JEE MAIN | IIT JEE

Surface Tension & Viscosity

REVISION in 30 Min

-Mohit Goenka, IIT Kharagpur

FLUID MECHANICS

FLUID STATICS

Fluid is at rest with respect to vessel

(Part 1)

FLUID DYNAMICS

Fluid is in motion w.r.t vessel / Pipe

(part 2)

FLUID PROPERTIES

Surface tension and viscosity

(part 3)

Chapter	Formulae_Concept VIDEO LINK
Unit & Dimensions	https://youtu.be/wdd-wlZF4Hk
Errors and Vectors	
Vernier Caliper	https://youtu.be/pVoN045dV8I
Screw Gauge	https://youtu.be/gYd2PtmZ0mw
Kinematics_Motion in 1d	
Kinematics_Motion in 2d	
Laws of Motion	
Work Energy Power	https://youtu.be/kjrXoE-kDI8
Centre of Mass	
Centre of Mass of Standard Bodies	https://youtu.be/oCeACfryB-U
Collision	
Rotational Motion_Moment of Inertia	https://youtu.be/9ckZdOhy3z0
Gravitation	https://youtu.be/rAj2huLVaEk
Properties of Solids	
Fluids Statics (Part 1)	https://youtu.be/RFKx9B9yo3M
Fluid Dynamics (Part 2)	https://youtu.be/Y717vQpUEJQ
Fluid Properties (Part 3)	
Simple Harmonic Motion	https://youtu.be/RIb7ofNG09I
Thermal Properties	
KTG	https://youtu.be/XO1tvFhla0I
Thermodynamics	https://youtu.be/iz_kf1jRDRw
Wave Motion -Organ Pipes and Resonance Tube	https://youtu.be/fB7pfJ77za8
Wave Motion - Doppler's Effect	https://youtu.be/9-BxOaamnwg

Electrostatics	https://youtu.be/3stXbGRMcrk
Capacitors	https://youtu.be/EXEiickNUkY
Current Electricity	https://youtu.be/gm8FUfjrX18
Moving Charges and Magnetic Effect of Current	https://youtu.be/ULD2Ok1CGJk
Earth's Magnetism	https://youtu.be/a4CT5uVwAK4
Magnetic Properties	https://youtu.be/63cwdYXNlYE
EMI	https://youtu.be/puVavm_GFRM
Alternating Current	https://youtu.be/74dTY-pzM_o
Ray Optics	https://youtu.be/BhnyTWzIlBA
Wave Optics Part 1_Interference	https://youtu.be/LG5nlE8XTeI
Wave Optics Part 2_Diffraction_Polarization	https://youtu.be/ymMyyJGGqnY
Optical Instruments	https://youtu.be/OQssbDH0A4I
Electromagnetic Waves	https://youtu.be/bcVXgEkyQZY
Semiconductors_Basics + Zener Diode	https://youtu.be/_A2JomQ7-50
Semiconductors_Transistors	https://youtu.be/psDwl84Nzb0
Semiconductors_Logic Gates	https://youtu.be/pZdQAzLbFTo
Communication Systems	https://youtu.be/8NgMqK9X79Y
Modern Physics_Part 1_Atomic Physics	https://youtu.be/9VKUnE3mpHk
Modern Physics_Part 2_Photoelectric Effect	https://youtu.be/24oTQp84jrk
Modern Physics_Part 3_Dual Nature of Light	https://youtu.be/0zoR_saMAQY
Modern Physics_Part 4_Radioactivity	https://youtu.be/AdX3YBhQyog
Modern Physics_Part 5_Nuclear Physics	https://youtu.be/VDWqVahGixc
Modern Physics_Part 6_X Rays	https://youtu.be/dSHXdzX7NX0

Topics to cover in Fluid Properties

1. Cohesive vs Adhesive Force
2. Understanding Surface Tension *(S = F/L)*
3. Lifting bodies *(ring, disc, plate etc.)*
4. Surface Energy *(S = E/A)*
5. Drop Coalesce & Bubble collapse
6. Excess Pressure *(Drop & Bubble)*
7. 2 Soap bubbles in contact *(Externally / Internally)*
8. Angle of contact
9. Capillary Action *(in tube as well as parallel plates)*
10. Insufficient tube length
11. Force to separate glass plates
12. Understanding Viscous Force
13. Poiseuille's Equation – Flow through narrow tube
14. Stokes' Law & Terminal velocity

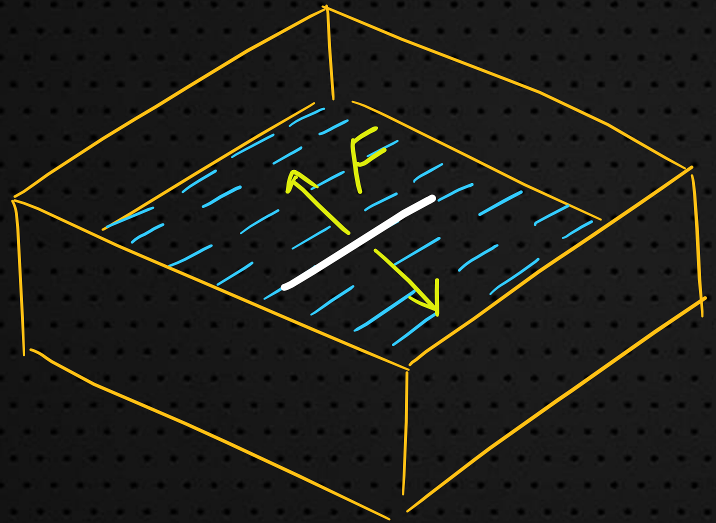
1. Cohesive vs Adhesive Force

Cohesive: Force of attraction between molecules of same substance

Adhesive: Force of attraction between molecules of different substance.

2. Understanding Surface Tension

→ property of Liquid where Surface
(i) tries have minimum Area
(ii) Acts as stretched membrane

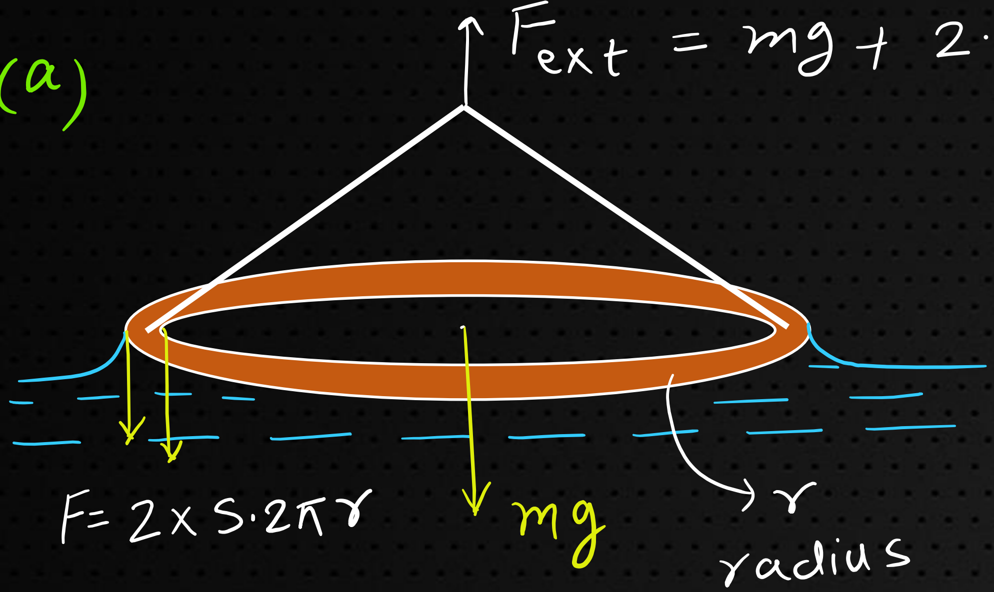


$\rightarrow S = \frac{F}{L}$ or $F = SL$

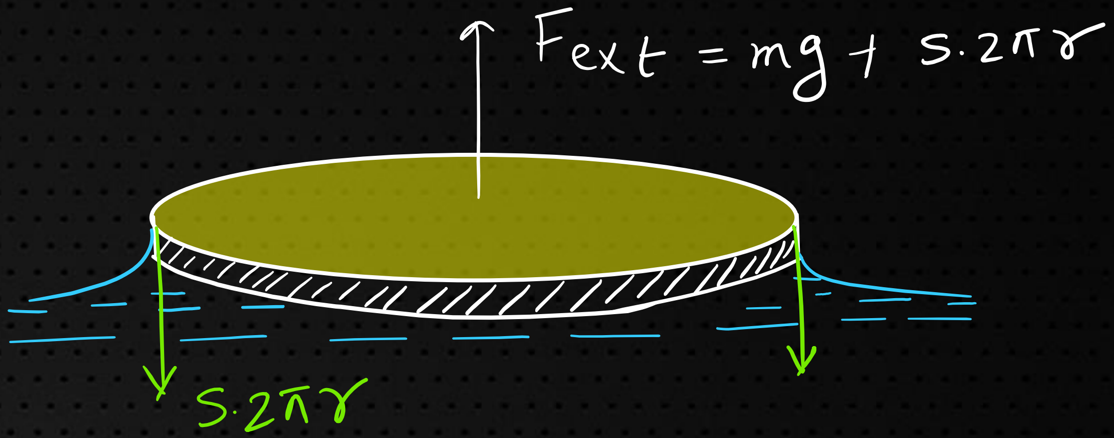
NOTE: F acts perpendicular to Line and tangential to free Surface.

3. Lifting of bodies

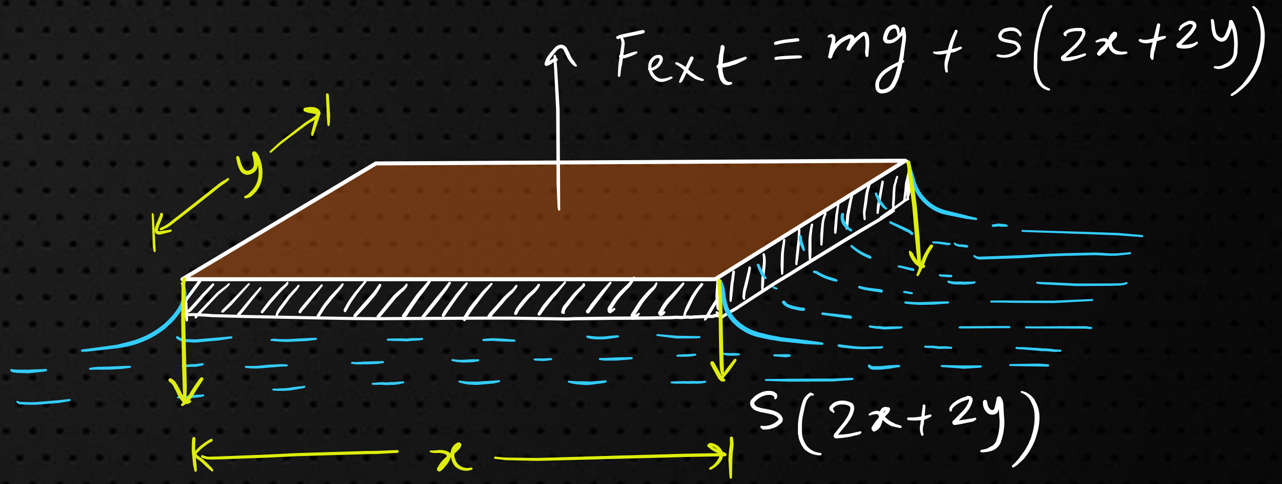
(a)



(b)



(c)



4. Surface Energy

↳ Due to intermolecular interaction, free surface of Liquid has energy called "Surface Energy"

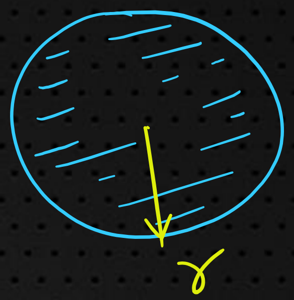
$S = \frac{E}{A}$ or $E = S \cdot A$

A : Surface Area

S : Surface Tension

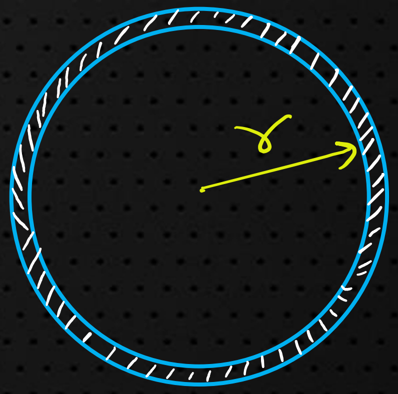
E : Surface energy

Ex 1. Energy of drop



$E = S \cdot 4\pi r^2$

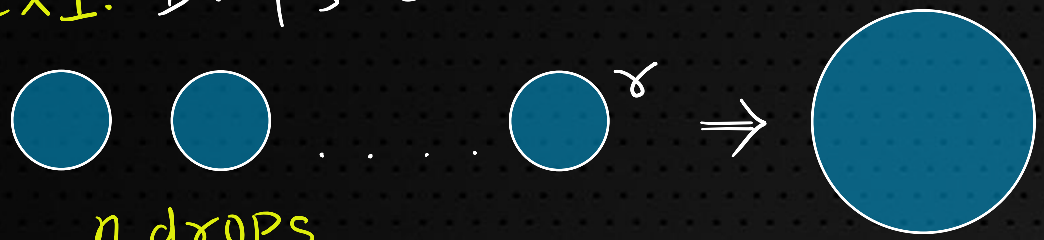
Ex 2. Energy of Bubble



$E = 2 \times S \cdot 4\pi r^2$

5. Standard Questions on Surface Energy

Ex1. Drops coalesce



n drops

$\because$ Volume is same

$$\Rightarrow \frac{4}{3}\pi R^3 = n \times \frac{4}{3}\pi r^3$$

$$\text{or,} \quad R = r n^{1/3}$$

Here Area $\downarrow$ $\Rightarrow$ Energy $\downarrow$

$$E_i = n \cdot S \cdot 4\pi r^2$$

$$E_f = S \cdot 4\pi R^2 = S \cdot 4\pi r^2 \cdot n^{2/3}$$

$\therefore$ $E_i - E_f$ increases Temp° of Bigger drop by $\Delta\theta$

$$\Rightarrow \boxed{E_i - E_f = m s \Delta\theta}$$

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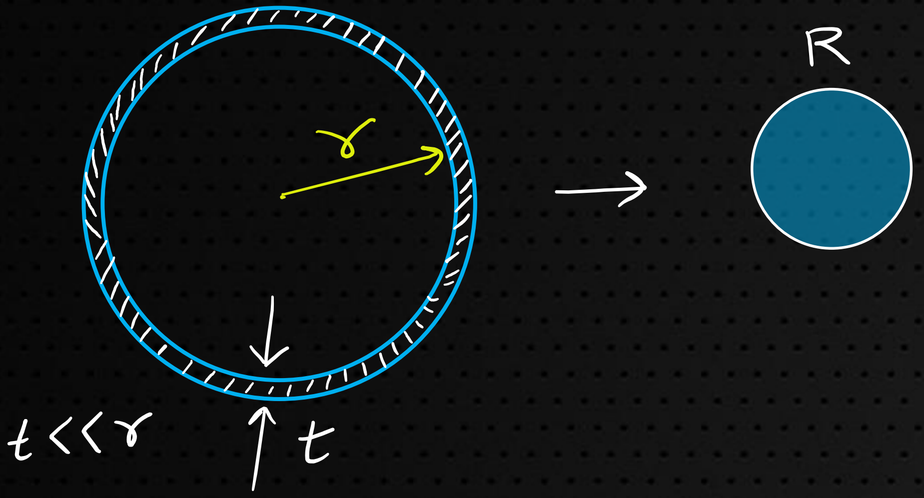
Ex 2. Bubble Collapse



$E_i = 2 \times S \cdot 4\pi r^2$

$E_f = S \cdot 4\pi R^2$

$= S \cdot 4\pi (3r^2 t)^{2/3}$

$\therefore \; E_i - E_f = ms\Delta\theta$

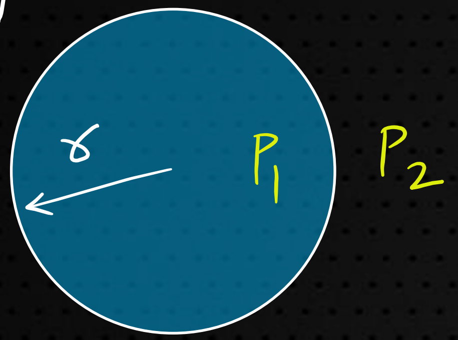
$\because$ Vol of Liq. is same

$\Rightarrow 4\pi r^2 \times t = \frac{4}{3}\pi R^3$

$R = (3r^2 t)^{1/3}$

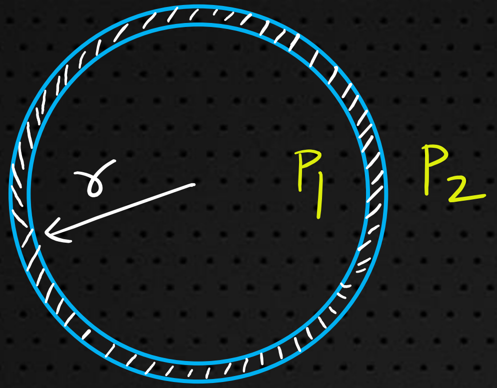
6. Excess Pressure in Liquid Drop and Bubble

Drop



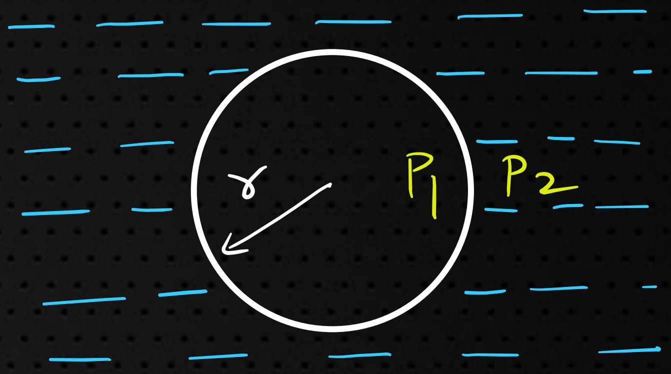
$$P_{ex} = P_1 - P_2 = \frac{2S}{r}$$

Bubble



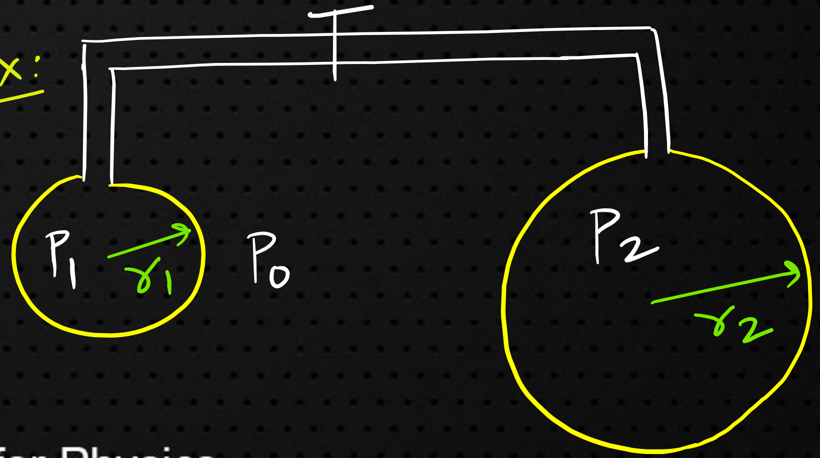
$$P_{ex} = P_1 - P_2 = \frac{4S}{r}$$

#NOTE: If the bubble is in liquid (ex. Aquarium)



$$P_1 - P_2 = \frac{2S}{r}$$

Ex:

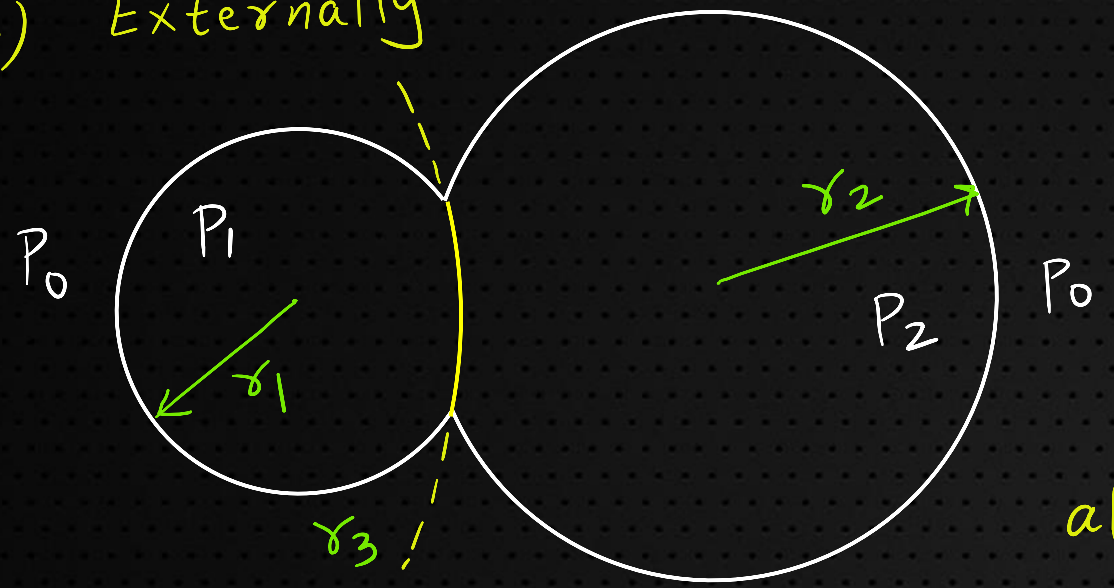


$$P_1 = \frac{4S}{r_1} + P_0$$

$$P_2 = \frac{4S}{r_2} + P_0$$

7. Two soap bubbles in contact

(i) Externally



$$P_2 - P_0 = \frac{4S}{r_2} \quad \text{—— (1)}$$

$$P_1 - P_0 = \frac{4S}{r_1} \quad \text{—— (2)}$$

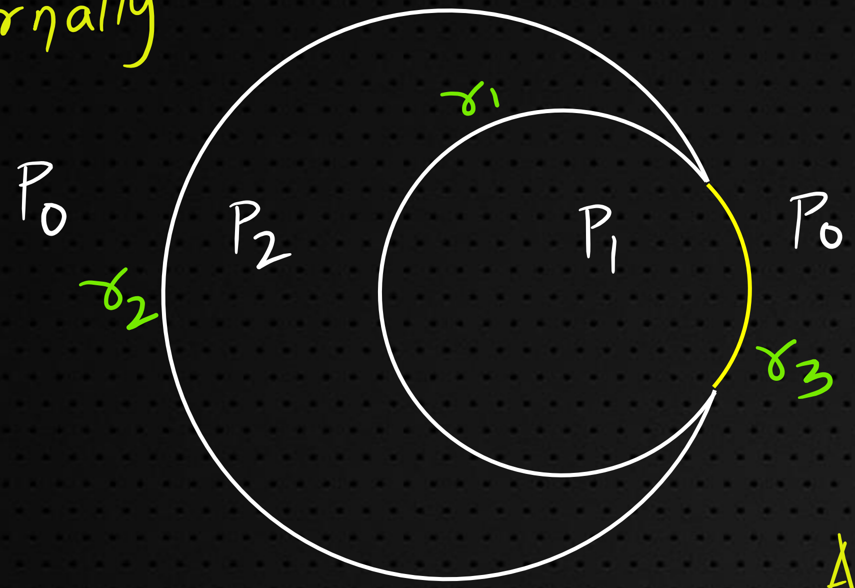
Subract (2) & (1) $\Rightarrow P_1 - P_2 = \frac{4S}{r_1} - \frac{4S}{r_2}$

also, $P_1 - P_2 = \frac{4S}{r_3}$

$$\therefore \frac{4S}{r_3} = \frac{4S}{r_1} - \frac{4S}{r_2} \Rightarrow \boxed{r_3 = \frac{r_1 r_2}{r_2 - r_1}}$$

... Continued

(ii) Internally



$$P_1 - P_2 = \frac{4S}{r_1} \quad \text{—— (1)}$$

$$P_2 - P_0 = \frac{4S}{r_2} \quad \text{—— (2)}$$

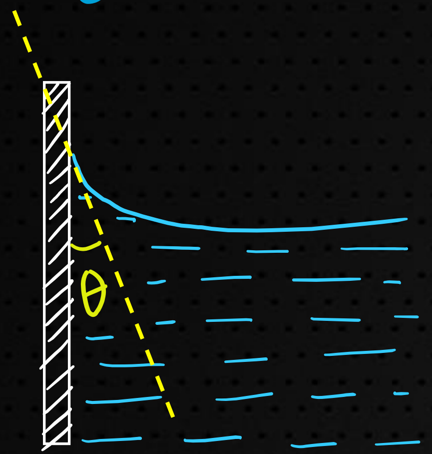
Adding (1) & (2) $\Rightarrow P_1 - P_0 = \frac{4S}{r_1} + \frac{4S}{r_2}$

Also, $P_1 - P_0 = \frac{4S}{r_3}$

$$\therefore \frac{4S}{r_3} = \frac{4S}{r_1} + \frac{4S}{r_2} \Rightarrow \boxed{r_3 = \frac{r_1 r_2}{r_1 + r_2}}$$

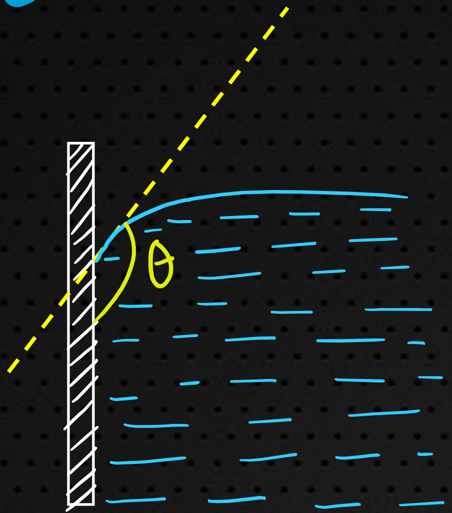
r_3 will be smallest

8. Angle of Contact



$\theta < 90^\circ$

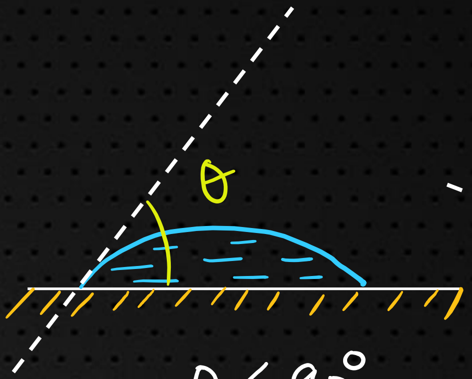
ex : water



$\theta > 90^\circ$

Cohesive force dominates

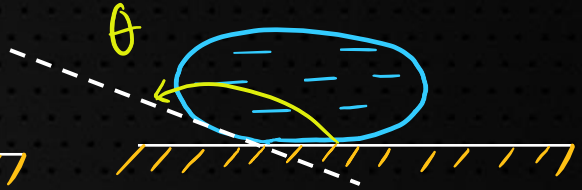
ex : Hg



$\theta < 90^\circ$

↳ Liquid wets the surface

water

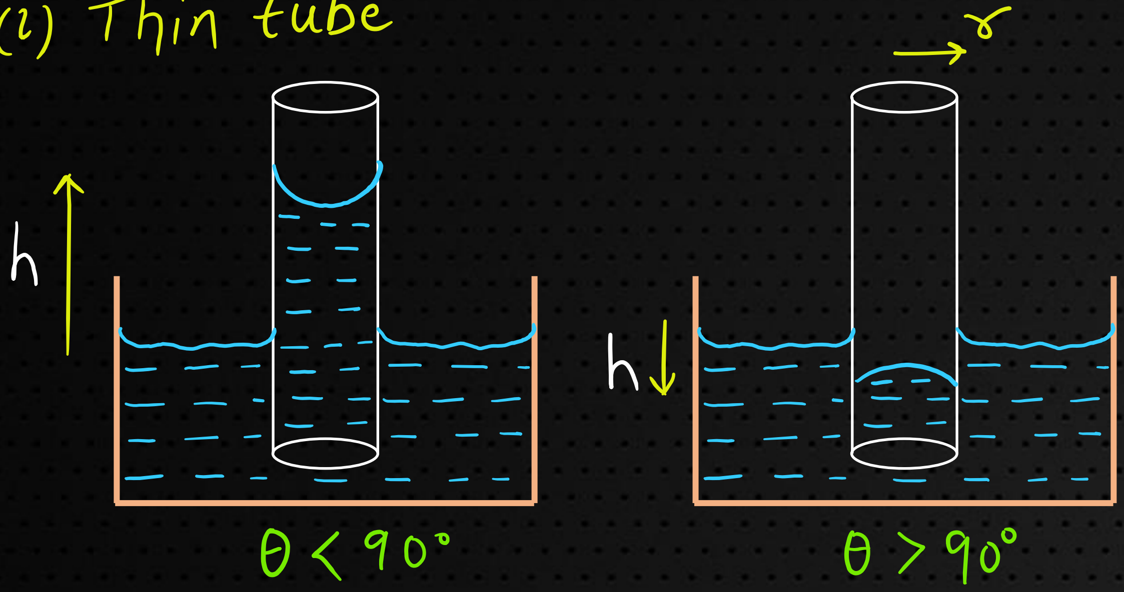


$\theta > 90^\circ$

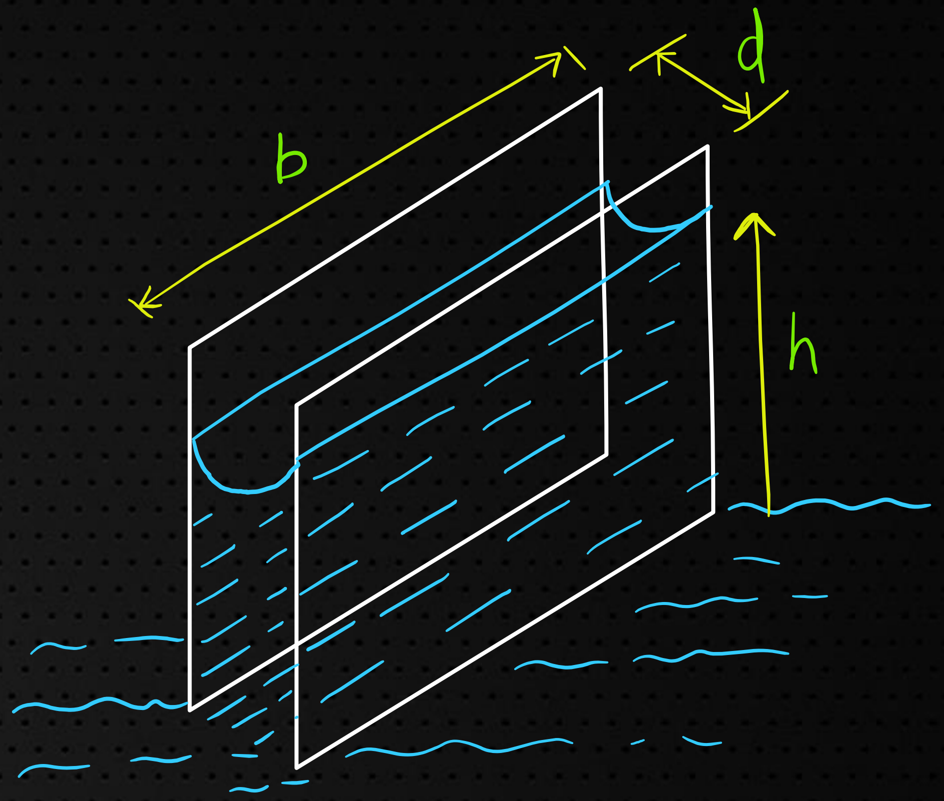
Note: Generally θ for distilled H_2O is 0°.

9. Capillary Action

(i) Thin tube



(ii)



$h = \dfrac{2s\cos\theta}{r\rho g}$ or $\dfrac{2s}{R\rho g}$

r is tube radius

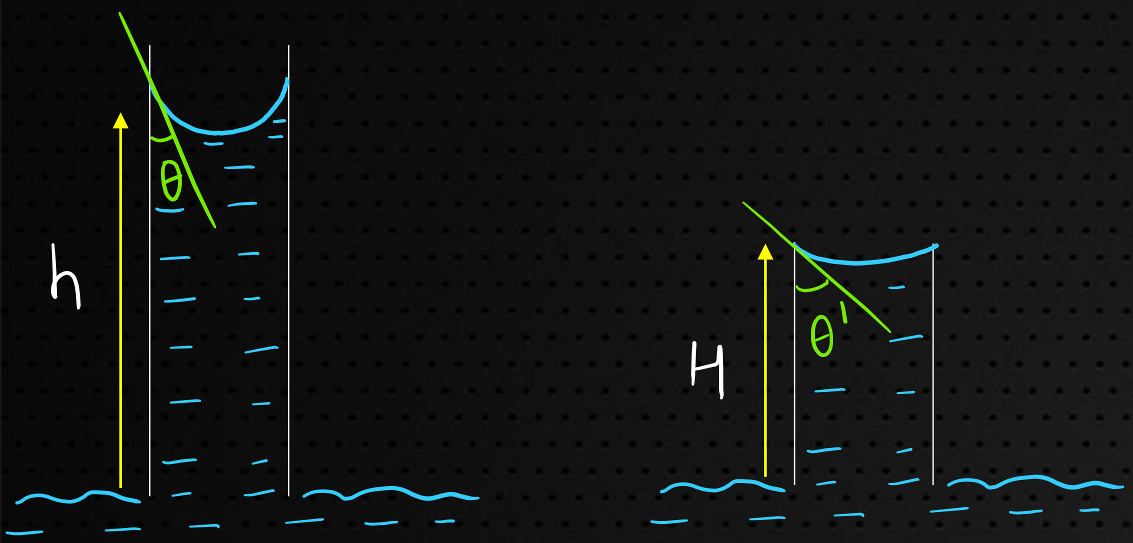
R is meniscus radius

$h = \dfrac{2s\cos\theta}{d\rho g}$

↳ Generally if its H_2O

$\cos\theta = 1$.

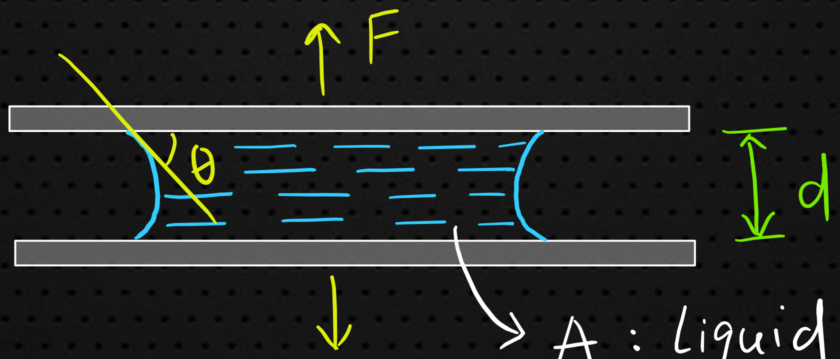
10. Insufficient Tube Length ($H<h$)



$$h = \frac{2s\cos\theta}{r\rho g} \quad \text{but} \quad H < h$$

↳ In this case liquid won't overflow rather it reaches top and adjusts contact angle to θ' $\quad (\theta' > \theta)$

11. Force to separate Glass Plates

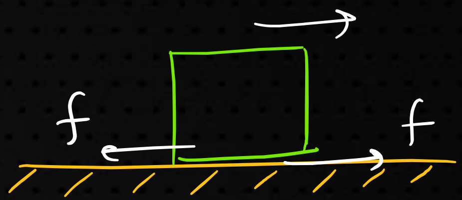


A : liquid cross-secn area

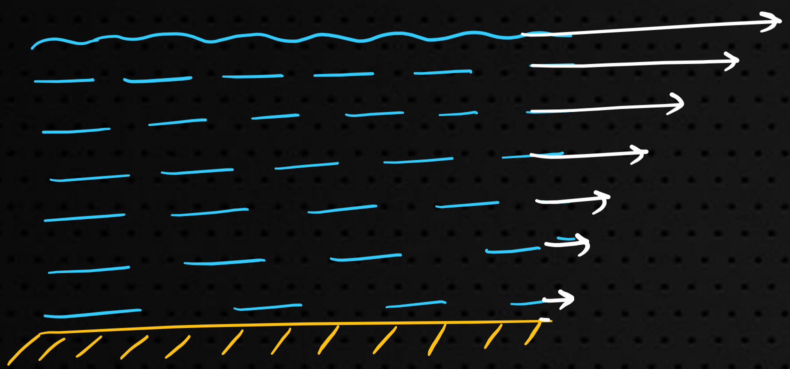
$$F = \frac{2SA}{d}\cos\theta$$

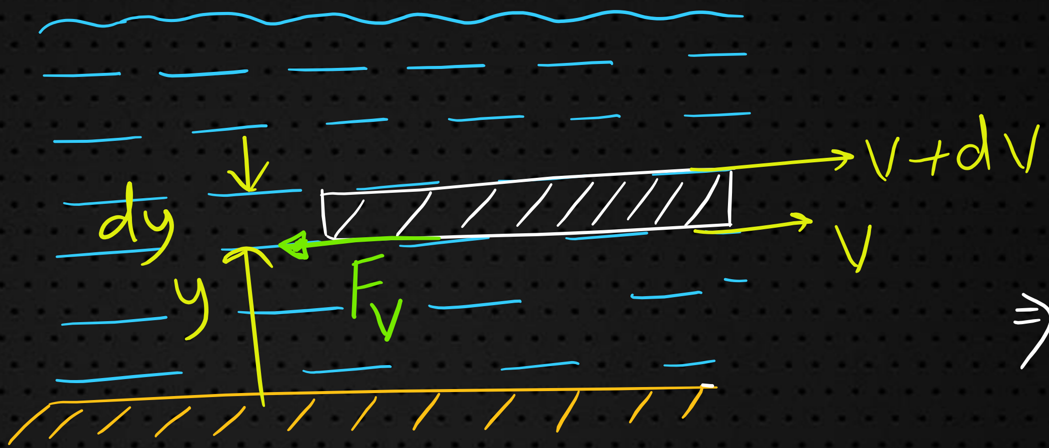
$\left\{ \begin{array}{l} \text{If its } H_2O \\ \cos\theta = 1 \end{array} \right.$

12. Understanding Viscous Force



↳ Fluid opposes the relative motion between its different layers.





$$F_V \propto A \frac{dv}{dy}$$

$$\Rightarrow F_V = -\eta A \frac{dv}{dy}$$

Coeff of viscosity

(i) $[\eta] = ML^{-1}T^{-1}$

SI unit : Poiseuille, PI

C.G.S : Poise

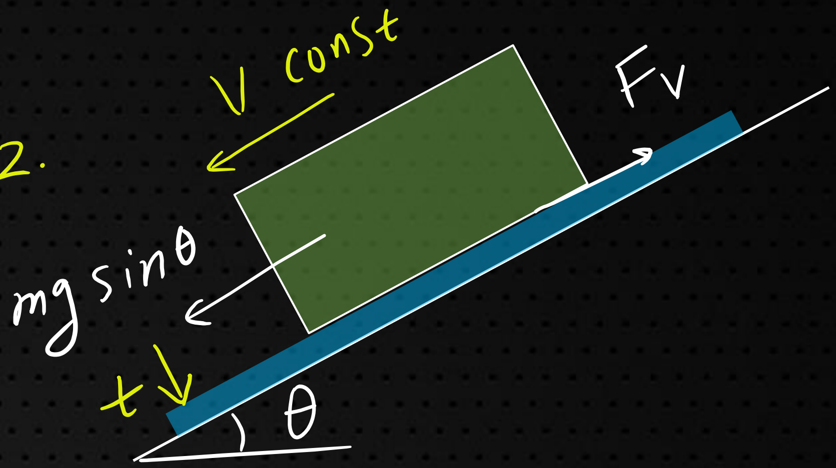
1 PI = 10 Poise

... continued

Ex 1.

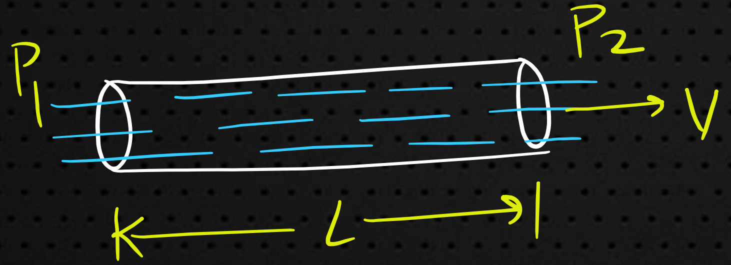
$$F_{ext} = F_V = \eta A \frac{dv}{dy} = \eta A \frac{V}{t}$$

Ex 2.



$$mg\sin\theta = \eta A \frac{V}{t}$$

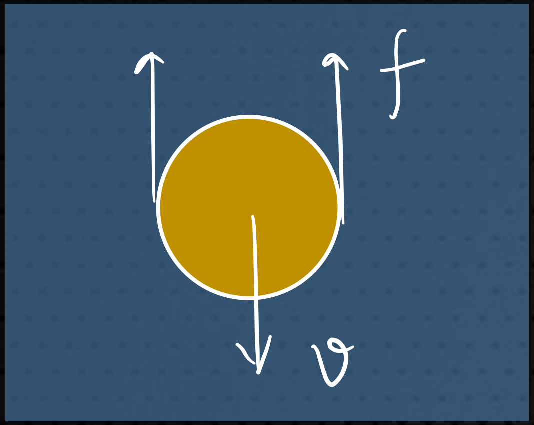
13. Poiseuille's Eqⁿ – Flow through Narrow Tube



Flow rate, $Q = \frac{\pi r^4}{8\eta L}(P_1 - P_2)$

(m^3/s)

14. Stokes' Law & Terminal Velocity



$f = 6\pi\eta r\vartheta$

$\hookrightarrow$ As $v\uparrow$, $F_v\uparrow$

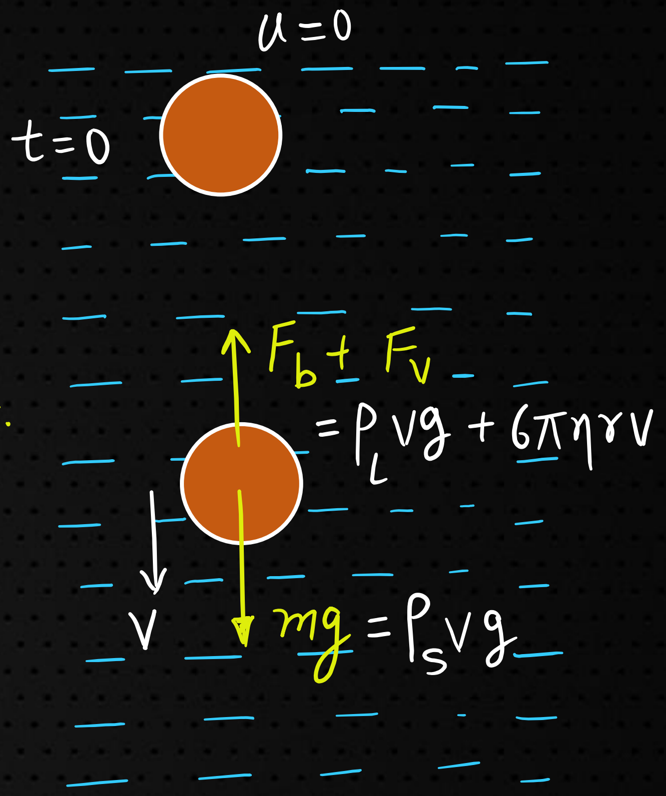
and at certain speed

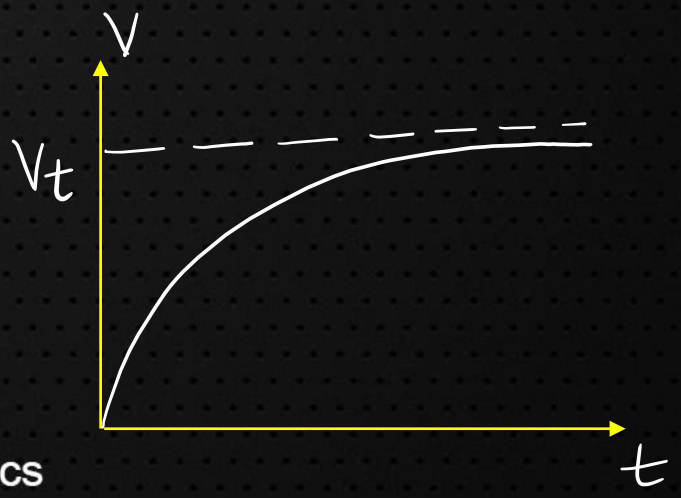
$F_b + F_v = mg$ $\{ \Rightarrow a = 0$, $V =$ const.

Terminal Velocity

$$\Rightarrow \rho_L \cdot \frac{4}{3}\pi r^3 g + 6\pi\eta r V_t = \rho_s \frac{4}{3}\pi r^3 g$$

$$\therefore \boxed{V_t = \frac{2r^2 g}{9\eta}(\rho_s - \rho_L)}$$





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