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Unit - 3 General Properties of Matter

★ defines

1 Stress:-

The restoring force arising per unit cross-sectional area of a deformed body is defined as stress.

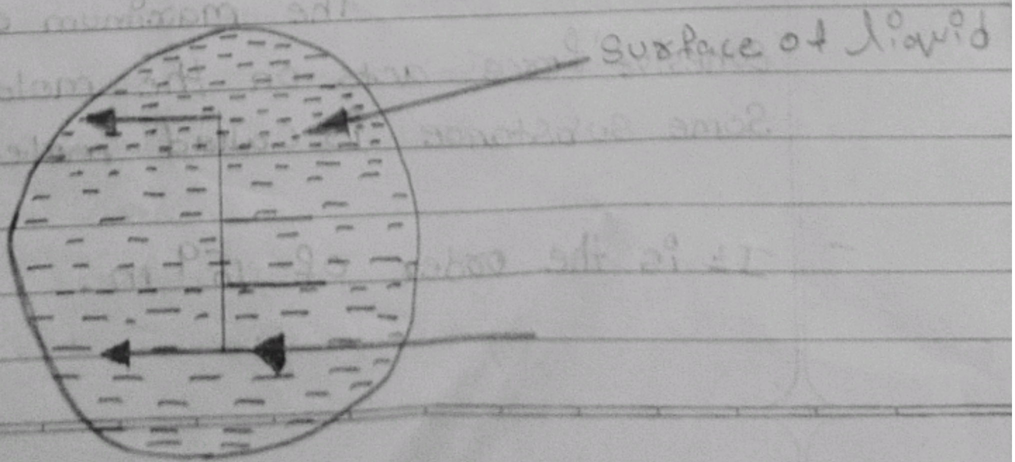
$$\therefore \text{Stress } \sigma = \frac{\text{force}}{\text{Area}} = \frac{F}{A}$$

2 Strain:-

When an external force is applied on a body its length, volume or shape changes and corresponding to each other we define it strain.

3. Surface Tension:-

Surface tension is defined as the force acting per unit length at the line drawn on the surface of a liquid, the direction being at right angle to this line and tangential to the surface of the liquid.



→ S.I. Unit :- N/M or Joule/m^2
C.G.S unit :- dyne/cm or erg/cm^2

4 Angle of contact:-
The angle made by the tangent to the liquid surface, at the point of contact with the wall of container, measured from inside the liquid is called angle of contact of liquid to the solid

5 Surface energy :-
The potential energy per unit area of the surface film is called surface energy

Surface energy = Surface tension × total increase in area

$$W = T.A$$

$$\text{or } T = \frac{W}{A}$$

SI : ⟶ J/m^2
CGS : ⟶ erg/cm^2

6 Molecular range :-
The maximum distance to which cohesive force acts on the molecules of the same substance is called molecular range.

- It is the order of 10^{-9} m.

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7 Molecular force :-

The force which keeps the molecules together is known as molecular force.

8 Sphere of influence :-

A sphere drawn, taking the position the molecule is as centre with a radius equal to molecular range, is known as sphere of fluence.

9. Elasticity :-

The property of certain materials of returning back to their position, after removing the external forces, is called elasticity

10. limit of elasticity :- "for a given section of the body, if the deformation caused by the external force, with in a certain limit such a limit is called elastic limit of the body

11 Viscocity :-

The property of fluid due to which relative motion between two consecutive layers is opposed, is known as viscosity of the fluid.

12 Viscous force :-

This force is applicatble when fluid has laminan flow. That is liquid flow in layers. The internal force of ~~fr~~ friction between layers of fluid is called viscous force.

13 velocity gradient :- $\frac{v_2 - v_1}{d}$

The difference in velocities of two adjacent layers of unit distance from each other in a laminar flow of liquid is called velocity gradient.

SI unit :- S^{-1}

14 Coefficient of viscosity :-

Thus, in case of steady flow if there is unit velocity gradient between two consecutive layers of unit surface area the viscous force is called coefficient of viscosity.

if $A = 1$, $\frac{v_2 - v_1}{d} = 1$

then $\eta = F$

SI unit :- Nsm^{-2} or Pascal

CGS unit :- $dyne \cdot s/cm^2$ or Poise

15 Criticle velocity:

At low velocity fluid flows in steady flow, But as velocity increases at certain velocity it converts as turbulant flow and it remains as turbulant flow for more velocity. Thus it is velocity of flow of fluid below which the flow turns into turbulant flow.

16 Stoke's law:-

It gives the upward force on spherical body falling freely in visous fluid due to viscosity of fluid, Let η be coefficient of viscosity of the fluid, r be the radius of sphere, v be the ~~v~~ Terminal velocity, then the opposing force on the body (viscous force) is given by

$$F_{(v)} = 6\pi \eta r v$$

17 Terminal velocity:-

When resultant force on the body reduces to zero, the body starts motion with constant velocity. this velocity is called terminal velocity of the body v_1

$$v_t = \frac{2}{9} \frac{r^2 g}{\eta} (\rho - \rho_0)$$

★ Differences

1) Deforming force and restoring force

Deforming force	Restoring force
- If an external force applied on a body produces a change in normal positions of the molecule of the body, which result in a change in the shape and size of the body, then the external force applied is called deforming force	When deforming force is applied on a body, an internal force is produced in the body to bring the constituent particles to its original position which opposes deforming force. Thus, the force that opposes deforming force and restores the size and shape of the body when deforming force is removed is called restoring force.

2. Cohesive force and adhesive force

Cohesive force	adhesive force
→ Cohesive force are the forces of attraction between the molecules of the same substances.	Adhesive force is the force of attraction between molecules of different substance
→ e.g - molecules of alcohol mercury.	eg - gum stick to paper.

3 Elastic body and Plastic body

	Elastic body	Plastic body
-	A body which regains its original shape and size Immedeatly and completely after the Removal of deforming force from it, is called elastic body.	A body which does not regains its original shape and size at all on the removal of deforming force, how ever small the deforming force may be is called Plastic body.
-	e.g. Quartz and Phosphor bronze. etc.	e.g. - Putty, mud, Paraffin wax. etc.

4. Stream line flow - turbulant flow

Stream line flow	Turbulant flow
- In stream lin flow the velocity of fluid Particles reaching a Particular Point is the same all time. Each Particle follows the same Path as taken by a Previous Particle Passing through that Point.	If the liquid is Pushed in the tube at a rapid rate, the flow may become turbulent. In this case, the velocity Passing through dame Point may be different and change suddenly with time
- If $N_R < 2000$, flow is stream line flow	If $N_R < 3000$ flow is turbulent flow
- eg flow of water in Pipe, flow of water in River	eg - motion of water fas flowing river

* Explain following in Breif

1 Hook's law

Statement:
For small deformations in a body the stress and strain are directly proportional to each other.

$$\text{stress} \propto \text{strain}$$

$$\therefore \text{Stress} = \text{Constant} \times \text{Strain}$$

$$\therefore \sigma = K\varepsilon$$

Here, Constant K appearing in the equation is known as modulus of elasticity.

- SI unit :- NM^{-2} or Pa
- CGS unit - Poise

2 young's modulus :-

when stress is applied on a wire and strain is linear strain, modulus of elasticity is called young's modulus

$$\text{stress} \propto \text{strain}$$

$$\sigma \propto \varepsilon$$

$$\therefore \sigma = y \cdot \varepsilon$$

$$\therefore y = \frac{\sigma}{\varepsilon}$$

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-3 Bulk modulus :-

When volume stress Produces volume strain in the body, The elastic modulus is Known as bulk modulus (B)

Volume stress ∝ volume strain

$$P \propto \frac{\Delta V}{V}$$

$$P = B \frac{\Delta V}{V}$$

$$\therefore B = \frac{P}{\frac{\Delta V}{V}}$$

- 4 moduli of elasticity :-

It is ratio of stress (shearing) to shearing strain for small deformation of a body is called moduli of elasticity

Shearing stress ∝ Shearing Strain

$$F \propto \phi$$

$$\therefore F = h \cdot \phi$$

$$\therefore h = \frac{F}{\phi}$$

5 Newton's law of viscosity.

- This law is for stream line flow of fluid.

- According to Newton's experiment, viscous force depends on following factors:

$F \propto A$ where A is area of surface.

$F \propto \frac{v_2 - v_1}{d}$ (velocity gradient)

$$F = \eta \cdot A \frac{(v_2 - v_1)}{d} \quad \ldots (1)$$

where η is coefficient of viscocity. η depends on the type of fluid and tempreature. if η is more, F is more and flow is reduced for liquid. η reduces with increase of tempreature and for gas it increases with increase of tempreature.

6 Stream line flow:-

In the stream line flow the velocity of fluid particles reaching a particular point is the same all time. Each particle follows the same path as taken by a previous particle passing through that point.

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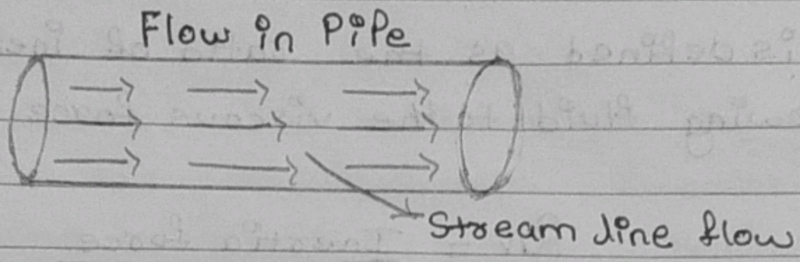
eg → flow in water

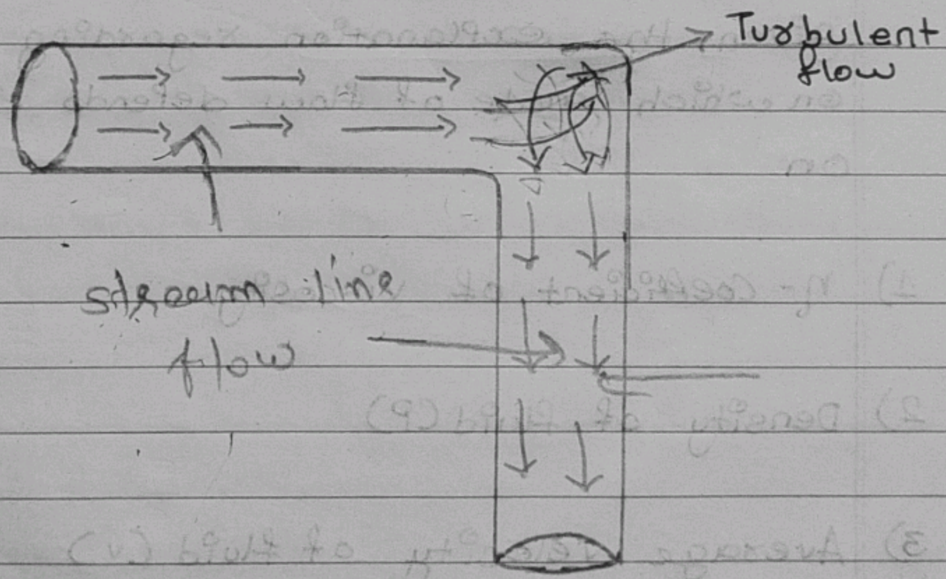


7) Turbulent flow :-

If the liquid is pushed in the tube at a rapid rate, the flow may become turbulant. In this case, the velocity is passing through same point may be different and change suddenly with time.

eg → motion of water, fast flowing river

figure ↓



8) Reynold number:-

It is defined as the ratio of inertia face of a flowing fluid to the viscous force of the fluid

$$R_N = \frac{\text{Inertia force}}{\text{viscous force}}$$

$$R_N = \frac{vD}{\eta}$$

when the liquid is passing through a glass tube, flow may be stream line or turbulent or mixed for determining coefficient of viscosity it should be streamline flow through out experiment.

British mathematician and Physics Scientist has given the explanation regarding the factors on which mode of flow depends. It depends on

1) η - Coefficient of viscosity

2) Density of fluid (ρ)

3) Average velocity of fluid (v)

4) Diameter of tube (D)

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Formula for Reynold's number

$$N_R = \frac{\rho v D}{\eta}$$

- Reynold's number is given by the relation $N_R = \frac{\rho v D}{\eta}$

- Mode of flow depends on value of N_R

1) If $N_R < 2000$, flow is Streamline

2 If $N_R < 3000$, flow is turbulent

3 If $2000 < N_R < 3000$, flow is not steady, type of flow changes.

- value of Reynold's number at criticle velocity is called Reynold's number.

- Flow of non-viscous liquid cannot have streamline flow.

✩ Explain stress and strain with their types

- **Stress:-**

The restoring force arising per unit cross-sectional area of a deformed body is defined.

$$\therefore \text{Stress } \sigma = \frac{\text{Force}}{\text{Area}} = \frac{F}{A}$$

Types of Stress

(1) longitudnel stress
(2) Volume stress
(3) Shearing stress

(1) **Longitudinal stress**

Consider the specimen is a rod i.e, length is more with comparision to cross-sectional area, when the external force is applied to rod which causes increase in the length resulting stress is called longitudinal stress.

If due to application of external forces, length of the rod decreases the resulting stress is compressive stress.

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(2) Volume Stress

The forces are Perpendicular to the Surface locally. Application of such forces cause change in the volume of the body and as a result volume strain is Produce in the body

If the Pressure at the location of Immersed solid is $\vec{P}$. The force on any area. A is PA. In equillibrium, condition the force Per unit area is volume stress.

$$\therefore \text{volume stress} = \sigma_v = \frac{\vec{F}}{A} = \frac{PA}{A}$$

(3) Shearing stress)

If a force acting on a body is tangential to a surface of the body it causes shearing strain in the body and the corresponding stress is called shearing stress.

— Strain :

when a external force is applied on a body its length, volume or shape changes and corresponding to each othere we define strain.

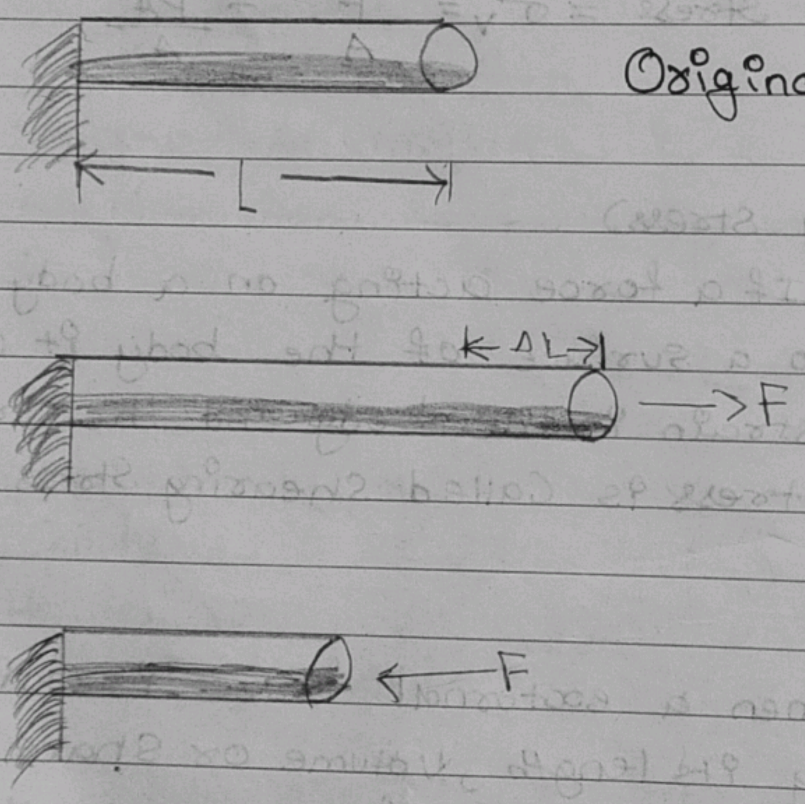
→ Types of strain

(1) longitudinal strain
(2) volume strain
(3) shearing strain

(1) longitudinal strain

The ratio of change in length of a body (ΔL) is when deforming force is applied at longitudinal strain.

Original rod



The longitudinal strain = $\varepsilon_l = \frac{\Delta L}{L}$

(2) Volume Strain

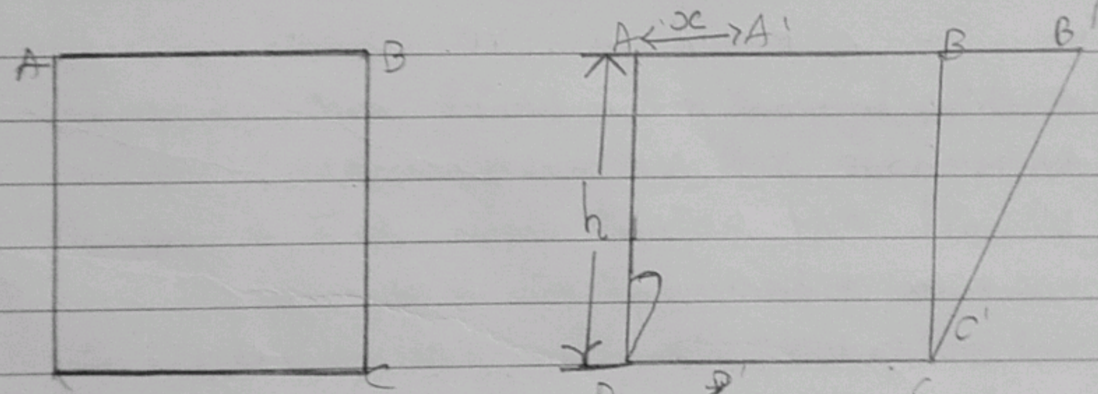
Volume Strain is defined as ratio of change in volume to the volume of undeformed body

$$\text{volume strain} = \varepsilon_v = \frac{\Delta V}{V}$$

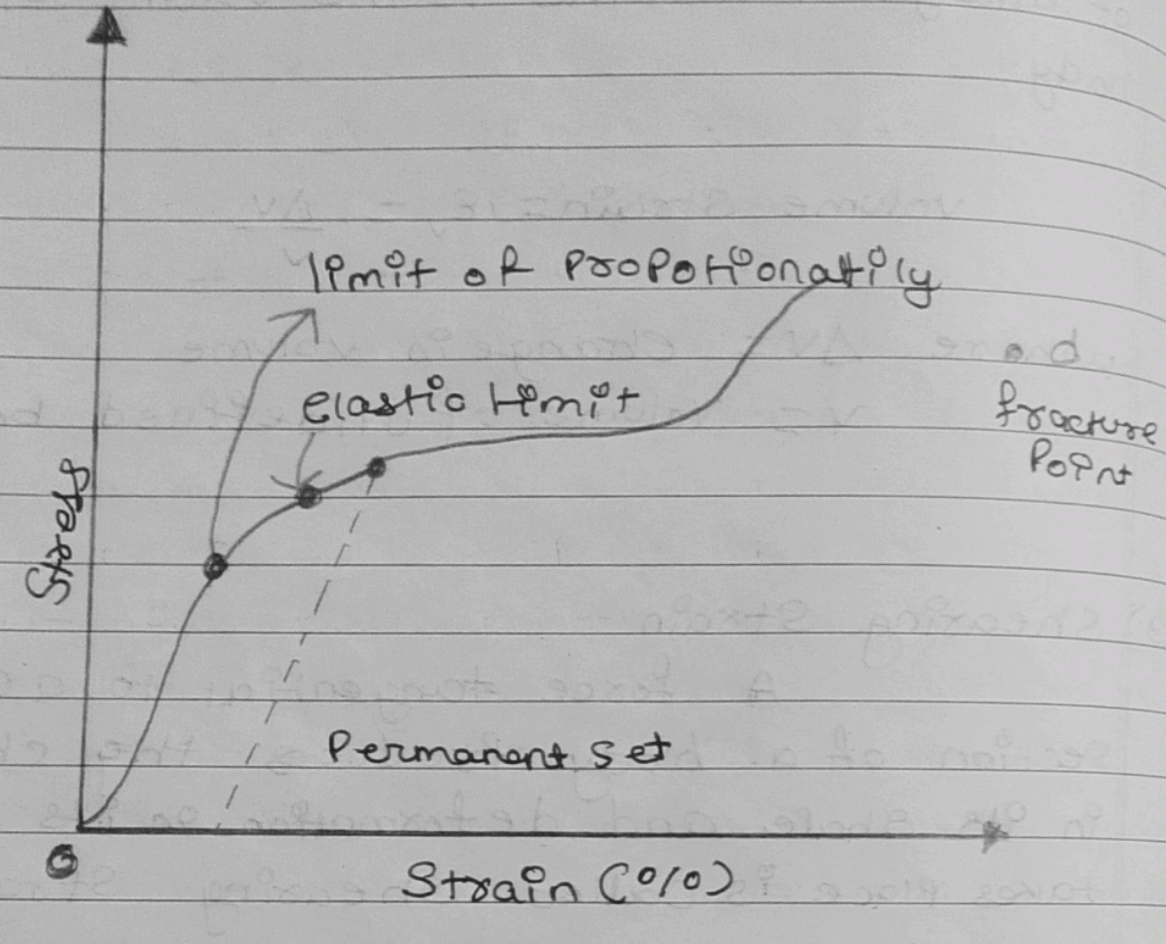
where ΔV = change in volume
V = Volume of undefined body

(3) Shearing Strain

A force tangential to a cross-section of a body produces the change in its shape and deformation in its shape takes place is called shearing strain



→ Draw Stress and Strain Curve



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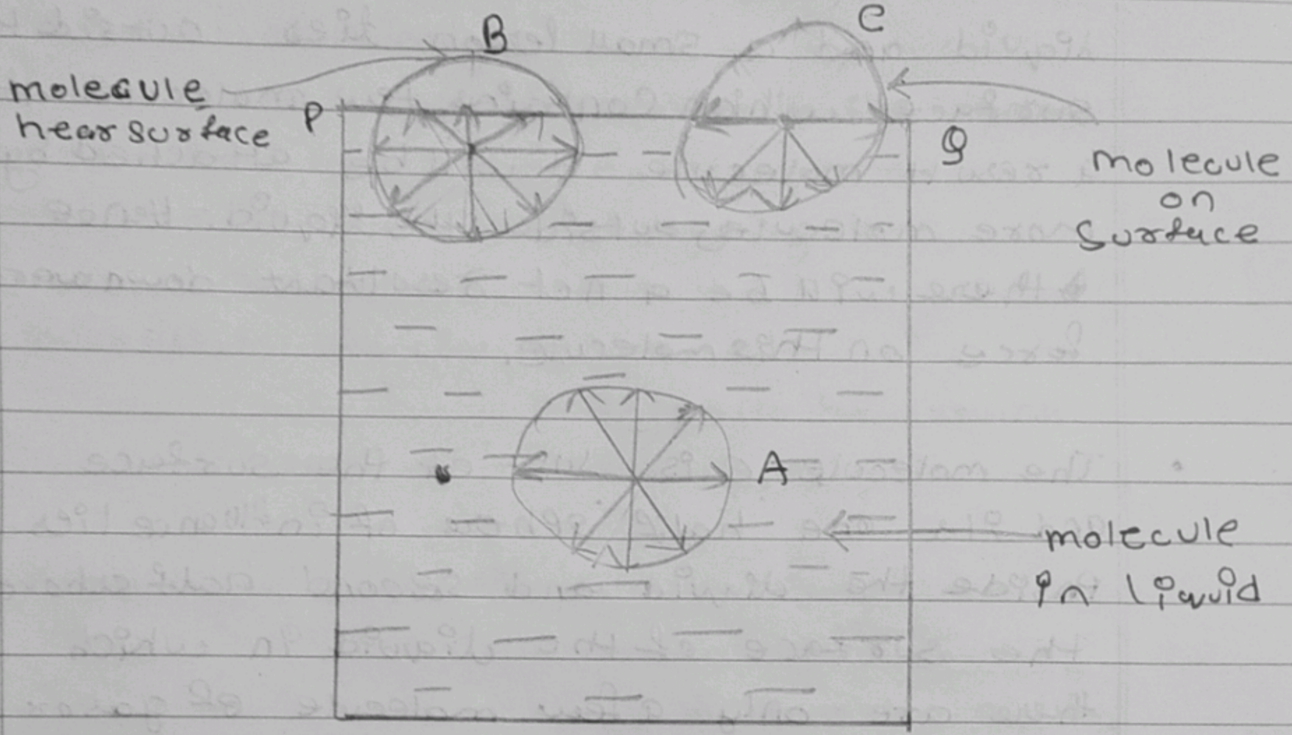
Explain Laplace's molecular theory to understand surface tension.



→ Laplace's Moleculer Theory

- Take a container filled with some liquid. Now, consider three molecules A, B, C such that molecule A lies well inside the liquid, B Just below the surface and C at the surface. let us examine the cohesive force acting on these molecules.

- In case of molecule A, the sphere of influence lies whole inside the liquid. As a result this molecule will be attracted by the adjacent molecules from all directions and the net resultant cohesive forces will be zero

- In case of molecule B the major part of the sphere of influence lies inside the liquid and a small person lies outside the surface which contains few molecules. As a result molecule B will be attached by more molecules outside the liquid. Hence there will be a net resultant downward force on this molecule.

- The molecule C is just at the surface and its one half sphere of influence lies inside the liquid and second half above the surface of the liquid in which there are only a few molecule of gas or vapour while there are liquid molecules in the one half below the surface. As a result, C molecule will be subjected to net resultant downward force, and its magnitude will be maximum.

- From the above we find that allover surface of a liquid there is a downward force due to attraction between the liquid molecules, As a result surface of liquid behaves as an elastic membrain having a tendancy to contract and tries to have least area. The layer of the liquid at the surface of thickness equal to the moleculer range is known as surface film.

* State applications of elasticity, viscosity and surface tension.

1) Viscosity :-

- Mechanical efficiency:
It refers to the hydraulic fluid's ability to reduce the mechanical friction of the internal moving parts.

- Volumetric efficiency:
It refers to how much power is lost due to leakage.

- Hydrodynamic function (lubrication):
It is also called 'fluid film' and refers to the ability for hydraulic fluid to lubricant moving parts by creating a thin film of oil between two surfaces so they donot come in contact with each other.

- Cavitation:
It occurs when the supply of oil is not sufficient for the speed of the system, which results in a low pressure situation.

- Heat Dissipation:
A key role of Hydraulic fluid is heat transfer

- Air release:
it is the ability of the hydraulic fluid to release andosed air Air release is important because trapped air causes Poor system efficiency and cavitation

- filtration ability:
this refers to the hydraulic fluids ability to pass through a filter to remove particles of debris and other Contaminants.

→ Elasticity applications

→ In the Ceiling of a building Steel or iron rod are used with Concrete. These rod are in the lower Position of Ceiling because concrete has more compressing strength while rods have more tensile strength.

→ Cranes are used for lifting and moving heavy loads from one Place to another Cranes have a thick metal rope to which the load is attached and so the Cable is understress, knowledge of elasticity gives the required value of thickness of metal ropes and pillars

→ we have to take to make Parts of machine so that stress beyond elastic limit is not applied on the Parts otherwise Parts may be damaged easily.

→ Knowledge of elasticity gives the length, breadth and height of metal or Concrete griders while making bridge on railway or road

3) Surface Tension:- applications

- when we Place a few drops of mercury on glass surface we find the mercury drops are sphericle. This is due to the fact that the tendency of the liquid is have minimum surface due to surface tension and since for a given volume the surface area of a sphere is minimum, The small drops take the shape of sphere.

- If we take a gressed needle on a Piece of blotting Paper and Put it gently over the surface of water, we find that the blotting Paper sinks down while the Needle keeps on floating. The weight of needle is supported by the surface tension of water.

- when a fine hair shaving brush is deeped in water its hair spreads in different directions but as soon as we take out the brush from water we find that cling together.

- To provide a narrow capillary the nip of a pen is split at the tip so as to allow the ink, they are able to soak the ink.

- The fine bores in a floating paper from capillaries and when they are brought near ink, They are able to soak the ink

- The wicks of stoves and lamps drain out oil through capillary action.

- The pores in the earth act as capillary and because of this rain water is soaked by earth.

- From the soil the plants suck water and sap through the capilary of leaves, trunk and branches.

☆ State Stok's law and explain freefall of spherical body in viscous medium.

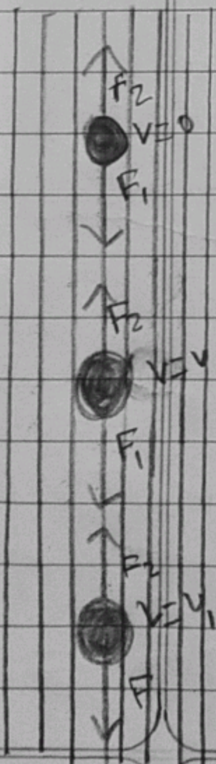
- Stoke's law :-

It gives the upward force on spherical body falling freely in viscous fluid due to viscosity of fluid,

Let η be coefficient of viscosity of the fluid, r be the radius of sphere, V be the terminal velocity, then the opposing force on the body (viscous force) is given by

$$F_{(v)} = 6\pi\eta r v$$

- Freefall of spherical body through viscous medium.



Let us consider a spherical body of radius r and density ρ falls freely through viscous medium of density ρ_0. Let $\rho > \rho_0$
we know that when a body moves in medium, layer of medium in contact with body also moves and the velocity is as of the body and a distant layer remains stable. Thus in the region between object and a distant layer there is stream line flow. Here also viscous force is appliedable between two consecutive layers which convers in resistive force on the moving body. It value is given by Stoke's law

☆ effects of temPreature and ImPurity on surface tension

Surface tension of liquid defends upon the temPreature. As temPreature increases its surface tension decreases. The temPreature at which the surface tension becomes zero is known as Critical temPreature

Critical temPreature of water is 374°K

Surface tension of liquid decreases with impurity.

e.g To reduce waves on the surface of sea water due to wind, oil is poured on the surface of water which spreads on the water surface and increase surface tension and reduces wave when detergent is added in hot water, surface tension of water decreases and instead of decreasing area it increases area and remove dirt and dust particles from dirty clothes.

☆ effect of tempreature on viscosity :-

viscosity of liquid decreases with increase of tempreature of liquid i.e. flow of fluid is fast with increase of tempreature but for gases viscosity increase with increase of tempreature i.e. flow of gas is so slow with increase of tempreature.

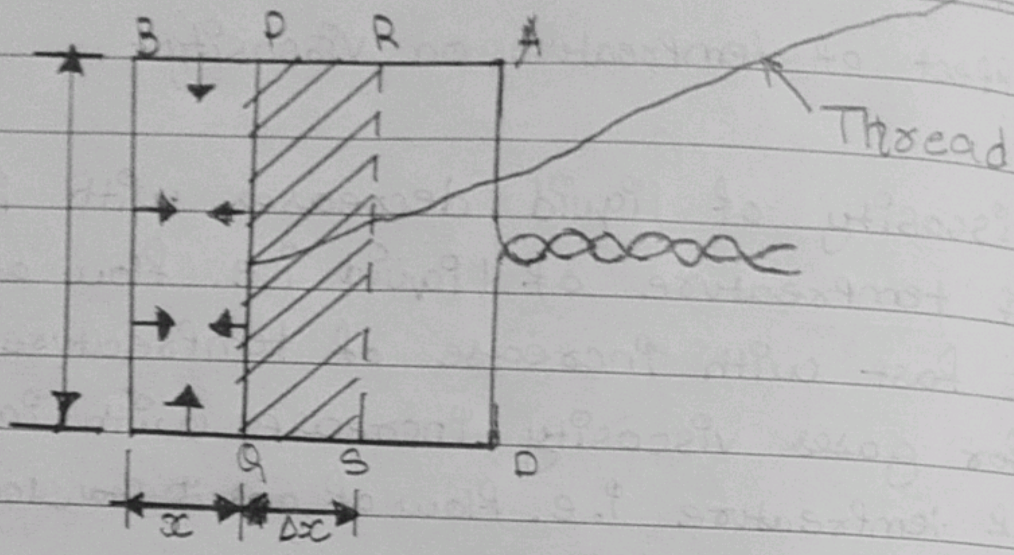
☆ State the relation between surface tension and surface energy

$$T = \frac{E}{A}$$

where, T = Surface tension
E = Surface energy
A = Total increase in area.

☆ Derive formula for relation between surface tension and surface energy

Surface energy of given liquid surface is defined as the amount of work done against the force of surface tension in forming the liquid surface of given area at a constant tempreature



To obtain an expression for surface energy, take a rectangular metallic frame ABCD having a wire PQ which can side along the sides AB and CD. From a soap film BCQP on the rectangular frame. There will be two free surfaces of the film where air and soap film are in contact. The forces of surface tension act tangentally inverse and perpendicular to the sides on both free surfaces of the film as shown in figure. All other size being fixed, we can increase the surface area of soap film by displacing the sliding wire PQ outwards.

Let T be surface tension of the soap solution, l be length of the wire PQ

To increase the area of the soap film, we have to pull the sliding wire PQ outwards with a force F let the film be streched by displacing the wire PQ through a small distance Δx to the position

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As for this work done W = force × displacement.

Since there are two free surfaces of the film and surface tension acts on both of them, hence total inward force on the wire PQ is

$$F = 2TL$$

work done in streching the film is $W = 2TL\Delta x$

The increase in area of the film, PQRS = $A = 2(L\Delta x)$

∴ work $W = 2TL\Delta x = T2L\Delta x = TA$