CHAPTER > 03

Motion in a Straight Line

KEY NOTES

- The study of motion of objects along a straight line is known as **rectilinear motion**.
- The point of intersection of three axes (i.e. X, Y and Z-axes) is called **origin O** and serves as **reference point**.
- If one or more coordinates of an object change with time, we can say that object is in motion. Otherwise, the object is said to be at rest with respect to this frame of reference.

Path Length and Displacement

- Total length of the path traversed by an object during motion is called **distance** or **total path length**. It is a scalar quantity. It cannot be negative or zero.
- The shortest distance between the initial and final positions of any object is called its **displacement**. It is a vector quantity. It can be positive, negative or zero.
- The magnitude of the displacement for a course of motion may be zero but the corresponding path length is not zero.
- If an object moving along the straight line covers equal distances in equal intervals of time, it is said to be in **uniform motion** along a straight line.

Average Velocity and Average Speed

- **Average velocity** is defined as the change in position or displacement Δx divided by the time interval Δt, in which the displacement occurs.

$$\bar{v} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$$

where, x_2 and x_1 are the positions of the object at time t_2 and t_1, respectively.

It can be positive or negative depending upon the sign of the displacement.

The SI unit of velocity is ms^{-1}.

- **Average speed** is defined as the total path length travelled divided by the total time interval during which the motion has taken place.

$$\text{Average speed} = \frac{\text{Total path length}}{\text{Total time interval}}$$

It is always positive.

- If the motion of an object is along a straight line and in the same direction, the magnitude of displacement is equal to the total path length. In that case, the magnitude of average velocity is equal to the average speed.

Instantaneous Velocity and Speed

- **Instantaneous velocity** at any instant is defined as the limit of the average velocity as the time interval Δt becomes infinite-simally small.

In other words,

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

Also, $\frac{dx}{dt}$ is the rate of change of position with respect to time at that instant.

- For uniform motion, velocity is same as the average velocity at all instants.
- **Instantaneous speed** or **simply speed** is the magnitude of velocity.

Acceleration

- **Average acceleration** $\bar{a}$ over a time interval is defined as the change of velocity divided by the time interval.

$$\bar{a} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}$$

where, v_2 and v_1 are the instantaneous velocities at time t_2 and t_1, respectively.

- **Instantaneous acceleration** at an instant is defined as the limit of average acceleration as the time interval Δt becomes infinite-simally small. In other words,

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt} = \frac{d^2s}{dt^2}$$

Kinematics Equations for Uniformly Accelerated Motion

For uniformly accelerated motion, kinematics equations are simple relations that relate displacement s, initial velocity u, final velocity v and acceleration a.

(i) $v = u + at$ (ii) $s = ut + \frac{1}{2}at^2$

(iii) $v^2 = u^2 + 2as$ (iv) $s_n = u + \frac{a}{2}(2n - 1)$

- For constant acceleration, we can write **average velocity** as $\bar{v} = \frac{v + u}{2}$.
- An object released near the surface of earth is accelerated downward under the influence of the force of gravity. The magnitude of acceleration due to gravity is represented by g. If air resistance is neglected, the object is said to be in **free fall**.
- For a freely falling body, the equations of motion are

(i) $v = u + gt$ (ii) $s = ut + \frac{1}{2}gt^2$ (iii) $v^2 - u^2 = 2gh$

- For a body falling freely under the action of gravity, g is taken as negative.
- When a body is just dropped, initial velocity $u = 0$.
- When brakes are applied to a moving vehicle, the distance travelled by it before stopping is called **stopping distance**.

Stopping distance, $d_s = \frac{-v_0^2}{2a}$

where, v_0 = initial velocity and a = deceleration.

- When acceleration of particle is not constant, then motion is called as **non-uniformly accelerated motion**.

For one-dimensional motion, basic equations of velocity and acceleration can be written as

(i) $v = \frac{dx}{dt}$ (ii) $a = \frac{dv}{dt}$

(iii) $ds = vdt$ (iv) and $dv = adt$ or $vdv = adx$

Relative Velocity

- The relative velocity of object A with respect to object B is defined as the time rate of change of relative position of object A with respect to object B.

If two objects A and B are moving with velocities v_A and v_B in one-dimension, then relative velocity of object A with respect to object B is as follows

(i) If both objects are moving in the same direction, then

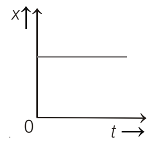
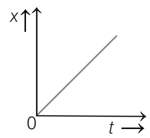
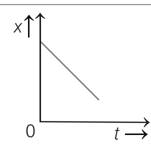
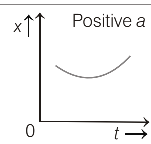
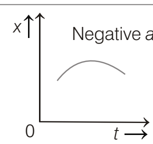
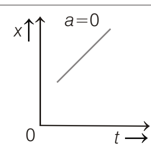
$$v_{AB} = v_A - v_B$$

(ii) If both objects are moving in opposite direction, then

$$v_{AB} = v_A - (-v_B)$$
$$v_{AB} = v_A + v_B$$

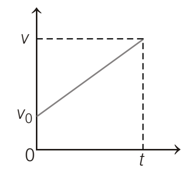
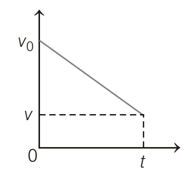
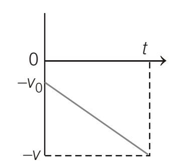
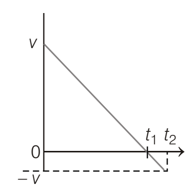
Graphs Related to Motion of an Object in a Straight Line

- Some important graphs related to the motion of an object in a straight line are shown in the table given below.

	Nature of the motion of object	Position-time graph
(i)	Stationary object	
(ii)	An object is in uniform motion with positive velocity	
(iii)	An object is in uniform motion with negative velocity	
(iv)	Motion of an object with positive acceleration	
(v)	Motion of an object with negative acceleration	
(vi)	Motion of an object with zero acceleration	

Important Points related to Position-time Graphs for Motion of an Object in a Straight Line

- A straight line graph has a single slope, if the position-time graph is a straight line as shown in graph (i), then it represents a constant velocity.
- Slope of position-time graph gives **average velocity**.

	Nature of the motion of object	Velocity-time graph
(vii)	Motion in positive direction with positive acceleration	
(viii)	Motion in positive direction with negative acceleration	
(ix)	Motion in negative direction with negative acceleration	
(x)	Motion of an object with negative acceleration that changes direction at time t_1. (Between 0 to t_1, it moves in the + ve x-direction and between t_1 and t_2 it moves in opposite direction.)	

Important Points related to Velocity-time Graphs for Motion of an Object in a Straight Line

- In velocity-time graph, acceleration at an instant is the slope of the tangent to the velocity-time curve at that instant.
- In velocity-time graph, area under the velocity-time curve represents the displacement over a given time interval.

Mastering NCERT

MULTIPLE CHOICE QUESTIONS

TOPIC 1 ~ *Position, Distance and Displacement*

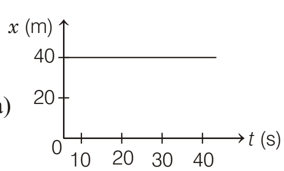
1 For a car moving on the road it will be considered to be at rest with respect to the
(a) frame of reference attached to the ground
(b) frame of reference attached to a person sitting inside the car
(c) frame of reference attached to a person outside the car
(d) None of the above

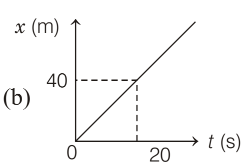
2 The coordinates of object with respect to a frame of reference at $t = 0$ s are $(-1, 0, 3)$. If at $t = 5$ s, its coordinates are $(-1, 0, 4)$, then the object is in
(a) motion along Z-axis
(b) motion along X-axis
(c) motion along Y-axis
(d) rest position between $t = 0$ s and $t = 5$ s

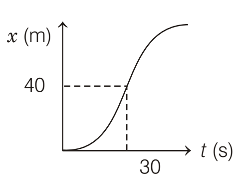
3 The displacement of a car is given as -240 m. Here, negative sign indicates
(a) direction of displacement
(b) negative path length
(c) position of car at that point
(d) no significance of negative sign

4 Snehit starts from his home and walks 50 m towards north, then he turns towards east and walks 40 m and then reaches his school after moving 20 m towards south. Then his displacement from his home to school is
(a) 50 m (b) 110 m
(c) 80 m (d) 40 m

5 For a stationary object at $x = 40$ m, the position-time graph is

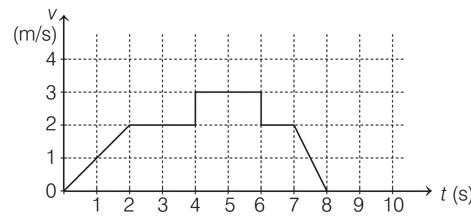
(a)


(b)


(c)


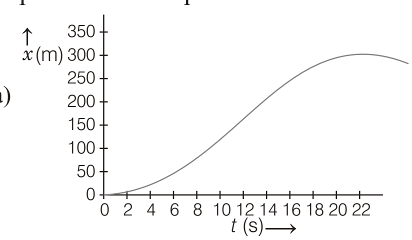
(d) None of these

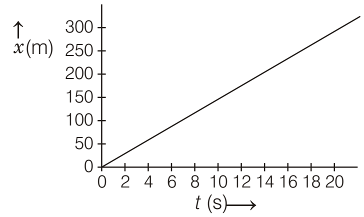
6 A particle starts from the origin at time $t = 0$ and moves along the positive X-axis. The graph of velocity with respect to time is shown in figure. What is the position of the particle at time $t = 5$ s? ***JEE Main 2019***

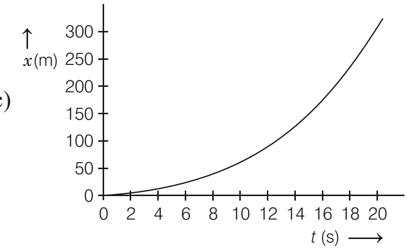


(a) 6 m (b) 3 m (c) 10 m (d) 9 m

7 A car starts from rest at time $t = 0$ s from the origin O and picks up speed till $t = 10$ s and thereafter moves with uniform speed till $t = 18$ s. The brakes are applied and the car stops at $t = 20$ s and $x = 296$ m. The position-time graph which best represents the above situation is

(a)


(b)


(c)


(d) None of the above

TOPIC 2 ~ *Speed, Velocity and Acceleration*

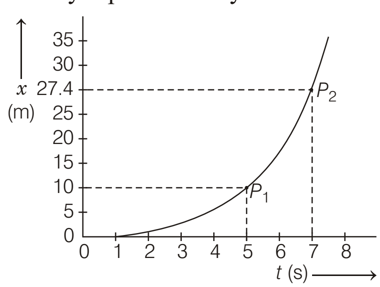
8 The sign (+ ve or − ve) of the average velocity depends only upon
(a) the sign of displacement
(b) the initial position of the object
(c) the final position of the object
(d) None of the above

9 Find the average velocity when a particle complete the circle of radius 1m in 10 s. ***JIPMER 2019***
(a) 2 m/s (b) 3.14 m/s (c) 6.28 m/s (d) zero

10 A cyclist is moving on a circular track of radius 40 m completes half a revolution in 40 s. Its average velocity is
(a) zero (b) $2\ ms^{-1}$ (c) $4\pi\ ms^{-1}$ (d) $8\pi\ ms^{-1}$

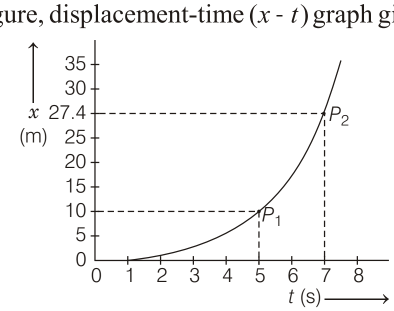
11 The position of a particle as a function of time t, is given by $x(t) = at + bt^2 - ct^3$, where a, b and c are constants. When the particle attains zero acceleration, then its velocity will be ***JEE Main 2019***
(a) $a + \frac{b^2}{2c}$ (b) $a + \frac{b^2}{4c}$ (c) $a + \frac{b^2}{3c}$ (d) $a + \frac{b^2}{c}$

12 In the following graph, average velocity is geometrically represented by



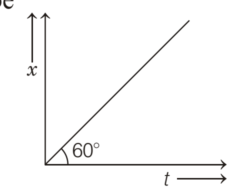
(a) length of the line $P_1 P_2$
(b) slope of the straight line $P_1 P_2$
(c) slope of the tangent to the curve at P_1
(d) slope of the tangent to the curve at P_2

13 In figure, displacement-time (x - t) graph given below,



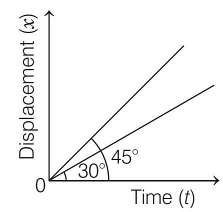
the average velocity between time $t = 5$ s and $t = 7$ s is
(a) $8\ ms^{-1}$ (b) $8.7\ ms^{-1}$
(c) $7.8\ ms^{-1}$ (d) $13.7\ ms^{-1}$

14 From the given x-t graph, the average velocity of the object will be

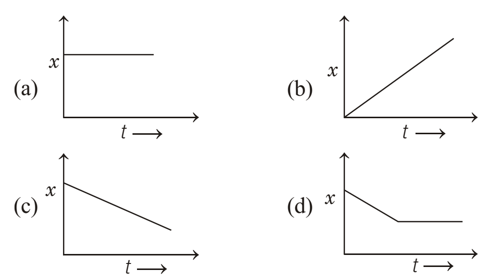


(a) $0.5\ ms^{-1}$ (b) $\sqrt{3}\ ms^{-1}$
(c) Data insufficient (d) $\sqrt{3}/2\ ms^{-1}$

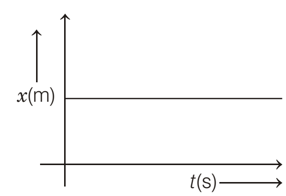
15 The displacement-time graph of two moving particles make angles of 30° and 45° with the X-axis. The ratio of their velocities is
(a) $1:\sqrt{3}$ (b) $1:2$
(c) $1:1$ (d) $\sqrt{3}:2$

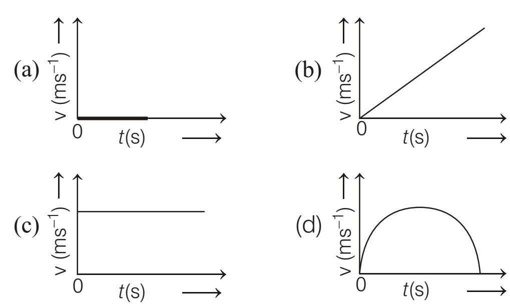


16 Which of the following graphs shows the motion of an object with positive velocity?

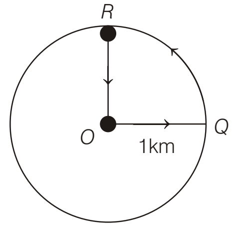


17 For the x-t graph given below, the v - t graph is shown correctly in





18 A runner starts from O and comes back to O following path $OQRO$ in 1h. What is net displacement and average speed?

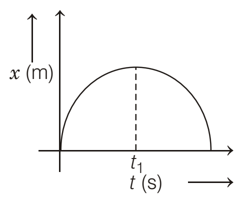


(a) 0,3.57 km/h
(b) 0,0 km/h
(c) 0,2.57 km/h
(d) 0,1 km/h

19 A car is moving on a straight road from A to B for first one-fourth distance with speed 40 m/s and the next half with speed 80 m/s and the last one-fourth with speed 120 m/s. Then, the average speed of the car will be

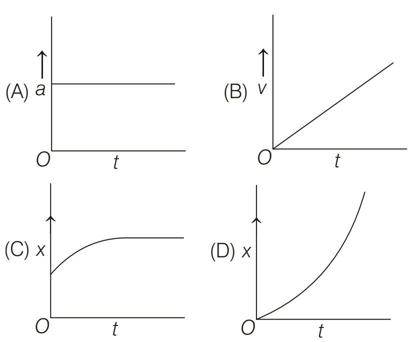
(a) 49.26 m/s (b) 90.46 m/s
(c) 68.57 m/s (d) 54.26 m/s

20 A car moves along a straight line according to the *x-t* graph given alongside. The instantaneous velocity of the car at $t = t_1$ is



(a) zero
(b) positive
(c) Data insufficient
(d) Cannot be determined

21 A particle starts from origin O from rest and moves with a uniform acceleration along the positive X-axis. Identify all figures that correctly represent the motion qualitatively. (a = acceleration, v = velocity, x = displacement, t = time) ***JEE Main 2019***



(a) (A) (b) (A), (B), (C)
(c) (B), (C) (d) (A), (B), (D)

22 If an object is moving in a straight line, then

(a) the directional aspect of vector can be specified by + ve and − ve signs
(b) instantaneous speed at an instant is equal to the magnitude of the instantaneous velocity at that instant
(c) Both (a) and (b)
(d) Neither (a) nor (b)

23 A particle moves in a straight line. It can be accelerated,

(a) only if its speed changes by keeping its direction same
(b) only if its direction changes by keeping its speed same
(c) Either by changing its speed or direction
(d) None of the above

24 Speeds of a particle at 3rd and 8th seconds are 20 m/s and 0 m/s respectively, then average acceleration between 3rd and 8th seconds will be ***JIPMER 2019***

(a) $3\ m/s^2$ (b) $4\ m/s^2$ (c) $5\ m/s^2$ (d) $6\ m/s^2$

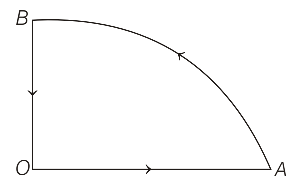
25 The slope of the straight line connecting the points corresponding to (v_2, t_2) and (v_1, t_1) on a plot of velocity *versus* time gives

(a) average velocity (b) average acceleration
(c) instantaneous velocity (d) None of these

26 A car starts from rest, attains a velocity of 18 kmh^{-1} with an acceleration of 0.5 ms^{-2}, travels 4 km with this uniform velocity and then comes to halt with a uniform deceleration of 0.2 ms^{-2}. The total time of travel of the car is

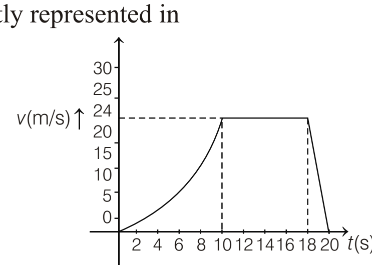
(a) 853 s (b) 800 s (c) 855 s (d) 835 s

27 An object is moving along the path $OABO$ with constant speed, then ***JEE Main 2013***

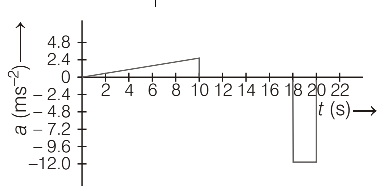


(a) the acceleration of the object while moving along to path $OABO$ is zero
(b) the acceleration of the object along the path OA and BO is zero
(c) there must be some acceleration along the path AB
(d) Both (b) and (c)

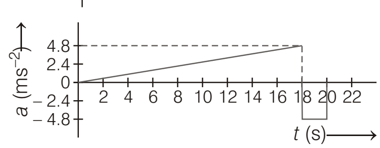
28 The resulting *a-t* graph for the given *v-t* graph is correctly represented in

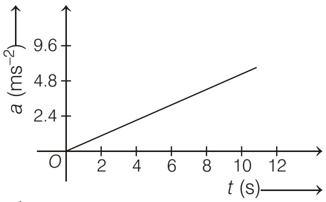


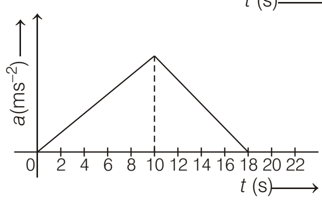
(a)



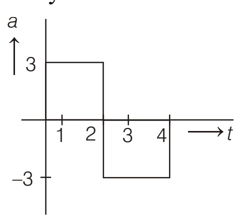
(b)

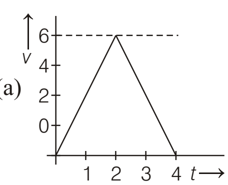


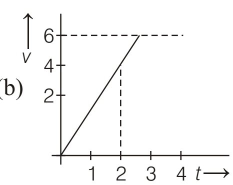
(c)


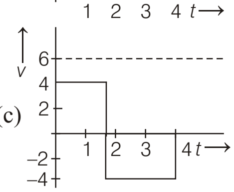
(d)


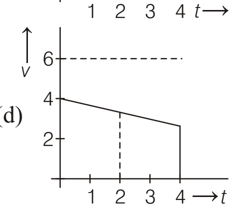
29 A particle starts from rest at $t = 0$ s and undergoes an acceleration a in ms^{-2} with time t in seconds which is shown in figure. Which one of the following plot represents velocity v in ms^{-1} *versus* time t in second?



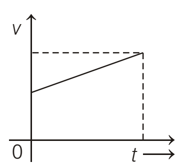
(a)


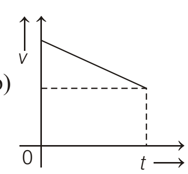
(b)


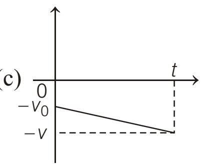
(c)


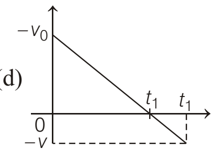
(d)


30 An object is moving in a positive direction with a positive acceleration. The velocity-time graph with constant acceleration, which represents the above situation is

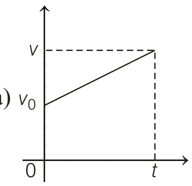
(a)


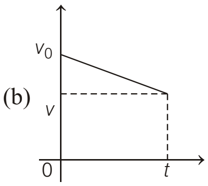
(b)


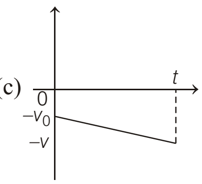
(c)


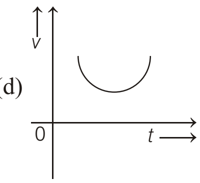
(d)


31 The velocity-time graph for motion of an object moving in positive direction with a constant and negative acceleration is

(a)


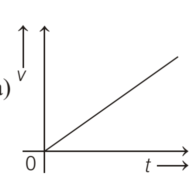
(b)


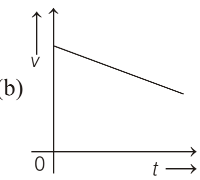
(c)


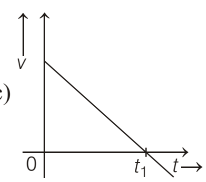
(d)


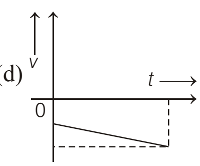
32 An object is moving in negative direction with a negative acceleration.

The velocity-time graph with constant acceleration which represents the above situation is

(a)


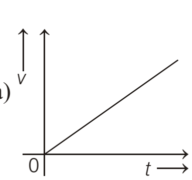
(b)


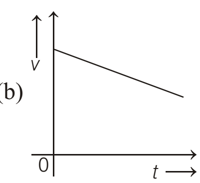
(c)


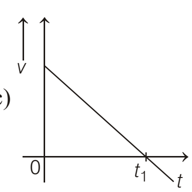
(d)


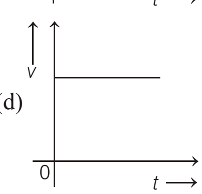
33 An object is moving in positive direction till time t_1 and then turns back with the same negative acceleration.

The velocity-time graph which best describes the situation is

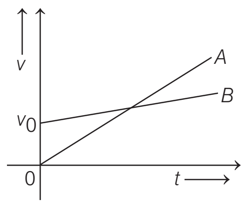
(a)


(b)


(c)


(d)


34 Two cars A and B are moving along straight line with constant acceleration as shown in the velocity-time graph.

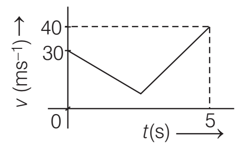


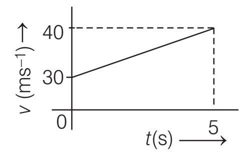
The correct relation between their accelerations is

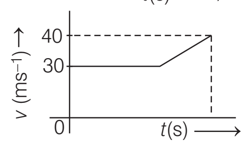
(a) $a_A > a_B$ (b) $a_A < a_B$

(c) $a_A = a_B$ (d) $a_A = a_B / 2$

35 An object is moving with an initial velocity of 30 ms^{-1} with uniform acceleration. The velocity of object correctly increases to 40 ms^{-1} in next 5 s. The v-t graph which represents this situation is

(a)


(b)


(c)


(d) None of the above

TOPIC 3 ~ *Kinematic Equations for Uniformly Accelerated Motion*

36 The kinematic equations of rectilinear motion for constant acceleration for a general situation, where the position coordinate at $t = 0$ is non-zero, say x_0 is

(a) $v = v_0 + at$ (b) $x = x_0 + v_0 t + \frac{1}{2} at^2$

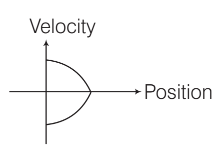
(c) $v^2 = v_0^2 + 2a(x - x_0)$ (d) All of these

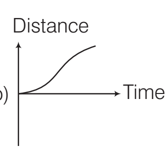
37 A car is moving with a velocity of 30 ms^{-1}. On applying the brakes, the velocity decreases to 15 ms^{-1} in 2 s. The acceleration of the car is

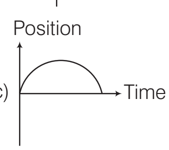
(a) $+ 7.5\ ms^{-2}$ (b) $- 7.7\ ms^{-2}$

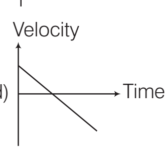
(c) $- 7.5\ ms^{-2}$ (d) $+ 15\ ms^{-2}$

38 All the graphs below are intended to represent the same motion. One of them does it incorrectly. Pick it up. ***JEE Main 2018***

(a)


(b)


(c)


(d)


39 An object starts from rest and moves with uniform acceleration a. The final velocity of the particle in terms of the distance x covered by it is given as

(a) $\sqrt{2ax}$ (b) $2ax$

(c) $\sqrt{\frac{ax}{2}}$ (d) $\sqrt{ax}$

40 A particle is situated at $x = 3$ units at $t = 0$. It starts moving from rest with a constant acceleration of 4 ms^{-2}. The position of the particle at $t = 3$ s is

(a) $x = +21$ units (b) $x = +18$ units

(c) $x = -21$ units (d) None of these

41 A toy car with charge q moves on a frictionless horizontal plane surface under the influence of a uniform electric field **E**. Due to the force q**E**, its velocity increases from 0 to 6 m/s in one second duration. At that instant, the direction of the field is reversed. The car continues to move for two more seconds under the influence of this field. The average velocity and the average speed of the toy car between 0 to 3 s are respectively ***NEET 2018***

(a) 1 ms^{-1}, 3.5 ms^{-1} (b) 1 ms^{-1}, 3 ms^{-1}

(c) 2 ms^{-1}, 4 ms^{-1} (d) 1.5 ms^{-1}, 3 ms^{-1}

42 A body sliding on a smooth inclined plane requires 6 s to reach the bottom, starting from rest at the top. How much time does it take to cover one-ninth (1/9) the distance starting from rest at the top?

(a) (1/54) s (b) 2 s (c) (9/6) s (d) 4 s

43 The velocity of a particle at an instant is 15 ms^{-1}. After 5s, its velocity will become 25 ms^{-1}. The velocity at 4s, before the given instant will be

(a) 23 ms^{-1} (b) 7 ms^{-1} (c) 25 ms^{-1} (d) 15 ms^{-1}

44 A body covers a distance of 6 m in 3rd second and 12 m in 6th second, if the motion is uniformly accelerated. How far will it travel in the next 3 s?

(a) 46 cm (b) 48 cm (c) 84 cm (d) 132 cm

45 When a body is falling freely and air resistance is neglected, then on the basis of which assumption the value of g can be taken to be constant?

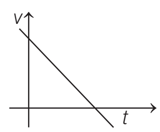
(a) The height through which the object falls is small compared to Earth's radius

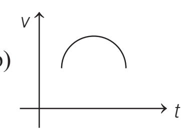
(b) The height through which the object falls is large compared to Earth's radius

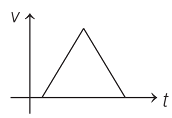
(c) The object is situated far from the Earth's surface

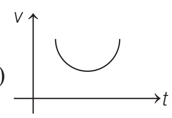
(d) None of the above

46 A particle is thrown upwards, then correct v-t graph will be ***NEET 2017***

(a) 

(b) 

(c) 

(d) 

47 The object is released from rest under gravity at $y=0$. The equation of motion which correctly expresses the above situation is

(a) $v=-9.8\,t\ \text{ms}^{-1}$ (b) $y=-4.9\,t^2$ m

(c) $v^2=-19.6\,y\ \text{m}^2\text{s}^{-2}$ (d) All of these

48 A ball is thrown vertically upwards with a velocity of $10\ \text{m s}^{-1}$ from a building of height 100 m. The maximum height attained by the ball above the ground is (use $g=10\ \text{ms}^{-2}$)

(a) 105 m (b) 110 m (c) 10 m (d) 5 m

49 From a tower of height H, a particle is thrown vertically upwards with a speed u. The time taken by the particle to hit the ground is n times the time taken by it to reach the highest point of its path. The relation between H, u and n is

(a) $2gH=n^2u^2$ (b) $gH=(n-2)^2u^2$

(c) $2gH=nu^2(n-2)$ (d) $gH=(n-2)^2u^2$

50 A man is standing on the top of a building 100 m high. He throws two stones vertically, one at $t=0$ and other after a time interval (less than 2 s). The later stone is thrown at a velocity of half the first. The vertical gap between first and second stone is 15 m at $t=2$ s. The gap is found to remain constant. The velocities with which the stones were thrown are (take $g=10\ \text{ms}^{-2}$)

(a) $20\ \text{ms}^{-1}$, $10\ \text{ms}^{-1}$ (b) $10\ \text{ms}^{-1}$, $5\ \text{ms}^{-1}$

(c) $16\ \text{ms}^{-1}$, $8\ \text{ms}^{-1}$ (d) $30\ \text{ms}^{-1}$, $15\ \text{ms}^{-1}$

51 A stone is dropped from the top of a tall cliff and n seconds later another stone is thrown vertically downwards with a velocity u. Then, the second stone overtakes the first, below the top of the cliff at a distance given by

(a) $\frac{g}{2}\left[\frac{n\left(u-\frac{gn}{2}\right)}{(u-gn)}\right]^2$ (b) $\frac{g}{2}\left[\frac{n\left(\frac{u}{2}-gn\right)}{(u-gn)}\right]^2$

(c) $\frac{g}{2}\left[\frac{n\left(\frac{u}{2}-gn\right)}{\left(\frac{u}{2}-gn\right)}\right]^2$ (d) $\frac{g}{2}\left[\frac{(u-gn)}{\left(\frac{u}{2}-gn\right)}\right]^2$

52 A stone falls freely under gravity. It covers distance h_1, h_2 and h_3 in the first 5 s, the next 5 s and the next 5 s, respectively. The relation between h_1, h_2 and h_3 is ***NEET 2013***

(a) $h_1=2h_2=3h_3$ (b) $h_1=\frac{h_2}{3}=\frac{h_3}{5}$

(c) $h_2=3h_1$ and $h_3=3h_2$ (d) $h_1=h_2=h_3$

53 The table below shows the motion of an object under free fall. The position of the object after different time intervals of 0, τ, 2τ and 3τ, are given in the second column. With the reference to this table, the missing entries A and B are

t	y	y in terms of y_0 $[=(-1/2)\ g\tau^2]$	Distance traversed in successive intervals	Ratio of distances traversed
0	0	0		
τ	$-(1/2)\,g\,\tau^2$	y_0	y_0	1
2τ	$-4\,(1/2)\,g\,\tau^2$	$4\,y_0$	$3\,y_0$	3
3τ	$-9\,(1/2)\,g\,\tau^2$	A	$5\,y_0$	5
4τ	$-16(1/2)\,g\,\tau^2$	$16\,y_0$	$7\,y_0$	7
5τ	$-25\,(1/2)\,g\,\tau^2$	$25\,y_0$	$9\,y_0$	9
6τ	$-36\,(1/2)\,g\,\tau^2$	$36\,y_0$	B	11

(a) $A\rightarrow 9y_0$; $B\rightarrow 11y_0$

(b) $A\rightarrow 11\,y_0$; $B\rightarrow 9\,y_0$

(c) $A\rightarrow\frac{9\,y_0}{2}$; $B\rightarrow 11\,y_0$

(d) $A\rightarrow 9y_0$; $B\rightarrow\frac{11\,y_0}{2}$

54 Two persons A and B conduct an experiment to measure reaction time of A. B drops a ruler vertically through the gap between A's thumb and fore finger. After A catches it, the distance d travelled by the ruler is $d = 21.0$ cm. The reaction time for this particular case is

(a) 0.2 s (b) 0.3 s
(c) 0.4 s (d) 0.1 s

55 A car is moving with a constant acceleration of 4 ms^{-2}. On seeing a person infront of it, the driver suddenly applies brake. If the car is moving with a velocity of 20 ms^{-1} at the moment when driver sees the person and the reaction time of the driver is 2 s, then the distance it travels after the moment he sees the person and just before applying the brake is

(a) 48 m (b) 40 m (c) 8 m (d) 45 m

TOPIC 4 ~ *Kinematic Equations for Non-Uniformly Accelerated Motion*

56 The displacement of a particle is given by $x(t) = (t-2)^2$, where x is in metres and t in seconds. The distance covered by the particle in first 4 s is

(a) 8 m (b) 4 m (c) 12 m (d) 16 m

57 The motion of a particle along a straight line is described by equation, $x = 8 + 12t - t^3$, where x is in metre and t in second. The retardation of the particle, when its velocity becomes zero, is ***CBSE AIPMT 2012***

(a) 24 ms^{-2} (b) zero (c) 6 ms^{-2} (d) 12 ms^{-2}

58 If the velocity of a particle is $v = At + Bt^2$, where A and B are constants, then the distance travelled by it between 1s and 2 s is ***NEET 2016***

(a) $3A + 7B$ (b) $\frac{3}{2}A + \frac{7}{3}B$
(c) $\frac{A}{2} + \frac{B}{3}$ (d) $\frac{3}{2}A + 4B$

59 The velocity of a particle is given by the expression

$$v(x) = 3x^2 - 4x$$

where, x is distance covered by the particle. The expression for acceleration is

(a) $(3x^2 - 4x)(6x - 4)$ (b) $6(3x^2 - 4x)$
(c) $(6x - 4)^2$ (d) $(3x^2 - 4x)6x$

60 A particle of unit mass undergoes one-dimensional motion such that its velocity varies according to $v(x) = \beta x^{-2n}$, where β and n are constants and x is the position of the particle. The acceleration of the particle as a function of x is given by ***CBSE AIPMT 2016***

(a) $-2n\beta^2 x^{-2n-1}$ (b) $-2n\beta^2 x^{-4n-1}$
(c) $-2\beta^2 x^{-2n+1}$ (d) $-2n\beta^2 e^{-4n+1}$

61 Velocity is given by $v = 4t(1-2t)$, then find time at which velocity is maximum. ***JIPMER 2018***

(a) 0.25 s (b) 1 s
(c) 0.45 s (d) 4 s

62 The relation between time and distance is $t = \alpha x^2 + \beta x$, where α and β are constants. The retardation is

(a) $2\alpha v^3$ (b) $2\beta v^3$ (c) $2\alpha\beta v^3$ (d) $2\beta^2 v^3$

63 The displacement x of a particle varies with time t, $x = ae^{-pt} + be^{qt}$, where a, b, p and q are positive constants. The velocity of the particle will ***JEE 2016***

(a) go on increasing with time
(b) be independent of p and q
(c) drop to zero when $p = q$
(d) go on decreasing with time

TOPIC 5 ~ *Relative Velocity in One-dimension*

64 Consider two objects A and B moving uniformly with average velocities v_A and v_B in one dimension, along X-axis. If $x_A(0)$ and $x_B(0)$ are positions of objects A and B, respectively at time $t = 0$, the displacement from object A to object B is given by ***JEE Main 2014***

(a) $x_{BA}(t) = x_B(t) - x_A(t)$
(b) $x_{AB}(t) = x_B(t) - x_A(t)$
(c) $x_{BA}(t) = [x_B(0) - x_A(0)] + (v_B - v_A)t$
(d) Both (a) and (c)

65 Consider the relation for relative velocities between two objects A and B, $v_{BA} = -v_{AB}$

The above equation is valid, if

(a) v_A and v_B are average velocities
(b) v_A and v_B are instantaneous velocities
(c) v_A and v_B are average speed
(d) Both (a) and (b)

66 The relative velocity v_{BA} or v_{AB} is zero for two particles moving along *X*-axis uniformly. The position-time graph for this situation will be

(a) straight lines parallel but inclined to time axis
(b) straight lines parallel and also parallel to time axis
(c) straight lines intersecting each other at some point
(d) curves and not straight lines

67 The average velocities of the objects *A* and *B* are v_A and v_B respectively. The velocities are related such that $v_A > v_B$..
Which of the following options is true for this situation?

(a) v_{AB} is positive and object *A* overtakes object *B* after some time
(b) v_{BA} is positive and object *A* overtakes object *B* after some time
(c) The *x*-*t* graph for the situation is such that one graph is steeper than the other and they meet at a common point
(d) Both (a) and (c)

68 A passenger train of length 60 m travels at a speed of 80 km/h. Another freight train of length 120 m travels at a speed of 30 km/h. The ratio of times taken by the passenger train to completely cross the freight train when : (i) they are moving in the same direction and (ii) in the opposite direction is

JEE Main 2019

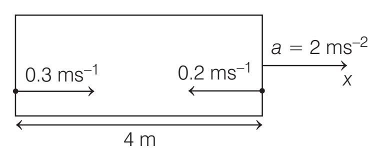
(a) $\frac{3}{2}$ (b) $\frac{25}{11}$ (c) $\frac{11}{5}$ (d) $\frac{5}{2}$

69 A person is moving with a velocity of 10 m s^{-1} towards north. A car moving with a velocity of 20 ms^{-1} towards south crosses the person. The velocity of car relative to the person is

(a) -30 ms^{-1}
(b) $+20 \text{ms}^{-1}$
(c) 10 ms^{-1}
(d) -10 ms^{-1}

70 A rocket is moving in a gravity free space with a constant acceleration of 2 ms^{-2} along $+x$-direction (see figure). The length of a chamber inside the rocket is 4 m. A ball is thrown from the left end of the chamber in $+x$-direction with a speed of 0.3 ms^{-1} relative to the rocket. At the same time, another ball is thrown in $-x$-direction with a speed of 0.2 ms^{-1} from its right end relative to the rocket. The time in seconds when the two balls hit each other is

CBSE AIPMT 2013



(a) 6 s (b) 7 s
(c) 2 s (d) 9 s

SPECIAL TYPES QUESTIONS

I. Assertion and Reason

■ **Direction** (Q. Nos. 71-78) *In the following questions, a statement of Assertion is followed by a corresponding statement of Reason. Of the following statements, choose the correct one.*

(a) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) Both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.
(c) Assertion is correct but Reason is incorrect.
(d) Assertion is incorrect but Reason is correct.

71 **Assertion** In real-life, in a number of situations, the object is treated as a point object.
Reason An object is treated as point object as far as its size is much smaller than the distance it moves in a reasonable duration of time.

72 **Assertion** For motion along a straight line and in the same direction, the magnitude of average velocity is equal to the average speed.

Reason For motion along a straight line and in the same direction, the magnitude of displacement is equal to the path length.

73 **Assertion** For uniform motion, velocity is the same as the average velocity at all instants.
Reason In uniform motion along a straight line, the object covers equal distances in equal intervals of time.

74 **Assertion** In realistic situation, the *x*-*t*, *v*-*t* and *a*-*t* graphs will be smooth.
Reason Physically acceleration and velocity cannot change values abruptly at an instant.

75 **Assertion** A body cannot be accelerated, when it is moving uniformly.

Reason When direction of motion of the body changes, then body may have acceleration.

76 **Assertion** A body is momentarily at rest at the instant, if it reverse the direction.

Reason A body cannot have acceleration, if its velocity is zero at a given instant of time. ***AIIMS 2018***

77 **Assertion** For a body falling freely under the action of gravity, g is taken as negative.

Reason For a body thrown vertically upward, g is taken as negative.

78 **Assertion** When the objects A and B move in the same direction, then relative velocity of object A w.r.t. object B is $v_{AB} = v_A - v_B$.

Reason When the objects A and B move in opposite direction, then relative velocity of object B w.r.t. object A is $v_{BA} = v_B - v_A$.

II. Statement Based Questions

79 Even when we are sleeping, air moves into and out of our lungs and blood flow in arteries and veins. With reference to the above statement, which of the following statement(s) is/are correct?

I. This means, even while sleeping, human beings are in motion.
II. Air flowing in and out of our lungs is in motion.
III. Blood flowing in arteries and veins are in motion.

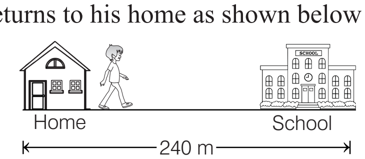
(a) Only I (b) Only II
(c) Both II and III (d) Both I and II

80 An object is located at any point O at $t = 0$ s. From $t = 0$ s to $t = 5$ s, it continuously changes its position and reaches point P. In the next 5 s, it does not change its position. For the above situation, which of the following statement is/are correct?

I. The object is in motion from point O to point P.
II. The object is at rest from $t = 5$ s to $t = 10$ s.
III. The object is in motion from $t = 0$ s to $t = 10$ s.

(a) Only I (b) Only II
(c) Both I and III (d) Both I and II

81 If Rahul starting from his home, goes to school and then returns to his home as shown below



Then, study the following statements.

I. Final position coincides with the initial position.
II. Magnitude of the displacement for the course of his motion is zero and corresponding path length is 480 m.

Which of the following statement(s) is/are correct?

(a) Only I (b) Only II
(c) Both I and II (d) Neither I nor II

82 Two initial and final positions of Ragubhir on Y-axis, respectively are as

(i) –4 m, 8 m (ii) 8 m, –4 m

Then,

I. his displacement is negative in case (i) but positive in case (ii)
II. his displacement in both the cases (i) and (ii) is zero.
III. his displacement is positive in case (i) and negative in case (ii).

Which of these statement (s) is/are correct?

(a) Only I (b) Only II
(c) Only III (d) All of these

83 Study the following statements.

I. The unit of average speed is same as that of velocity.
II. If one or more coordinates of an object changes with time, we say that the object is at rest with respect to the given reference frame.

Which of the following statement(s) is/are correct?

(a) Only I (b) Only II
(c) Both I and II (d) Neither I nor II

84 With reference to the concept of stopping distance, which of the following statement(s) is/are incorrect?

I. The stopping distance is inversely proportional to the square of the initial velocity.
II. Doubling the initial velocity increases the stopping distance by a factor of 4 (for the same deceleration).
III. Stopping distance is an important factor considered in setting speed limits.

(a) Only I (b) Only II
(c) Only III (d) Both I and III

85 The average velocities of the objects A and B are v_A and v_B, respectively. If v_A and v_B are of opposite signs, then which of the following statement below is incorrect?

I. The two objects will never meet.
II. The magnitude of v_{BA} or v_{AB} is greater than the magnitude of velocity of A or that of B.
III. If the objects under consideration are two trains, then for a person sitting in either of the two, the other train seems to be at rest.

(a) Only III (b) Only II
(c) Only I (d) Both I and II

86 Which of the following statement is incorrect?

(a) Distance cannot be negative or zero.
(b) Displacement can be positive, negative or zero.
(c) Average speed is always positive.
(d) Path length is a vector quantity whereas displacement is scalar quantity.

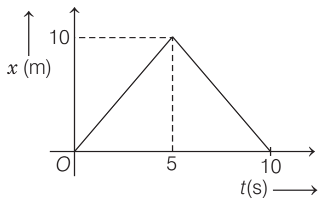
87 Which of the following statement is correct?

(a) The magnitude of average velocity is the average speed.
(b) Average velocity is the displacement divided by time interval.
(c) When acceleration of particle is constant, then motion is called as non-uniformly accelerated motion.
(d) When a particle returns to its starting point its displacement is not zero.

88 Which of the following statement is correct?

(a) Stopping distance is directly proportional to deceleration a of the vehicle.
(b) If two objects A and B are moving with velocities v_A and v_B in one dimension, then relative velocity of object A with respect to object B is given by $v_{AB} = v_A - v_B$.
(c) For constant acceleration, average velocity is $\bar{v} = \dfrac{v - u}{2}$.
(d) For a body thrown vertically upwards, then acceleration due to gravity will be taken as positive.

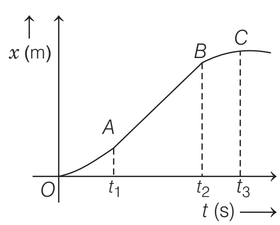
89 The x-t graph for motion of a car is given below.



With reference to the graph, which of the given option(s) is/are incorrect?

(a) The instantaneous speed during the interval $t = 5$ s to $t = 10$ s is negative at all time instants during the interval.
(b) The velocity and the average velocity for the interval $t = 0$ s to $t = 5$ s are equal and positive.
(c) The car changes its direction of motion at $t = 5$ s.
(d) The instantaneous speed and the instantaneous velocity are positive at all time instants during the interval $t = 0$ s to $t = 5$ s.

90 A car starts from rest from origin O and continues to move till point C as shown in the graph. Select the correct statement about the motion of car as shown in the graph.



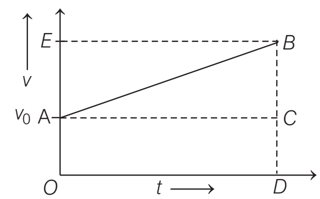
(a) Part AB represents uniform motion
(b) At instant time $t = t_2$, brakes must have been applied
(c) The car stops at $t = t_3$
(d) All of the above

91 The displacement of an object in given time interval t can be expressed as $x = \bar{v}t$, where $\bar{v} = \dfrac{v + v_0}{2}$.

With reference to the above expression, which of the given statement(s) is/are correct?

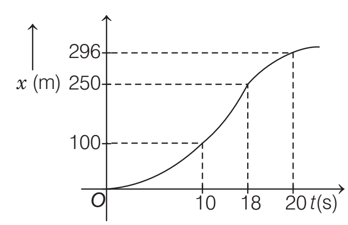
(a) This means that the object has undergone displacement x with an average velocity equal to the arithmetic average of the initial and final velocities.
(b) This means that the object has undergone displacement x with an instantaneous velocity equal to arithmetic average of the initial and final velocities.
(c) Either (a) or (b)
(d) None of the above

92 Given below is a velocity-time graph. With reference to the graph, which of the following statement is correct?



(a) The area under the given curve is $\dfrac{1}{2}(v + v_0)t - v_0 t$.
(b) The area under the given curve is $\dfrac{1}{2}(v + v_0)t + v_0 t$.
(c) The displacement of the object in terms of v_0 and a is $x = v_0 t + \dfrac{1}{2}at^2$.
(d) The relation $x = v_0 t + \dfrac{1}{2}at^2$ is same as $x = \left(\dfrac{v - v_0}{2}\right)t$.

93 For motion of the car between $t = 18$ s and $t = 20$ s, which of the given statement is correct?



(a) The car is moving in a positive direction with a positive acceleration.
(b) The car is moving in a negative direction with a positive acceleration.
(c) The car is moving in positive direction with a negative acceleration.
(d) The car is moving in negative direction with a negative acceleration.

94 Two particles A and B are moving in a straight line with the same speed. Which of the following statement(s) is/are correct for the relative motion of the two particles?

(a) The relative velocity v_{AB} or v_{BA} is zero, only if they are moving in the same direction.

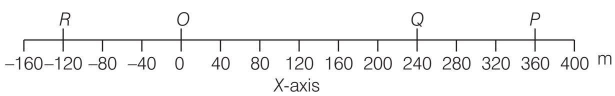
(b) If the particles are moving in opposite direction, the magnitude of v_{BA} or v_{AB} is twice than the magnitude of velocity of A or that of B.

(c) The relative velocity v_{AB} or v_{BA} is always zero.

(d) Both (a) and (b)

III. Matching Type

95 In the given figure, let P, Q and R represent the position of a car at different instants of time.

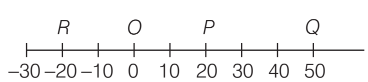


With reference to the above given figure, match the Column I (displacement/path length) with Column II (value) and select the correct answer from the codes given below.

	Column I		Column II
A.	Displacement of car in moving O to P	1.	480 m
B.	Path length of car from O to R	2.	360 m
C.	Path length of car for its motion from O to P and back to Q	3.	240 m
D.	Displacement of car for its motion from O to P and back to Q	4.	120 m

	A	B	C	D
(a)	2	4	1	3
(b)	4	3	2	1
(c)	3	4	1	2
(d)	1	2	4	3

96 An object is moving along a straight line as shown in the figure. It moves from O to P in 10 s and returns from P to R in 20 s.

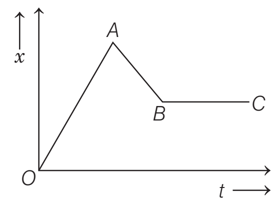


With reference to the above given figure, match the Column I (average velocity and average speed) with Column II (values) and select the correct answer from the codes given below.

	Column I		Column II
A.	The average velocity and the average speed of the object in going from O to P are	1.	$-0.5\ ms^{-1}$, $3\ ms^{-1}$
B.	The average velocity and the average speed of the object in going from O to P and back to R are	2.	$+2\ ms^{-1}$, $2\ ms^{-1}$
C.	If the object moves from O to Q and back to R in 40 s, then the average velocity and average speed of the object are	3.	$-\frac{2}{3}\ ms^{-1}$, $2\ ms^{-1}$

	A	B	C		A	B	C
(a)	1	3	2	(b)	1	2	3
(c)	2	1	3	(d)	2	3	1

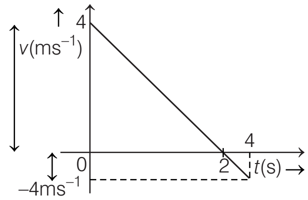
97 Given x-t graph represent the motion of an object. Match the Column I (parts of graph) with Column II (representation) and select the correct answer from the codes given below.



	Column I		Column II
A.	Part OA of graph	1.	Positive velocity
B.	Part AB of graph	2.	Object at rest
C.	Part BC of graph	3.	Negative velocity
D.	Point A in the graph	4.	Change in direction of motion

	A	B	C	D		A	B	C	D
(a)	1	2	3	4	(b)	1	3	2	4
(c)	2	1	3	4	(d)	4	3	2	1

98 Given below is a velocity-time graph for an object in motion along a straight line.

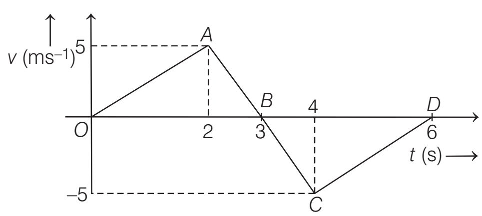


With reference to the above given figure, match the Column I (displacement/distance) with Column II (value) and select the correct answer from the codes given below.

Column I		Column II
A. The distance covered by the object in time $t = 0$ s to $t = 2$ s.	1.	8 m
B. The displacement of the object in time $t = 0$ s to $t = 2$ s.	2.	+ 4 m
C. The displacement of the object in time $t = 0$ s to $t = 4$ s.	3.	4 m
D. The distance of object in time $t = 0$ s to $t = 4$ s.	4.	0

	A	B	C	D
(a)	3	2	1	4
(b)	1	2	3	4
(c)	3	2	4	1
(d)	4	2	1	3

99 Based on the below velocity-time graph for an object in motion along a straight line with constant acceleration, match the Column I (description of motion) with Column II (time interval) and select the correct answer from the codes given below.



Column I		Column II
A. Motion in positive direction with positive acceleration.	1.	$t = 2$ s to $t = 4$ s
B. Motion in positive direction till time t_1 and then turns back with same negative acceleration.	2.	$t = 4$ s to $t = 6$ s
C. Motion in negative direction with positive acceleration.	3.	$t = 0$ s to $t = 6$ s
D. Displacement is zero.	4.	$t = 0$ s to $t = 2$ s

	A	B	C	D		A	B	C	D
(a)	4	1	3	2	(b)	3	2	4	1
(c)	3	1	4	2	(d)	4	1	2	3

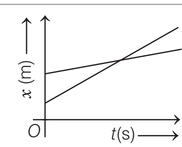
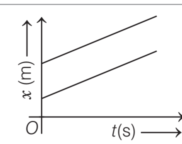
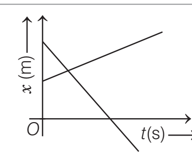
100 The position of an object moving along X-axis is given by $x(t) = a - bt^2$, where $a = 8.5$ m, $b = 2.5$ ms^{-2} and t is measured in seconds.

For the above situation, match the Column I (speed/velocity) with Column II (value) and select the correct answer from the codes given below.

Column I		Column II
A. Velocity of object at $t = 2.0$ s	1.	-15 ms^{-1}
B. Velocity of object at $t = 0$ s	2.	-10 ms^{-1}
C. Instantaneous speed of an object at $t = 2.0$ s	3.	0 ms^{-1}
D. Average velocity between $t = 2.0$ s and $t = 4.0$ s	4.	10 ms^{-1}

	A	B	C	D
(a)	1	2	3	4
(b)	2	3	4	1
(c)	4	3	4	1
(d)	3	2	1	4

101 Match the Column I (position-time graph) with Column II (representation) and select the correct answer from the codes given below.

Column I		Column II
A. Position-time graph of two objects with equal velocities.	1.	
B. Position-time graph of two objects with unequal velocities but in same direction.	2.	
C. Position-time graph of two objects with velocities in opposite direction.	3.	

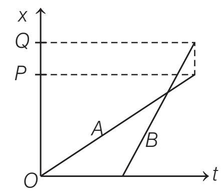
	A	B	C		A	B	C
(a)	1	2	3	(b)	2	1	3
(c)	1	3	2	(d)	2	3	1

NCERT & NCERT Exemplar

MULTIPLE CHOICE QUESTIONS

NCERT

102 The position-time (x-t) graph for two children A and B returning from their school O to their homes P and Q respectively, are as shown in the figure. Choose the incorrect statement regarding these graphs.



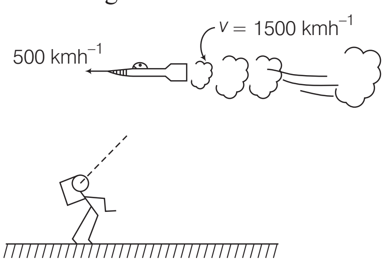
(a) A lives closer to the school than B
(b) A starts from the school earlier than B
(c) A walks faster than B
(d) A and B reach home at the same time

103 A drunkard is walking along a straight road. He takes 5 steps forward and 3 steps backward and so on. Each step is 1 m long and takes 1 s. There is a pit on the road 13 m away from the starting point. The drunkard will fall into the pit after

(a) 21 s (b) 29 s (c) 31 s (d) 37 s

104 A jet airplane travelling at speed of 500 kmh^{-1} rejects its products of combustion at speed of 1500 kmh^{-1} relative to jet plane.

Relative speed of ejected gases with respect to an observer on the ground as shown below is



(a) 1000 kmh^{-1} (b) 2000 kmh^{-1}
(c) 500 kmh^{-1} (d) 1500 kmh^{-1}

105 A car moving along a straight highway with speed of 126 kmh^{-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?

(a) 3.27 ms^{-2}, 10.27 s (b) 5.11 ms^{-2}, 6.8 s
(c) 3.06 ms^{-2}, 11.43 s (d) 7.26 ms^{-2}, 12.26 s

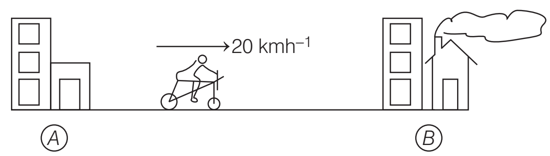
106 Two trains A and B each of length 400 m are moving on two parallel tracks with a uniform speed 72 kmh^{-1} in the same direction with A ahead of B. The driver of B decides to overtake A and accelerates by 1 ms^{-2}. If after 50 s, the guard of B just brushes past the driver of A, what was the original distance between them?

(a) 750 m (b) 1000 m (c) 1250 m (d) 2250 m

107 On a two-lane road, car A is travelling with a speed of 36 kmh^{-1}. Two cars B and C approach car A in opposite directions with a speed of 54 kmh^{-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?

(a) 2 ms^{-2} (b) 5 ms^{-2} (c) 1 ms^{-2} (d) 10 ms^{-2}

108 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 kmh^{-1} in the direction A to B as shown below, notices that a bus goes past him every 18 min in the direction of his motion and every 6 min in the opposite direction. The speed of the bus will be



(a) 40 kmh^{-1} (b) 80 kmh^{-1} (c) 30 kmh^{-1} (d) 60 kmh^{-1}

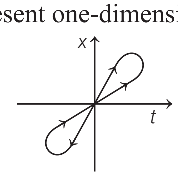
109 A player throws a ball upwards with an initial speed of 29.4 ms^{-1}. To what height does the ball rise and after how long does the ball return to the player's hand ? (Take $g = 9.8\ \text{ms}^{-2}$ and neglect air resistance).

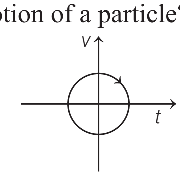
(a) 44.1 m, 6 s (b) 46 m, 10 s
(c) 55 m, 12 s (d) 60 m, 15 s

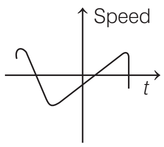
110 A boy walks on a straight road from his home to a market 2.5 km with a speed of 5 kmh^{-1}. Finding the market closed he instantly turns and walks back with a speed of 7.5 kmh^{-1}. What is the average speed and average velocity of the boy between $t = 0$ to $t = 50$ min?

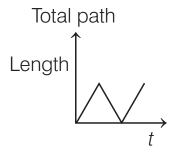
(a) 0,0 (b) 6 kmh^{-1}, 0
(c) 0,6 kmh^{-1} (d) 6 kmh^{-1}, 6 kmh^{-1}

111 Which of the following graphs cannot possibly represent one-dimensional motion of a particle?

(i)


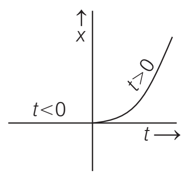
(ii)


(iii) 

(iv) 

(a) (i) and (ii) (b) (ii) and (iii)
(c) (i), (ii) and (iii) (d) All of these

112 Figure shows the x - t graph of one-dimensional motion of a particle.Suggest a suitable physical context for this graph.

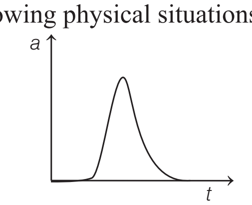


(a) Particle moves in a straight line for $t > 0$
(b) Particle moves in a straight line for $t < 0$
(c) Particle moves in a parabola for $t > 0$
(d) Motion of freely falling particle

113 A police van moving on a highway with a speed of 30 kmh^{-1} fires a bullet at a thief's car speeding away in the same direction with a speed of 192 kmh^{-1}. If the muzzle speed of the bullet is 150 ms^{-1}, with what speed does the bullet hit the thief's car?

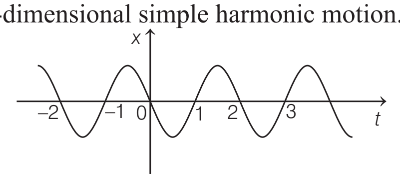
(a) 95 ms^{-1} (b) 105 ms^{-1} (c) 115 ms^{-1} (d) 125 ms^{-1}

114 The given acceleration-time graph represents which of the following physical situations?



(a) A cricket ball moving with a uniform speed is hit with a bat for a very short time interval.
(b) A ball is falling freely from the top of a tower.
(c) A car moving with constant velocity on a straight road.
(d) A football is kicked into the air vertically upwards.

115 Figure gives the x-t graph of a particle executing one-dimensional simple harmonic motion.

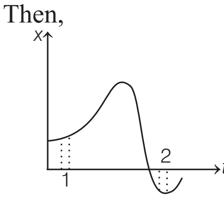


Match the Column I with Column II.

	Column I (Time)		Column II (Signs of position x, velocity v and acceleration a)
A.	At $t = -1.2$ s	1.	$x < 0, v < 0, a > 0$
B.	At $t = -0.3$ s	2.	$x > 0, v > 0, a < 0$
C.	At $t = 0.3$ s	3.	$x > 0, v < 0, a < 0$
D.	At $t = 1.2$ s	4.	$x < 0, v > 0, a > 0$

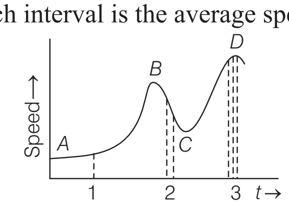
	A	B	C	D		A	B	C	D
(a)	4	3	1	2	(b)	1	2	3	4
(c)	3	3	4	3	(d)	3	4	2	1

116 Figure shows the x-t plot of a particle in one-dimensional motion. Two different equal intervals of time show speed in time intervals 1 and 2 respectively. Then,



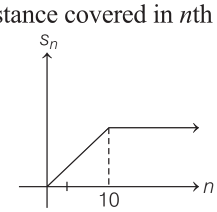
(a) $v_1 > v_2$ (b) $v_2 > v_1$
(c) $v_1 = v_2$ (d) data is insufficient

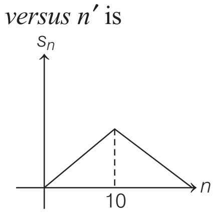
117 Figure gives a speed-time graph of a particle in motion along a constant direction. Three equal intervals of time are shown. (i) In which interval is the average acceleration greatest in magnitude?
(ii) In which interval is the average speed is greatest?

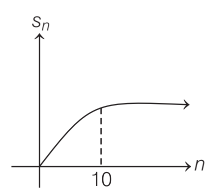


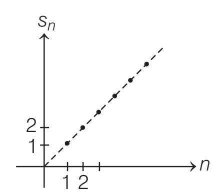
(a) 2, 1 (b) 3, 2 (c) 3,1 (d) 2, 3

118 A three wheeler starts from rest, accelerates uniformly with 1 ms^{-2} on a straight road for 10 s and then moves with uniform velocity. For the three wheeler, the graph of distance covered in nth second *versus* n' is

(a) 

(b) 

(c) 

(d) 

119 A boy standing on a stationary lift (open from above) throws a ball upwards with the maximum initial speed he can, equal to 49 ms^{-1}. (i) How much time does the ball take to return to his hands? (ii) If the lift starts moving up with a uniform speed of 5 ms^{-1} 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?

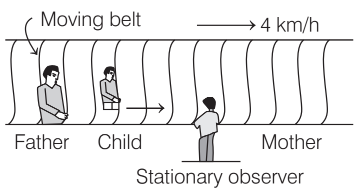
(a) 10 s, 15 s (b) 5 s, 5 s
(c) 5 s, 10 s (d) 10 s, 10 s

120 On a long horizontally moving belt, a child runs to and fro with a speed $9\,\text{kmh}^{-1}$ (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 $4\,\text{kmh}^{-1}$. For an observer on a stationary platform outside, what is the

(i) speed of the child running in the direction of motion of the belt,

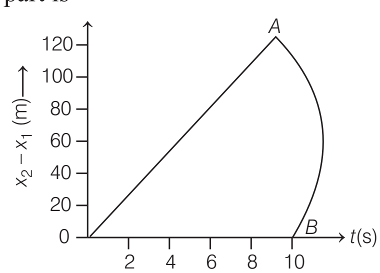
(ii) speed of the child running opposite to the direction of motion of the belt and

(iii) time taken by the child in (i) and (ii)?



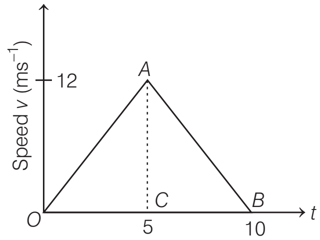
(a) $5\,\text{kmh}^{-1}, 13\,\text{kmh}^{-1}, 25\,\text{s}$ (b) $13\,\text{kmh}^{-1}, 5\,\text{kmh}^{-1}, 20\,\text{s}$
(c) $5\,\text{kmh}^{-1}, 13\,\text{kmh}^{-1}, 20\,\text{s}$ (d) $13\,\text{kmh}^{-1}, 5\,\text{kmh}^{-1}, 25\,\text{s}$

121 Two stones are thrown up simultaneously from the edge of a cliff 200 m high with initial speeds of $15\,\text{ms}^{-1}$ and $30\,\text{ms}^{-1}$, respectively. The time variation of the relative position of the second stone with respect to the first is shown in the figure. The equation of the linear part is



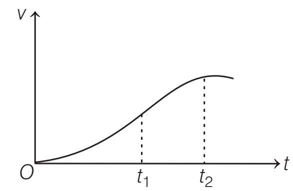
(a) $x_2 - x_1 = 50t$ (b) $x_2 - x_1 = 10t$
(c) $x_2 - x_1 = 15t$ (d) $x_2 - x_1 = 20t$

122 The speed-time graph of a particle moving along a fixed direction is shown in the figure. The distance traversed by the particle between $t = 0$ s to $t = 10$ s is



(a) 20 m (b) 40 m
(c) 60 m (d) 80 m

123 The velocity-time graph of a particle in one-dimensional motion is shown in the figure. Which of the following formulae is correct for describing the motion of the particle over the time interval t_1 to t_2?



(i) $x(t_2) = x(t_1) + v(t_1)(t_2 - t_1) + \left(\frac{1}{2}\right) a(t_2 - t_1)^2$

(ii) $v(t_2) = v(t_1) + a(t_2 - t_1)$

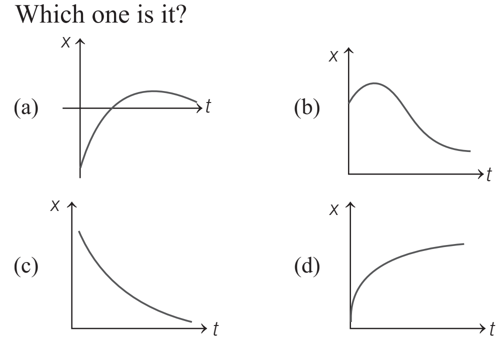
(iii) $v_{\text{average}} = \dfrac{x(t_2) + x(t_1)}{(t_2 - t_1)}$

(iv) $a_{\text{average}} = \dfrac{v(t_2) - v(t_1)}{(t_2 - t_1)}$

(a) (i), (ii) and (iii) (b) (iii) and (iv)
(c) (i) and (iv) (d) All of these

NCERT Exemplar

124 Among the four graphs shown in the figure, there is only one graph for which average velocity over the time interval $(0, T)$ can vanish for a suitably chosen T. Which one is it?



125 A lift is coming from 8th floor and is just about to reach 4th floor. Taking ground floor as origin and positive direction upwards for all quantities, which one of the following is correct?

(a) $x < 0, v < 0, a > 0$ (b) $x > 0, v < 0, a < 0$
(c) $x > 0, v < 0, a > 0$ (d) $x > 0, v > 0, a < 0$

126 In one-dimensional motion, instantaneous speed v satisfies $0 \le v < v_0$.

(a) The displacement in time T must always take non-negative values
(b) The displacement x in time T satisfies, $-v_0T < x < v_0T$
(c) The acceleration is always a non-negative number
(d) The motion has no turning points

127 A vehicle travels half the distance l with speed v_1 and the other half with speed v_2, then its average speed is

(a) $\frac{v_1 + v_2}{2}$ (b) $\frac{2v_1 + v_2}{v_1 + v_2}$

(c) $\frac{2v_1v_2}{v_1 + v_2}$ (d) $\frac{l(v_1 + v_2)}{v_1v_2}$

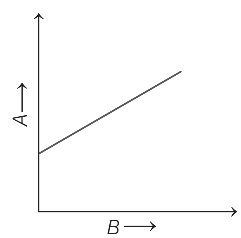
128 The displacement of a particle is given by $x = (t-2)^2$, where x is in metre and t in second. The distance covered by the particle in first 4 seconds is

(a) 4 m (b) 8 m
(c) 12 m (d) 16 m

129 At a metro station, a girl walks up a stationary escalator in time t_1. If she remains stationary on the escalator, then the escalator takes her up in time t_2. The time taken by her to walk upon the moving escalator will be

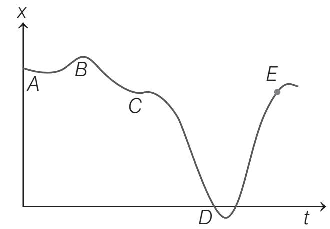
(a) $(t_1 + t_2)/2$ (b) $t_1 t_2/(t_2 - t_1)$
(c) $t_1t_2/(t_2 + t_1)$ (d) $t_1 - t_2$

130 The variation of quantity A with respect to quantity B, plotted in figure describes the motion of a particle in a straight line.



(a) Quantity B may represent time
(b) Quantity A is velocity, if motion is uniform
(c) Quantity A is distance, if motion is non-uniform
(d) Quantity B is velocity, if motion is uniformly accelerated

131 A graph of x *versus* t is shown in figure. Choose correct alternatives given below.



(a) The particle having some initial velocity at $t = 0$
(b) At point B, the acceleration $a > 0$
(c) At point C, the velocity and the acceleration vanish
(d) The speed at E exceeds that at D

132 For one-dimensional motion, described by

$$x = t - \sin t$$

(a) $x(t) = 0$ for all $t > 0$ (b) $v(t) > 0$ for all $t > 0$
(c) $a(t) < 0$ for all $t > 0$ (d) $v(t)$ lies between 0 and 2

133 A ball is bouncing elastically with a speed 1 ms^{-1} between walls of a railway compartment of size 10 m in a direction perpendicular to walls. The train is moving at a constant velocity of 10 ms^{-1} parallel to the direction of motion of the ball. As seen from the ground,

(a) the direction of motion of the ball is constant for every 10 s
(b) speed of ball is constant
(c) average speed of ball over any 20 s intervals is variable
(d) the acceleration of ball is not the same as from the train

Answers

Mastering NCERT with MCQs

1 (b)	2 (a)	3 (a)	4 (a)	5 (a)	6 (d)	7 (a)	8 (a)	9 (d)	10 (b)
11 (c)	12 (b)	13 (b)	14 (b)	15 (a)	16 (b)	17 (a)	18 (a)	19 (c)	20 (a)
21 (d)	22 (c)	23 (c)	24 (b)	25 (b)	26 (d)	27 (d)	28 (a)	29 (a)	30 (a)
31 (b)	32 (d)	33 (c)	34 (a)	35 (b)	36 (d)	37 (c)	38 (b)	39 (a)	40 (a)
41 (b)	42 (b)	43 (b)	44 (b)	45 (a)	46 (a)	47 (d)	48 (a)	49 (c)	50 (a)
51 (a)	52 (b)	53 (a)	54 (a)	55 (a)	56 (a)	57 (d)	58 (b)	59 (a)	60 (b)
61 (a)	62 (a)	63 (a)	64 (d)	65 (d)	66 (a)	67 (d)	68 (c)	69 (a)	70 (c)

Special Types Questions

71 (a)	72 (a)	73 (b)	74 (a)	75 (d)	76 (c)	77 (b)	78 (b)	79 (c)	80 (d)
81 (c)	82 (c)	83 (a)	84 (a)	85 (a)	86 (d)	87 (b)	88 (b)	89 (a)	90 (d)
91 (a)	92 (c)	93 (c)	94 (d)	95 (a)	96 (d)	97 (b)	98 (c)	99 (d)	100 (b)
101 (b)									

NCERT & NCERT Exemplar MCQs

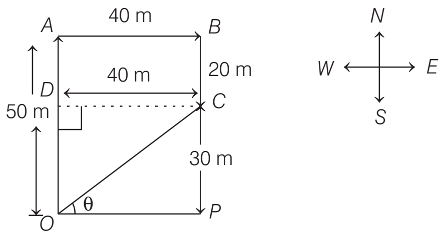
102 (c)	103 (d)	104 (a)	105 (c)	106 (c)	107 (c)	108 (a)	109 (a)	110 (b)	111 (d)
112 (d)	113 (b)	114 (a)	115 (a)	116 (b)	117 (d)	118 (a)	119 (d)	120 (b)	121 (c)
122 (c)	123 (b)	124 (b)	125 (a)	126 (b)	127 (c)	128 (b)	129 (c)	130 (a)	131 (c)
132 (d)	133 (a)								

Hints & Explanations

1 (*b*) For a car in motion, if we describe this event with respect to a frame of reference attached to a person sitting inside the car, the car will considered to be at rest as the person inside the car is also moving with same velocity and in the same direction as car.
However, with respect to the frame of reference attached to the ground/person outside the car, the car is moving.

2 (*a*) Given, at $t = 0\,\text{s}$, position of an object is $(-1,0,3)$ and at $t = 5\,\text{s}$, its coordinates are $(-1,0,4)$. So, there is no change in x and y-coordinates, while z-coordinate changes from 3 to 4. So,the object is in motion along Z-axis.

4 (*a*) Let O be the starting point, i.e. home. So, according to the question, Snehit moves from O to A (50 m) towards north, then from A to B (40 m) towards east and from B to C (20 m) towards south as shown in the figure below.



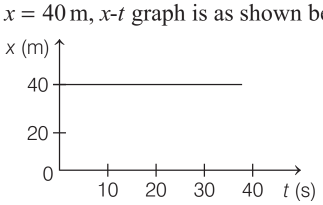
Displacement of Snehit is OC, which can be calculated by Pythagoras theorem, i.e.

In ΔODC, $\quad OC^2 = OD^2 + CD^2 = (30)^2 + (40)^2$

$$= 900 + 1600 = 2500$$

$\Rightarrow \quad OC = 50\text{ m}$

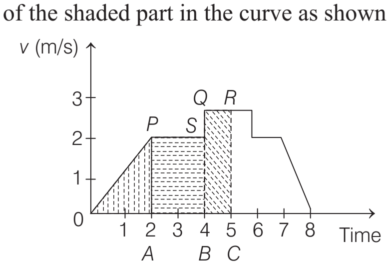
5 (*a*) For a stationary object, the position-time graph is a straight line parallel to the time axis, so for the given object at $x = 40\,\text{m}$, x-t graph is as shown below



This is shown in option (a).

6 (*d*) **Key Idea** Area under the velocity-time curve represents displacement.

To get exact position at $t = 5$ s, we need to calculate area of the shaded part in the curve as shown below

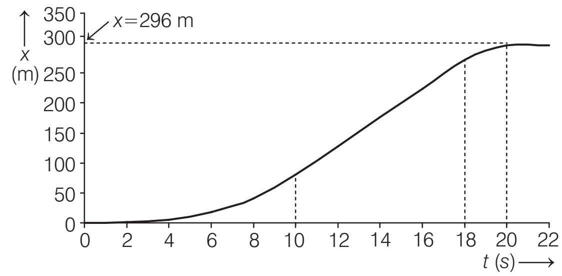


$\therefore$ Displacement of particle

$$= \text{Area of } OPA + \text{Area of } QBCRQ$$

$$= \left(\frac{1}{2} \times 2 \times 2\right) + (2 \times 2) + 3 \times 1 = 2 + 4 + 3 = 9\text{ m}$$

7 (*a*) According to given situation, we observe that the car is speeding up from origin to $t = 10\,\text{s}$, so x-t graph has a curve with increasing slope. It is in uniform motion only between $t = 10\,\text{s}$ and $t = 18\,\text{s}$. So, for $t = 10\,\text{s}$ and $t = 18\,\text{s}$, the graph must be a straight line inclined to time axis as shown below



At $t = 20\,\text{s}$, the car stops at position $x = 296\,\text{m}$ and hence the x-t graph from $t = 20\,\text{s}$ onwards must be a straight line parallel to time axis.
From $t = 18\,\text{s}$ to $t = 20\,\text{s}$, the car slows down by applying brakes. So, the curve has decreasing slope between this interval.
The situation is correctly shown in option (a).

8 (*a*) Since, average velocity, $\bar{v} = \dfrac{\Delta x}{\Delta t} = \dfrac{\text{Displacement}}{\text{Time interval}}$

Thus, average velocity depends on the displacement and hence, it can be positive or negative depending upon the sign of the displacement.

9 (*d*) When a particle completes one revolution in circular motion, then average displacement travelled by particle is zero.

Hence, average velocity $= \dfrac{\text{average displacement}}{\Delta t}$

$$= \frac{0}{\Delta t} = 0$$

10 (*b*) Given, $R = 40\,\text{m}$ and $t = 40\,\text{s}$

Average velocity $= \dfrac{\text{Displacement}}{\text{Time taken}} = \dfrac{2R}{t} = \dfrac{2 \times 40}{40}$

$$= 2\,\text{ms}^{-1}$$

11 (*c*) Position of particle is, $x(t) = at + bt^2 - ct^3$

So, its velocity is, $v = \dfrac{dx}{dt} = a + 2bt - 3ct^2$

and acceleration is, $a = \dfrac{dv}{dt} = 2b - 6ct$

Acceleration is zero, then $2b - 6ct = 0$

$\Rightarrow \quad t = \dfrac{2b}{6c} = \dfrac{b}{3c}$

Substituting this 't' in expression of velocity, we get

$$v = a + 2b\left(\frac{b}{3c}\right) - 3c\left(\frac{b}{3c}\right)^2 = a + \frac{2b^2}{3c} - \frac{b^2}{3c} = a + \frac{b^2}{3c}$$

12 (b) From the position-time graph, the average velocity is geometrically represented by the slope of curve, i.e. slope of straight line P_1P_2.

13 (b) Given, $x_2 = 27.4$ m, $x_1 = 10$ m, $t_2 = 7$ s and $t_1 = 5$ s.

Average velocity between 5 s and 7s is

$$\bar{v} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{27.4 - 10}{7 - 5} = \frac{17.4}{2} = 8.7 \text{ ms}^{-1}$$

14 (b) Geometrically,

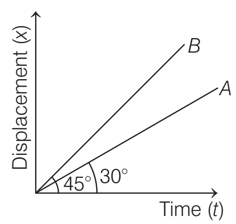
Average velocity = Slope of line joining initial and final positions in x- t graph

In this case, slope = $\tan 60° = \sqrt{3}$

Average velocity, $\bar{v} = \sqrt{3}$ ms^{-1}

15 (a) In case x- t graph is a straight line, the slope of this line gives velocity of the particle.

As slope = $\tan\theta$, where θ is the angle which the tangent to the curve makes with the horizontal in anti-clockwise direction. So, in the given case,



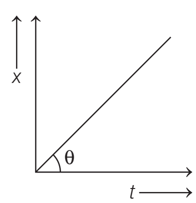
The velocities of two particles A and B are

$$v_A = \tan 30° = \frac{1}{\sqrt{3}}$$

$$v_B = \tan 45° = 1$$

The ratio of velocities, $v_A : v_B = \frac{1}{\sqrt{3}} : 1 = 1 : \sqrt{3}$

16 (b) Here, x- t graph for motion of an object with positive velocity is as follows



The slope of the x- t graph must be positive for positive velocity. This is because, slope of x-t graph = average velocity = $\tan\theta$ = +ve, as θ is an acute angle.

This is shown in option (b).

While for graph (c), slope of line = $\tan\theta$ = – ve

($\because$ θ is an obtuse angle)

So, velocity is negative.

For graph (a), object is at rest.

For graph (d), slope of graph is first decreasing and after sometimes object is at rest.

17 (a) The x- t graph shown, is parallel to time axis. This means that the object is at rest. Hence, the velocity of the object is zero for all time instants. Hence, v-t graph coincides with the time axis as shown in graph (a).

In graph (b) velocity is increasing uniformly with respect to time.

In graph (c), straight line represents constant acceleration

while in graph (d) acceleration is first increasing then decreasing.

Hence, option (a) is correct.

18 (a) As runner starts from O and comes back to O, so net displacement is zero.

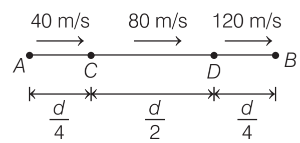
$$\text{Average speed} = \frac{\text{Total distance}}{\text{Total time}} = \frac{OQ + QR + RO}{\text{total time}}$$

$$= \frac{1\text{ km} + (2\pi r)\left(\frac{90°}{360°}\right)\text{km} + 1\text{ km}}{1\text{h}}$$

($\because$ angle of sector OQR is 90°)

$$= \frac{1 + 2\pi \times 1\left(\frac{1}{4}\right) + 1}{1} = 2 + \frac{\pi}{2} = 3.57 \text{ km/h}$$

19 (c) According to the question, the situation is as shown,



where, d = total distance between A and B.

From A to C,

$$\text{Time taken, } t_1 = \frac{d/4}{40} = \frac{d}{160}$$

From C to D,

$$\text{Time taken, } t_2 = \frac{d/2}{80} = \frac{d}{160}$$

From D to B,

$$\text{Time taken, } t_3 = \frac{d/4}{120} = \frac{d}{480}$$

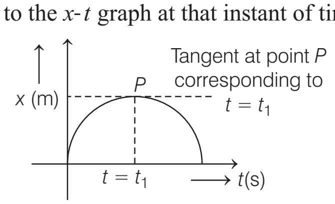
$$\text{Total time} = t_1 + t_2 + t_3 = \frac{d}{160} + \frac{d}{160} + \frac{d}{480}$$

$$= \frac{3d + 3d + d}{480} = \frac{7d}{480}$$

$$\text{Average speed} = \frac{\text{Total distance}}{\text{Total time}} = \frac{d}{7d/480}$$

$$= \frac{480}{7} = 68.57 \text{ m/s}$$

20 (a) The instantaneous velocity is the slope of the tangent to the x-t graph at that instant of time.



At $t = t_1$, the tangent is parallel to time axis as shown above and hence, its slope is zero. Thus, instantaneous velocity at $t = t_1$ is zero.

21 (d) Since, the particle starts from rest, this means, initial velocity, $u = 0$

Also, it moves with uniform acceleration along positive X-axis. This means, its acceleration (a) is constant.

$\therefore$ Given, a - t graph in (A) is correct.

As we know, for velocity-time graph, slope = acceleration.

Since, the given v-t graph in (B) represents that its slope is constant and non-zero.

$\therefore$ Graph in (B) is also correct.

Also, the displacement of such a particle w.r.t. time is given by

$$x = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}at^2 \Rightarrow x \propto t^2$$

So, x *versus* t graph would be a parabola with starting from origin.

This is correctly represented in displacement-time graph given in (D).

22 (c) In one-dimensional motion, i.e. motion along a straight line, there are only two directions in which an object can move and these two directions can be easily specified by + ve and – ve signs.

Also, in this motion instantaneous speed or simply speed at an instant is equal the magnitude of instantaneous velocity at the given instant.

23 (c) Since velocity is a vector quantity, having both magnitude and direction, so a change in velocity may involve change in either or both of these factors. Acceleration, therefore may result from a change in speed (magnitude), a change in direction or changes in both.

24 (b) Time interval between 8th and 3rd seconds,

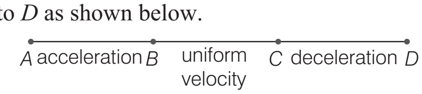
$$\Delta t = 8 - 3 = 5\,\text{s}$$

Change in velocity, $\Delta v = 20 - 0 = 20\,\text{m/s}$

$$\therefore \text{Average acceleration} = \frac{\Delta v}{\Delta t} = \frac{20}{5} = 4\,\text{m/s}^2$$

25 (b) Average acceleration is defined as the average change of velocity per unit time. On a plot of v-t, the average acceleration is the slope of the straight line connecting the points corresponding to (v_2, t_2) and (v_1, t_1).

26 (d) Let the car be accelerated from A to B, it moves with uniform velocity from B to C of 4 km distance and then moves with uniform deceleration of 0.2 ms^{-2} from C to D as shown below.



For motion of car from A to B, $a = 0.5\,\text{ms}^{-2}$

$$u = 0 \text{ and } v = 18\,\text{km h}^{-1}$$

$$= 18 \times \frac{5}{18}\,\text{ms}^{-1} = 5\,\text{ms}^{-1}$$

Time, $$t_1 = \frac{v - u}{a} \quad \ldots\text{(i)}$$

Substituting given values of v, u and a for A to B motion, we get

$$t_1 = \frac{5 - 0}{0.5} = 10\text{s} \quad \ldots\text{(ii)}$$

For motion of car from B to C,

$$s = 4\,\text{km} = 4000\,\text{m and } v = 5\,\text{ms}^{-1}$$

$$t_2 = \frac{\text{distance}}{\text{velocity}} = \frac{4000}{5} = 800\text{s} \quad \ldots\text{(iii)}$$

For motion of car from C to D, $v = 0$, $u = 5\,\text{ms}^{-1}$

and $a = -\,0.2\,\text{ms}^{-2}$ (negative sign shows deceleration)

$$\text{Time taken, } t_3 = \frac{v - u}{a} = \frac{0 - 5}{-0.2} = \frac{-5}{-0.2} = 25\text{s} \quad \ldots\text{(iv)}$$

Total time taken, $T = t_1 + t_2 + t_3$

Substituting values of t_1, t_2 and t_3 from Eqs. (ii), (iii) and (iv) respectively, we get

$$T = (10 + 800 + 25)\,\text{s} = 835\,\text{s}$$

Thus, total time of travel of the car is 835 s.

27 (d) For path OA and BO, the magnitude of velocity (speed) and direction is constant, hence acceleration is zero.

For path AB, since this path is a curve, so the direction of the velocity changes every moment but the magnitude of velocity (speed) remains constant.

Since, the direction of velocity is changing, i.e., there must be some acceleration along the path AB.

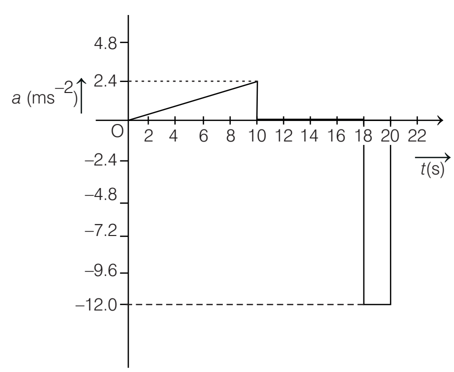
28 (a) Average acceleration for different time intervals is the slope of v-t graph, which is as follows

For 0 s -10 s, $\bar{a} = \dfrac{(24 - 0)\,\text{ms}^{-1}}{(10 - 0)\,\text{s}} = 2.4\,\text{ms}^{-2}$

For 10 s -18 s, $\bar{a} = \dfrac{(24 - 24)\,\text{ms}^{-1}}{(18 - 10)\,\text{s}} = 0\,\text{ms}^{-2}$

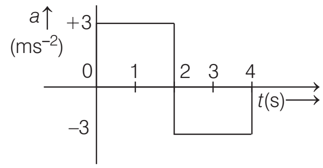
For 18 s-20 s, $\bar{a} = \dfrac{(0 - 24)\,\text{ms}^{-1}}{(20 - 18)\,\text{s}} = -\,12\,\text{ms}^{-2}$

So, the corresponding a -t graph for the given v-t graph is as follows

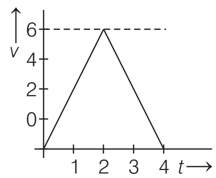


This is shown correctly in graph (a).

29 (*a*) From a - t graph, we observe that



For $t = 0$ s to $t = 2$ s ; a is positive, i.e. $a > 0$. So, v - t graph will be a straight line with positive slope.
For $t = 2$ s to $t = 4$ s, a is negative ($a < 0$), so v-t graph will be a straight line with negative slope.
Complete v-t graph will be as below.



Also, v = Area under a-t graph for $t = 0$ s to $t = 2$s
$= 3 \times 2$
$\Rightarrow \quad v = 6 \text{ ms}^{-1}$, which is the maximum velocity attained.
This is shown in graph (a).

30 (*a*) For an object moving in positive direction, the velocity must be positive. For positive and constant acceleration, the velocity must be increasing with time or the slope of the straight line must be positive. This is shown in graph (a).

31 (*b*) The velocity-time graph for motion with uniform acceleration (constant acceleration) is a straight line inclined to time axis.

For negative acceleration, the slope of the graph must be negative.

For positive direction, velocity is positive, so graph (b) is correct.

32 (*d*) For negative direction, the velocity must be negative throughout the journey.

So, for negative acceleration the correct graph is shown in graph (d).

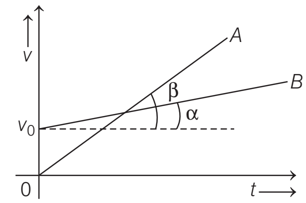
33 (*c*) From question, we observe that the object is moving in positive direction till time $t = 0$ to $t = t_1$ and at $t = t_1$, we find that the velocity becomes negative, i.e. the object changes its direction at $t = t_1$ and continues in negative direction hence forth.

The given situation is correctly depicted in option (c).

34 (*a*) For motion with uniform acceleration, the v - t graph is a straight line inclined to time axis. Slope of the v - t graph gives the value of constant acceleration.

Also, slope of a straight line in general = $\tan\theta$, where θ is the angle in the anti-clockwise direction, which the line makes with the positive direction of time axis.

So, in the given graph as shown below



$$\beta > \alpha \Rightarrow \tan\beta > \tan\alpha$$

Hence, $a_A > a_B$

35 (*b*) Given, $v_0 = 30 \text{ ms}^{-1}$ and $v = 40 \text{ ms}^{-1}$.

Since, the motion is uniformly accelerated motion, the v - t graph must be a straight line with a constant slope.

Since, the velocity is increasing in the given time interval, the slope must be positive due to positive acceleration. This is shown in graph (b).

37 (*c*) Given, $v = 15 \text{ ms}^{-1}$, $v_0 = 30 \text{ ms}^{-1}$ and $t = 2$ s

Using relation, $v = v_0 + at$
Acceleration of the car,

$$a = \frac{v - v_0}{t} = \frac{(15 - 30) \text{ ms}^{-1}}{2 \text{ s}}$$

$$= -\frac{15}{2} \text{ ms}^{-2} = -7.5 \text{ ms}^{-2}$$

38 (*b*) If velocity *versus* time graph is a straight line with negative slope, then acceleration is constant and negative.
With a negative slope distance-time graph will be parabolic $\left(s = ut - \frac{1}{2}at^2\right)$.

So, option (b) will be incorrect.

39 (*a*) Given, $v_0 = 0$

Using relation, $v^2 = v_0^2 + 2ax$

$$v^2 = 2ax$$

$\therefore \quad v = \sqrt{2ax}$

40 (*a*) Given, $x_0 = 3$ units, $a = 4 \text{ ms}^{-2}$, $t = 3$ s
and $v_0 = 0$

Using relation, $x = x_0 + v_0 t + \frac{1}{2}at^2$

$$= 3 + \frac{1}{2} \times 4 \times (3)^2$$

$$= +21 \text{ units}$$

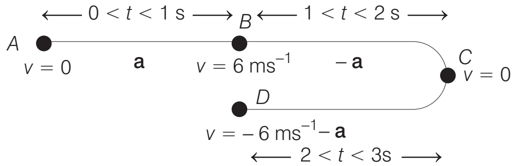
41 (*b*) According to the question,

For time duration $0 < t < 1$s, the velocity increase from 0 to 6 ms^{-1}.

As the direction of field has been reversed, so for $1 < t < 2$s, the velocity firstly decreases from 6 ms^{-1} to 0.

Then, for $2 < t < 3$s; as the field strength is same the magnitude of acceleration would be same, but velocity increases from 0 to -6 ms^{-1}.

This is shown below



Acceleration of the car,

$$|a| = \left|\frac{v-u}{t}\right| = \frac{6-0}{1} = 6\text{ms}^{-2}$$

The displacement of the particle is given as

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

For $t = 0$ s to $t = 1$s, $u = 0$ and $a = +6\,\text{ms}^{-2}$

$$\Rightarrow \quad s_1 = 0 + \frac{1}{2}\times 6 \times (1)^2 = 3\text{ m}$$

For $t = 1$s to $t = 2$s, $u = 6\,\text{ms}^{-1}$, $a = -6\,\text{ms}^{-2}$

$$\Rightarrow \quad s_2 = 6\times 1 - \frac{1}{2}\times 6\times (1)^2$$

$$= 6 - 3 = 3\text{m}$$

For $t = 2$s to $t = 3$s,

$$u = 0, a = -6\,\text{ms}^{-2}$$

$$\Rightarrow \quad s_3 = 0 - \frac{1}{2}\times 6\times (1)^2 = -3\text{m}$$

$\therefore$ Net displacement, $s = s_1 + s_2 + s_3$

$$= 3\text{ m} + 3\text{ m} - 3\text{ m} = 3\text{ m}$$

Hence, average velocity $= \dfrac{\text{net displacement}}{\text{total time}}$

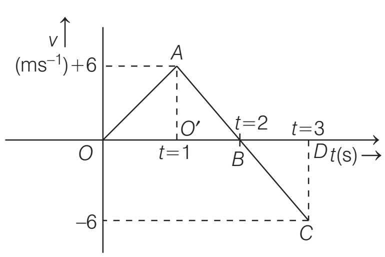
$= \dfrac{3}{3} = 1\text{m s}^{-1}$

Total distance travelled, $d = |s_1| + |s_2| + |s_3| = 9$m

Hence, average speed $= \dfrac{\text{total distance}}{\text{total time}} = \dfrac{9}{3} = 3\ \text{ms}^{-1}$

Alternative Method

Given condition can also be represented through v -t graph as shown below



$\therefore$ Displacement in three seconds

= Area under the graph

= Area of $\Delta OAO'$ + Area of $\Delta AO'B$ − Area of ΔBCD

$= \dfrac{1}{2}\times 1\times 6 + \dfrac{1}{2}\times 1\times 6 - \dfrac{1}{2}\times 6\times 1 = 3\text{m}$

$\therefore$ Average velocity $= \dfrac{\text{Displacement}}{\text{Time}} = \dfrac{3}{3} = 1\text{ms}^{-1}$.

Total distance travelled, $d = |\text{Area under the graph}| = 9$m

$\therefore$ Average speed $= \dfrac{\text{Distance}}{\text{Time}} = \dfrac{9}{3} = 3\text{ms}^{-1}$

42 (*b*) Body is initially at rest, $u = 0$

The displacement or distance of particle is given as

$$s = ut + \frac{1}{2}at^2 \quad \ldots\text{(i)}$$

Substituting, $u = 0$ in Eq. (i), we get

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

$$s \propto t^2 \Rightarrow \frac{t_1}{t_2} = \sqrt{\frac{s_1}{s_2}} \quad \ldots\text{(ii)}$$

Given, $t_2 = 6$ s

$$s_1 = \frac{s}{9}, s_2 = s$$

where, s is the total distance covered by body, so from Eq. (ii), we get

$$t_1 = \sqrt{\frac{\frac{s}{9}}{s}} \times t_2 = \frac{1}{3}\times 6 = 2\text{ s}$$

43 (*b*) Given, $u = 15\,\text{ms}^{-1}$, $t = 5$ s and $v = 25\,\text{ms}^{-1}$

As, $v = u + at \quad \ldots\text{(i)}$

where, v is final velocity, u is initial velocity, a is acceleration and t is time.

From Eq. (i) $\quad a = \dfrac{v-u}{t}$

Substituting given values of v, u and t, we get

$$a = \frac{25-15}{5} = \frac{10}{5} = 2\,\text{ms}^{-2}$$

Now, velocity at 4s, before the given instant is given as

$$v = u + at$$

where, $v = 15\ \text{ms}^{-1}$, $a = 2\,\text{ms}^{-2}$ and $t = 4$ s.

$$\Rightarrow \quad 15 = u + (2)(4)$$

$$\Rightarrow \quad u = 7\,\text{ms}^{-1}$$

44 (*b*) The distance covered in nth second is given by

$$s_n = u + \frac{a}{2}(2n-1)$$

For $n = 3$, $s_3 = 6$ m, we get

$$s_3 = u + \frac{a}{2}(2\times 3 - 1) = u + \frac{5a}{2}$$

$$\Rightarrow \quad 6 = u + \frac{5a}{2} \quad \ldots\text{(i)}$$

Similarly for distance of 12 m in 6th second,

$$s_6 = u + \frac{11}{2}a$$

$$\Rightarrow \quad 12 = u + \frac{11}{2}a \quad \ldots\text{(ii)}$$

From Eqs. (i) and (ii), we get

$$6-\frac{5a}{2}=12-\frac{11a}{2}$$

$$\Rightarrow \quad a=\frac{6}{6}\times 2=2\,\text{ms}^{-2}$$

and $$u=6-\frac{5a}{2}=6-\frac{10}{2}=1\,\text{ms}^{-1}$$

Distance travelled in next 3s = $s_9 - s_6$

$$=\left(ut+\frac{1}{2}at^2\right)_{t=9\text{s}}-\left(ut+\frac{1}{2}at^2\right)_{t=6\text{s}}$$

Substituting $u = 1\,\text{ms}^{-1}$ and $a = 2\,\text{ms}^{-2}$, we get

$$s=\left(1\times 9+\frac{1}{2}\times 2\times 81\right)-\left(1\times 6+\frac{1}{2}\times 2\times 36\right)$$

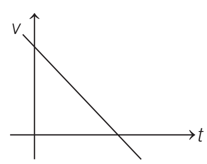
$$s = 90-42 = 48\,\text{cm}$$

46 (a) A particle thrown upward is an example of motion under gravity.

Throughout, the motion of the particle, acceleration due to gravity acts downward, i.e. in $-y$-direction, so $a = -g =$ constant.

Since, acceleration is negative, slope of v- t graph must be negative.

At highest point, the velocity becomes zero. After that, the particle moves downward with negative velocity as shown below.



47 (d) For free fall, $v_0 = 0$ and $a = -g = -9.8\,\text{ms}^{-2}$

The equations of motion are

$$v = -9.8\,t\ \text{ms}^{-1} \qquad (\text{using } v = v_0 + at)$$

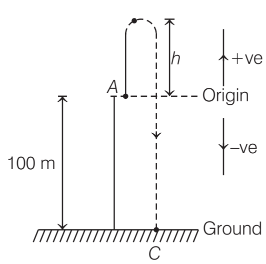
$$y=\frac{1}{2}\times(-9.8)\times t^2\ \text{m} = -4.9\,t^2\ \text{m}$$

$$(\text{Using } y = v_0 t + 1/2\,at^2)$$

$$v^2 = 2\times(-9.8)\times y \qquad (\text{Using } v^2 = v_0^2 + 2ay)$$

$$= -19.6\,y\ \text{m}^2\text{s}^{-2}$$

48 (a) The given situation can be shown below as



Let us consider A on origin (the point of launch)

At maximum height, v = final velocity = $0\,\text{ms}^{-1}$

v_0 = initial velocity = $10\,\text{ms}^{-1}$, , $a = -g = -10\,\text{ms}^{-2}$

Using the relation, $v^2 = v_0^2 + 2ay$

$$\Rightarrow \quad v^2 = v_0^2 + 2ah$$

or $$(0)^2 = (10)^2 + 2\times(-10)\times h$$

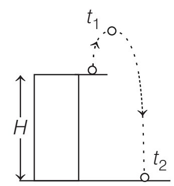
$$h=\frac{-100}{-20}=5\,\text{m}$$

∴ Maximum height above ground

$$= (100+5)\,\text{m} = 105\,\text{m}$$

49 (c) Time taken to reach the maximum height,

$$t_1=\frac{u}{g}$$



If t_2 is the time taken to hit the ground, then

$$-H = ut_2 - \frac{1}{2}gt_2^2$$

But $$t_2 = nt_1 \qquad \text{(Given)}$$

So, $$-H = u\frac{nu}{g}-\frac{1}{2}g\frac{n^2u^2}{g^2}$$

$$\Rightarrow \quad -H=\frac{nu^2}{g}-\frac{1}{2}\frac{n^2u^2}{g}$$

$$\Rightarrow \quad 2gH = nu^2\,(n-2)$$

50 (a) For first stone,

Taking the vertical upward motion of the stone upto highest point.

Here, $u = u_1, v = 0$ (∵ at highest point, velocity is zero.)

$$a = -g \text{ and } s = h_1$$

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

∴ $$(0)^2 - u_1^2 = 2(-g)h_1$$

or $$h_1=\frac{u_1^2}{2g} \qquad \ldots\text{(i)}$$

For second stone,

Taking the vertical upward motion of the second stone upto highest point.

Here, $u = u_2$, $v = 0$, $a = -g$ and $s = h_2$

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

$$\Rightarrow \quad (0)^2 - u_2^2 = 2(-g)h_2$$

$$h_2=\frac{u_2^2}{2g} \qquad \ldots\text{(ii)}$$

As per question, $h_1 - h_2 = 15\text{m}$, $u_2=\frac{u_1}{2}$

Subtracting Eq. (ii) from Eq. (i), we get

$$h_1-h_2=\frac{u_1^2}{2g}-\frac{u_2^2}{2g}$$

On substituting the given information, we get

$$15 = \frac{u_1^2}{2g} - \frac{u_1^2}{8g} = \frac{3u_1^2}{8g}$$

or $\quad u_1^2 = \frac{15 \times 8g}{3} = \frac{15 \times 8 \times 10}{3} = 400$

or $\quad u_1 = 20 \text{ ms}^{-1}$ and $u_2 = \frac{u_1}{2} = 10 \text{ ms}^{-1}$

51 (*a*) Let the two stones meet at time t.

For the first stone, $s_1 = \frac{1}{2}gt^2 \qquad (\because u = 0) \ldots\text{(i)}$

For the second stone, $s_2 = u(t-n) + \frac{1}{2}g(t-n)^2 \quad \ldots\text{(ii)}$

Since, displacement is same.

$\therefore \quad s_1 = s_2$

$\Rightarrow \frac{1}{2}gt^2 = u(t-n) + \frac{1}{2}g(t-n)^2$ [using Eqs. (i) and (ii)]

$\Rightarrow \frac{1}{2}gt^2 = ut - un + \frac{1}{2}gt^2 - gtn + \frac{1}{2}gn^2$

$\Rightarrow ut - gtn = un - \frac{1}{2}gn^2$

$$\Rightarrow \quad t = \frac{un - \frac{1}{2}gn^2}{u - gn} = \frac{n\left(u - \frac{gn}{2}\right)}{u - gn}$$

Substituting this value of t in Eq. (i), we get

$$s_1 = \frac{1}{2}g\left[\frac{n\left(u - \frac{gn}{2}\right)}{u - gn}\right]^2$$

52 (*b*) Distance covered in first 5 s,

$$h_1 = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}a(5)^2 \qquad [\because u = 0]$$

$$\Rightarrow \quad h_1 = \frac{25a}{2} \qquad \ldots\text{(i)}$$

Distance covered in first 10 s

$$s_2 = 0 + \frac{1}{2}a(10)^2 = \frac{100a}{2}$$

So, distance covered in second 5 s,

$$h_2 = s_2 - h_1 = \frac{100a}{2} - \frac{25a}{2} = \frac{75a}{2} \qquad \ldots\text{(ii)}$$

Distance covered in first 15 s,

$$s_3 = 0 + \frac{1}{2}a(15)^2 = \frac{225a}{2}$$

So, distance covered in last 5 s,

$$h_3 = s_3 - s_2 = \frac{225a}{2} - \frac{100a}{2} = \frac{125a}{2} \qquad \ldots\text{(iii)}$$

Using Eqs. (i), (ii) and (iii), we get

$$\frac{h_1}{\frac{25a}{2}} = \frac{h_2}{\frac{75a}{2}} = \frac{h_3}{\frac{125a}{2}}$$

$$\Rightarrow \quad h_1 = \frac{h_2}{3} = \frac{h_3}{5}$$

53 (*a*) Since, initial velocity is zero ($v_0 = 0$).

We have, $\quad y = -(1/2)g\tau^2 \qquad \ldots\text{(i)}$

For missing term A,

Time interval $= 3\tau$

$$y = -\frac{1}{2} \times g \times (3\tau)^2 = -9\left(\frac{1}{2}g\tau^2\right) \quad \ldots\text{(ii)}$$

For time interval, $t = \tau$

$$y = -\frac{1}{2}g\,\tau^2 = y_0 \qquad \ldots\text{(iii)}$$

Using Eq. (iii), we can express Eq. (ii) as

$$A = y = +9\,y_0$$

For missing term B,

B is the distance traversed between successive intervals, i.e. between $t = 5\tau$ to $t = 6\tau$.

For $t = 5\tau$, using Eq. (i)

$$y_1 = -\frac{1}{2} \times g \times (5\tau)^2 = 25\,y_0$$

For $t = 6\tau$, $\quad y_2 = -\frac{1}{2} \times g \times (6\tau)^2 = 36\,y_0$

$\therefore \quad B = y_2 - y_1 = 36\,y_0 - 25\,y_0 = 11\,y_0$

54 (*a*) The ruler drops under free fall, therefore $v_0 = 0$ and $a = -g = -9.8 \text{ ms}^{-2}$. The distance travelled d and the reaction time t_r are related by

$$d = -\frac{1}{2}g\,t_r^2 \quad \text{or} \quad t_r = \sqrt{\frac{2d}{g}}$$

(as time cannot be negative)

Given, $\quad d = 21.0 \text{ cm} = 0.21 \text{ m}, g = 9.8 \text{ ms}^{-2}$

$$t_r = \sqrt{\frac{2 \times 0.21}{9.8}} \approx 0.2 \text{ s}$$

55 (*a*) Given, $\quad a = +4 \text{ ms}^{-2}$

Reaction time, $t_r = 2$ s

$v_0 = 20 \text{ ms}^{-1}$

In between the time elapse of seeing the person and applying the brake, the car continues to move with same uniform acceleration. The time elapsed between the moment is reaction time t_r.

$$\therefore \quad s = v_0 t_r + (1/2)at_r^2 = 20 \times 2 + (1/2)4 \times (2)^2$$

$$= 40 + (2)(2)^2 = 48 \text{ m}$$

56 (*a*) Given, $x(t) = (t-2)^2 \qquad \ldots\text{(i)}$

Velocity of a particle at any time $t, v = \frac{dx}{dt}$

$$\Rightarrow \quad v(t) = \frac{d}{dt}(t-2)^2 = 2(t-2) \qquad \ldots\text{(ii)}$$

Let us find the time at which velocity is zero.

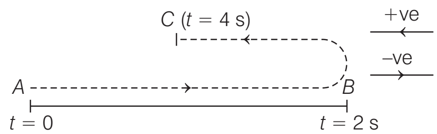
i.e. $\quad v = 0 \Rightarrow 2(t-2) = 0 \quad \Rightarrow t = 2 \text{ s}$

So, before 4 s is completed, the particle's velocity becomes zero and it takes a turn.

Acceleration of particle

$$= \frac{dv}{dt} = \frac{d}{dt}(2t-2) = 2 \text{ ms}^{-2} \qquad \ldots\text{(iii)}$$

The motion of the particle along a straight line can be seen as



Total distance = Path length $(AB + BC)$

$\therefore$ At $t = 0$, $v(0) = 2(0-2) = v_0 = -4\ \text{ms}^{-1}$ [From Eq. (ii)]

Also, $a = +2\ \text{ms}^{-2}$ [from Eq. (iii)]

For first 2s,

Using, $x(t) = v_0 t + (1/2)\, at^2$

$\Rightarrow x_1(2) = -4 \times 2 + (1/2) \times 2 \times (2)^2 = -8 + 4 = -4\ \text{m}$

Distance during this interval, $AB = |x_1(2)| = 4\ \text{m}$

For next 2 s, $v_0 = v(2) = 2(2-2) = 0\ \text{ms}^{-1} \Rightarrow a = 2\ \text{ms}^{-2}$

$\Rightarrow \quad x_2(2) = BC = 0 + 1/2 \times 2 \times (2)^2 = 4\ \text{m}$

$\therefore \quad$ Total distance $= 4 + 4 = 8\ \text{m}$

57 (d) Given, $x = 8 + 12t - t^3$

We know, $v = \dfrac{dx}{dt}$ and acceleration, $a = \dfrac{dv}{dt}$

So, $v = 12 - 3t^2$ and $a = -6t$

When $v = 0$, then $t = \sqrt{\dfrac{12}{3}} = 2\ \text{s}$

and $a = -6 \times 2 = -12\ \text{ms}^{-2}$

So, retardation of the particle $= 12\ \text{ms}^{-2}$.

58 (b) Velocity of the particle is given as $v = At + Bt^2$

where, A and B are constants.

$$\Rightarrow \quad \frac{dx}{dt} = At + Bt^2 \qquad \left(\because v = \frac{dx}{dt}\right)$$

$$\Rightarrow \quad dx = (At + Bt^2)\,dt$$

Integrating on both sides within the limit, we get

$$\int_{x_1}^{x_2} dx = \int_1^2 (At + Bt^2)\,dt$$

$$= A\left(\frac{t^2}{2}\right)_1^2 + B\left(\frac{t^3}{3}\right)_1^2$$

$$x_2 - x_1 = \frac{A}{2}(2^2 - 1^2) + \frac{B}{3}(2^3 - 1^3)$$

$\therefore$ Distance travelled between 1 s and 2 s,

$$\Delta x = \frac{A}{2} \times (3) + \frac{B}{3}(7) = \frac{3A}{2} + \frac{7B}{3}$$

59 (a) Given, $v(x) = 3x^2 - 4x$

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

$$= (3x^2 - 4x) \times \frac{dv}{dx}$$

$$= (3x^2 - 4x) \times (6x - 4)$$

60 (b) Given, $v(x) = \beta x^{-2n}$

$$a = \frac{dv(x)}{dt} = \frac{dx}{dt} \cdot \frac{dv}{dx}$$

$$\Rightarrow \quad a = v\frac{dv}{dx} = (\beta x^{-2n})(-2n\beta x^{-2n-1})$$

$$\Rightarrow \quad a = -2n\beta^2 x^{-4n-1}$$

61 (a) To find value of time at which velocity is maximum, take differentiation of v with respect to time

$$\Rightarrow \quad \frac{dv}{dt} = 0$$

Given, $v = 4t(1 - 2t) \Rightarrow v = 4t - 8t^2$

$$\Rightarrow \quad \frac{d}{dt}(4t - 8t^2) = 0$$

$$\Rightarrow \quad 4 - 16t = 0 \Rightarrow t = \frac{1}{4}\ \text{s} = 0.25\ \text{s}$$

Again taking differentiation, we get

$$\Rightarrow \quad \frac{d^2v}{dt^2} = -16 < 0$$

So, at $t = 0.25$ s velocity is maximum.

62 (a) Given, $t = \alpha x^2 + \beta x$

$$\frac{dt}{dx} = 2\alpha x + \beta \Rightarrow \frac{dx}{dt} = v = \frac{1}{2\alpha x + \beta}$$

As acceleration, $a = \dfrac{dv}{dt} = \dfrac{dv}{dx}\dfrac{dx}{dt}$

$$\Rightarrow \quad a = v \cdot \frac{dv}{dx} = \frac{1}{2\alpha x + \beta}\left(\frac{-v2\alpha}{2\alpha x + \beta}\right)$$

$$= -2\alpha v \cdot v^2 = -2\alpha v^3$$

$\therefore \quad$ Retardation $= 2\alpha v^3$

63 (a) Given, $x = ae^{-pt} + be^{qt}$

Velocity, $v = \dfrac{dx}{dt} = \dfrac{d}{dt}(ae^{-pt} + be^{qt})$

$$= -pae^{-pt} + qbe^{qt}$$

Acceleration, $a = \dfrac{dv}{dt} = \dfrac{d}{dt}(-pae^{-pt} + qbe^{qt})$

$$= p^2ae^{-pt} + q^2be^{qt}$$

Acceleration is positive, so velocity goes on increasing with time.

64 (d) For uniform velocity, $x_A(t) = x_A(0) + v_A t$

and $\quad x_B(t) = x_B(0) + v_B t$

$\therefore$ The displacement from object A to object B is given by

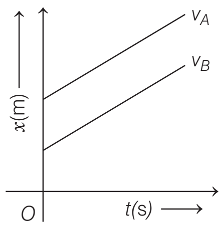
$$x_{BA}(t) = x_B(t) - x_A(t)$$
$$= [x_B(0) - x_A(0)] + (v_B - v_A)\,t$$

65 (d) Given, $\quad v_{BA} = -v_{AB}$

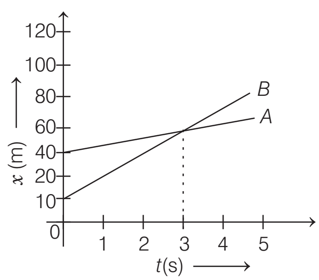
The above relation is true for both average velocities of particles and instantaneous velocities of particles.

As speed is scalar quantity, ignorant of direction, so average speed may not be equal.

66 (a) If v_{BA} or v_{AB} is zero, then $v_A = v_B$ as $v_{AB} = v_{BA} = |v_A - v_B|$.
For uniform motion, the position-time graph will be straight lines parallel to each other and inclined to time axis as shown below for given situation.



67 (d) If $v_A > v_B$, then $v_{BA} = v_B - v_A$ will be negative and $v_{AB} = v_A - v_B$ will be positive.
The x-t graph thus plotted for A and B is as shown below in which object A overtakes object B at some time $t = 3$.
From graph it can be concluded that, one graph is steeper than the other and they meet at a common point.



Hence, both option (a) and (c) are true for given situation.

68 (c) When trains are moving in same direction relative speed $= |v_1 - v_2|$ and in opposite direction relative speed $= |v_1 + v_2|$
Hence, ratio of time when trains move in same direction with time when trains move in opposite direction is

$$\frac{t_1}{t_2} = \frac{\left(\dfrac{l_1 + l_2}{|v_1 - v_2|}\right)}{\left(\dfrac{l_1 + l_2}{|v_1 + v_2|}\right)} = \frac{|v_1 + v_2|}{|v_1 - v_2|}$$

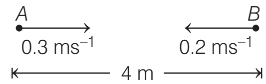
where, $l_1 + l_2$ = sum of lengths of trains which is same as distance covered by trains to cross each other

So, $$\frac{t_1}{t_2} = \frac{80 + 30}{80 - 30} = \frac{110}{50} = \frac{11}{5}$$

69 (a) Let south to north direction be positive.
Velocity of car, $v_C = -20 \text{ ms}^{-1}$
Velocity of person, $v_P = +10 \text{ ms}^{-1}$

$$v_{CP} = v_C - v_P = (-20) - (10) = -30 \text{ ms}^{-1}$$

70 (c) The situation is depicted as given below

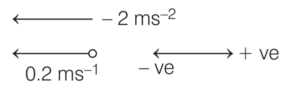


Motion of ball A relative to rocket
Consider motion of two balls with respect to rocket.
Maximum distance of ball A from left wall,

$$s = \frac{u^2}{2a} = \frac{0.3 \times 0.3}{2 \times 2} = \frac{0.09}{4} \approx 0.02 \text{ m}$$

$(\text{as}, 0 = u^2 - 2as)$

So, collision of two balls will take place very near to left wall.



Motion of ball B relative to rocket,

For ball B, $$s = ut + \frac{1}{2}at^2$$

$$\Rightarrow \quad -4 = 0.2t - \left(\frac{1}{2}\right)2t^2 \Rightarrow$$

$t^2 - 0.2t - 4 = 0$
Solving this equation, we get

$$t = \frac{0.2 \pm \sqrt{0.04 + 16}}{2} \Rightarrow t \simeq 2 \text{ s}$$

$\therefore$ Time of hitting = 2 s

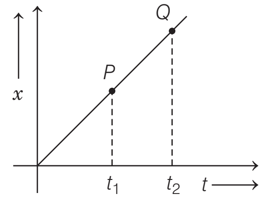
71 (a) The approximation of an object as point object is valid only, when the size of the object is much smaller than the distance it moves in a reasonable duration of time.
Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

72 (a) Average velocity $= \dfrac{\text{Displacement}}{\text{Time interval}}$

Average speed $= \dfrac{\text{Total path length}}{\text{Time interval}}$

For motion in a straight line and in the same direction,
Displacement = Total path length
$\Rightarrow$ Average velocity = Average speed
Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

73 (b) In uniform motion along a straight line, the object covers equal distances in equal intervals of time.
For uniform motion, x-t graph is represented as a straight line inclined to time axis. The average velocity during any time interval $t = t_1$ to $t = t_2$ is the slope of the line PQ which coincides with the graph.



Also, velocity at any instant say $t = t_1$ is the slope of the tangent at point P which again coincides with PQ or with the graph. Hence, velocity is same as the average velocity at all instants.

Therefore, Assertion and Reason are correct but Reason is not the correct explanation of Assertion.

74 (*a*) The x-t, v-t and a-t graphs will be smooth, which means that physically, the values of acceleration and velocity cannot change abruptly as changes are always continuous.
Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

75 (*d*) The uniform motion of a body means that the body is moving with constant velocity.

But if the direction of motion is changing (such as in uniform circular motion), its velocity changes and thus acceleration is produced in a body moving uniformly.
Therefore, Assertion is incorrect but Reason is correct.

76 (*c*) When a particle is released from rest position under gravity, then $v = 0$ but $a \neq 0$.
Also, a body is momentarily at rest at the instant, if it reverse the direction.
Therefore, Assertion is correct but Reason is incorrect.

78 (*b*) In given case, when objects move in same direction then relative velocity of object A w.r.t. object B is $v_{AB} = v_A - v_B$.
When objects A and B move in opposite direction then relative velocity of object B w.r.t. object A will be $v_{BA} = v_B - v_A$.

Therefore, Assertion and Reason are correct but Reason is not the correct explanation of Assertion.

79 (*c*) Statements II and III are correct but I is incorrect and it can be corrected as,

Even, when we are sleeping, air and blood flow are treated as objects which are in motion w.r.t. the body. Also, while sleeping human beings are in rest, not in motion.

80 (*d*) Statements I and II are correct, but III is incorrect and it can be corrected as,

Object is in motion only when it changes its position with time. So, the object is in motion from point O to point P, i.e. from $t = 0$ s to 5 s and object is at rest from $t = 5$ s to $t = 10$ s.

81 (*c*) Since, Rahul's initial and final positions coincides. Thus, his displacement,

$$\Delta x = x_{\text{final}} - x_{\text{initial}} = 0$$

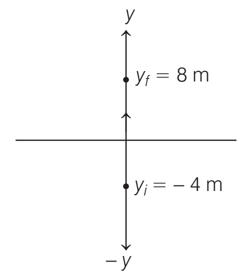
However, corresponding path length

$$= 240 + 240 = 480 \text{ m}$$

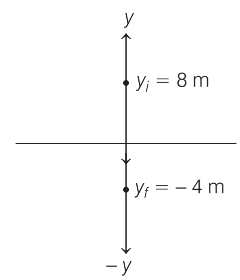
Thus, the magnitude of the displacement for the given course of motion is zero but the corresponding path length is 480 m.

So, all statements are correct.

82 (*c*) Displacement is defined as the shortest distance between the initial and the final positions of an object or body. It is given as $\Delta x = x_f - x_i$
where, x_f and x_i are final and initial positions of the object/body, respectively.
Case (i) $\Delta y_1 = 8 - (-4) = +12$ m



Case (ii) $\Delta y_2 = -4 - 8 = -12$ m



Thus, his displacement is negative in Case (ii) and positive in Case (i).
So, statement III is correct but I and II are incorrect.

83 (*a*) Only statement I is correct but II is incorrect and it can be corrected as

Coordinate of an object with respect to a rectangular coordinate system is described as (x, y, z). Here, at least one of the coordinates, i.e. either x or y or z must change for an object in motion. If none of the coordinates change, then the object is said to be at rest with respect to the given reference frame.

84 (*a*) From the relation of stopping distance, $d_s = -\dfrac{v_0^2}{2a}$

Keeping $a =$ constant, $d_s \propto v_0^2$

When initial velocity is doubled,

$$v_0' = 2v_0$$

$$\Rightarrow \quad d_0' = -\frac{(2v_0)^2}{2a} = -\frac{4v_0^2}{2a} = 4d_s$$

Hence, doubling the initial velocity increases the stopping distance by a factor of 4.

Stopping distance is an important factor considered in setting speed limits because it is the distance travelled by vehicle before stopping, e.g. in school zones.

So, statement I is incorrect but II and III are correct.

85 (a) If v_A and v_B are of opposite signs, relative velocity for two cases will be

$$v_{AB} = v_A - v_B \quad \ldots(\text{i})$$
$$v_{BA} = v_B - v_A \quad \ldots(\text{ii})$$

Case I $v_A > 0$ and $v_B < 0$

Let $v_A = x \text{ ms}^{-1}$

and $v_B = -y \text{ ms}^{-1}$

$$v_{AB} = v_A - v_B = x - (-y) = x + y$$
$$|v_{AB}| = |x + y| = x + y$$
$$v_{BA} = v_B - v_A = -y - x = -(y + x)$$
$$\Rightarrow \quad |v_{BA}| = (y + x)$$

Case II If $v_A < 0$ and $v_B > 0$

Let, $v_A = -x \text{ ms}^{-1}$

and $v_B = +y \text{ms}^{-1}$

$$v_{AB} = v_A - v_B = -x - y = -(x + y)$$
$$\Rightarrow \quad |v_{AB}| = x + y$$
$$v_{BA} = v_B - v_A = y - (-x) = y + x$$
$$\Rightarrow \quad |v_{BA}| = x + y$$

So, from Case I and Case II $|v_{AB}| = |v_{BA}| > |v_A|$ or $|v_B|$

Magnitude of v_{BA} or v_{AB} is greater than the magnitude of velocity of A or that of B.

Also, they will never meet.

If the objects under consideration are two trains, then for a person sitting in either of the two, the other train seems to go very fast.

So, statement III is incorrect but I and II are correct.

86 (d) Statement given in option (d) is incorrect and it can be corrected as,

Path length is a scalar quantity as it has only magnitude but no direction whereas displacement has magnitude as well as direction, so displacement is vector quantity.

Rest statements are correct.

87 (b) Statement given in option (b) is correct but the rest are incorrect and these can be corrected as,

In general, average speed is not equal to magnitude of average velocity. It can be so if the motion is along a straight line without change in direction.

When acceleration of particle is not constant, then motion is called as non-uniformly accelerated motion.

Displacement is zero, when a particle returns to its starting point.

88 (b) Statement given in option (b) is correct, rest are incorrect, these can be corrected as,

Stopping distance is inversely proportional to deceleration a of the vehicle as

Stopping distance, $d_s = -\dfrac{v_0^2}{2a}$

For constant acceleration, average velocity is $\bar{v} = \dfrac{v + u}{2}$.

When a body thrown vertically upwards, then acceleration due to gravity g will be taken as negative.

89 (a) The instantaneous speed is always positive as it is the magnitude of the velocity at an instant. So, it is positive during $t = 5$ s to $t = 10$ s.

For $t = 0$ s to $t = 5$ s, the motion is uniform and x-t graph has positive slope. So, the velocity and average velocity, instantaneous velocity and instantaneous speed are equal and positive.

During $t = 0$ s to $t = 5$ s, the slope of the graph is positive, hence the average velocity and the velocity both are positive.

During $t = 5$ s to $t = 10$ s, the slope of the graph is negative, hence the velocity is negative. Since, there is a change in sign of velocity at $t = 5$ s, so the car changes its direction at this instant.

Hence, option (a) is incorrect, while all other are correct.

90 (d) Here, AB represents uniform motion of a car as x-t graph from t_1 to t_2 varies linearly.

At $t = t_2$ brakes must have been applied such that it stops at $t = t_3$.

After which the x-t graph becomes parallel to time axis.

Thus, all given statements are correct.

91 (a) The relation $x = \left(\dfrac{v + v_0}{2}\right) t$ means that the object has undergone displacement x with an average velocity equal to the arithmetic average of the initial and final velocities.

Thus, the statement given in option (a) is correct, rest are incorrect.

92 (c) Displacement of the object = Area under v-t curve.

$$x = \frac{1}{2}(v - v_0)t + v_0 t \quad \ldots(\text{i})$$

Also, $\quad v = v_0 + at \Rightarrow v - v_0 = at \quad \ldots(\text{ii})$

Putting the value of $(v - v_0)$ from Eq. (ii) in Eq. (i), we get

$$x = \frac{1}{2} at \times t + v_0 t$$
$$\Rightarrow \quad x = \frac{1}{2} at^2 + v_0 t$$

Thus, the statement given in option (c) is correct, rest are incorrect.

93 (c) For negative acceleration, the x- t graph moves downward. But the car is moving in positive direction as the position coordinate is increasing in the positive direction.

Thus, the statement given in option (c) is correct, rest are incorrect.

94 (d) Given, $\quad |v_A| = |v_B|$ (given, speed of A = speed of B)

Case I $\quad v_{AB} = v_A - v_B = 0$

$$\Rightarrow \quad v_A = v_B \quad \ldots(\text{i})$$

Also, $\quad v_{BA} = v_B - v_A = 0$

$$\Rightarrow \quad v_B = v_A \quad \ldots(\text{ii})$$

From Eqs. (i) and (ii), we get

A and B must be moving in same direction as ($v_A = v_B$).

Case II If particles are moving in opposite direction, i.e. $v_A = -v_B$

$$v_{AB} = v_A - v_B = -v_B - v_B = -2v_B$$
$$|v_{AB}| = 2|v_B| = 2|v_A|$$

Also, $v_{BA} = v_B - v_A = v_B - (-v_B) = 2v_B$

$$|v_{BA}| = 2|v_B| = 2|v_A|$$

Hence, for motion in opposite direction, the magnitude of v_{BA} or v_{AB} is twice than the magnitude of velocity of A or that of B.

Thus, the statements given in options (a) and (b) are correct, rest is incorrect.

95 (*a*)

A. Displacement of the car is moving O to P is

$$\Delta x = x_2 - x_1 = (+360\text{ m}) - 0\text{ m} = +360\text{ m}$$

B. Path length of the car is moving O to R is 120 m, as path length is the total distance traversed by the car from O to R.

C. For the motion of the car from O to P and back to Q.

Path length $= (+360\text{ m}) + (+120\text{ m}) = +480\text{ m}$

D. However, in the above case displacement

$$= (+240\text{ m}) - (0\text{ m})$$
$$= +240\text{ m}$$

Hence, A → 2, B → 4, C → 1 and D → 3.

96 (*d*)

A. Here, average velocity $= \dfrac{\text{displacement}}{\text{time interval}}$

$$= \frac{x_2 - x_1}{t_2 - t_1} = \frac{+20 - 0}{10\text{ s}} = +2\text{ms}^{-1}$$

Average speed $= \dfrac{\text{Total path length}}{\text{Time interval}}$

$$= \frac{OP}{t_2 - t_1} = \frac{20\text{ m}}{10\text{ s}} = 2\text{ms}^{-1}$$

B. For path travelled from O to P and and back to R,

Average velocity $= \dfrac{\text{Displacement}}{\text{Time interval}} = \dfrac{x_2 - x_1}{t_2 - t_1}$

$$= \frac{(-20) - 0}{(10+20)} = -\frac{20}{30}\text{ ms}^{-1}$$
$$= -\frac{2}{3}\text{ ms}^{-1}$$

Average speed $= \dfrac{\text{Path length}}{\text{Time interval}}$

$$= \frac{OP + PR}{10 + 20}$$
$$= \frac{(20+40)\text{ m}}{30\text{ s}} = \frac{60}{30}\text{ ms}^{-1}$$
$$= 2\text{ms}^{-1}$$

C. When object moves from O to Q and back to R, then

Average velocity $= \dfrac{x_2 - x_1}{t_2 - t_1} = \dfrac{[(-20) - 0]\text{ m}}{40\text{ s}}$

$$= -\frac{20}{40}\text{ms}^{-1} = -0.5\text{ms}^{-1}$$

Average speed $= \dfrac{OQ + QR}{\Delta t}$

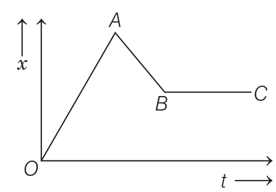
$$= \frac{(50+70)\text{ m}}{40\text{ s}} = \frac{120}{40}\text{ ms}^{-1} = 3\text{ms}^{-1}$$

Hence, A → 2, B → 3 and C → 1.

97 (*b*) In x-t graph, OA → Positive slope → Positive velocity

AB → Negative slope → Negative velocity

BC → Zero slope → Object at rest



At point A, there is a change in sign of velocity, hence the direction of motion must have changed at A.

Hence, A → 1, B → 3, C → 2 and D → 4.

98 (*c*)

A. Distance of the object between $t = 0$ s to $t = 2$ s.

= Area under v-t graph

= Area of triangle of base = 2 and height = 4

$$= \frac{1}{2} \times \text{base} \times \text{height} = \frac{1}{2} \times 2 \times 4 = 4\text{ m}$$

B. Displacement of the object between $t = 0$ s to $t = 2$ s

= Distance covered in same interval = + 4 m

C. For $t = 0$ s to $t = 4$ s,

Displacement = Area under v-t curve ($t = 0$ s to $t = 2$ s) + Area under v-t curve ($t = 2$s to $t = 4$ s)

$$= \frac{1}{2} \times 2 \times 4 + \frac{1}{2} \times 2 \times (-4) = 4\text{ m} + (-4\text{ m}) = 0$$

D. For $t = 0$ s to $t = 4$ s,

Distance covered = Area under v-t curve considering all areas as positive.

= Area under v-t curve ($t = 0$ s to $t = 2$ s) + Area under v-t curve ($t = 2$ s to $t = 4$ s)

= 4 m + 4 m = 8 m

Hence, A → 3, B → 2, C → 4 and D → 1.

99 (*d*)

A. For $t = 0$ s to $t = 2$ s, the motion is in positive direction as the velocity is positive and the acceleration is positive, since the slope of the straight line is positive.

B. For $t = 2$ s to $t = 4$ s, the object is moving in positive direction, till time $t_1 = 2$ s, and then turns back with the same negative acceleration till $t = 4$ s.

C. For $t = 4$ s to $t = 6$ s, the object is moving in negative direction, since the velocity is negative. The acceleration is positive, since the slope of the straight line is positive.

D. Displacement for overall journey ($t = 0$ s to $t = 6$ s) = Total area under v- t graph considering the area below time axis as negative = [Area under v- t curve for $t = 0$ to $t = 3$ s] + [Area under v- t curve for $t = 3$ s to $t = 6$ s] = Area of triangle (OAB) + Area of triangle (BCD) $= \frac{1}{2} \times 3 \times 5 + \frac{1}{2} \times 3 \times (-5) = 0$

Hence, A → 4, B → 1, C → 2 and D → 3.

100 (b) Given, $x(t) = a - bt^2$, $a = 8.5$ m and $b = 2.5$ ms^{-2}

$\therefore \quad x(t) = 8.5 - 2.5t^2$

Velocity of object $= \frac{dx}{dt} = -2bt$

A. Velocity at $t = 2.0$ s $= \left.\frac{dx}{dt}\right|_{t=2} = -4b$

$= -4 \times 2.5 = -10$ ms^{-1}

B. Velocity at $t = 0$s $= \left.\frac{dx}{dt}\right|_{t=0} = 0$ ms^{-1}

C. Instantaneous speed at $t = 2$ s = Magnitude of velocity $= |-10 \text{ ms}^{-1}| = 10$ ms^{-1}

D. Average velocity $= \frac{x(t_2) - x(t_1)}{t_2 - t_1} = \frac{x(4) - x(2)}{4 - 2}$

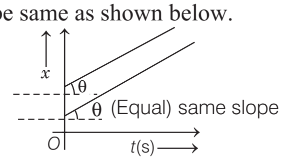
$= \frac{[a - b(4)^2] - [a - b(2)^2]}{2} = \frac{4b - 16b}{2}$

$= -\frac{12b}{2} = -6b = -6 \times 2.5$ ms^{-1} $= -15$ ms^{-1}

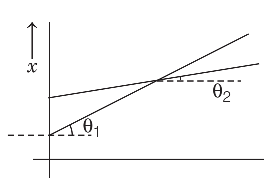
Hence, A → 2, B → 3, C → 4 and D → 1.

101 (b)

A. For equal velocities, the slope of the straight lines must be same as shown below.



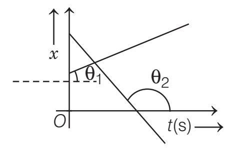
B. For unequal velocity, slope is different, but since, the objects are moving in the same direction, the slope for both the graphs must be of same sign (positive or negative) and they meet at a point as shown below



C. For velocities in opposite direction, slopes must be of opposite sign. Slope = tan θ, where θ is the angle of the straight line with horizontal in anti-clockwise direction. As, we know $\tan\theta_1 > 0$, $\tan\theta_2 < 0$

Hence, slopes are of opposite sign.

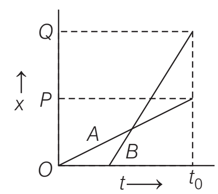
This condition is shown below.



Hence, A → 2, B → 1 and C → 3.

102 (c)

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



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

(c) Speed = Slope of x-t graph

Slope for B > Slope for A

$\therefore$ B walks faster than A.

(d) Corresponding to the positions P and Q, time t_0 is same on t-axis.

$\therefore$ A and B reach home at the same time.

Hence, statement given in option (c) is incorrect.

103 (d) As drunkard takes 5 steps forward and 3 steps backward, therefore he moves 5 m forward and 3 m backward.

Time taken in 8 steps = 8 s

$\therefore$ Distance travelled in 8 s in 8 steps = 5 − 3 = 2 m

Distance travelled in 16 s in 16 steps = 2 × 2 = 4 m

Distance travelled in 24 s in 24 steps = 2 × 3 = 6 m

Distance travelled in 32 s in 32 steps = 2 × 4 = 8 m

Distance travelled in next 5 s in next 5 steps taken in forward direction = 5 m

$\therefore$ Total distance travelled in (32 + 5 =) 37 s in 37 steps

= 8 + 5 = 13 m

Distance of the pit from the starting point = 13 m

Therefore, drunkard will fall in the pit in 37 s.

104 (a) Let jet airplane be moving left (+ ve direction) with velocity v_j and ejected gases be moving right (− ve direction) with velocity v_g while observer be at rest on the ground, i.e. $v_0 = 0$

$\therefore \quad v_j = 500$ kmh^{-1}

$\Rightarrow \quad v_g = -1500$ kmh^{-1} $\Rightarrow v_0 = 0$

Relative velocity of plane with respect to the observer,

$v_j - v_0 = 500 - 0 = 500$ kmh^{-1} ...(i)

Relative velocity of products of combustion with respect to the jet plane,

$$v_g - v = -1500\,\text{kmh}^{-1} \quad \text{(given)} \quad \ldots\text{(ii)}$$

(Velocity of ejected gas v_g and velocity of v_j are in opposite directions)

Adding Eqs. (i) and (ii), we get

$$(v_j - v_0) + (v_g - v_j) = 500 - 1500$$

$$\Rightarrow \quad v_g - v_0 = -1000\,\text{kmh}^{-1}$$

Therefore, relative velocity of the ejected gases with respect to the observer is 1000 kmh^{-1}, –ve sign shows that this velocity is in a direction opposite to the motion of the jet airplane.

105 (*c*) Given, $u = 126\,\text{kmh}^{-1} = 126 \times \frac{5}{18} = 35\,\text{ms}^{-1}$,

$$v = 0, s = 200\,\text{m}$$

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

$$\Rightarrow \quad 0^2 - 35^2 = 2a \times 200$$

or $$a = -\frac{35 \times 35}{2 \times 200} = -\frac{49}{16} = -3.06\,\text{ms}^{-2}$$

$\therefore$ Retardation, $a = 3.06\,\text{ms}^{-2}$

As, $v = u + at \Rightarrow 0 = 35 + \frac{49}{16}t$

As, time cannot be negative

$\therefore$ Time, $t = \frac{35 \times 16}{49} = \frac{80}{7} = 11.43$ s

106 (*c*) Length of each train, $l_A = l_B = 400\,\text{m}$

Initial velocities of both trains,

$$u_A = u_B = 72\,\text{kmh}^{-1} = 72 \times \frac{5}{18}\,\text{ms}^{-1}$$

$$\left(\because 1\,\text{kmh}^{-1} = \frac{5}{18}\,\text{ms}^{-1}\right)$$

$$= 20\,\text{ms}^{-1}$$

Distance travelled by train A in 50 s, $s_A = u_A \times t$

(as for unaccelerated motion, distance = speed × time)

$$s_A = 20 \times 50 = 1000\,\text{m}$$

Distance travelled by train B in 50 s,

$$s_B = u_B t + (1/2) a_B t^2$$

(as motion of train B is an accelerated motion)

$$s_B = 20 \times 50 + (1/2) \times 1 \times (50)^2$$

$$= 1000 + 1250 = 2250\,\text{m}$$

Original distance between the two trains $= s_B - s_A$

$$= 2250 - 1000 = 1250\,\text{m}$$

107 (*c*) At the instant when B decides to overtake A, the speeds of three cars are

$$v_A = 36\,\text{kmh}^{-1} = 36 \times \frac{5}{18} = +10\,\text{ms}^{-1}$$

$$v_B = +54\,\text{kmh}^{-1} = +54 \times \frac{5}{18} = +15\,\text{ms}^{-1}$$

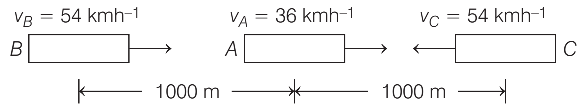
$$v_C = -54\,\text{kmh}^{-1} = -54 \times \frac{5}{18} = -15\,\text{ms}^{-1}$$

Relative velocity of C w.r.t. A,

$$v_{CA} = v_C - v_A = -15 - 10 = -25\,\text{ms}^{-1}$$

$\therefore$ Time that C requires to just cross A

$$= \frac{1\,\text{km}}{v_{CA}} = \frac{1000\,\text{m}}{25\,\text{ms}^{-1}} = 40\,\text{s}$$



In order to avoid the accident, B must overtake A in a time less than 40 s. So, for car B we have

Relative velocity of car B w.r.t. A,

$$v_{BA} = v_B - v_A = 15 - 10 = 5\,\text{ms}^{-1}$$

Here, $s = 1\,\text{km} = 1000\,\text{m}$, $u = 5\,\text{ms}^{-1}$, $t = 40\,\text{s}$

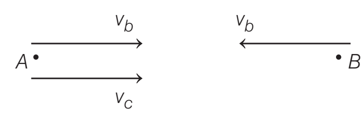
As, $$s = ut + \frac{1}{2}at^2$$

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

or $$1000 = 200 + 800a \quad \text{or} \quad a = 1\,\text{ms}^{-2}$$

Thus, 1 ms^{-2} is the minimum acceleration that car B requires to avoid an accident.

108 (*a*) Let the speed of each bus $= v_b\,\text{kmh}^{-1}$



Speed of cyclist, $v_c = 20\,\text{kmh}^{-1}$

(i) **In the direction of motion of the cyclist (from *A* to *B*)**

Relative velocity of bus w.r.t. cyclist $= v_b - v_c$

$$= (v_b - 20)\,\text{kmh}^{-1}$$

The bus goes past the cyclist after every 18 min.

$\therefore$ Distance covered by the bus w.r.t. the cyclist in this time interval $= (v_b - 20) \times \frac{18}{60}$ km …(i)

A bus leaves in either direction after every T min.

$\therefore$ Distance travelled by a bus in T min $= v_b \times \frac{T}{60}$ km …(ii)

From Eqs. (i) and (ii), we get

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

or $$v_b - 20 = v_b \times \frac{T}{18} \quad \ldots\text{(iii)}$$

(ii) **In the opposite direction of the cyclist (from *B* to *A*)**

Relative velocity of bus w.r.t. cyclist coming from B to $A = (v_b + 20)\,\text{kmh}^{-1}$

The bus goes past the cyclist after every 6 min.

∴ Distance covered by the bus w.r.t. the cyclist in this time interval $= (v_b + 20) \times \frac{6}{60}$ km ...(iv)

Distance travelled by the bus in T min

$$= v_b \times \frac{T}{60} \text{ km} \quad \text{...(v)}$$

From Eqs. (iv) and (v), we get

$$(v_b + 20) \times \frac{6}{60} = v_b \times \frac{T}{60}$$

$$v_b + 20 = v_b \times \frac{T}{6} \quad \text{...(vi)}$$

Dividing Eq. (vi) by Eq. (iii), we get

$$\frac{v_b + 20}{v_b - 20} = \frac{18}{6} = 3$$

$\Rightarrow$ $v_b + 20 = 3v_b - 60$

or $2v_b = 80 \Rightarrow v_b = 40\,\text{kmh}^{-1}$

109 (*a*) For upward motion,

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

If s is the height to which the ball rises, then

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

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

or $s = \frac{(29.4)^2}{2 \times 9.8} = 44.1$ m

If the ball reaches the highest point in time t, then

$$v = u + at \text{ or } 0 = 29.4 - 9.8t$$

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

As, time of ascent = time of descent

∴ Total time taken $= 3 + 3 = 6$ s

110 (*b*) Displacement covered in going to market = 2.5 km

Displacement covered coming back to home = 2.5 km

Net displacement $= 2.5 - 2.5 = 0$

Total distance covered $= 2.5 + 2.5 = 5$ km

(a) Average speed $= \frac{\text{Total distance covered}}{\text{Total time taken}}$

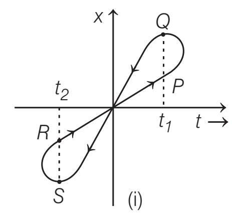
$$= \frac{5\text{km}}{(50/60)\text{h}} = 6\ \text{kmh}^{-1}$$

(b) Average velocity $= \frac{\text{Net displacement}}{\text{Time taken}}$

$$= \frac{0}{(50/60)\text{h}} = 0$$

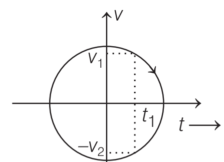
111 (*d*)

(i) No, graph (i) cannot represents one-dimensional motion of a particle, because graph shows two different positions of the particle at same instant of time. (At time t_1 particle is at position P and Q and at time t_2 particle is at position R and S), which is not possible.



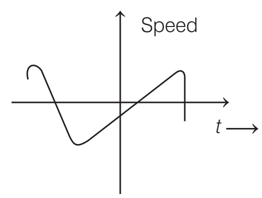
(i)

(ii) No, graph (ii) cannot represents one-dimensional motion of a particle, because graph shows one positive velocity (v_1) and another negative velocity ($-v_2$) of the particle at the same instant of time (t_1) which is not possible.



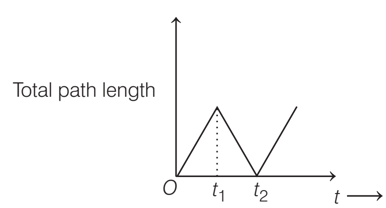
(ii)

(iii) No, graph (iii) cannot represents one-dimensional motion of a particle, because graph shows negative speed of the particle while speed cannot be negative.



(iii)

(iv) No, graph (iv) cannot represents one-dimensional motion of a particle, because graph shows that total path length increases from time $t = 0$ to $t = t_1$, but decreases from $t = t_1$ to $t = t_2$. But total path length of a moving particle can never decrease with time.



(iv)

112 (*d*) No, it is wrong to say that the particle moves in a straight line for $t < 0$ and on a parabolic path for $t > 0$, because a position-time (x-t) graph does not represents the trajectory of a moving particle.

This graph can represents the motion of a freely falling particle dropped from a tower, when we take its initial position as $x = 0$ at $t = 0$.

113 (b) Speed of police van, $v_P = 30\,\text{kmh}^{-1}$

$$= 30 \times \frac{5}{18}\,\text{ms}^{-1} \quad (\because 1\ \text{kmh}^{-1} = \frac{5}{18}\,\text{ms}^{-1})$$

$$= \frac{25}{3}\,\text{ms}^{-1}$$

Speed of thief's car, $v_T = 192\,\text{kmh}^{-1} = 192 \times \frac{5}{18}\,\text{ms}^{-1}$

$$= \frac{160}{3}\,\text{ms}^{-1}$$

Muzzle speed of bullet, $v_B = 150\,\text{ms}^{-1}$

The bullet is sharing the speed of the police van, therefore effective speed of the bullet,

$$v_B' = v_B + v_P = 150 + \frac{25}{3} = \frac{475}{3}\,\text{ms}^{-1}$$

Speed of the bullet with which it hits the thief's car

= Relative speed of the bullet w.r.t. thief's car (v_{BT})

$$v_{BT} = v_B' - v_T = \left(\frac{475}{3} - \frac{160}{3}\right)\text{m/s} = \frac{315}{3} = 105\,\text{ms}^{-1}$$

Therefore, bullet will hit the thief's car with a speed 105 ms^{-1}.

114 (a) The acceleration-time graph represents the motion of a uniformly moving cricket ball turned back by hitting it with a bat for a very short time interval.

115 (a) In simple harmonic motion, the acceleration is given by

$$a = -\omega^2 x \qquad \text{...(i)}$$

where, x is the displacement, ω is the angular frequency and negative sign shows that the direction of acceleration is opposite to the direction of displacement. The velocity is given by

$$v = \frac{dx}{dt} = \text{Slope of } x\text{-}t \text{ graph} \qquad \text{...(ii)}$$

(i) At time $t = 0.3$ s, x is negative and slope of x-t graph is negative, therefore position and velocity of the particle is negative but according to Eq. (i) acceleration is positive.

(ii) At time $t = 1.2$ s, x is positive and slope of x-t graph is positive, therefore position and velocity of the particle is positive but according to Eq. (i) acceleration is negative.

(iii) At time $t = -1.2$ s, x and t both are negative, therefore position of the particle is negative. As x and t both are negative, therefore from Eq. (ii) velocity is positive and according to Eq. (i) acceleration is positive.

(iv) At $t = -0.3$ s, x is positive but v and a are negative.

Hence, A $\rightarrow$ 4, B $\rightarrow$ 3, C $\rightarrow$ 1 and D $\rightarrow$ 2.

116 (b) Slope of x-t graph in a small interval = Average speed in that interval

As slope for interval 2 > slope for interval 1.

$\therefore \qquad v_2 > v_1$

117 (d) (i) As the change in speed is greatest in interval 2, so magnitude of average acceleration is greatest in interval 2.

(ii) Obviously from the graph, average speed is greatest in interval 3.

118 (a) Distance travelled in nth second, $s_n = u + \frac{a}{2}(2n - 1)$

As, $\qquad u = 0, a = 1\text{ms}^{-2}$

$\Rightarrow \qquad s_n = \frac{(2n-1)}{2}$

Thus, the distances travelled by the three wheeler at the end of each second are given by

n(s)	1	2	3	4	5	6	7	8	9	10
$s_{n\text{th}}$ (m)	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5

Now, velocity of the three wheeler at the end of 10th second is given by

$$v = u + at = 0 + 1 \times 10 = 10\ \text{ms}^{-1}$$

Upto $n = 10$ s, the motion is accelerated and the graph between $s_{n\text{th}}$ and n is a straight line inclined to time axis as shown in Fig. (a) After 10th second, the three wheeler moves with uniform velocity of 10 ms^{-1}, so graph is a straight line parallel to time axis.

119 (d)

(i) **When the lift is stationary** For upward motion of the ball, we have

$$u = 49\text{ms}^{-1}, g = -9.8\text{ms}^{-1}, v = 0, t = ?$$

As, $\qquad v = u + at$

$\therefore \qquad 0 = 49 - 9.8t$ or $t = \frac{49}{9.8} = 5$ s

As, time of ascent = time of descent

$\therefore$ Total time taken = 5 + 5 = 10 s

(ii) **When the lift moves up with uniform** The uniform speed of the lift does not change the relative velocity of the ball w.r.t. the boy, i.e., still remain 49ms^{-1}. Hence, total time in which the ball returns is 10 s.

120 (b)

(i) Speed of the child running in the direction of motion of the belt

$$= (9 + 4)\ \text{kmh}^{-1} = 13\ \text{kmh}^{-1}$$

(ii) Speed of the child running opposite to the direction of the belt

$$= (9 - 4)\ \text{kmh}^{-1} = 5\ \text{kmh}^{-1}$$

(iii) Speed of the child w.r.t. either parent

$$= 9\ \text{kmh}^{-1} = 9 \times \frac{5}{18} = 2.5\ \text{ms}^{-1}$$

Distance to be covered = 50 m

$$\text{Time taken} = \frac{50}{2.5} = 20\ \text{s}$$

121 (c) Height of the edge of the cliff, $x_0 = 200\,\text{m}$

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

For first stone, $u_1 = 15\,\text{m/s}$

Using equation, $x_1 = x_0 + u_1 t + \frac{1}{2}at^2$

$$= 200 + 15t + \frac{1}{2}(-10)t^2$$

$$x_1 = 200 + 15t - 5t^2 \quad \ldots\text{(i)}$$

For second stone, $u_2 = 30\,\text{ms}^{-1}$

Using equation, $x_2 = x_0 + u_2 t + \frac{1}{2}at^2$

$$= 200 + 30t + \frac{1}{2}(-10)\,t^2$$

$$x_2 = 200 + 30t - 5t^2 \quad \ldots\text{(ii)}$$

Now, subtracting Eq. (i) from Eq. (ii), we get

$$x_2 - x_1 = 15t$$

122 (c) Distance travelled by the particle between time interval $t = 0\,\text{s}$ to $t = 10\,\text{s}$

$$= \text{Area of triangle } OAB = \frac{1}{2} \times \text{Base} \times \text{Height}$$

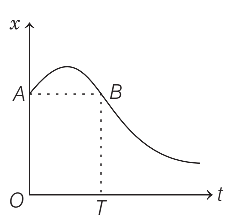
$$= \frac{1}{2} \times OB \times AC$$

$$= \frac{1}{2} \times 10 \times 12 = 60\,\text{m}$$

123 (b) The slope of the given graph over the time interval t_1 to t_2 is not constant and is not uniform. It means acceleration is not constant and is not uniform, therefore relations (i) and (ii) are not correct which is for uniform accelerated motion.

But relations (iii) and (iv) are correct, because these relations are true for both uniform or non-uniform accelerated motion.

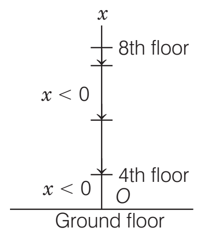
124 (b) In graph (b), for one value of displacement, there are two different points of time. Hence, for one time, the average velocity is positive and for other time, it is negative. As there are opposite velocities in the interval 0 to T, hence average velocity can vanish in (b). This can be seen in the figure given.



Here, $OA = BT$ (same displacement) for two different points of time.

125 (a) As the lift is coming in downward direction, displacement will be negative i.e., $x < 0$. When the lift reaches 4th floor, it is about to stop and hence motion is retarding in nature, hence $a > 0$.

As displacement is in negative direction, so velocity will also be negative, i.e. $v < 0$. This can be shown in the graph below.



126 (b) For maximum and minimum displacement, we have to keep in mind the magnitude and direction of maximum velocity.

As maximum velocity in positive direction is v_0, maximum velocity in opposite direction is also v_0 with negative sign.

Maximum displacement in one direction $= v_0 T$

Maximum displacement in opposite directions $= -v_0 T$

Hence, $-v_0 T < x < v_0 T$.

127 (c) Time taken to travel first half distance,

$$t_1 = \frac{l/2}{v_1} = \frac{l}{2v_1}$$

Time taken to travel second half distance, $t_2 = \dfrac{l}{2v_2}$

$$\text{Total time} = t_1 + t_2 = \frac{l}{2v_1} + \frac{l}{2v_2} = \frac{l}{2}\left[\frac{1}{v_1} + \frac{1}{v_2}\right]$$

We know that,

$$v_{av} = \text{Average speed} = \frac{\text{Total distance}}{\text{Total time}}$$

$$= \frac{l}{\frac{l}{2}\left[\frac{1}{v_1} + \frac{1}{v_2}\right]} = \frac{2v_1 v_2}{v_1 + v_2}$$

128 (b) Given, $x = (t-2)^2$

$$\text{Velocity, } v = \frac{dx}{dt} = \frac{d}{dt}(t-2)^2 = 2(t-2)\,\text{ms}^{-1}$$

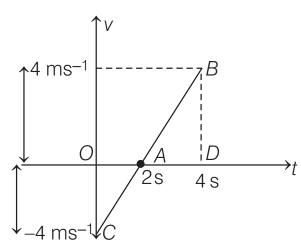
$$\text{Acceleration, } a = \frac{dv}{dt} = \frac{d}{dt}[2(t-2)] = 2[1-0] = 2\,\text{ms}^{-2}$$

When $t = 0$; $v = -4\,\text{ms}^{-1}$

$t = 2\,\text{s}$; $v = 0\,\text{ms}^{-1}$

$t = 4\,\text{s}$; $v = 4\,\text{ms}^{-1}$

v-t graph for these values is shown below



Distance travelled = Area of the graph

$= \text{Area } OAC + \text{Area } ABD$

$= \frac{1}{2} \times 4 \times 2 + \frac{1}{2} \times 2 \times 4 = 8\text{ m}$

129 (c) Let displacement is L, then

Velocity of girl, $v_g = \frac{L}{t_1}$

Velocity of escalator, $v_e = \frac{L}{t_2}$

Net velocity of the girl $= v_g + v_e = \frac{L}{t_1} + \frac{L}{t_2}$

If t is total time taken in covering distance L, then

$$\frac{L}{t} = \frac{L}{t_1} + \frac{L}{t_2} \Rightarrow t = \frac{t_1 t_2}{t_1 + t_2}$$

130 (a) When we are representing motion by a graph, it may be displacement-time, velocity-time or acceleration-time, hence B may represent time.

For uniform motion, velocity-time graph should be a straight line parallel to time axis and displacement-time graph a straight line inclined to time axis.

Hence, quantity A is displacement. For uniformly accelerated motion, slope will be positive and A will represent velocity.

131 (c) As point A is the starting point. Therefore, particle is starting from rest.

At point B, the graph is parallel to time axis, so the velocity is constant here. Thus, acceleration is zero.

Also point C, the graph changes slope, hence velocity also changes.

After graph at C is almost parallel to time axis, hence we can say that velocity and acceleration vanishes.

From the graph, it is clear that

$$|\text{slope at } D| > |\text{slope at } E|$$

Hence, speed at D will be more than at E.

132 (d) Given, $x = t - \sin t$

Velocity, $v = \frac{dx}{dt} = \frac{d}{dt}[t - \sin t] = 1 - \cos t$

Acceleration, $a = \frac{dv}{dt} = \frac{d}{dt}[1 - \cos t] = \sin t$

As acceleration $a > 0$ for all $t > 0$

Hence, $x(t) > 0$ for all $t > 0$

Velocity, $v = 1 - \cos t$

When $\cos t = 1$, velocity $v = 0$

$v_{\text{max}} = 1 - (\cos t)_{\text{min}} = 1 - (-1) = 2$

$v_{\text{min}} = 1 - (\cos t)_{\text{max}} = 1 - 1 = 0$

Hence, v lies between 0 and 2.

133 (a) Since, the ball is moving with a small speed in the moving train, the direction of motion of the ball is the same as that of the train. The direction of motion of ball does not changes with respect to an observer on ground, i.e. constant for every 10 s.

Compared to velocity of trains (10 ms^{-1}), speed of ball is less (1 ms^{-1}). The speed of the ball before collision with side of train is $10 + 1 = 11\text{ ms}^{-1}$.

Speed after collision with the side of train

$= 10 - 1 = 9\text{ ms}^{-1}$.

Since, the collision of the ball with side of train is perfectly elastic; the total momentum and kinetic energy are conserved, so average speed of the ball over any 20 s interval is constant or fixed as observed by observer on ground.

Since, the train is moving with constant velocity hence, it will act as inertial frame of reference like Earth and acceleration of ball will be same as from the train.