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Uniform Motion

Mechanics - Branch of physics which deals with the study of motion of material objects.

Branches of mechanics

(i) **Statics** - study of material objects at rest.

(ii) **Kinematics** - study of motion of objects without considering the factors causing motion.

(iii) **Dynamics** - study of motion of objects considering the factors causing motion.

Rest & motion

Rest - An object is said to be at rest if it doesn't change its position with time, w.r.t its surrounding.

Motion - An object is said to be in motion if it changes its position with time, w.r.t its surrounding.

* Motion & rest are relative.

Point mass object

An object can be considered as a point object if during motion in a given time, it covers a very large distance as compared to its own size.

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Q. In which of the following examples of motion, can the body be considered a point object :

(a) a railway carriage moving without jerks betⁿ 2 stations.

(b) a monkey sitting on top of a man cycling smoothly on a circular track.

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

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

(e) earth revolving around the sun

(f) a car travelling from Kashmir to Kanyakumari

(g) a car travelling 100 m distance ?

Motion in one, two and three dimensions

Motion in one dimension

The motion of an object is said to be one dimensional motion if only one of the three co-ordinates specifying the position of the object changes w.r.t time.

e.g. (i) motion of a car on a straight road.
(ii) " " " man walking on a narrow road.
(iii) " " an object dropped from a height

Motion in two dimension

The motion - two of the three - - - - - - - - - changes w.r.t time.

e.g. (i) an insect crawling on the floor.
(ii) earth revolving around the sun.

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Motion in three dimension

The motion - - - - - - - - - - - - if all the three co-ordinates - - - - - - - - - - - - - - changes w.r.t time.

e.g. (i) a flying aeroplane

(ii) a kite flying on a windy day

Scalar & Vector quantities

Scalar - The physical quantities which depend only on magnitude are called scalar.

e.g. → Distance, speed, time, ~~force~~ work

Vector - The physical quantities which depend both on magnitude & direction are called vector.

e.g → Displacement, velocity, force, torque

Distance and Displacement

Distance - It is the length of actual path traversed by the object in given time.

Displacement - It is the shortest distance bet^{n} the initial & final position of an object.

	Distance	Displacement
1.	Def^{n}	Def^{n}
2.	scalar	vector
3.	can never be zero or -ve	can be zero or -ve.
4.	Distance $\geq$ displacement	Displacement $\leq$ Distance
5.	can have multiple values depending upon path.	unique

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Speed

1. It is the ratio of distance over time.
2. scalar quantity
3. Unit : S.I - ms^{-1} , c.g.s - cms^{-1}
4. can't be negative

(a) **Uniform speed**

An object is said to be moving with a uniform speed, if it covers equal distances in equal intervals of time.

(b) **Variable speed**

An object is said to be moving with a variable speed, if it covers unequal distances in equal intervals of time.

(c) **Average speed**

It is defined as the ratio of the total distance travelled by the object to the total time taken.

$$\text{Average speed} = \frac{\text{Total distance}}{\text{Total time}}$$

Numerical on average speed/velocity

Q1.	A car travels a distance A-to B at a speed of 40kmh^{-1} and returns to A at a speed of 30 kmh^{-1}. (i) what is the average speed for the whole journey? (ii) what is the average velocity ?
Q2.	The body travels a distance S_1 with velocity V_1 and S_2 with velocity V_2 in the same direction. Calculate the average velocity of the body.
Q3.	A person travels along a straight road for the first half length with a velocity V_1 and the Second half length with velocity V_2. What is the mean velocity of the person?
Q4.	A particle traversed half the distance with a velocity V_o. The remaining part of the distance was covered with the velocity V_1 for half the time, and with velocity V_2 for the other half of the time. Find the average speed of the particle averaged over the whole time of motion.

Ans-1 Let the distance bet^n A & B be 'x'.

Time taken to go from A to B, $t_1 = \frac{x}{40}$ hr

" " " return " B to A, $t_2 = \frac{x}{30}$ hr.

Total time, $t = t_1 + t_2$

$= \frac{x}{40} + \frac{x}{30}$

$= \frac{7x}{120}$ hr.

Total distance $= x + x = 2x$ km

Average speed $= \frac{\text{total distance}}{\text{total time}}$

$= \frac{2x}{\frac{7x}{120}}$

$= \frac{2 \times 120}{7}$

$= 34.3 \text{ km hr}^{-1}$

Total displacement $= 0$

$\therefore$ Average velocity $= \frac{\text{total displacement}}{\text{total time}} = 0$

Ans-2 Time for distance s_1, $t_1 = \frac{s_1}{v_1}$

" " " s_2, $t_2 = \frac{s_2}{v_2}$

Total distance $= s_1 + s_2$

Total time $= t_1 + t_2$

$$= \frac{s_1}{v_1} + \frac{s_2}{v_2}$$

$$= \frac{s_1 v_2 + s_2 v_1}{v_1 v_2}$$

Average speed $= \dfrac{s_1 + s_2}{\dfrac{(s_1 v_2 + s_2 v_1)}{v_1 v_2}}$

$$= \frac{(s_1 + s_2) v_1 v_2}{s_1 v_2 + s_2 v_1}$$

Ans-3 Time for 1st half length, $t_1 = \dfrac{d/2}{v_1}$

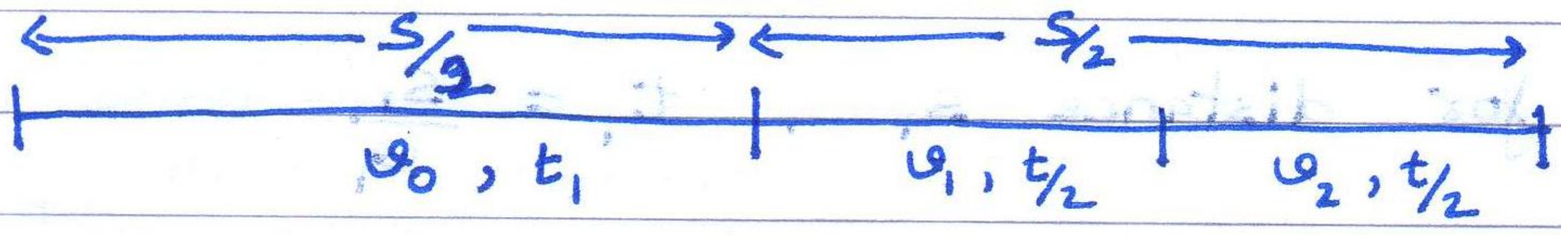
" " 2nd " " , $t_2 = \dfrac{d/2}{v_2}$

Total time, $t = t_1 + t_2 = \dfrac{d}{2}\left(\dfrac{1}{v_1} + \dfrac{1}{v_2}\right)$

Average speed $= \dfrac{d}{\dfrac{d}{2}\left(\dfrac{v_1 + v_2}{v_1 v_2}\right)}$

$$= \frac{2 v_1 v_2}{v_1 + v_2}$$

Ans-4



Let it takes 't_1' time to travel the 1st half, with velocity v_0 so,

$$v_0 = \frac{s/2}{t_1}$$

$$t_1 = \frac{s}{2v_0}$$

For the 2nd half

$$\frac{s}{2} = v_1 \cdot \frac{t}{2} + v_2 \cdot \frac{t}{2}$$

$$\frac{s}{2} = (v_1 + v_2)\frac{t}{2}$$

$$t = \frac{s}{v_1 + v_2}$$

Total time $t' = t_1 + t$

$$= \frac{s}{2v_0} + \frac{s}{v_1 + v_2}$$

$$= \frac{s(v_1 + v_2 + 2v_0)}{2v_0(v_1 + v_2)}$$

Average speed $= \dfrac{s}{\dfrac{s(v_1 + v_2 + 2v_0)}{2v_0(v_1 + v_2)}}$

$$= \frac{2v_0(v_1 + v_2)}{v_1 + v_2 + 2v_0}$$

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Velocity

- It is the ratio of displacement over time.
- It is a vector quantity
- Unit : S.I - ms^{-1} , C.G.S = cms^{-1}
- $velocity = \frac{displacement}{time}$

Relative velocity in one dimension

The relative velocity of an object w.r.t another is the velocity with which one object moves w.r.t another object.

(a) When both the objects are moving in the same direction

$v_{AB} = v_A - v_B$ [$\because v_{AB}$ - velocity of A w.r.t B]

(b) opposite direction

$v_{AB} = v_A + v_B$

Numerical on relative velocity	
Q1.	Two trains 120m and 80m in length are running in opposite directions with velocities 42 kmh^{-1} and 30kmh^{-1}. In what time they will completely cross each other?
Q2.	Two buses started simultaneously towards each other from towns A and B which are 480 km apart. It took the first bus travelling from A to B eight hours to cover the distance and the second bus travelling from B to A, ten hours. Determine, when the buses will meet after starting and at what distance from A.
Q3.	A police jeep is chasing a culprit going on a motorbike. The motorbike crosses a turning at a speed of 72kmh^{-1}. The jeep follows it at a speed of 108kmh^{-1}, crossing the turning ten seconds later than the bike. Assuming that they travel at constant speeds, how far from the turning will the jeep catch up with the bike?
Q4.	Two trains, each of length 100m, are running on parallel tracks. One overtakes the other in 20 second and one crosses the other in 10 second. Calculate the velocities of two trains.

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Ans-1

$$v_A = 42\ km\,h^{-1} = 42 \times \frac{5}{18}\ m\,s^{-1}$$

$$v_B = 30\ km\,h^{-1} = 30 \times \frac{5}{18}\ m\,s^{-1}$$

$$l_A = 120\ m$$

$$l_B = 80\ m$$

$$t = ?$$

$$v_{AB} = v_A + v_B = 72 \times \frac{5}{18} = 20\ m\,s^{-1}$$

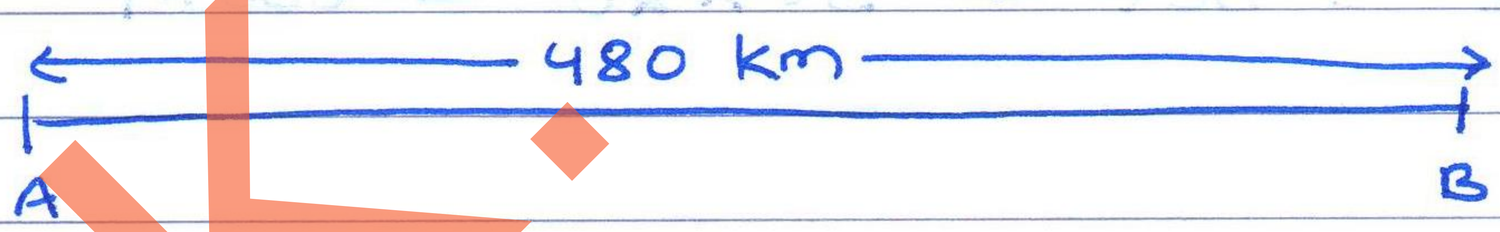
$$l = l_A + l_B = 200\ m$$

$$v_{AB} = \frac{l}{t}$$

$$20 = \frac{200}{t}$$

$$t = 10\ second$$

Ans-2



$$v_A = \frac{480}{8} = 60\ km\,h^{-1}$$

$$v_B = \frac{480}{10} = 48\ km\,h^{-1}$$

$$v_{AB} = 60 + 48 = 108\ km\,h^{-1}$$

$$v_{AB} = \frac{480}{t}$$

$$108 = \frac{480}{t}$$

$$t = \frac{480}{108}\ 40 = \frac{40}{9}\ h$$

Distance from A $= v_A \times t$

$= 60 \times \frac{40}{9}$

$= \frac{800}{3} = 266.7$ km

Ans-3 $v_T = 72\ kmh^{-1} = 72 \times \frac{5}{18} = 20\ ms^{-1}$

$v_P = 108\ kmh^{-1} = 108 \times \frac{5}{18} = 30\ ms^{-1}$

Let the police catch the thief after 't' sec.

A.T.Q

$20(t+10) = 30t$

$20t + 200 = 30t$

$10t = 200$

$t = 20s$

Distance $= 30t = 30 \times 20 = 600$ m

Ans-4

$v_A + v_B = \frac{200}{10} = 20$ —— (1)

$v_A - v_B = \frac{200}{20} = 10$ —— (2)

(1) + (2) →

$2v_A = 30$

$v_A = 15\ ms^{-1}$

from (1) $15 + v_B = 20$

$v_B = 5\ ms^{-1}$