CHAPTER-3 MOTION IN A STRAIGHT LINE

Mechanics: Mechanics is the oldest and fundamental branch of physics and it is the study of the state of rest as well as the state of motion of object under the action of force.
The study of mechanics is broadly classified in to (i) Statics and (ii) Dynamics

Statics: It deals with bodies at rest under the action of system of force.

Dynamics: It deals with motion of a body under the action of force.
Dynamics is again divided into (a) Kinematics and (b) Kinetics

Kinematics: It deals with the description of motion without reference to the cause of motion.

Kinetics: It deals with what moves and what causes motion.

Some of the terms used in describing motion are given below.
Particle: A particle is ideally just a piece or quantity of matter, having no linear dimensions but only position and mass.

Event: An event is a physical process that occurs at a point in space and at an instant of time.

Observer: A person or equipment which can locate, record, measure and interpret an event is called an observer.

Frame of reference: It is the reference in which an observer sits and makes the observations.
In order to specify the position, we need to use a reference point and set of axes. The choice of set of axes in a frame of reference depends on the situation.

Motion: Motion is change in position of an object with time.

Rectilinear motion: Motion of objects along a straight line.
Ex: A car moving along a straight road, A freely falling body.

Rest: A body is said to be at rest when it does not changes its position with time.

Path length: It is the actual distance covered by a body in time t.
It is also called as distance travelled.
* Path length is a scalar quantity.
* SI unit of path length is "$metre$" (m). Dimensions are M^0LT^0
* Path length depends on the actual path.
* Path length is always positive.

Displacement: It is the shortest distance between the initial point and final point.
* It is vector quantity.
* SI unit of displacement is "$metre$"(m). Dimensions are M^0LT^0
* Displacement may be positive, negative and zero.
* Magnitude of the displacement can never be greater than path length.
* When a body moves in straight line displacement is equal to path length.
* It is independent of the actual path travelled and it denoted by Δx

Difference between path length and displacement

Path length	Displacement
It is the actual distance covered by a body in time$t$. It is also called as distance travelled	It is the shortest distance between the initial point and final point
Path length is a scalar quantity	It is vector quantity
Path length is always positive	Displacement may be positive, negative and zero
Path length is always greater than or equal to displacement	Displacement is always less than or equal to path length

Speed: Speed is defined as rate of change of position of a particle.

$$Speed = \frac{path\ length}{time\ taken} = \frac{x}{t}$$

* Speed is a scalar quantity.
* Its SI unit is $metre\ per\ second$ (ms^{-1}). Dimensions are M^0LT^{-1}
* It is always positive.
* Speed gives no indication about the direction of motion of the particle.

Average speed: The average speed of a particle in motion is defined as the ratio of the total path length to the total time taken.

$$Average\ speed = \frac{total\ path\ length}{total\ time\ taken}$$

Instantaneous speed (speed): It is defined as the limit of average speed as the time interval is infinitesimally small.

Velocity: Velocity is defined as the rate of change of displacement of a body.

$$Velocity = \frac{displacement}{time\ taken}$$

$$\boldsymbol{v = \frac{x}{t}}$$

* Velocity is a vector quantity.
* SI unit is $per\ second$ (ms^{-1}) . Dimensions are M^0LT^{-1}
* Velocity may be positive, negative or zero.

Average velocity: The average velocity of a particle in motion is defined as the ratio of total displacement to the total time taken.

$$Average\ velocity = \frac{total\ displacement}{total\ time\ taken}$$

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

$$\bar{v} = \frac{\Delta x}{\Delta t}$$

Instantaneous velocity: Velocity is defined as the limit of average velocity as the time interval Δt becomes infinitesimally small.

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

* Instantaneous velocity is also called velocity.
* In position-time graph, instantaneous velocity at a point is the slope to the tangent drawn to the curve at that point.
* Instantaneous speed or speed is the magnitude of velocity.

Uniform velocity: If equal changes of displacement take place in equal intervals of time is called uniform velocity.

Note: When a body moves with uniform velocity, neither the magnitude nor the direction of the velocity changes.

Difference between speed and velocity

Speed	Velocity
It is defined as the ratio of the path length to the time taken.	It is defined as the ratio of displacement to the time taken.
Speed is a scalar quantity.	Velocity is a vector quantity.
It is always positive	Velocity may be positive, negative or zero.

Acceleration: It is defined as rate change of velocity of a particle.

$$Acceleration = \frac{change\ in\ velocity}{time\ taken}$$

$$\boldsymbol{a = \frac{v - v_0}{t}}$$

* Acceleration is a vector quantity.
* SI unit is $metre\ per\ square\ of\ second$ (ms^{-2}) and dimensions are M^0LT^{-2}
* Since velocity is a quantity having both magnitude and direction, Acceleration may result from a change in magnitude or a change in direction or changes in both.
* Acceleration can be positive, negative or zero.
* The negative acceleration is called retardation or deceleration.

Average acceleration: It is defined as the total change in velocity divided by the total time taken.

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

Instantaneous acceleration: It is defined as the limit of the average acceleration as the time interval Δt becomes infinitesimally small.

$$\boldsymbol{a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}}$$

Uniform acceleration: If the velocity of a body changes by equal amount in equal intervals of time, however small these time intervals may be, is called uniform acceleration.

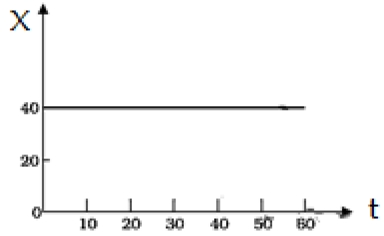
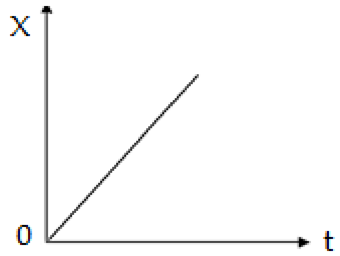
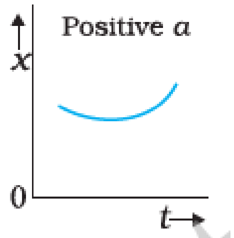
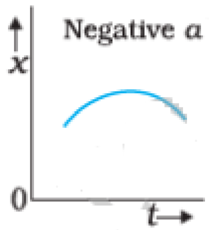
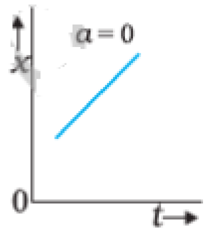
Graphical representation of motion:

Graph: A diagrammatical representation of variation of one quantity with respect to another quantity is called a graph.

Position-time graph: It is a graph obtained by plotting instantaneous positions of a particle versus time.

* The slope of the position time graph gives the velocity of the particle.

Position-time graphs:

Slno	Type of motion	Position-time graph
1	Object at rest	
2	Uniform motion along a straight line	
3	Motion with positive acceleration	
4	Motion with negative acceleration	
5	Motion with zero acceleration	

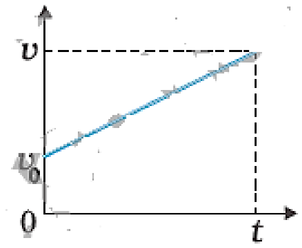
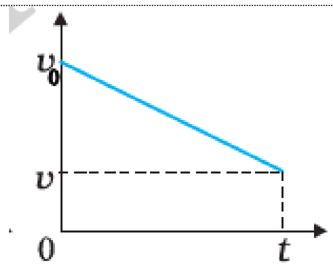
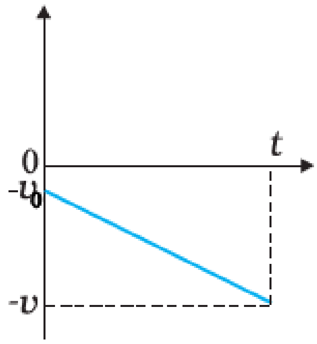
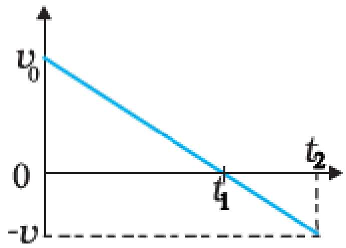
Velocity time-graph: A graph of velocity versus time is called velocity-time graph.

* The area under v-t graph with time axis gives the value of displacement covered in given time.
* The slope of tangent drawn on graph gives instantaneous acceleration.

Uses of velocity-time (v-t) graph / Significance of velocity-time (v-t) graph:

* It is used to study the nature of the motion.
* It is used to find the velocity of the particle at any instant of time.
* It is used to derive the equations of motion.
* It is used to find displacement and acceleration.

Velocity time-graphs

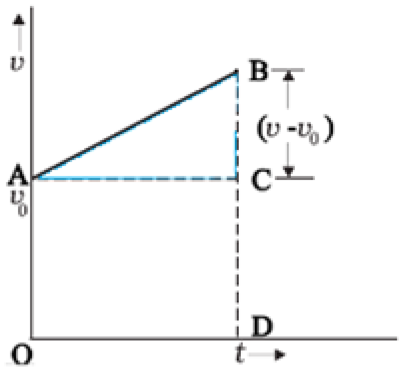
Slno	Type of motion	v-t graph
1	Motion in positive direction with positive acceleration or uniform acceleration having some initial velocity.	
2	Motion in positive direction with negative acceleration having some initial velocity.	
3	Motion in negative direction with negative acceleration having some initial velocity.	
4	Motion of an object with negative acceleration that changes direction at time t_1 having some initial velocity.	

Kinematic equation for uniformly accelerated motion: For uniformly accelerated motion, we can derive some simple equations that relate displacement (x), time taken (t), initial velocity (v_0), final velocity (v), and acceleration (a). These equations are called Kinematic equations for uniformly accelerated motion.

The Equations are, (i) $v = v_0 + at$

(ii) $x = v_0 t + \frac{1}{2}at^2$

(iii) $v^2 = {v_0}^2 + 2ax$



Derivation of equation of motion by graphical method

(i) $v = v_0 + at$

Consider a particle in motion with initial velocity v_0 and constant acceleration a.

Let v be the final velocity of the body at time t.

From graph,

$$\text{slope} = \frac{BC}{AC} = \frac{BD - CD}{AC}$$

But, $CD = OA$ and $AC = OD$

$$\text{Slope} = \frac{BD - OA}{OD} = \frac{v - v_0}{t}$$

But, slope of v-t graph gives the acceleration.

$$a = \frac{v - v_0}{t}$$

$$at = v - v_0$$

$$v - v_0 = at$$

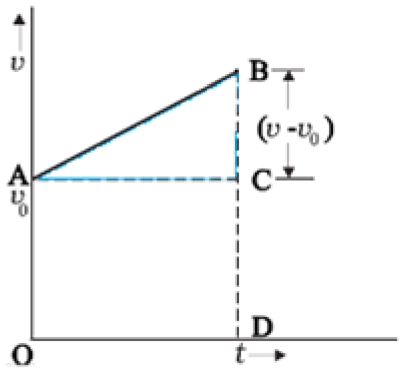
$$\boldsymbol{v = v_0 + at}$$

(ii) $\boldsymbol{x = v_0 t + \frac{1}{2} a t^2}$

Consider a particle in motion with initial velocity v_0 and constant acceleration a.

Let v be the final velocity of the body at time t.

From graph,



$$Displacement = Area\ under\ v - t\ graph$$

$$x = Area\ of\ trapezium\ OABD$$

$$x = area\ of\ \Delta^{le} ABC + area\ of\ rectangle\ OACD$$

$$x = \left[\frac{1}{2} \times AC \times BC\right] + [OD \times OA]$$

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

But, $v - v_0 = at$

$$x = \frac{1}{2} t(at) + v_0 t$$

$$x = \frac{1}{2} a t^2 + v_0 t$$

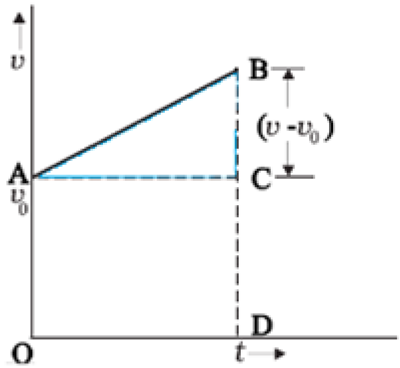
$$\boldsymbol{x = v_0 t + \frac{1}{2} a t^2}$$

(iii) $\boldsymbol{v^2 = v_0^2 + 2ax}$

Consider a particle in motion with initial velocity v_0 and constant acceleration a.

Let v be the final velocity of the body at time t.

From graph,



$$Displacement = Area\ under\ v - t\ graph$$

$$x = Area\ of\ trapezium\ OABD$$

$$x = \frac{1}{2}(OA + BD)AC$$

$$x = \frac{1}{2}(v_0 + v)t$$

But, $v - v_0 = at$ and $t = \frac{v - v_0}{a}$

$$x = \frac{1}{2}(v_0 + v)\left(\frac{v - v_0}{a}\right)$$

$$x = \frac{1}{2}\frac{(v^2 - v_0^2)}{a}$$

$$2ax = v^2 - v_0^2$$

$$v^2 - v_0^2 = 2ax$$

$$\boldsymbol{v^2 = v_0^2 + 2ax}$$

Note: The set above equations were obtained by assuming that at $t = 0$, the position of the Particle x is 0 (zero).

When at $t = 0$, If the position of the particle is at $x_0(non\,zero)$, then the equations are,

(i) $v = v_0 + at$ (ii) $x - x_0 = v_0t + \frac{1}{2}at^2$ (iii) $v^2 = {v_0}^2 + 2a(x - x_0)$

Free fall: An object released near the surface of the earth is accelerated downward under the influence of the force of gravity. If the air resistance is neglected, then the motion of the body is known as free fall.

Acceleration due to gravity: The acceleration produced in object due to gravity is called acceleration due to gravity, denoted by g.

Free fall is an example for motion along a straight line under constant acceleration.

* Acceleration due to gravity is always a downward vector directed towards the centre of the earth.
* The magnitude of g is approximately $9 \cdot 8ms^2$ near the surface of the earth.
* Acceleration due to gravity is the same for all freely falling bodies irrespective of their size, shape and mass.
* The distance traversed by a body falling freely from rest during equal intervals of time are in the ratio $1:3:5:7:\ldots\ldots$.... this is known as Galileo's law of ODD numbers.

Equations of motion under gravity: The motion of a freely falling body is in Y-direction. If we take vertically upward as positive Y-axis, acceleration is along the negative Y-axis, therefore $a = -g$. Then, (i) $v = v_0 - gt$

(ii) $y = v_0t - \frac{1}{2}gt^2$

(iii) $v^2 = {v_0}^2 - 2gy$

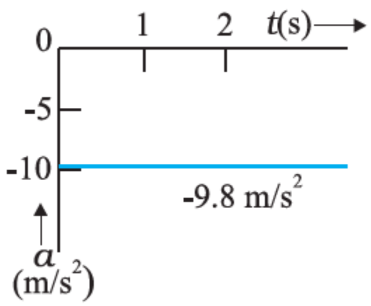
For freely falling body the initial velocity, $v_0 = 0$. Then,

(i) $v = -gt$

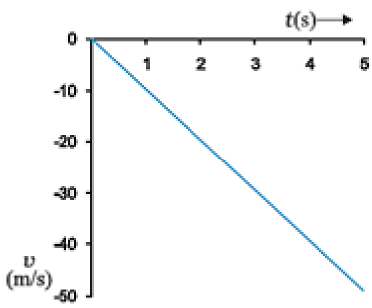
(ii) $y = -\frac{1}{2}gt^2$

(iii) $v^2 = -2gy$

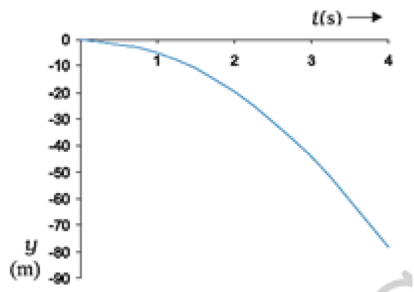
The $a - t$ graph, $v - t$ graph and $y - t$ graph to a body released from rest at $y = 0$ are as shown.



$a - t$ graph



$v - t$ graph



$y - t$ graph

Note: <u>(i) Stopping distance:</u> When breaks are applies to a moving vehicle, the distance travelled before travelled before stopping is called stopping distance.

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

It is an important factor for road safety and it depends on initial velocity and deceleration ($-a$).

(ii) Reaction time: When a situation demands our immediate action, it takes some time before we really respond this time is called reaction time.

Relative velocity: The relative velocity of body A with respect to body B is defined as the time rate of change of displacement of A with respect to B.

Explanation: Consider two bodies A and B moving with constant velocity v_A and v_B respectively, along positive X-axis.

Let $x_A(t)$ and $x_B(t)$ be the position of A and B at any given instant of time t, then

$$x_A(t) = x_A(0) + v_A t$$
$$x_B(t) = x_B(0) + v_B t$$

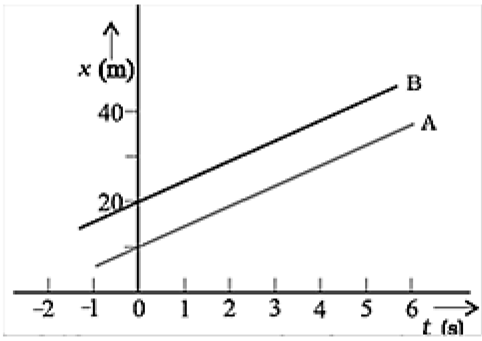
Separation between A and B at time t is, $x_B(t) - x_A(t) = x_B(0) - x_A(0) + (v_B - v_A)t$

Here, $x_B(0) - x_A(0)$ is the separation between A and B at $t = 0$ and $(v_B - v_A)$ is the time rate of change of relative velocity of B with respect to A, denoted by v_{BA}.

Hence, $\boldsymbol{v_{BA} = v_B - v_A}$

Similarly velocity of A with respect to B is $\boldsymbol{v_{AB} = v_A - v_B}$

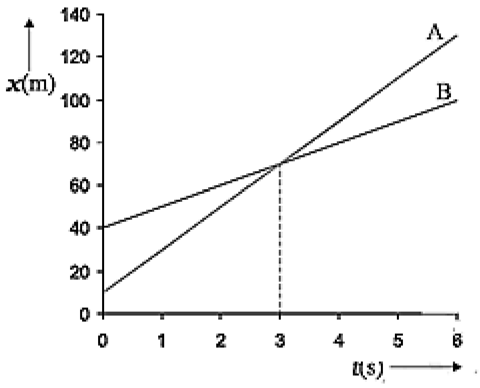
and it can be shown that $v_{AB} = -v_{BA}$



Case(1): When two bodies move with the same velocity in same direction, then $v_A = v_B$ and $v_A - v_B = 0$ and $v_{AB} = v_{BA} = 0$,

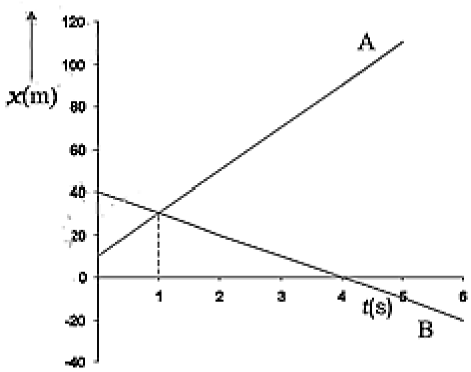
Then two bodies appear at rest with respect to each other.

In this case relative velocity is minimum.



Case(2): When two bodies move in the same direction with different velocities,

If $v_A > v_B$ then $v_{BA} = negative$ and $v_{AB} = positive$.



Case(3): When two bodies move in different velocities or same velocities in opposite direction.

The magnitude of the relative velocity of either of them with respect to the other is equal to the sum of the magnitude of their velocities.

$$v_{BA} = v_{AB} = v_A + v_B$$

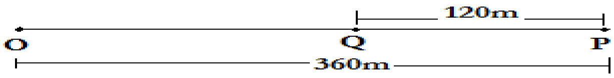
In this case relative velocity is maximum.

<u>Problems:</u>

1) A car is moving along a straight line. It moves O to P in 18 second covering a distance of 360m and returns from P to Q in 6second by covering a distance of 120m. Calculate average velocity and average speed of a car in going (a) from O to P (b) from O to P and back to Q.

Given

$$OP = 360m$$
$$QP = 120m$$
$$OQ = OP - QP = 360 - 120 = 240m$$



(a) $\text{Avg. velocity} = \dfrac{displacement}{time}$

$$v = \frac{OP}{t} = \frac{360}{18} = 20ms^{-1}$$

$$\text{Avg. speed} = \frac{distance}{time}$$

$$\text{Avg. speed} = \frac{360}{18} = 20ms^{-1}$$

(b)) $\text{Avg. velocity} = \dfrac{displacement}{time}$

$$v = \frac{OQ}{t} = \frac{240}{24} = 10ms^{-1}$$

$$\text{Avg. speed} = \frac{distance}{time} = \frac{360 + 120}{24}$$

$$\text{Avg. speed} = \frac{480}{24} = 20ms^{-1}$$

2) A car moving along a straight line takes 5 second to increase its velocity from $15ms^{-1}$ to $30ms^{-1}$. What is the acceleration of the car? Also calculate the distance travelled by the car in 5 second.

Given $t = 5s, v_0 = 15ms^{-1}, v = 30ms^{-1}, a = ?, x = ?$

$$v = v_0 + at$$
$$30 = 15 + a \times 5$$
$$5a = 30 - 15$$
$$a = \frac{15}{5} = 3ms^{-2}$$

$$x = v_0 t + \frac{1}{2}at^2$$
$$x = 15 \times 5 + \frac{1}{2} \times 3 \times 5^2$$
$$x = 75 + \frac{75}{2}$$
$$x = 75 + 37.5 = 112.5m$$

3) A car moving along a straight road increases its velocity from $10ms^{-1}$ to $30ms^{-1}$ in 4 second. Calculate (a) the acceleration of the car and
(b) the distance travelled by the car in 4 second.

Given $v_0 = 10ms^{-1}, v = 30ms^{-1}, t = 4s, a = ?, x = ?$

$$v = v_0 + at$$
$$30 = 10 + a \times 4$$
$$4a = 30 - 10$$
$$a = \frac{20}{4} = 5ms^{-2}$$

$$x = v_0 t + \frac{1}{2}at^2$$
$$x = 10 \times 4 + \frac{1}{2} \times 5 \times 4^2$$
$$x = 40 + \frac{80}{2}$$
$$x = 40 + 40 = 80m$$

4) A truck moving along a straight highway with a speed of $20ms^{-1}$ is brought to rest in $10s$. What is the retardation of the truck? How far will the truck travel before it comes to rest?

Given $v_0 = 20ms^{-1}, v = 0ms^{-1}, t = 10s, a = ?, x = ?$

$$v = v_0 + at$$
$$0 = 20 + a \times 10$$
$$10a = -20$$

$$a = \frac{-20}{10} = -2ms^{-2}$$

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

$$= 20 \times 10 + \frac{1}{2} \times (-2) \times 10^2$$

$$x = 200 - 100$$

$$x = 100m$$

5) A player throws a ball upwards with an initial speed of $29.4ms^{-1}$
(a) What is the direction of acceleration during the upward motion of the ball?
(b) What is the velocity and acceleration at the highest point of its path?
(c) To what height does the ball rise and after how long does the ball returns to the player's hand?

Given $v_0 = 29.4ms^{-1}$

(a) The ball is moving under the gravity, so the direction of acceleration is vertically downwards and towards the centre of the earth.

(b) At the highest point, $v = 0ms^{-1}$ and acceleration is equal to acceleration due to gravity, $a = 9.8ms^{-2}$

(c)

$$v^2 = v_0^2 + 2ax$$

$$0 = (29.4)^2 + 2 \times (-9.8) \times x$$

$$x = \frac{(29.4)^2}{2 \times (9.8)} = 44.1m$$

$$v = v_0 + at$$

$$0 = 29.4 + (-9.8) \times t$$

$$t = \frac{29.4}{9.8} = 3\ s$$

Total time = time of ascent + time of decent = 3s +3s = 6s

6) A car is moving along a straight highway with a speed of 126kmph is brought to stop with in a distance of 200m. What is the retardation of the car and how long does it take for the car to stop?

Given

$$v_0 = 126kmph$$

$$v_0 = \frac{126 \times 1000}{3600} ms^{-1} = 35ms^{-1}$$

$$x = 200m$$

$$v = 0ms^{-1}$$

$$a = ?,$$

$$t = ?$$

$$v^2 = v_0^2 + 2ax$$

$$0 = 35^2 + 2 \times a \times 200$$

$$400a = -35 \times 35$$

$$a = -\frac{35 \times 35}{400} = -3.06\ ms^{-2}$$

$$v = v_0 + at$$

$$0 = 35 + (-3.06) \times t$$

$$t = \frac{35}{3.06} = 11.42\ s$$

7) Two trains A and B of length 300m each are moving on two parallel tracks with an uniform speed of 54kmph in the same direction, with the train A ahead of B. The driver of train B decides to overtake A and accelerates by $2ms^{-2}$. If after 25s, the guard of train B just brushes past the driver of A. What original distance between them?

Given $l_A = 300m$

$$l_B = 300m$$

$$v_A = 54kmph = 15ms^{-1}$$

$$v_B = 15ms^{-1}$$

$$a_A = 0ms^{-2}$$

$$a_B = 2ms^{-2}$$

$$t = 25s$$

Original distance, $l = ?$

Distance travelled by A in 25s,

$$x_A = v_A t + \frac{1}{2}a_A t^2$$

$$x_A = 15 \times 25 + 0$$

$$x_A = 375m$$

Distance travelled by B in 25s,

$$x_B = v_B t + \frac{1}{2}a_B t^2$$

$$x_B = 15 \times 25 + \frac{1}{2} \times 2 \times 25 \times 25$$

$x_B = 375 + 625 = 1000$

Distance travelled by B in 25s,

$x_B = l_B + l + x_A + l_A$

$1000 = 300 + l + 375 + 300$

$1000 = 975 + l$

$l = 1000 - 975 = 25m$

8) The displacement (in metre) of a particle moving along x-axis is given by $x = 2t^2 + 3$.
Calculate (i) Average velocity between $t = 3\ s$ and $t = 5\ s$.
(ii) Instantaneous velocity at $t = 5\ s$ and
(iii) Instantaneous acceleration.

Given $x = 2t^2 + 3$

(i)Avg. velocity $= \dfrac{total\ displacement}{total\ time\ taken}$

When $t_1 = 3\ s, x_1 = 2(3)^2 + 3 = 21\ m$

When $t_2 = 5\ s,\ \ x_2 = 2(5)^2 + 3 = 53\ m$

Average velocity $= \dfrac{x_2 - x_1}{t_2 - t_1}$

$$\bar{v} = \frac{53 - 21}{5 - 3} = \frac{32}{2} = 16\ ms^{-1}$$

(ii) Instantaneous velocity, $v = \dfrac{dx}{dt}$

$x = 2t^2 + 3$

$$v = \frac{dx}{dt} = 2(2)t + 0 = 4t$$

When $t = 5\ s, v = \dfrac{dx}{dt} = 4(5) = 20\ ms^{-1}$

(iii)Instantaneous acceleration, $a = \dfrac{dv}{dt}$

$v = 4t$

$$a = \frac{dv}{dt} = 4\ ms^{-2}$$

9) Obtain equations of motion for constant acceleration using method of calculus.

(i) By definition, $a = \dfrac{dv}{dt}$

$dv = a\ dt$

Integrating both sides, $\displaystyle\int_{v_0}^{v} dv = \int_0^t a\ dt$

$[v]_{v_0}^{v} = a[t]_0^t$

$v - v_0 = a[t - 0]$

$v - v_0 = at$

$\boldsymbol{v = v_0 + at}$

(ii) Now, we have $v = \dfrac{dx}{dt}$

$dx = vdt$

Integrating both sides, $\displaystyle\int_{x_0}^{x} dx = \int_0^t vdt$

$$\int_{x_0}^{x} dx = \int_0^t (v_0 + at)dt$$

$$[x]_{x_0}^{x} = [v_0 t]_0^t + a\left[\frac{t^2}{2}\right]_0^t$$

$$\boldsymbol{(x - x_0) = v_0 t + \frac{1}{2}at^2}$$

(iii) we have, $a = \dfrac{dv}{dt} = \dfrac{dv}{dx} \cdot \dfrac{dx}{dt}$

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

$$a \cdot dx = v \cdot dv$$

Integrating on both sides, $\int_{x_0}^{x} adx = \int_{v_0}^{v} vdv$

$$[ax]_{x_0}^{x} = \left[\frac{v^2}{2}\right]_{v_0}^{v}$$

$$a(x - x_0) = \frac{1}{2}(v^2 - v_0^2)$$

$$2a(x - x_0) = (v^2 - v_0^2)$$

$$\boldsymbol{v^2 = v_0^2 + 2a(x - x_0)}$$

Suggested Questions.

One mark.

1) When will the magnitude of displacement equal to the path length?
2) Define average speed.
3) Define instantaneous speed.
4) Define instantaneous velocity.
5) Define average velocity.
6) Define acceleration.
7) What is retardation?
8) What is the acceleration of a body moving with uniform velocity?
9) What does the slope of position-time graph represent?
10) What does the slope of velocity-time graph represent?
11) Draw v-t graph for motion in uniform acceleration.

Two marks.

1) Distinguish between distance travelled and displacement of a particle.
2) Distinguish between speed and velocity.
3) Define uniform velocity and uniform acceleration.
4) What is position time graph? Draw $x - t$ graph for an object at rest.
5) Draw position time graph for (a) a particle at rest,(b) a body moving with uniform velocity.
6) Draw the position time graph of a particle moving with
   a) Positive acceleration. b) Negative acceleration.
7) Draw v-t graph for body moving in uniform acceleration.
8) Define relative velocity. When will the relative velocity of two bodies be zero?
9) Define relative velocity with an example.

Three marks.

1) Write the significance of v-t graph.
2) Derive the equation $v = v_0 + at$ with usual notation by using v-t graph.
3) Define relative velocity. When does the relative velocity become maximum and minimum if two particles are moving along a straight line?

Five marks.

1) What is v-t graph? Derive the equation $v^2 = v_0^2 + 2ax$ with usual notation by using v-t graph.
2) What is v-t graph? Derive the equation $x = v_0 t + \frac{1}{2}at^2$ with usual notation by using v-t graph.

Additional Problems:

1) The displacement of the particle moving along x-axis is given by $x = 3t^3 - 5t^2 + 1$ where x is in metre and t is in second. Calculate
   (i) Instantaneous velocity at $t = 2\ s$
   (ii) Instantaneous acceleration at $t = 3\ s$
2) A body is thrown up with velocity of $78.4\ ms^{-1}$. Find how high it will rise and how much time it will take to return to its point of projection.
3) A ball thrown vertically upwards and it reaches a height of $90\ m$. Find the velocity with which it was thrown and the height reached by the ball 7 second after it was thrown?
4) A body travelling with an initial velocity $36\ ms^{-1}$ comes to rest after travelling $90\ m$. Assuming the retardation to be uniform, find its value. What time does it take to cover that distance?
5) A car is moving along a straight highway with a speed of $108\ km\ hr^{-1}$ is brought to stop with a distance $200\ m$. What is the retardation of the car? And how long does it take for the car to stop?
6) A car travels a distance from A to B at a speed of $40\ km\ hr^{-1}$ and returns to A at the speed of $30\ km\ hr^{-1}$. What is the average speed for the whole journey?