Motion

In chemistry 3 states of matter — Solid, liquid, gas

In Physics, there are two states — Rest / Stationary, Motion

Rest — Ex — Table, House, School, etc.

Motion

An object is said to be in motion when it's position changes continuously with respect to a stationary object taken as reference point.

The phenomenon in which object changes its position with respect to time

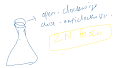
Motion State
✓ Blood in a vein ✓ Rotating Planets.

Physical Quantities

- All those quantities which can be measured.
- Example :- length, mass, time, temperature, force, Pressure, work.

Physical Quantity

- Scalar Quantities
  - Not dependent on direction.
  - Can be described only by magnitude.
  - Ex - length, mass, time, temperature, density.
- Vector Quantities
  - dependent on both direction as well as magnitude.
  - Ex - force.



vector quantities are denoted by $\vec{F}$

System of Units

42

✓ Tools using which we can measure physical quantities effectively.

✓ Measurement of physical quantities are expressed in terms of units which are standardized value.
SI — International system of units

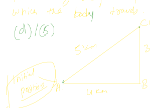
M K S
C G S

Distance and Displacement

Total distance covered = 7 + 4 + 13 = 24 Km

Distance - It is the actual length of the path by a moving body irrespective of the direction in which the body travels.

(d) / (S)



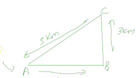
$(AC)^2 = (AB)^2 + (BC)^2$
$= (4)^2 + (3)^2$
$= 16 + 9$
$AC = \sqrt{25}$
$= 5$ Km

Displacement - when the body moves from one position to another, the shortest distance between the initial position & final position of the body along with the direction is known as displacement.

Representation $\vec{S}$

d = Path dependent
$\vec{S}$ = Path Independent.

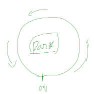
$\vec{S}$ = Final posn - Initial Position
↑
Shortest distance b/w initial & final position.



Is my Journey clear?

Distance = AB + BC + AC
= 4 + 3 + 5
= 12 km

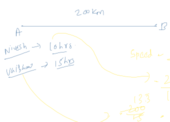
Displacement → Distance b/w initial & final posn.



Distance
2πr
Displacement
0

Distance 15km
Displacement 5km

Speed



Speed = Distance / Time
$= \frac{200}{10\,hr} = 20$ km/hr
$= \frac{200}{15} = 13.3$ km/hr

→ Gives an idea of how slow or fast that body is moving.

→ Speed of the body is the distance travelled by it per unit time.

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} = \frac{\text{Scalar}}{\text{Scalar}} = \text{Scalar}$$

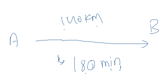
as it has magnitude only.

S.I unit of speed $= ms^{-1}$

✓ To convert km/hr into m/s

$20\,km/hr \longrightarrow \frac{20 \times 1000\,m}{1 \times 60 \times 60}$
$= 20 \times \frac{1000}{60 \times 60} = 20 \times \frac{5}{18}$
$= \frac{20 \times 5}{18}\,ms^{-1}$

1hr → 60 min
1 min = 60 sec
1 min = 60 sec
60 min = 60 × 60
= 3600 sec



km/hr
m/s

$S = \frac{D}{T}$

$= \frac{140\,km}{3\,hr} = 46.6...$

60 min = 1 hr
180 min = $\frac{1}{60} \times 180 = 3$

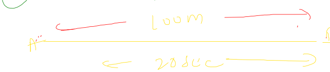
For 60 m = 1 hr
10 m = $\frac{1}{60} \times 10 = \frac{1}{6}$

$6 \overline{)\,1.0}$ 0.1

$\frac{140}{3} \times \frac{5}{18} =$ m/s

Q. Can velocity be greater than speed?

Never, Velocity can be equal to speed.

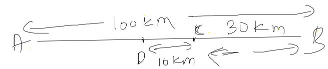


$S = \frac{D}{T} = \frac{100}{20} = 5\,m/s$

$V = \frac{D}{T} = \frac{100}{20} = 5\,ms^{-1}$

Speed & Velocity both are same!

Speed & Velocity are not always equal in magnitude



Ans

20km in 1hr

$S = \frac{D}{T} = \frac{140\,km}{7\,hr} = 20\,km/hr$

$V = \frac{Disp}{Time} = \frac{60}{3} = 20\,km/hr$

Q. Speed & velocity

Q. A car travels a distance of 100km in 2hrs. Calculate speed of the car & velocity.

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} = \frac{100}{2} = 50\,km/hr$$

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}} = \frac{100}{2} = 50\,km/hr$$

Velocity

→ Speed does not gives the idea of direction of motion.

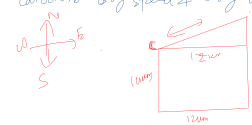
→ $$\vec{V} = \frac{\text{Displacement}}{\text{Time}}$$

velocity measures the rate of change in position that is change in position per unit time.

∴ Velocity of the body is the displacement per unit time. SI unit - ms^{-1}

→ Velocity is a vector quantity as it has magnitude as well as direction

Q. A car travels 22 km South, 12 km West & 14 km North in half an hour. Calculate avg speed & avg velocity.



$\frac{\sqrt{208}}{0.5}$

Total distance / Total time

$= \frac{22+12+14}{0.5}$

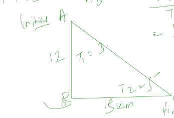
$= 480$ km/hr

$(AC)^2 = (AB)^2 + (BC)^2$

Avg velocity = Displacement / Time

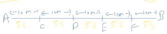
$= \frac{\sqrt{144+225}}{8}$

$\frac{\sqrt{369}}{8}$



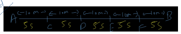
Uniform & Non Uniform Motion

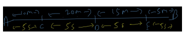
Uniform motion – When body travels equal distances in equal intervals of time.



Non uniform motion – When body travels unequal distances in equal interval of time.

Speed → Average Speed = Total Distance / Total time





Avg Speed = $\frac{10+20+15+5}{5+5+5+5} = \frac{50}{20} = 2.5$ m/s

Example 8.1 An object travels 16 m in 4 s and then another 16 m in 2 s. What is the average speed of the object?

Average speed = $\frac{d_1+d_2+d_3+d_4}{t_1+t_2+t_3+t_4}$

Average velocity

Average velocity = Total displacement / Total time.

If the velocity is changing but at uniform rate then average velocity will be arithmetic mean of initial & final velocities.

Average Velocity = (Initial Velocity + Final Velocity) / 2

Q

Example 8.3 Usha swims in a 90 m long pool. She covers 180 m in one minute by swimming from one end to the other and back along the same straight path. Find the average speed and average velocity of Usha.

Avg Speed = $3 ms^{-1}$.

Avg velocity = $0 ms^{-1}$

3. *Which of the following is true for displacement?*
   (a) *It cannot be zero.* False
   (b) *Its magnitude is greater than the distance travelled by the object.* False.

Displacement can never be greater than Speed.

A ——— B

1. *Distinguish between speed and velocity.*

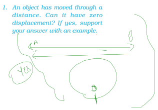
Speed	Velocity
(i) Rate of change of distance.	(i) Rate of change of displacement
(ii) Scalar quantity	(ii) Vector quantity.
(iii) S = Distance / Time	(iii) Velocity = Displacement / Time.

2. *Under what condition(s) is the magnitude of average velocity of an object equal to its average speed?*

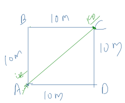
✓ only when the object moves along a straight line path.

A ——— B

1. *An object has moved through a distance. Can it have zero displacement? If yes, support your answer with an example.*



2. *A farmer moves along the boundary of a square field of side 10 m in 40 s. What will be the magnitude of displacement of the farmer at the end of 2 minutes 20 seconds from his initial position?*



Displacement = Final posn – Initial posn

Total time = $2 \times 60 + 20 = 140$ sec

Rounds covered in 40 sec = 1

Rounds covered in 140 sec = $\frac{1}{40} \times 140 = 3.5$

In the 3 full rounds displacement is 0.

$(AC)^2 = (AD)^2 + (DC)^2$

$(AC)^2 = (10)^2 + (10)^2$

$= 100 + 100$

$= 200$

$AC = \sqrt{200}$

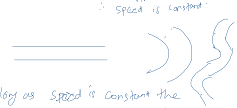
$= 14.15$ m

3. *What does the odometer of an automobile measure?*

Distance travelled by the vehicle.

4. *What does the path of an object look like when it is in uniform motion?*

Uniform motion = Equal distance in equal intervals of time. ∴ Speed is constant.



As long as speed is constant the path of an object in uniform motion can have any shape.

5. *During an experiment, a signal from a spaceship reached the ground station in five minutes. What was the distance of the spaceship from the ground station? The signal travels at the speed of light, that is, 3×10^8 m s^{-1}.*

Speed = Distance / Time

Distance = Speed × Time

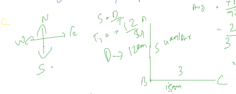
$= 3 \times 10^8$ m/s × 5 min

$= 3 \times 10^8$ m/s × 300

$= 9 \times 10^{10}$ m

Q. A Person covers 20 m in 5 seconds and then next 20 m in 10 seconds along the x axis. Find average speed & average velocity.

Q. Ishani drove South 12 Kms at 4 km/hr & then East 15 km at 3 km/hr.
a) Avg speed of the whole journey.
b) Avg velocity of the whole journey.



$S = \frac{D}{T}$

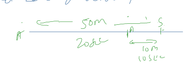
$T_1 = \frac{12}{4} = 3$

Avg = TD / Time

$= \frac{27}{3+5}$

$= \frac{27}{8}$

Q. Nivesh go to the market from his home which is 50 m away from the shop in 20 sec. On his way back he visited Aniket's house which is 10 m away from the shop in 10 sec. Find the avg speed & avg velocity.



Uniform Velocity

→ A body has a uniform velocity if it travels in a specified direction in a straight line and moves over equal distances in equal intervals of time.

How can we change the velocity for object?

→ By changing the speed.

→ By keeping the speed constant but by changing the direction.

Acceleration

Per second velocity change = $\frac{v-0}{2} = \frac{v}{2} = 2 ms^{-1}$

$\therefore v = \frac{0}{t} = ? ms^{-1}$ $\quad a = \frac{v-u}{t} = \frac{ms^{-1}}{s} = ms^{-2}$

It is defined as the rate of change of velocity of body with time

or

Change in velocity per second

→ Change in velocity = Final velocity − Initial velocity

u = initial velocity
v = Final velocity
t = time taken
a = acceleration

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

SI unit = m/s^2 or ms^{-2}

$\frac{10}{10^2} = \frac{1}{10^{-2}}$

It is a vector quantity.

Example

u = 5 m/s
v = 10 m/s
t = 5 s

$a = \frac{v-u}{t} = \frac{10-5}{5} = 1 m/s^2$

Speed is increasing.

Speed is decreasing

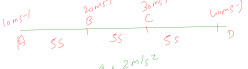
u = 10 m/s t = 5s
v = 5 m/s

$a = \frac{v-u}{t} = \frac{5-10}{5} = -1 m/s^2$

Negative acceleration / Retardation

Example 5.1 Starting from a stationary position, Rahul paddles his bicycle to obtain a velocity of 6 m s^{-1} in 30 s. Then he applies brakes such that the velocity of the bicycle comes down to 4 m s^{-1} in the next 5 s. Calculate the acceleration of the bicycle in both the cases.

Uniform Acceleration



$a = 2 m/s^2$

A body has a uniform acceleration if it travels in a straight line & its velocity increases by equal amounts in equal intervals of time.

Example

Non uniform acceleration

A body has a non uniform acceleration if its velocity increases by unequal amounts in equal intervals of time.

Q. A truck accelerates uniformly from 36 km/hr to 54 km/hr in 10 s. Calculate its acc^n.

$a = \frac{v-u}{t} = \frac{15-10}{10} = 0.5 m/s^2$

$36 km/hr = \frac{36 \times 5}{18} = 10 m s^{-1}$

$54 km/hr = \frac{54 \times 5}{18} = 15 m s^{-1}$

Q. An object is dropped from the top of the building with the constant acc^n of 5 m/s^2. Find its speed after 5s after it was dropped.

$a = \frac{v-u}{t} \rightarrow v = u + at$

$5 = \frac{v-0}{5}$

$v = 25 - 0$

$v = 25 m s^{-1}$

(i) $u = 0$
$v = 44$ km/hr
$a = 5$ km/hr²

$a = \frac{v-u}{t}$ $t = \frac{v-u}{a} = \frac{44-0}{5} = \frac{44}{5} = 8.8$ hr

(ii) = 100 m/s → 0
A —— 50 s

$a = \frac{v-u}{t} = \frac{0-100}{50} = -2\,ms^{-2}$

(iii) $u = 90$ km/hr $= 25\,ms^{-1}$
$v = 36$ km/hr $= 10\,ms^{-1}$
$t = 7$ sec

$a = \frac{v-u}{t} = \frac{10-25}{7} = \frac{-15}{7} = -2.14\,ms^{-2}$

(iv) A —— 140 km —— B

$S = \frac{d}{t} = \frac{140}{7} = 20$ km/hr

$\vec{a} = \frac{v-u}{t} = \frac{0-0}{7} = 0$

$= \frac{140-140}{7} = \frac{0}{7} = 0$ km/hr

✓ Speed ⟷ Velocity
Distance ⟷ Displacement

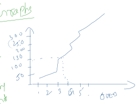
$S = \frac{\text{Dist}}{T}$

$V = \frac{\text{Displace}}{T}$

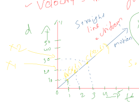
A ———— B

Graphs

Convenient method to present basic information about variety of events



Types of Graph
- Distance - Time graph
- Velocity - Time graph.



Straight line → Uniform motion

X-axis independent variable

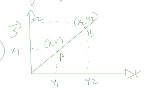
Speed → Slope of graph

$S = \frac{D}{T} = \frac{30}{3} = 10\,ms^{-1}$

$= \frac{x_2 - x_1}{t_2 - t_1} = \frac{30-10}{3-1} = \frac{20}{2} = 10\,ms^{-1}$

Non uniform motion - slightly curved

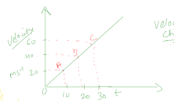
Slope of d-t graph gives speed.



Velocity from A to B

$S = \frac{d}{t}$
$V = \frac{\vec{s}}{t}$

Slope of $\vec{d}$-t graph gives Velocity.



Velocity change AB = Final velocity - Initial velocity / Time

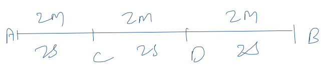
$= \frac{40 - 20}{10\,s}\,ms^{-1}$

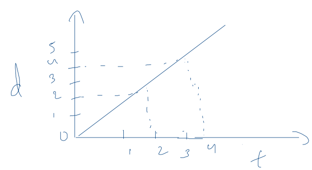
$= \frac{20}{10} = 2\,ms^{-2}$

Slope of v-t graph gives me acceleration

time → $\frac{m}{s^2}$ (ms^{-2}) accl

Uniform motion

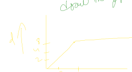




20 km, 10 km, 2 hr, 3 hr

A —— B —— C

There was a car which covered 8m in 4s & then came to rest. Can you draw the graph.

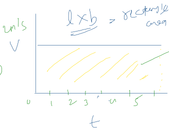


Velocity time graph

✓ In v-t graph linear graph constant acceleration.

Acceleration is 0 →

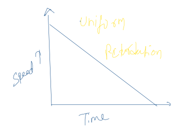
$l \times b$ = rectangle area



→ Area under velocity-time graph gives you displacement

✓ Can we find out displacement under v-t graph.

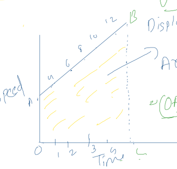
$\vec{V} = \frac{d}{t}$ $(d = \vec{v} \times t)$

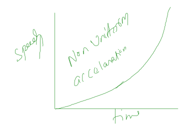


Uniform Retardation -ve accn

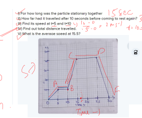
Area under VT graph
Displacement
↓
Area of Trapezium

$= \frac{(OA + BC) \times OC}{2}$





Non uniform accelaration

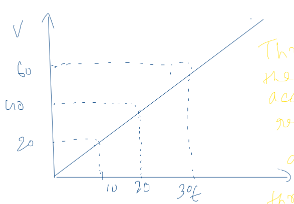


OA + BC + DE = 10 + 30 + 40 = 80 m

10 - 5 + 25 - 15 + 5 + 10 = 15 sec

Avg speed = Total distance travelled / Total time

Uniformly accelarated motion



Throughout the journey acceleration remaining constant as car is moving through uniform velocity.

Circular motion is accelerated → In UCM → Speed is constant

→ Velocity is not constant as its direction is changing every moment.

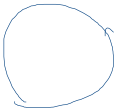
→ Acceleration – because velocity is changing

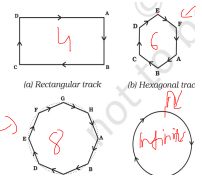
→ UCM is an example of accelerated motion.

Uniform circular motion

Motion in a straight line, linear motion.

motion in a circular path, circular motion





(a) Rectangular track (b) Hexagonal trac

When a body moves in a circular path with uniform speed (constant speed), its motion is called uniform circular motion. (UCM).

Distance – circumference of circular path = $2\pi r$

Velocity → direction, Magnitude

Equation of Motion by Graphical Method

These equations give relationship between u, v, t, a & distance travelled by the body

Applicable on the motion of bodies with uniform acc.

Initial velocity = u
Final velocity = v

Acc. = Change in velocity / Time

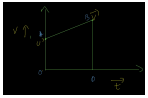
$a = \frac{v_2 - v_1}{t_2 - t_1} = \frac{BD - OA}{OD}$

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

$v - u = at$

$v = u + at$

1st equation of motion



Area under v-t graph gives displacement

In v-t graph

s = area of trapezium ABDO

$s = \frac{(OA + BD) \times OD}{2}$

$= \frac{1}{2}(u + v) \times t$

Using eqn (1) $v = u + at$

Substituting the value of t $t = \frac{v - u}{a}$

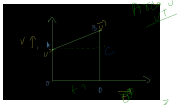
$= \frac{1}{2}(u + v) \times \left(\frac{v - u}{a}\right)$

$= \frac{1}{2}\left(\frac{v^2 - uv + uv - u^2}{a}\right)$

$s = \frac{1}{2}\left(\frac{v^2 - u^2}{a}\right)$

2nd equation of motion

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



Area under v-t graph

s = Area of trapezium ABDO

= Area of $\triangle ABC$ + Area of rectangle BCDO

$= \frac{1}{2}[AC \times BC) + (BC \times OD)$

$= \frac{1}{2}(t \times (v - u)) + ut$

$= \frac{1}{2}(t \times at) + ut$

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

Using eqn (1) $v = u + at$, $v - u = at$

3rd equation of motion

Example 8.5 A train starting from rest attains a velocity of 72 km h^{-1} in 5 minutes. Assuming that the acceleration is uniform, find (i) the acceleration and (ii) the distance travelled by the train for attaining this velocity.

$u = 0$

$v = 72$ km/hr $= 72 \times \frac{5}{18} = 20$ m/s

$t = 5$ min $= 300$ sec

(i) $v = u + at$, $a = \frac{v - u}{t}$

(ii) $v^2 - u^2 = 2as$, $s = \frac{v^2 - u^2}{2a}$

Example 8.6 A car accelerates uniformly from 18 km h^{-1} to 36 km h^{-1} in 5 s. Calculate (i) the acceleration and (ii) the distance covered by the car in that time.

$u = 18$ km hr^{-1} $= 18 \times \frac{5}{18} = 5$ m/s

$v = 36$ km hr^{-1} $= 36 \times \frac{5}{18} = 10$ m/s

$t = 5$ sec

(i) $v = u + at$

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