MECHANICAL PROPERTIES OF FLUIDS

1. Fluids – liquid, gas

2. $P = \frac{F}{A}$

   P = Pressure
   F = Force
   A = Area

Units

$P = Nm^{-2}$

$F = N$

$A = m^2$

$1Pa = 1Nm^2$

3. P →
   - Nm^{-2}
   - Pa
   - atm
   - torr
   - mm Hg
   - bar
   - psi

(4) Dimensions

$A = L^2$

$F = MLT^{-2}$

$P = \frac{F}{A} = \frac{MLT^{-2}}{L^2}$

$P = ML^{-1}T^{-2}$

(5) Atmospheric Pressure

P =
- 1atm
- 760 mmHg
- 76 cm Hg
- $1.013 \times 10^5 Nm^{-2}$
- $1.013 \times 10^5 Pa$

(6) PASCAL'S LAW

$$\frac{F_1}{a_1} = \frac{F_2}{a_2}$$

$$\frac{F}{a} = \text{constant}$$

in every portion of liquid.

$F \propto a$

$F_1 \propto a_1$

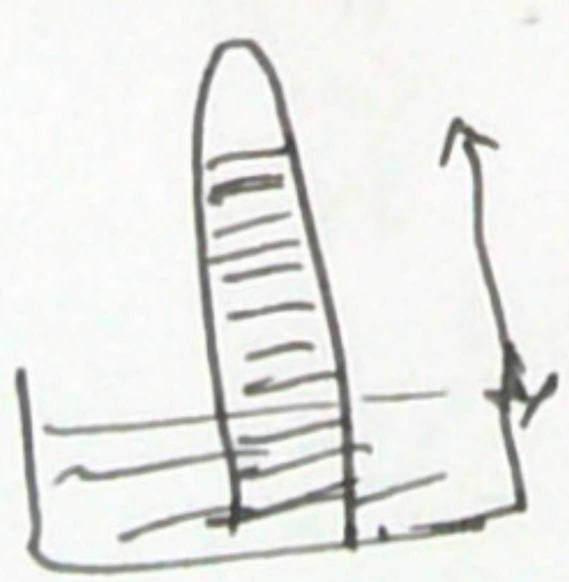
$F_2 \propto a_2$

$$\frac{F_1}{F_2} = \frac{a_1}{a_2}$$

$$\frac{F_1}{a_1} = \frac{F_2}{a_2}$$

(7) $$P = h\rho g$$

h = height of liquid column.



h = height

$\rho = \frac{m}{V}$ = density of liquid.

g = acc. due to gravity

(8) $P = P_a + h\rho g$

P_a = atmospheric pressure.

P = Pressure of liquid

* Applicable for incompressible liquids only.

(9) Absolute pressure (P)

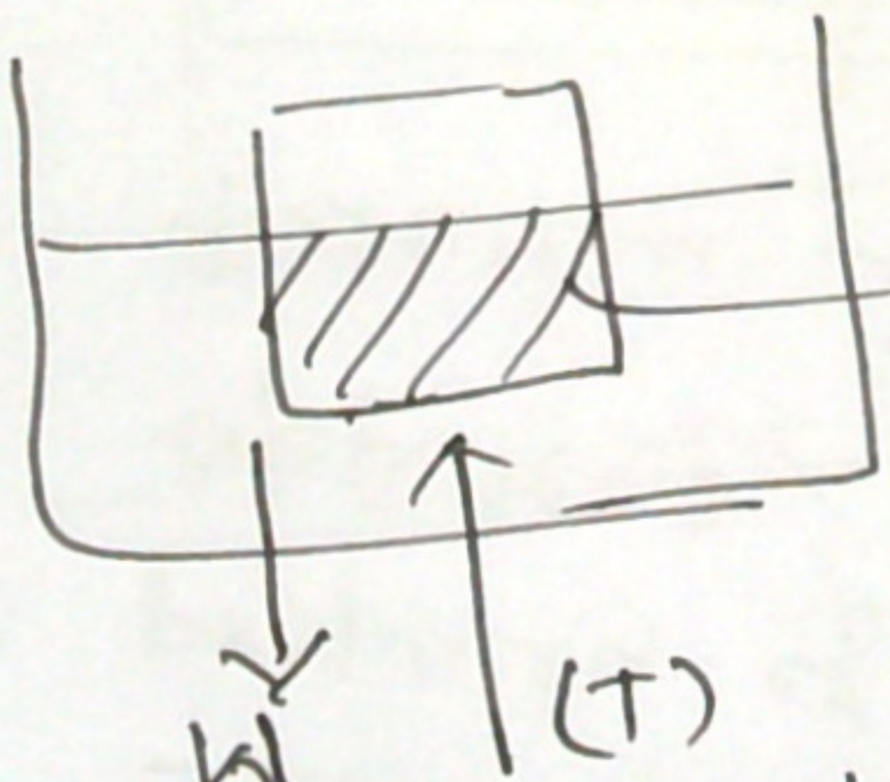
$$P = P_g + P_a$$

P_g = gauge pressure

P_a = atmospheric pressure.

(10) ARCHIMEDES PRINCIPLE

* A body partially | completely immersed in a liquid.
* it loses some of its weight
* The loss in weight = weight of liquid displaced by the immersed part of the body.



immersed part

Loss in wt = wt of liquid displaced

upward force exerted by the liquid (BUOYANCY)

W = weight of the body ↓

T = upward thrust (buoyancy)

(11) LAW OF FLOATATION

(i) T = Wt. of liquid displaced ↑

(ii) W = weight of the body

(iii) W ↓

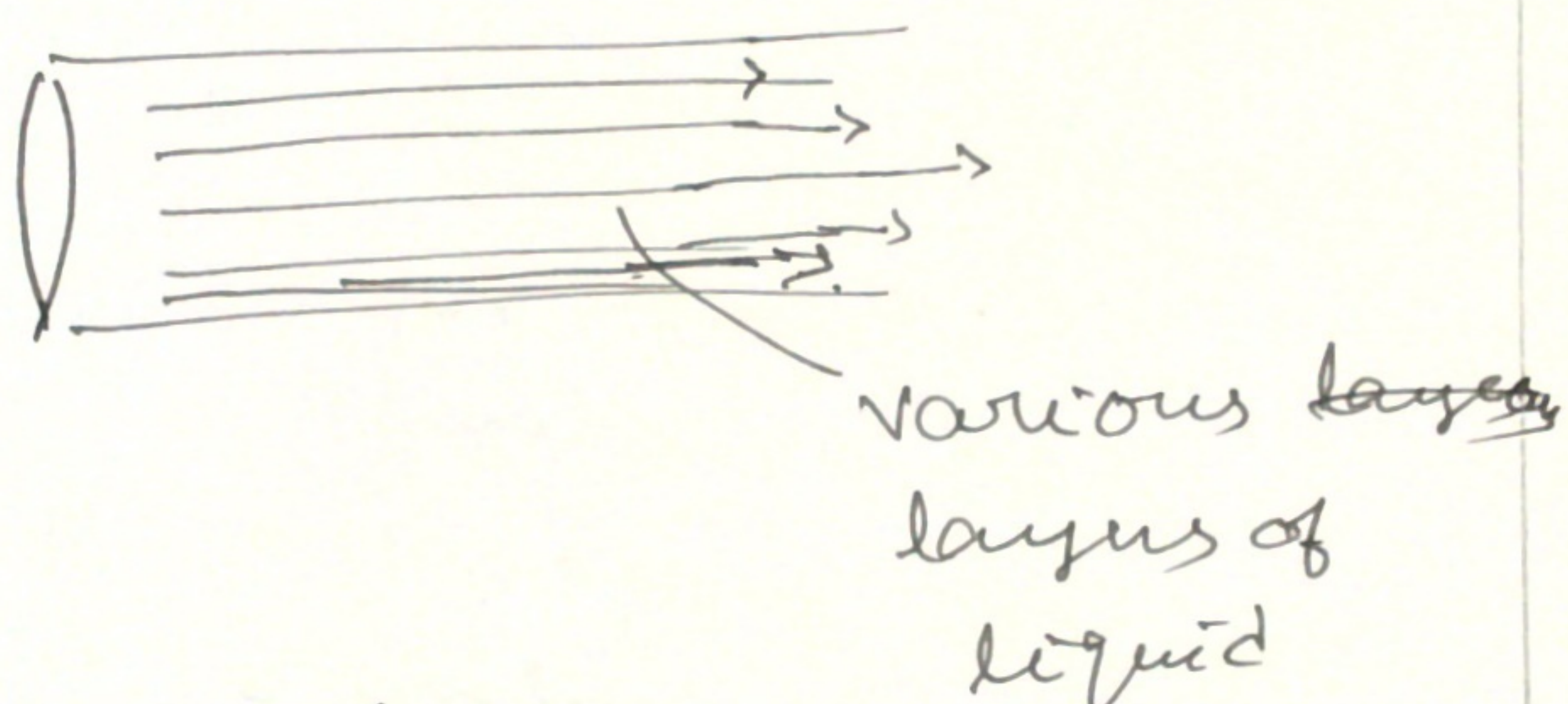
(iv) when W > T ⇒ sinks

(v) W = T ⇒ equilibrium

(vi) W < T ⇒ Floats

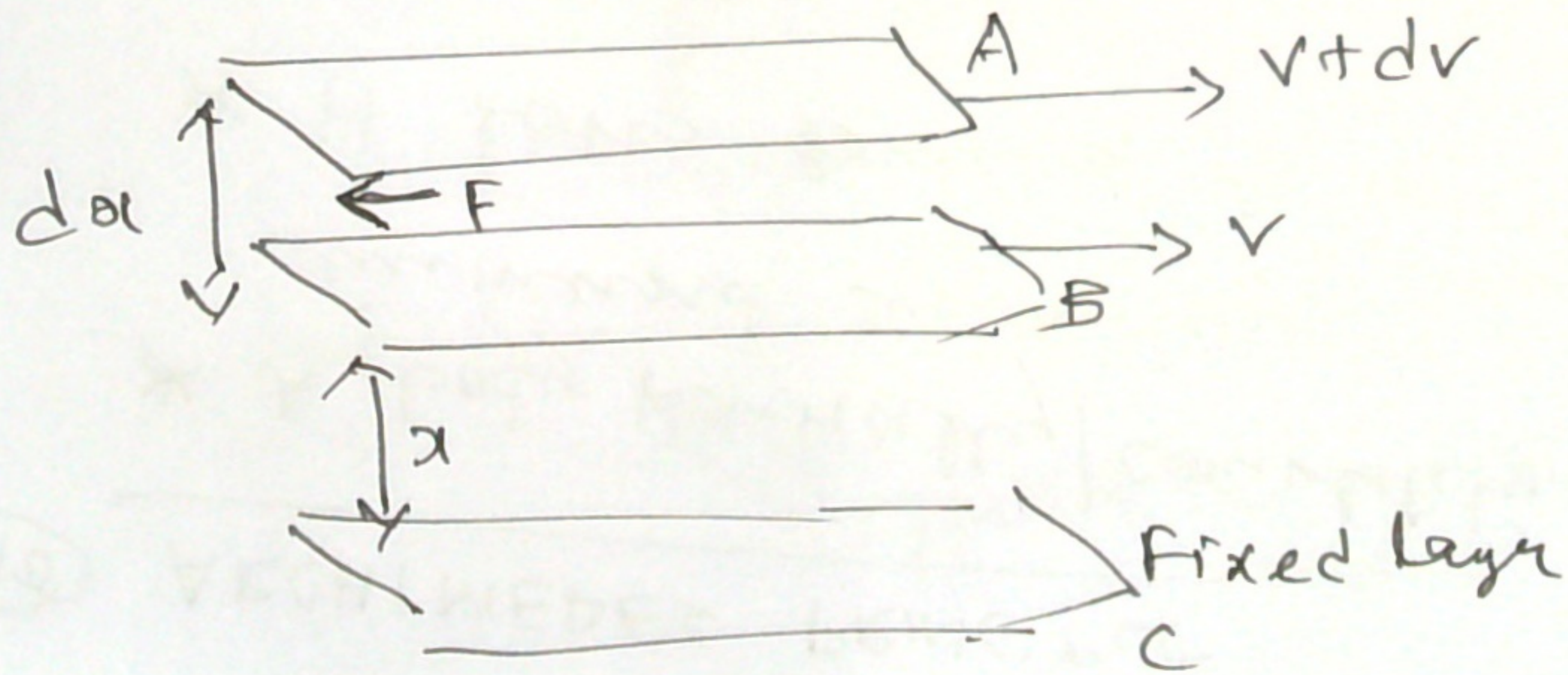
(12) VISCOSITY

* property of a fluid to oppose the relative motion between its layers.



(13)

Coefficient of viscosity



A, B = neighbouring moving layers of liquid

C = Fixed layer

V = velocity of moving layer B

V + dV = velocity of moving layer of A

dx = distance between two moving layers

x = distance between moving layer and fixed layer.

F = Viscous Force acting tangentially between two moving layers.

(14) Newton's law of viscosity

$F \propto A$

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

A = area of the liquid

$\frac{dv}{dx}$ = velocity gradient

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

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

-ve sign → force is frictional
→ opposes the relative motion

Dimensional formula of η

$\eta = ML^{-1}T^{-1}$

η = Coefficient of viscosity

$$\eta = \frac{F}{A \cdot dv/dx}$$

$$\frac{MLT^{-2}}{L^2 \times LT^{-1} \cdot L^{-1}}$$

$ML^{-1}T^{-2+1} = ML^{-1}T^{-1}$

(15) REYNOLD'S NO. (R_c)

$$R_c = \frac{\rho V D}{\eta}$$

$R_c < 1000$
streamline flow
velocity is steady

$1000 < R_c < 2000$
Unsteady flow

$R_c > 2000$
Turbulent
totally unsteady
v is diff. at diff places.

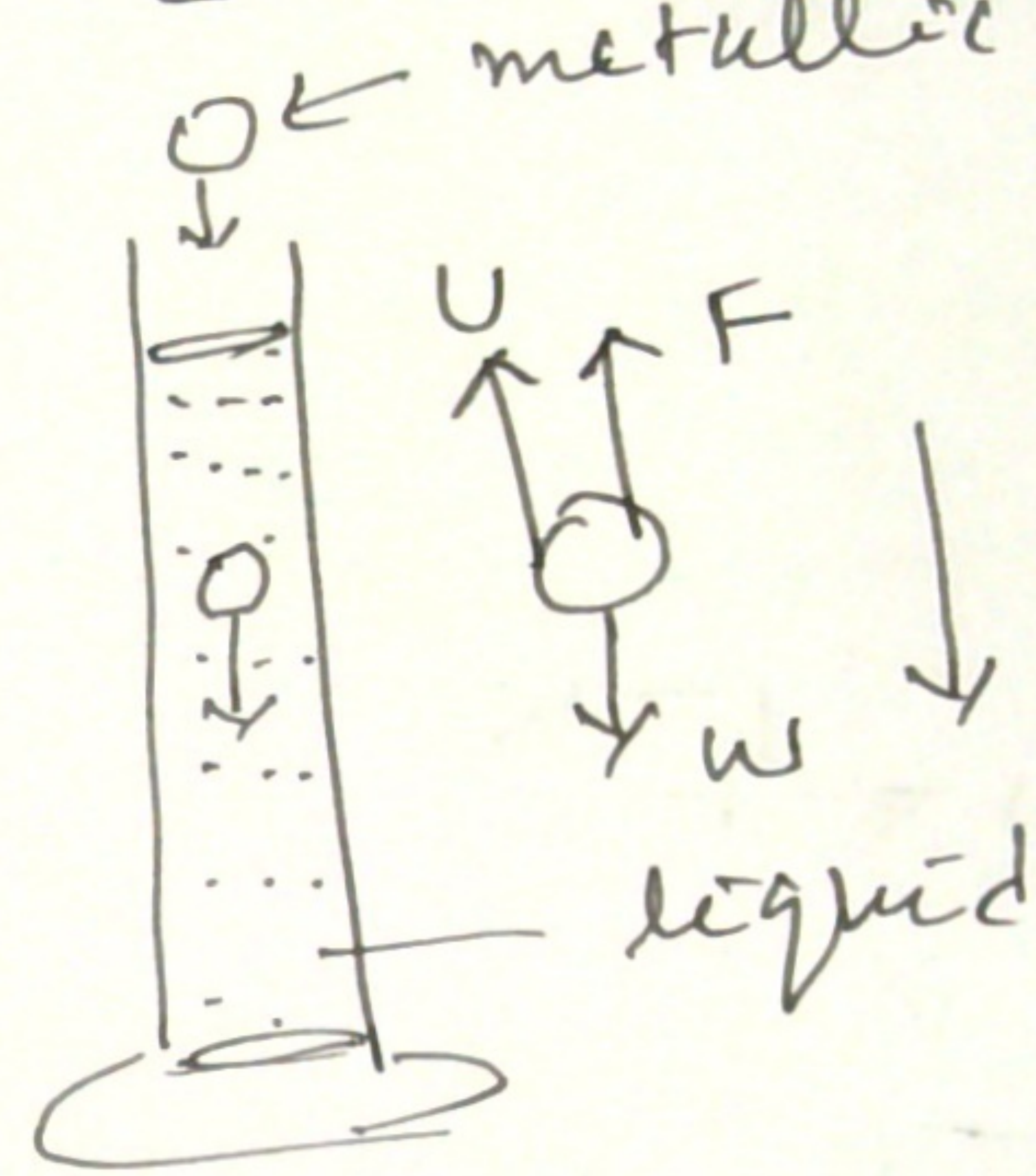
ρ = density of liquid

V = velocity of flowing liquid

D = diameter of the pipe

η = coefficient of viscosity of liquid

(16) Terminal velocity



U = Upthrust due to buoyancy

F = Upward viscous force

W = weight due g

(i) Initially sphere is accelerated downward.
upward force < downward force

(ii) After travelling some distance,
viscous force increases

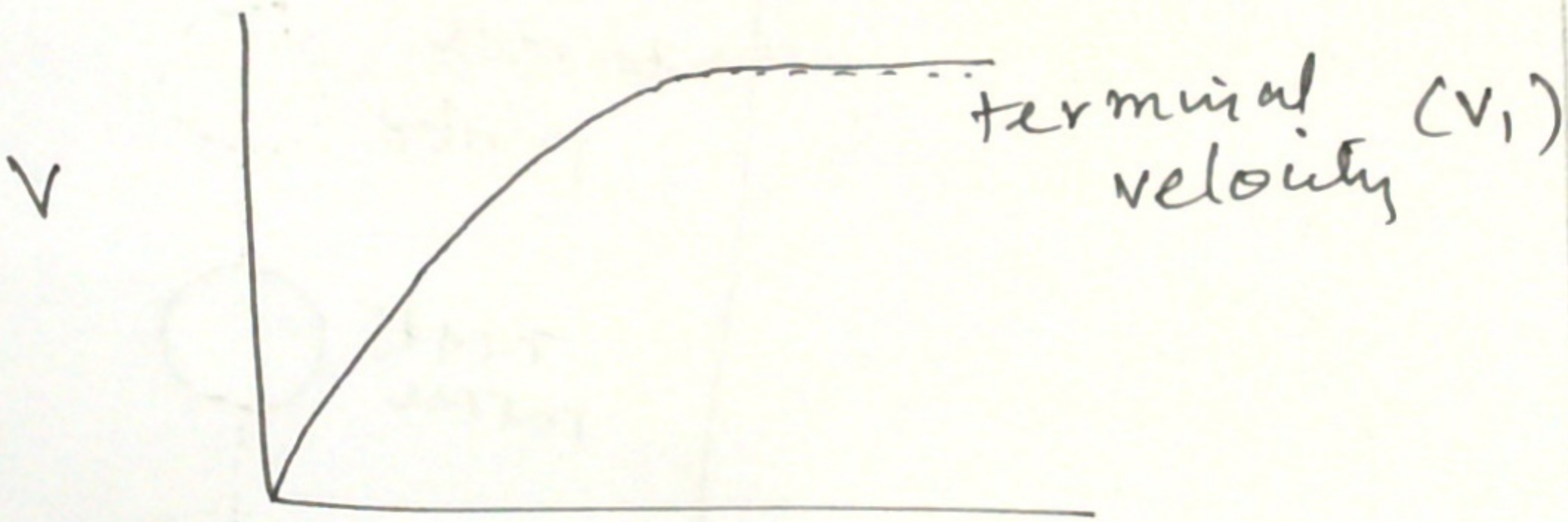
(iii) Terminal velocity (v_1)
downward force = upward force.

Terminal velocity (V_1)

→ constant max ~~max~~ velocity

→ of a freely falling body

→ through a viscous medium



x axis

t = time (s)

Y axis

V = velocity (ms^{-1}) of falling metallic sphere

$$F_G = mg \downarrow$$

$$F_G = \frac{4}{3}\pi r^3 \rho g \downarrow$$

ρ = density of ~~liquid~~ metal.

$$\rho = \frac{m}{V}$$

$$\rho = \frac{m}{\frac{4}{3}\pi r^3}$$

$$m = \frac{4}{3}\pi r^3 \cdot \rho$$

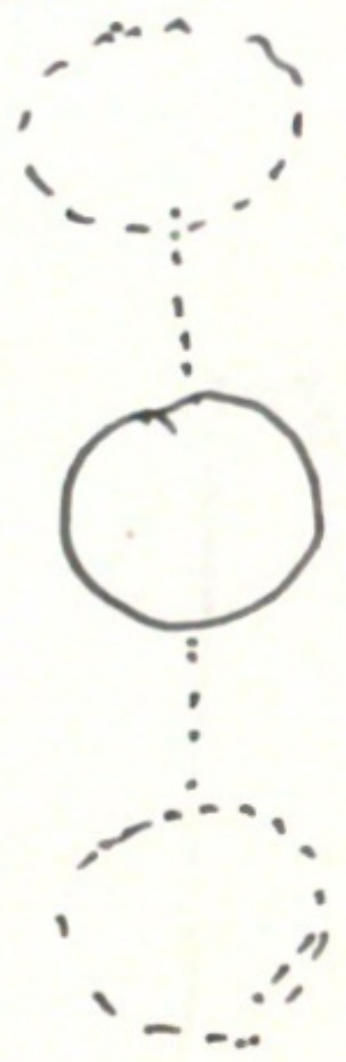
Viscous force, ↑

$$F = 6\pi\eta r V_1$$

by Stokes' law.

Buoyancy ↑

$U = \frac{4}{3}\pi r^3 \sigma g$



$F_G = U + F$

F = viscous force of liquid

η = coefficient of viscosity of liquid

r = radius of the ~~~~ sphere

v_1 = terminal velocity of the metallic sphere

σ = density of liquid

Resultant downward force = upward force

$$F_G = U + F$$

$$F_G - U = F$$

$$\frac{4}{3}\pi r^3 \rho g - \frac{4}{3}\pi r^3 \sigma g = 6\pi\eta r v_1$$

$$\frac{\cancel{4}^{2}}{3}\cancel{\pi} \cancel{r^3}^{r^2} g(\rho - \sigma) \times \frac{1}{\cancel{6}_{3}\cancel{\pi}\eta \cancel{r}} = v_1$$

$$\frac{2}{9} r^2 \frac{(\rho - \sigma)}{\eta} g = v_1$$

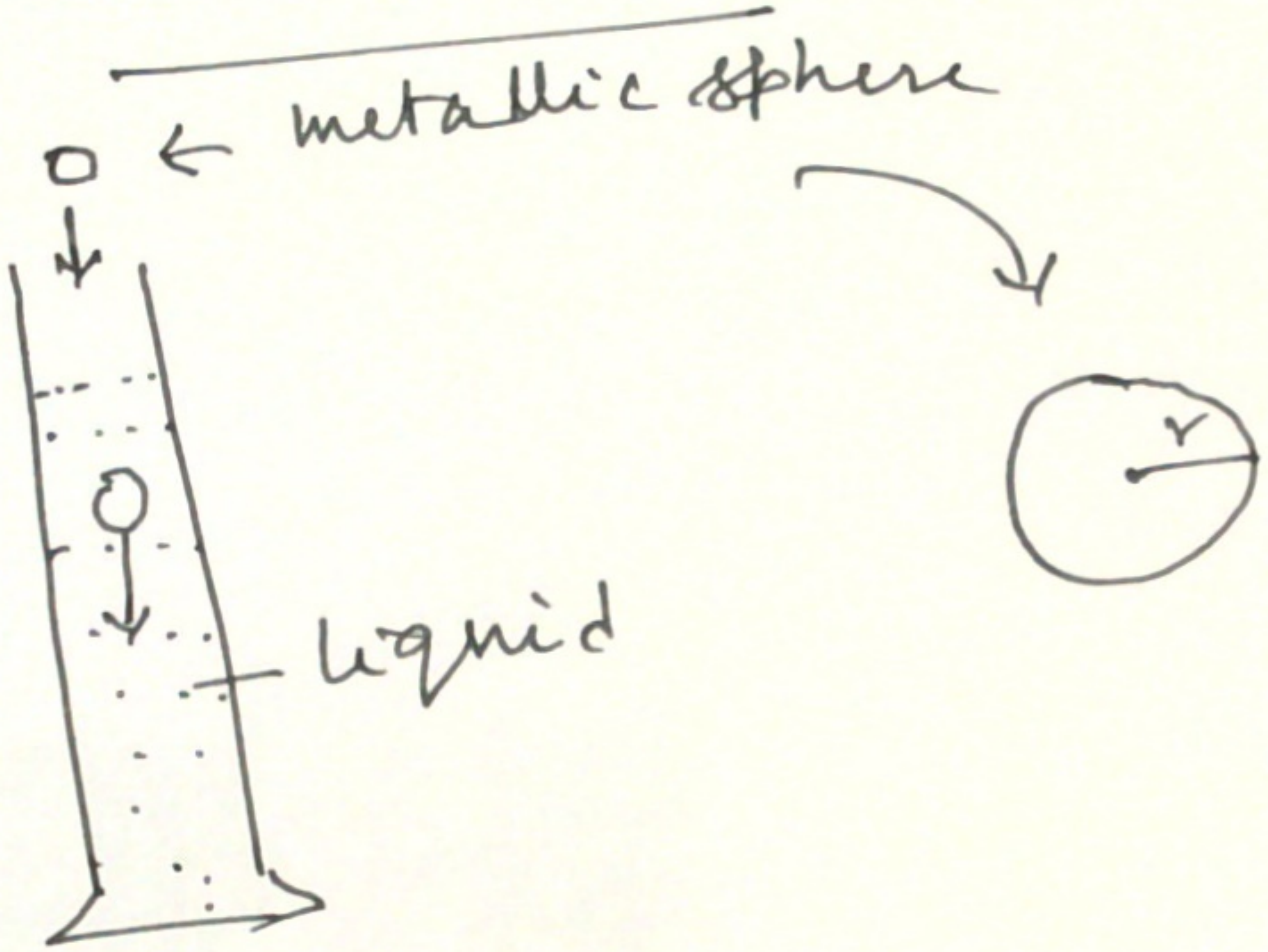
$$v_1 \propto r^2$$

where ρ, σ, g, η are constant

(18) Applications of Stokes law

* Floatation of clouds
* Larger raindrops hurt us than smaller ones.
* Parachute jumpers acquires constant ~~termination~~ terminal velocity

(17) STOKE'S LAW



$F \propto r$

$\propto v$

$\propto \eta$

$F \propto \eta^x r^y v^z$

$F = k\, \eta^x r^y v^z$

$k = 6\pi$

Dimensional Formula

$MLT^{-2} = k\left[ML^{-1}T^{-1}\right]^x L^y (LT^{-1})^z$

$\uparrow$ F

$MLT^{-2} = k\left[M^x L^{-x} T^{-x} L^y L^z T^{-z}\right]$

$MLT^{-2} = k\left[M^x L^{-x+y+z} T^{-x-z}\right]$

$x = 1$

$-x + y + z = 1$

$-x - z = -2$

$-1 - z = -2$

$-z = -2 + 1$

$-z = -1$

$z = 1$

$-1 + y + 1 = 1$; $y = 1$

$F = 6\pi \eta r v$ Stoke's law.

(18) Applications of Stokes law

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