

$0^2 = 20^2 + 2(-10)(y - y_0)$

Solving, we get, $(y - y_0) = 20\, m$

(b) There are two ways to address this section of the problem. Take careful note of the methods employed.

$0 = 25 + 20\, t + (½)(-10)t^2$

$5t^2 - 20t - 25 = 0$

We find $t = 5s$ by solving this quadratic equation for t.

5: Free-fall : Discuss the motion of an object under free fall. Neglect air resistance.

Ans: Under the effect of gravity, an object that is released near the Earth's surface accelerates downward. The magnitude of gravity's acceleration is indicated by the letter g. The object is considered to be in free fall if air resistance is ignored. If the object's height is tiny in comparison to the radius of the earth, g can be assumed to be constant, equal to 9.8 m s–2. As a result, free fall is a uniformly accelerating motion.

Because we chose upward direction as positive, we assume that the motion is in the y-direction, or more accurately in the –y-direction. Gravitational acceleration is always downward, hence it is in the negative direction, and we have

$a = -\ g = -\ 9.8\, m\, s-2$

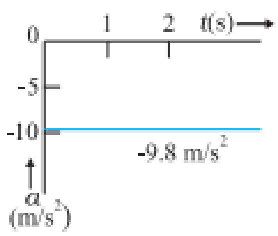
The object is released from rest at $y = 0$. Therefore, $v_0 = 0$ and the equations of motion become

$$v = 0 - g\,t = -9.8\,t\,m\,s^{-1}$$

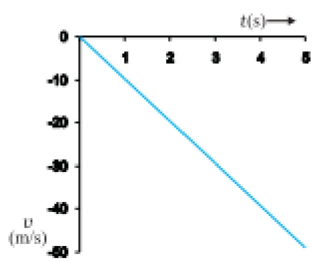
$$y = 0 - ½\,g\,t^2 = -4.9\,t^2\,m$$

$$v^2 = 0 - 2\,gy = -19.6\,y\,m^2\,s^2$$

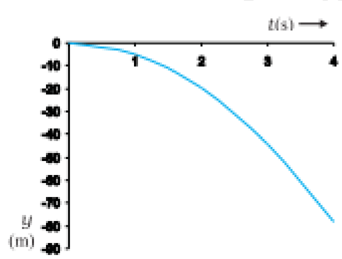
These equations calculate the velocity and distance travelled as a function of time, as well as the velocity fluctuation with distance. In Fig. 3.14(a), (b), and (c), the variation of acceleration, velocity, and distance with time has been plotted (c).



(a)



(b)



6. Galileo's law of odd numbers : "The distances traversed, during equal intervals of time, by a body falling from rest, stand to one another in the same ratio as the odd numbers beginning with unity [namely, 1: 3: 5: 7 ……]." Prove it.

Ans: Let's divide the time interval of motion of an object in free fall into numerous equal periods and calculate the distances travelled at each interval. We have no initial velocity because it is zero.

$$y = \frac{1}{2}gt^2$$

We may use this equation to compute the position of the item at various time intervals, such as $0, 2, 3$, and so on, as shown in the second column of Table 3.2. If we use $(-1/2)\ g^2$as y_0 — the location coordinate after the first time interval — then the third column represents the positions in yo units. The distances travelled in subsequent s are listed in the fourth column. As indicated in the last column, the distances are in the basic ratio $1: 3: 5: 7: 9: 11..$ Galileo Galilei $(1564 - 1642)$, the first to conduct quantitative investigations of free fall, formulated this law.

7. Stopping distance of vehicles : When brakes are applied to a moving vehicle, the distance it travels before stopping is called stopping distance. It is an important factor for road safety and depends on the initial velocity (v_0) and the braking capacity, or deceleration, –a that is caused by the braking. Derive an expression for stopping distance of a vehicle in terms of v_0 and a.

Ans: Let ds be the vehicle's distance travelled before stopping. Then, employing the equation of motion

$v^2 = {v_0}^2 + 2\ ax$ and noting that v = 0, we have the stopping distance.

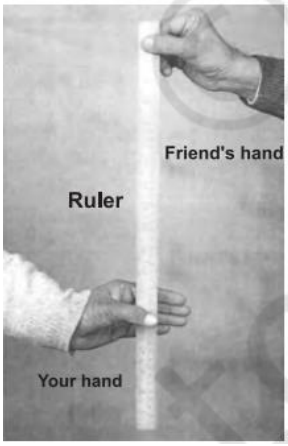
$$d_{s=\frac{-v_0^2}{2a}}$$

As a result, the stopping distance is proportional to the initial velocity squared. The stopping distance is increased by a factor of four when the initial velocity is doubled (for the same deceleration).

The braking distances for a specific make of car were found to be $10\ m, 20\ m, 34\ m, and\ 50\ m$, respectively, corresponding to velocities of $11, 15, 20, and\ 25\ m/s$, which are nearly consistent with the preceding calculation.

When setting speed limits, such as in school zones, stopping distance is an important issue to consider.

8. Reaction time : When a situation demands our immediate action, it takes some time before we really respond. Reaction time is the time a person takes to observe, think and act. For example, if a person is driving and suddenly a boy appears on the road, then the time elapsed before he slams the brakes of the car is the reaction time. Reaction time depends on complexity of the situation and on an individual. You can measure your reaction time by a simple experiment. Take a ruler and ask your friend to drop it vertically through the gap between your thumb and forefinger (Fig. 3.15). After you catch it, find the distance d travelled by the ruler. In a particular case, d was found to be $21.0\ cm$. Estimate reaction time.



Ans: The ruler falls to the ground in free fall.

As a result, $v_0 = 0$ and $a = -9.8\ m\ s^2$. The reaction time t r and the distance travelled d are related by $d = -\frac{1}{2}gt^2$

or, $t = \sqrt{\frac{2d}{g}}\ s$

The reaction time is given by $d = 21.0$ cm and $g = 9.8\ m\ s^2$.

$t_r = \sqrt{\frac{2\times0.21}{9.8}}\ s \cong 0.2s$

9. Two parallel rail tracks run north-south. Train A moves north with a speed of 54 km h –1, and train B moves south with a speed of 90 km h–1. What is the (a) velocity of B with respect to A ?, (b) velocity of ground with respect to B ?, and (c) velocity of a monkey running on the roof of the train A against its motion (with a velocity of 18 km h–1 with respect to the train A) as observed by a man standing on the ground ?

Ans: Make the x-axis positive by moving it from south to north. Then,

$$vA = +54\ km\ h-1 = 15\ m\ s^{-1}$$

$$vB = -\ 90\ km\ h-1 = -\ 25\ ms^{-1}$$

B's relative velocity with regard to $A = vB - vA = -40\ m\ s^{-1}$, implying that the train B seems to move at a speed of 40 $m\ s^{-1}$ from north to south to A.

Ground's relative velocity in relation to

$B = 0 - vB = 25\ m\ s^{-1}$

Let vM be the monkey's velocity relative to the ground in (c).

The monkey's relative velocity in relation to A

$vMA = vM - vA = -18\ km\ h^{-1} = -5\ ms^{-1}$.

Therefore, $vM = (15 - 5)\ m\ s^{-1} = 10\ m\ s^{-1}$.