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Chapter = 10

Mechanical properties of fluids

→ Fluids is a substance that flow under ~~the~~ the action of an applied force and does not have shape of its own.

→ when fluid is at rest the study of fluid in rest ~~state~~ position is known as hydrostatic or fluid static.

→ The study fluid in motion is known as hydrodynamics

• **Pressure**

The pressure is defined as the magnitude of force acting perpendicular to the surface of an object per unit surface area of the object

$$P = \frac{F}{A} = \frac{Newton}{met^2}$$

$$P = N/m^2$$

dimensional formula $= [ML^{-1}T^{-2}]$

→ Unit of pressure into cgs system
dyne / cm^2

→ Other unit of pressure is Pascal (Pa)
$1\ Pa = 1\ Nm^{-2}$

Ques – A circular pillar of area of cross section $6 \times 10^{-3} m^2$ support a weight of a 60 kg (600N) calculate the working of the pillar?

$A = 6 \times 10^{-3} m^2$

$F = 60g = 600N$

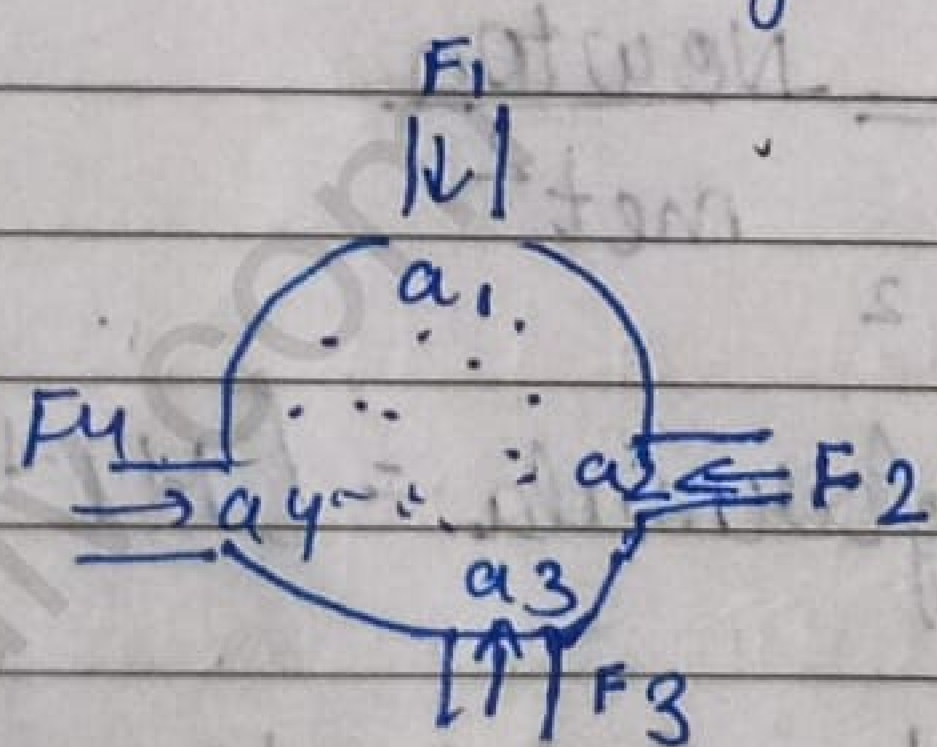
$P = ?$

$$P = \frac{600}{6 \times 10^{-3}}$$

$$= 10^5 \, Pa \; N/m^2$$

→ **Pascal's Law:-**

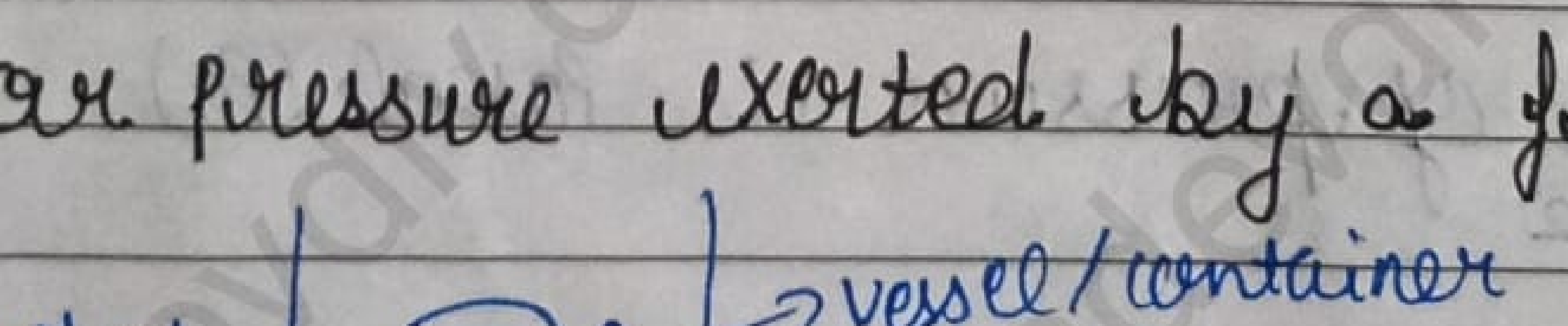
According to this law the pressure applied to an enclosed liquid or gas (fluids) is transmitted and undiminished to every portion of the liquid and the walls on the containing vessel



$$\frac{F_1}{a_1} = \frac{F_2}{a_2} = \frac{F_3}{a_3} = \frac{F_4}{a_4}$$

$$P_1 = P_2 = P_3 = P_4$$

→ **Expression for pressure exerted by a fluid column**



F = mass of fluid at column at depth $h \times g$

= Volume × depth × g

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$F = (Ah)\rho g$

$$\boxed{F = Ah\rho g} \quad - (1)$$

$$P = \frac{F}{A} = \frac{Ah\rho g}{A}$$

$$\boxed{P = h\rho g}$$

Ques ~~Bu~~ Blood pressure of the human being is greater at feet than and the brain?

Because we know that the pressure exerted by a fluid column $p = h\rho g$. Since the height 'h' of the blood column at feet is larger as compared to the brain

→ ~~The device~~ Hyraulic machine

The device which work on pascal law is known as hydraulic machine Eg:- dentist chair, hydraulic press, Hydraulic ~~press~~ brakes, ~~etc~~. Hydraulic lift, etc.

→ Hydraulic lift

It consist of a horizontal fluid-filled container both ends of the container are fitted with two cylinder having ~~cu~~ piston of different area of cross section. The piston of small cross sectional area 'a' exert a force 'f' directly on the fluid. The pressure $P = \frac{f}{a}$ is transmitted ~~at~~ undiminished through the

connecting pipe through a large cylinder which have a piston area 'A'. ~~The~~ but the pressure must be ~~on~~ ~~the~~ same ~~s~~ on both sides

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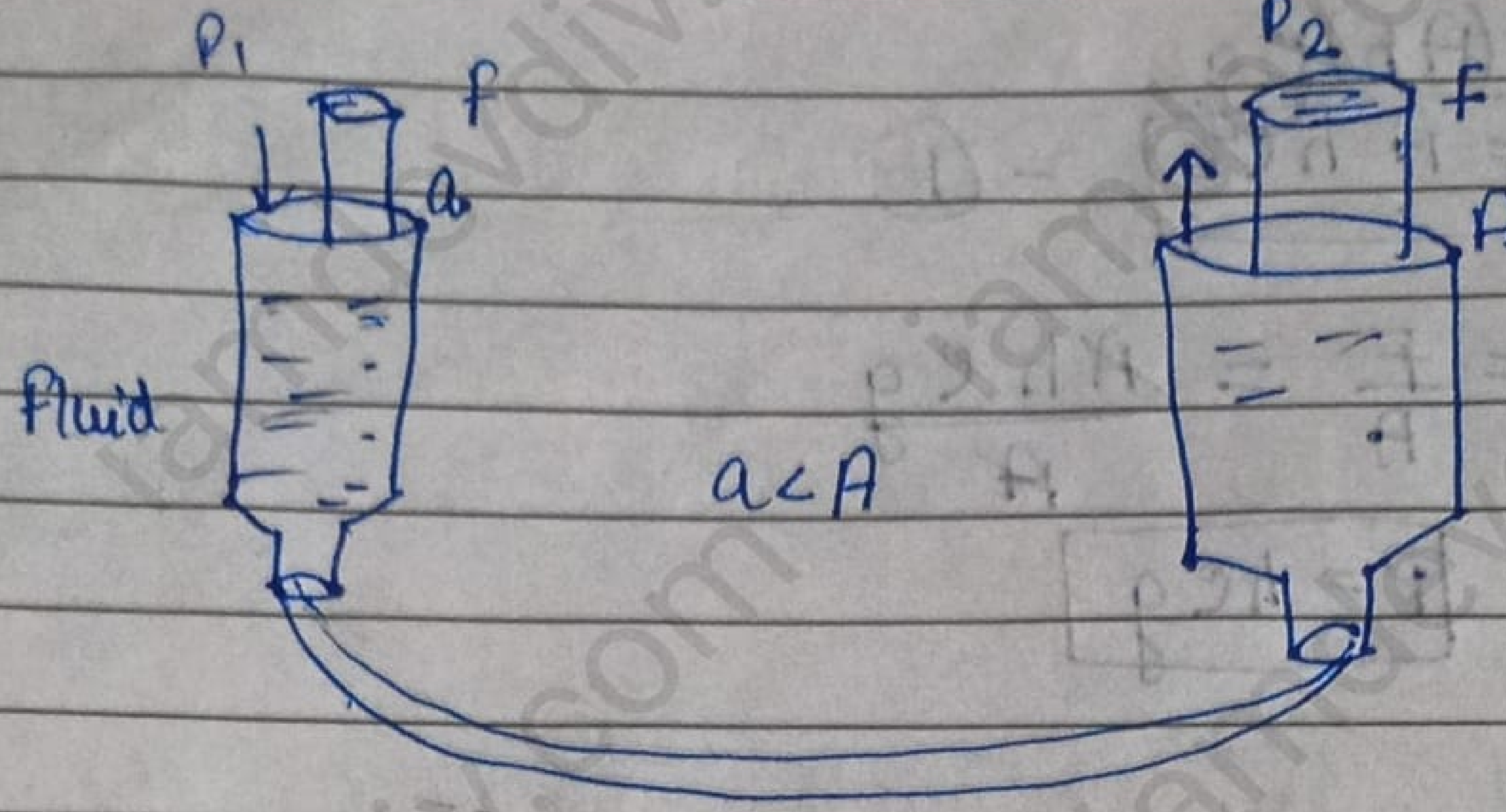

According to pascal law

$$P_1 = P_2$$

$$\frac{f}{a} = \frac{F}{A}$$

$$\boxed{F = \frac{f}{a} A}$$

$$a < A$$

$$f < F$$

But $a < A$

$$F > f$$

Force on large piston will be much far more than the force applied on the small piston. This can be used to lift a heavy load placed on the platform of large piston.

Hydraulic break

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Gauge Pressure

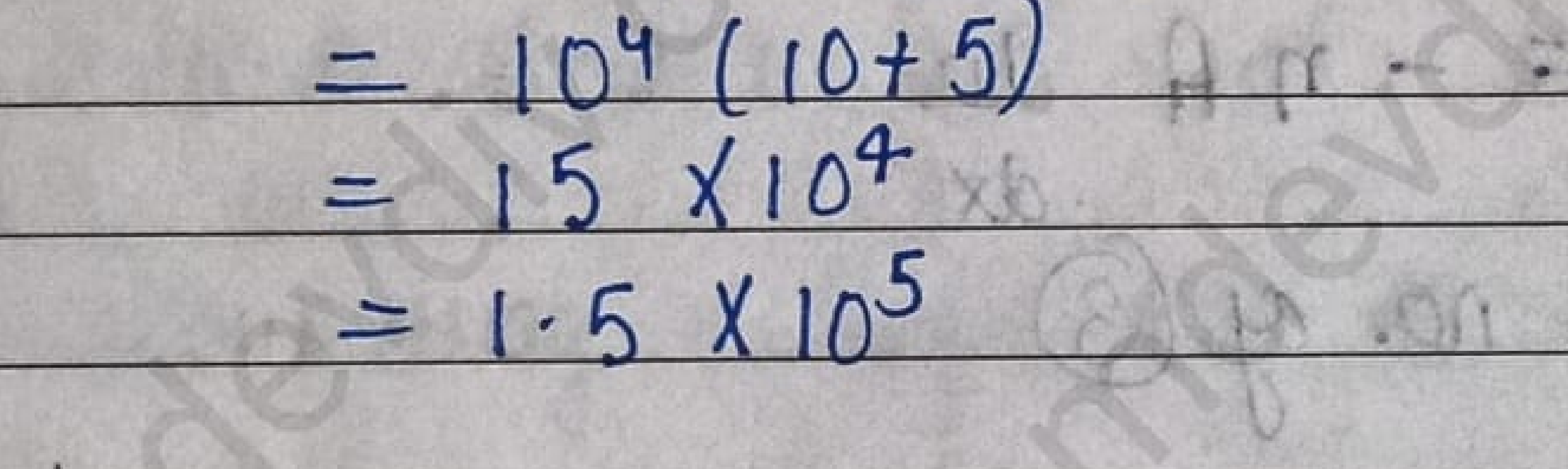
The difference of pressure between two points by a depth h from the free surface of the liquids or fluids is known as gauge pressure its given by as $P = P_a + h\rho g$

Ques - Calculate the pressure exerted by the water on a fish 5m below the surface of a pond of a water. atmospheric pressure $= 1.013 \times 10^5$ Pa

$$= 1.013 \times 10^5 + 5 \times 10^3 \times 10$$
$$= 10^4 (10+5) 10^4$$
$$= 10^4 (10+5)$$
$$= 15 \times 10^4$$
$$= 1.5 \times 10^5$$

☆ Viscosity, coefficient of viscosity

The property of fluid by virtue of which an opposing force or internal friction come into place between two different layer of liquid whenever a there a relative motion between these layers is called viscosity



→ According to the Newton backward force between the layers always depend on

1. directly proportional to the area of the layer → $F \propto A$ — ①

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2. directly proportional to velocity gradient between the layers $F \propto \frac{dv}{dx}$ — (2)

∴ From eq. (1) & (2)

$$F \propto A \frac{dv}{dx}$$

$$F = \eta A \frac{dv}{dx} \quad -(3)$$

OR

$$F = -\eta A \frac{dv}{dx}$$

from eq^n no. of (3)

$$A = 1, \frac{dv}{dx} = 1$$

$$\boxed{\eta = F}$$

Coffecient of viscosity of a liquid or fluid is defined as viscos for acting per unit area of the layer having unit velocity gradient perpendicular to the direction of the flow of the liquid

Note:- unit of coefficient of viscosity

$$\eta = \frac{F\, dx}{A\, dv}$$

$$= \frac{N}{m^2} \frac{m}{\frac{m}{s}} = \frac{Ns}{m}$$

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Its unit in the cgs system is dyne s cm^{-2} → poise
Dimensional formula $[M^1 L^{-1} T^{-1}]$

Stock's Law

$F = 6\pi \eta r v$

Stoke's proved that the viscous drag (F) acting on a spherical body of radius 'r' moving with a velocity 'v' in a fluid of coefficient of viscosity 'η' is given by

$$F = 6\pi \eta r v$$

This is called stoke's law

proof:- The viscous drag acting on a sphere depends upon.

1. The radius 'r' of the sphere
2. velocity 'v' and
3. coffecient of visocasity 'η' of the fluid

i.e.

$$F \propto \eta r v$$
$$F = K \eta^a r^b v^c \quad -(1)$$

on putting dimensions

$$[MLT^{-2}] = [ML^{-1}T^{-1}]^a \, [L]^b \, [LT^{-1}]^c$$
$$[MLT^{-2}] = [M^a] \, [L^{-a+b+c}] \, [T^{-a-c}]$$

comparing powers

$M^1 = M^a$

$\boxed{a=1}$

$L^1 = L^{-a+b+c}$

$1 = -a+b+c$

$1 = -1+b+1$

$\boxed{b=1}$

$T^{-2} = T^{-a-c}$

$-2 = -a-c$

$-2 = -1-c$

$-2+1 = -c$

$\boxed{-1 = -c}$

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Putting the values of a, b and c in eqⁿ ①

$F = K\eta r v$

Putting the value of $K = 6\pi$

$$\boxed{F = 6\pi\eta r v}$$

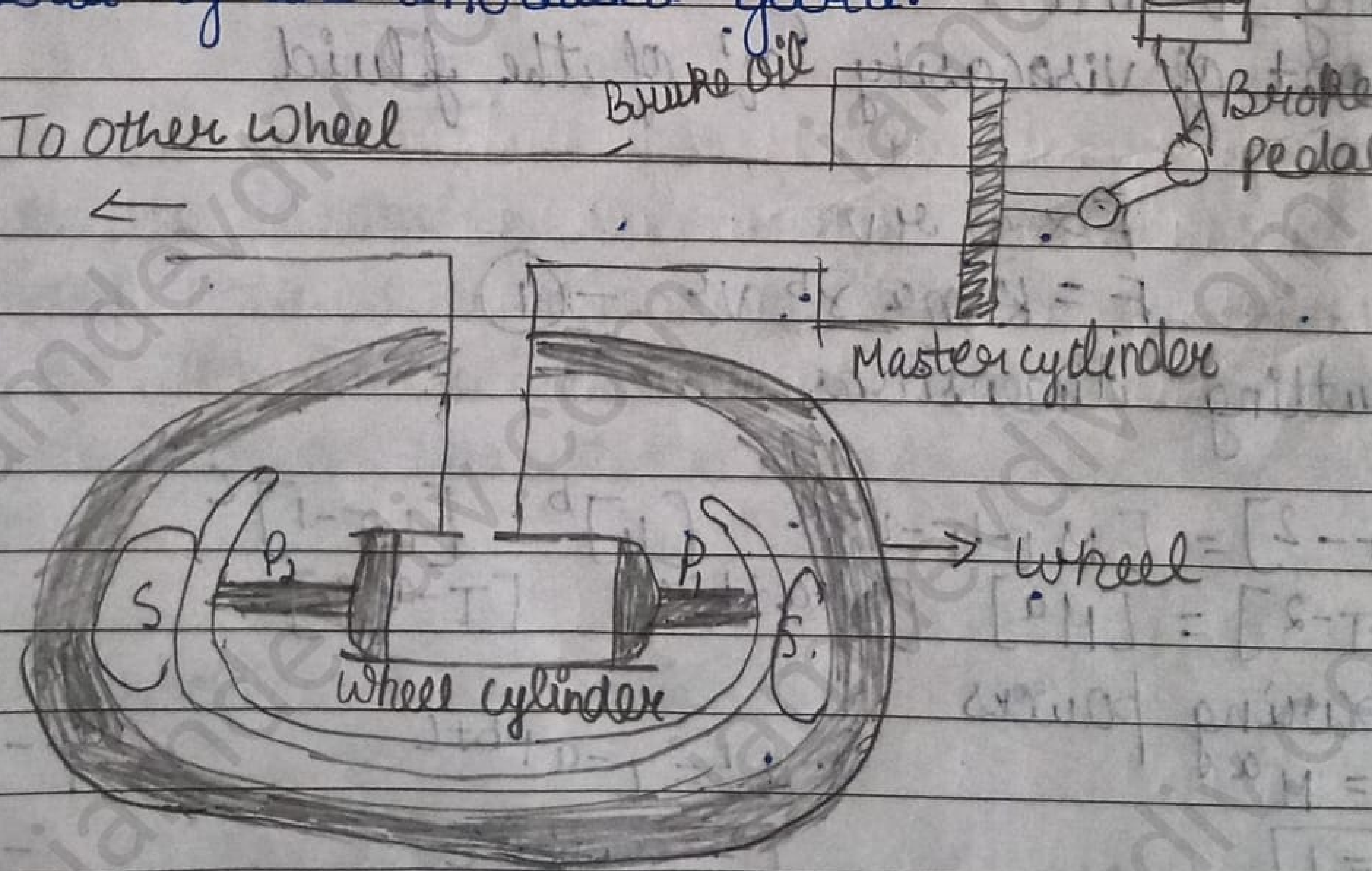
Hydraulic brakes

Hydraulic brakes system is used in automobiles to retard its motion.

→ Principle of pascal's law governs hydraulic brakes.

- When pressure is applied to a fluid it travels uniformly in all directions, according to this law.
- As a result, when we exert force on a small piston, pressure is created, which is communicated to a longer piston via the fluid.

- Uniform breaking is provided to all four wheel as a result of the increased force.



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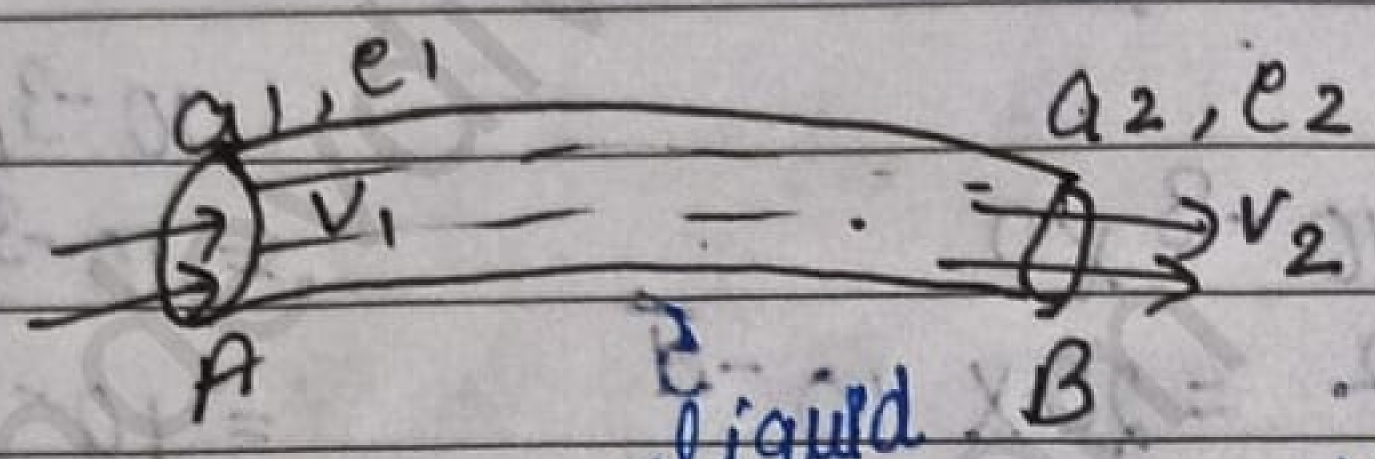
Equation of Continuity

Volume = Area × Length
$= a x$

Volume per second $= \frac{ax}{t} = a\left(\frac{x}{t}\right) = av$

Mass/s $= V.p.s \times \rho = av\rho$



Let us consider nonviscous in stream line flow through a tube AB of cross section A.B.

$av = con.$

$v \propto \frac{1}{a}$

$a_1 v_1 \rho_1$ $a_2 v_2 \rho_2$

$\Delta m = 0$

$m_1 = m_2$

$a_1 v_1 \rho_1 = a_2 v_2 \rho_2$

$a_1 v_1 = a_2 v_2$ $(\rho_1 = \rho_2)$

$a_1 v_1 = a_2 v_2$

$v \propto \frac{1}{a}$

~~# Bernoullie's theorem~~

Ques- Water through a horizontal pipe of radius 1cm at a speed of 2m/s. What should be the radius of its second pale from where water will come out at a speed of 10 m/s ?

$r_1 = 1cm = 10^{-2} m$
$a_1 = \pi r_1^2$
$v_1 = 2 m/s$

$a_2 = \pi r_2^2$
$v_2 = 10 m/s$

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$$a_1 v_1 = a_2 v_2$$

$$\pi r_1^2 v_1 = \pi r_2^2 v_2$$

$$r_1^2 v_1 = r_2^2 v_2$$

$$r_2^2 = \frac{r_1^2}{v_2} v_1$$

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

$$= 10^{-3} \times 2$$

$$r_2^2 = 20 \times 10^{-5}$$

$$r_2 = \sqrt{20} \times 10^{-3} m$$

$$r_2 = \sqrt{20} \times 10^{-1} cm$$

$10^{-3} m$
$= 10^{-3} \times 100$ cm
$= 10^{-1}$ cm

Bernoullie's theorem:-

Ques- Explain Bernoullie's theorem with pressure head, gravitational head and velocity head?

Ac. to this theorem for the stream line flow of an liquid the total energy means the sum of pressure energy, Potential energy and Kinetic energy at every crosssection throughout the liquid flow

$$P + \rho g h + \frac{1}{2}\rho v^2 = \text{Constant}$$

P → Pr.E., $\rho g h$ → P.E, $\frac{1}{2}\rho v^2$ → K.E.

$$\Delta P_{RE} = \Delta K.E. + \Delta P.E.$$

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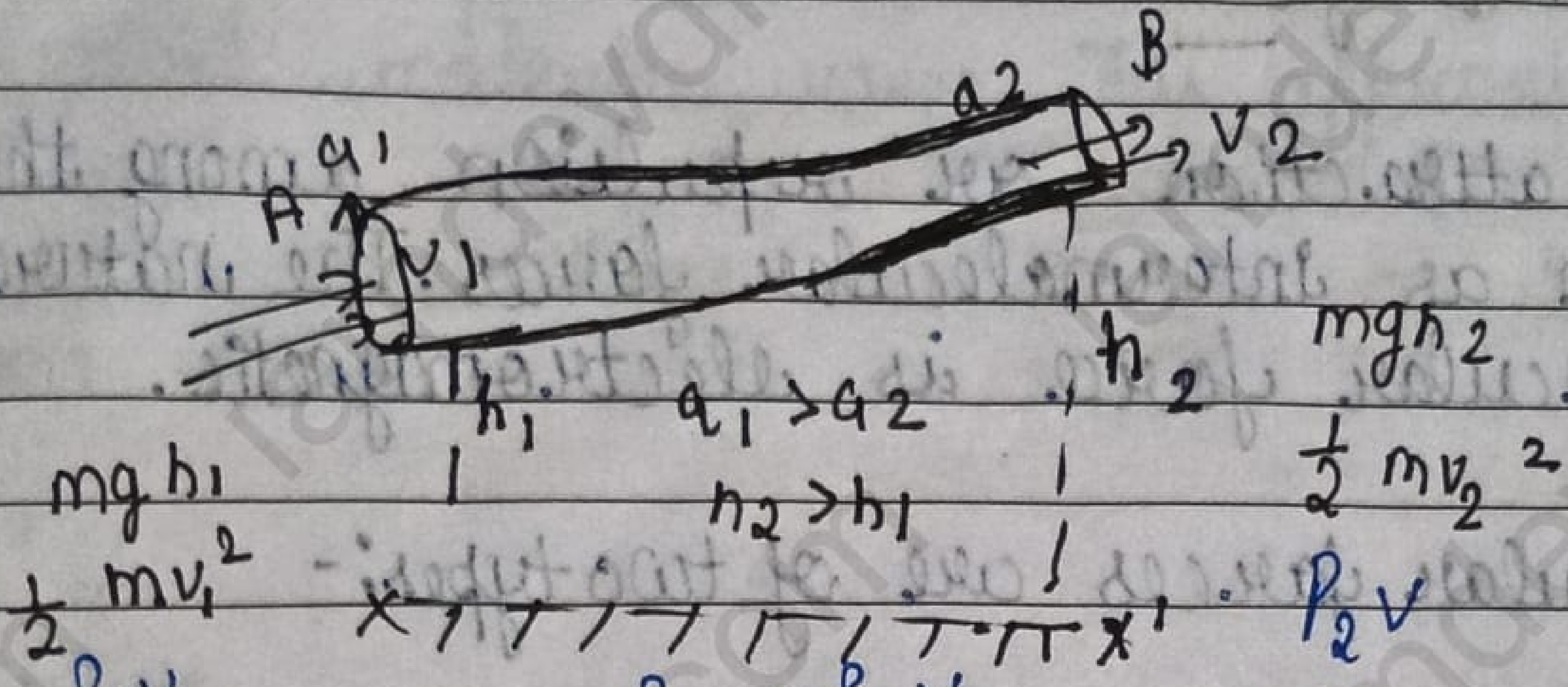

$P_1V > P_2V$

$mgh_2 > mgh_1$

$\frac{1}{2}mv_2^2 > \frac{1}{2}mv_1^2$

$$\frac{w}{t} = \frac{Fx}{t} = Pa\frac{x}{t}$$

$$= Pav$$

$$\Delta P_{R.E.} = \Delta K.E. + \Delta P.E.$$

$$P_1V - P_2V = \left(\frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2\right) + \left(mgh_2 - mgh_1\right)$$

$$P_1V + mgh_1 + \frac{1}{2}mv_1^2 = P_2V + mgh_2 + \frac{1}{2}mv_2^2$$

$$P.V + mgh + \frac{1}{2}mv^2 = \text{Constant}$$

$$P\frac{V}{m} + gh + \frac{1}{2}v^2 = \text{Constant}$$

$$\frac{P}{\rho} + gh + \frac{1}{2}v^2 = \text{constant}$$

$$P + \rho gh + \frac{1}{2}\rho v^2 = \text{constant}$$

$$\frac{P}{\rho g} + h + \frac{1}{2}\frac{v^2}{g} = \text{constant}$$

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☆ Intermolecular forces

Forces of attraction or repulsion among the molecule are known as intermolecular forces. The nature of intermolecular force is electromagnetic.

Intermolecular forces are of two types:-

1. Cohesive Force
2. Adhesive Force

→ Cohesive Force :- The force of attraction acting between the molecules of same material is defined as Cohesive Force. Ex:- Force acting between the water molecules. Force acting between mercury (Hg) molecules.

→ Adhesive Force:- The force of attraction acting between the two different materials is known as Adhesive force. Ex:- Force acting between the molecules of paper and ink, ~~and~~ blackboard and chalk and whiteboard and marker.

Ques - Which force is working when a teacher use a chalk to write on the board

a) gravitational force
b) Magnetic force
c) Cohesive force
d) Adhesive force

Note:- Intermolecular force are different from gravitational force in the sense that the former does not obey inversely square rule.

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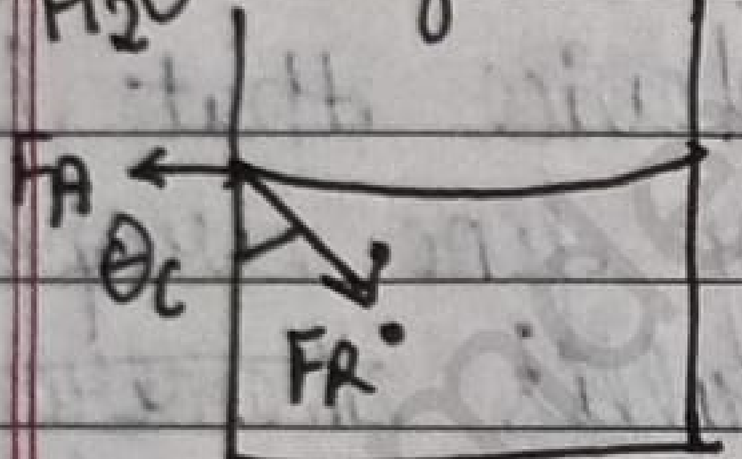
2. The distance upto which these forces remains effective is called molecular range. This approximate → 10^{-9} m.

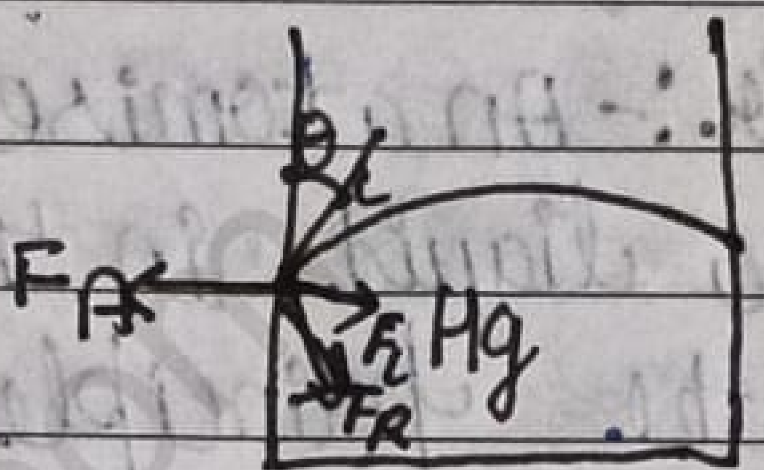
<u>Ques</u>- What is the molecular range for intermolecular force

a) 10^{9} m
b) 9×10^{2} m
c) 9×10^{-9} m
d) 10^{-9} m ✓

H_2O wet glass



Hg never wet glass?



$F_A > \frac{F_C}{\sqrt{2}}$

$\theta_c < 90°$

$F_A < \frac{F_C}{\sqrt{2}}$

$\theta_c > 90°$.

Note:- The angle enclosed between the tangent plane at the liquid ~~plan~~ surface and the tangent plane at solid surface at the point of contact inside the liquid is known as angle of contact. This always depend on the nature of solid and liquid in contact.

<u>Note</u>:- Water wet glass surface but mercury does not because when water come in contact with glass adhesive force acting ~~b/w~~ between water and glass molecules is greater than cohesive force of molecules. So water wet glass.

→ In other case of mercury (Hg) adhesive force is less than that of cohesive force and mercury molecules do not cling

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to the glass. So mercury does not wet the glass.

→ Application of Bernoullie theorem

1. Working of aeroplane:- An aeroplane works on the principle of Bernoulli's theorem. When an aeroplane flies, the wings create a low-pressure area above them. This low-pressure area sucks the air from below the wings and creates lift.

2. Action of atomiser:- An atomiser is a device that is used to spray a liquid in the form of fine droplets. It works on the principle of Bernoulli's ~~the area~~ theorem. The liquid is accelerated as it passes through a narrow construction in the atomiser. This causes a pressure decrease which vaporises the liquid and breaks it up into fine droplets.

3. Working of a venturi:- A venturi is a device that is used to measure the flow rate of a fluid. It works on the principle of Bernoulli's theorem. The fluid is accelerated as it passes through a narrow constriction in the venturi. This causes a decrease in pressure which can be measured.

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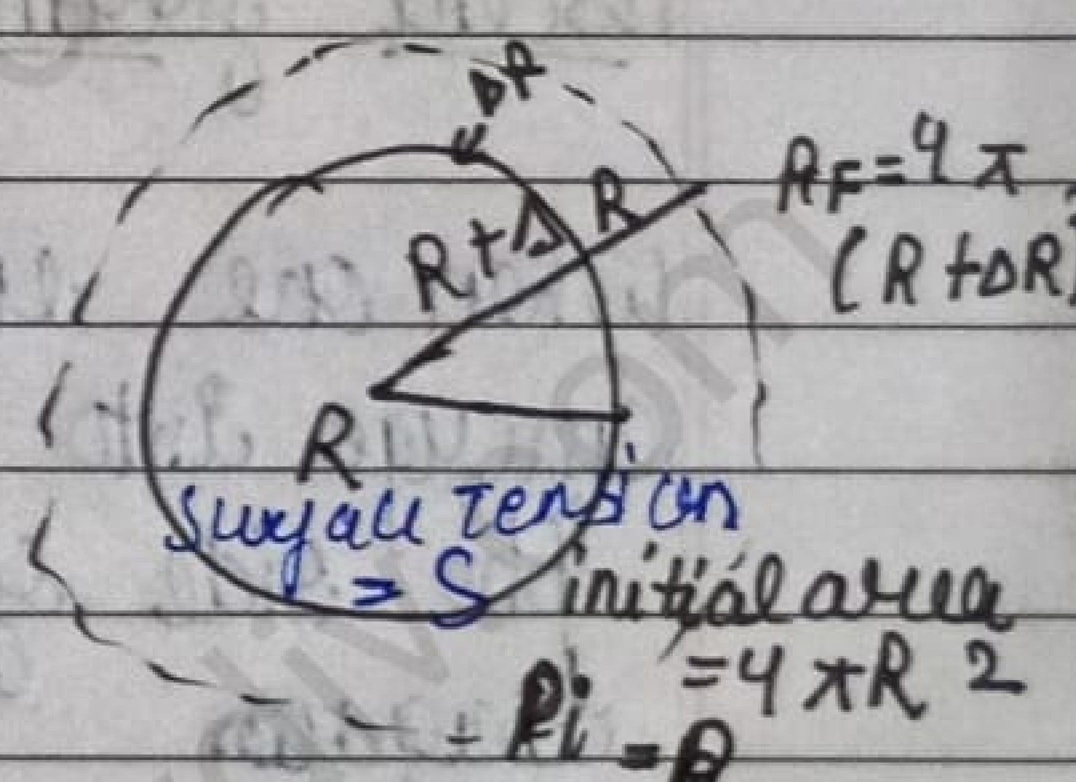
Imp # Excess pressure Inside a liquid drop

Let us consider a liquid drop of radius 'r' the molecules lying on the surface of liquid drop, due to the surface tension will experience a resultant force acting inward perpendicular to the surface

2.) The size of the liquid drop cannot be reduced to zero due to the force of surface Tension.

3.) The pressure inside the drop must be greater than the pressure outside it.

4.) This excess of pressure inside the drop will provide a force acting outward perpendicular to the surface, to counter balance the resultant force due to the surface tension(T).



→ The required work done to increase ΔR distance

$W = F \times \Delta R$

$= P 4\pi R^2 \times \Delta R$ — ①

F = Pressure x Area
$= P \times 4\pi R^2$

Change in Area $= A_F - A_I = 4\pi (R+\Delta R)^2 - 4\pi R^2$

$= 4\pi (R^2 + \Delta R^2 + 2R\Delta R) - 4\pi R^2$

$= \cancel{4\pi R^2} + 8\pi R \Delta R - \cancel{4\pi R^2}$

$\Delta A = 8\pi R \Delta R$ — ②

$W = S\Delta A$

$= S \times 8\pi R \Delta R$ = ③

① = ③

$P \times 4\pi R^2 \Delta R = S \times 8\pi R \Delta R = 2S$

$$\boxed{P = \frac{2S}{R}}$$

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~~Ascent formula:-~~

★ **Capillary Tube:-**

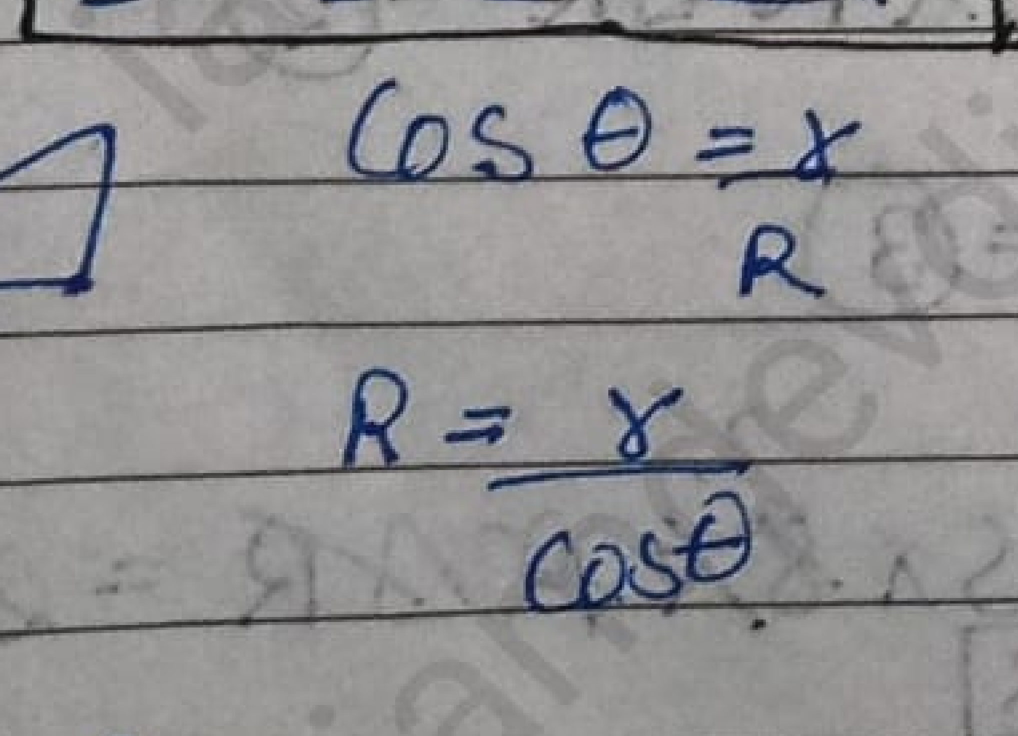
A tube with a fine and uniform bore throughout its length is called capillary tube. And the phenomenon of rise and fall of liquid in a capillary tube is called capillarity.

eg: ⇒ A towel soaks water on account of capillarity action.

⇒ Oil rise in the long narrow space between the threads of wick because they act as fine capillary

Ascent formula:-

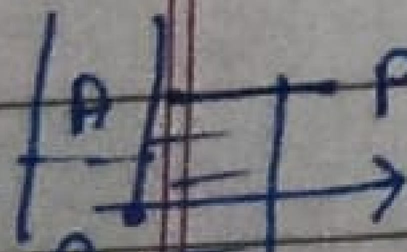
When one end of capillary tube of radius 'r' is emerge into a liquid of density 'ρ' which wet the side of capillary tube. According to the following diagram



level of B = level of C = level E

$P_B \neq P_C \neq P_E$

$P_B + P_{due\ to\ h} = P_E$



$\cos\theta = \frac{r}{R}$

$R = \frac{r}{\cos\theta}$

$\left(P - \frac{2S}{R}\right) + h\rho g = P$

$P - \frac{2S}{R} + h\rho g = P$

$h\rho g = \frac{2S}{R}$

$P_B = P - \frac{2S}{R}$

$h = \frac{2S}{R\rho g}$

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$$Rh = \frac{r}{\cos\theta} \rho g$$

Rising height → Surface Tension

$$\boxed{h = \frac{2S\cos\theta}{r\rho g}} \quad \text{— (1)}$$

Radius of tube → r ; density → ρ

From the above eqn (1) it is clear that h always inversely proportional to 'r'

$$h \propto \frac{1}{r}$$

$$a \propto \frac{1}{v}$$

~~$v \propto \frac{1}{a}$~~

$$v \propto \frac{1}{r^2} \quad \text{because} \quad v \propto \frac{1}{a}$$

Acc. to eqn of continuity.