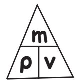
- Density $(\rho) = \frac{\text{mass (m)}}{\text{volume (v)}}$



- unit= kg/m^3
- density of water=1000 $kg / m^3 = 1 g/cc$
- for same mass

$\rho_1 v_1 = \rho_2 v_2$

if $\rho_1 > \rho_2$

$v_1 < v_2$

Mixing of liquid

Calculation of resultant/final density

1) Volumes are equal

$$d = \frac{d_1 + d_2}{2}$$

2) Masses are equal

For 2- liquid $\Rightarrow d = \frac{2d_1d_2}{d_1 + d_2}$

For 3- liquid $\Rightarrow d = \frac{3d_1d_2d_3}{d_1d_2 + d_2d_3 + d_1d_3}$

3) Masses and volumes are different

$$d = \frac{\text{Total mass}}{\text{Total volume}} = \frac{m_1 + m_2}{v_1 + v_2}$$

$m_1 = \rho_1 v_1$ & $m_2 = \rho_2 v_2$

$v_1 = \frac{m_1}{\rho_1}$ & $v_2 = \frac{m_2}{\rho_2}$

Relative density (R.D)/Specific gravity

1) Relative density of a body

$$(R.D)_s = \frac{d_s}{d_w} = \frac{w_a}{w_a - w_w}$$

2) Relative density of liquid

$$(R.D)_L = \frac{d_L}{d_w} = \frac{w_a - w_L}{w_a - w_w}$$

3) Relative density of a solid to that of liquid

$$\frac{(R.D)_S}{(R.D)_L} = \frac{w_a}{w_a - w_L}$$

Pressure

Normal force or thrust exerted by liquid at rest per unit area

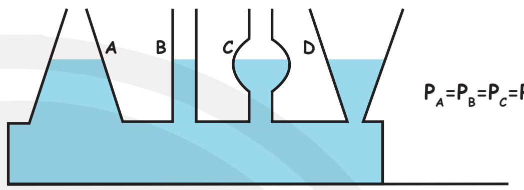
$$\boxed{P = \frac{F}{A}}$$

Pressure depth relation

$$P = h \rho g$$

Hydrostatic paradox

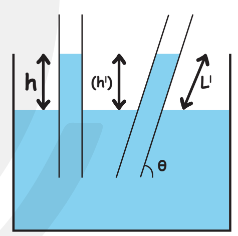
Whatever the shape or width the pressure at any particular depth is same



$P_A = P_B = P_C = P_D$

- Gauge pressure $= P - P_{atm} = h\rho g$
- Patm= 1.01325×10^5 Pa

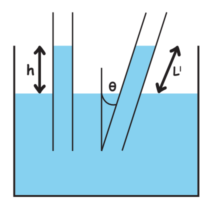
Inclined barometer



if θ=angle with horizontal

$\sin\theta = \frac{h}{L'}$

$\boxed{L' = \frac{h}{\sin\theta}}$



if θ=angle with vertical

$\cos\theta = \frac{h}{L'}$

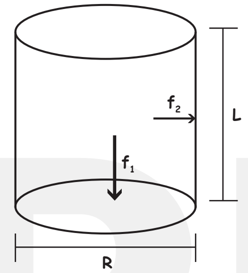
$L' = \frac{h}{\cos\theta}$

Bubble rising up at constant temperature

radius 'r' becomes 'R' when bubble rises in liquid from bottom to the surface

$\rho g h = P_{atm} [n^3 - 1]$ $\boxed{R = n r}$

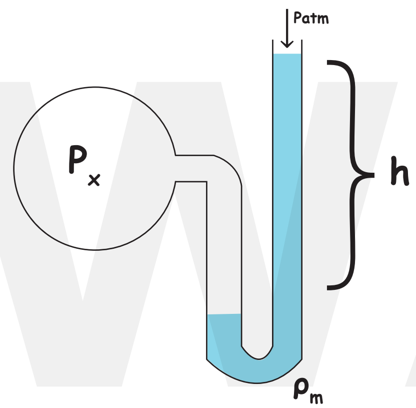
Conditions for equal forces on wall and bottom in a cylinder



If $\boxed{L = R}$

then, $F_1 = F_2$

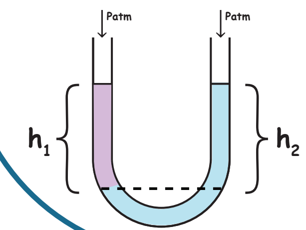
Manometer



$P_x = P_o + h\rho_m g$

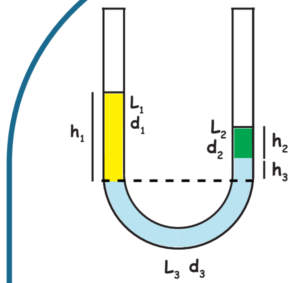
$h\rho_m g = P_x - P_o$

1) U-Tube manometer



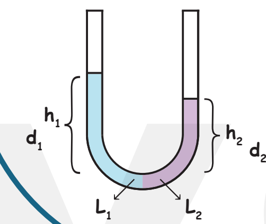
$h_1d_1 = h_2d_2$

4)



$h_1d_1 = h_2d_2 + h_3d_3$

2) U-Tube type



$h_1d_1 = h_2 d_2$

$\frac{d_1}{d_2} = \frac{h_2}{h_1}$

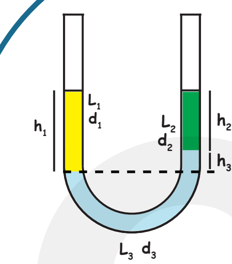
Note:

If one of the liquid H_2O,

sp. gravity = (R.D) = $\frac{dL}{dw} = \frac{h_w}{h_L}$

$(R.D) = \frac{h_w}{h_L}$

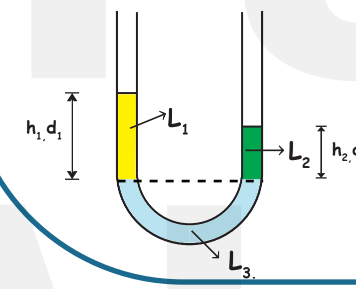
5)



$h_1 = h_2 + h_3$

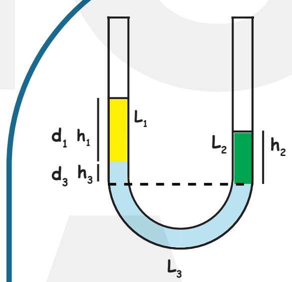
$h_1d_1 = h_2d_2 + h_3d_3$

3) The third liquid is in level with other



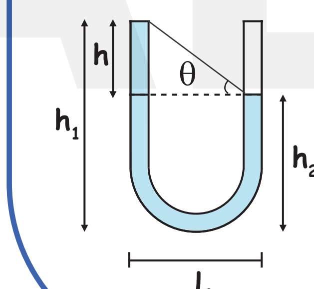
$h_1d_1 = h_2d_2$

6)



$h_1d_1 + h_3d_3 = h_2d_2$

U - tube accelerating

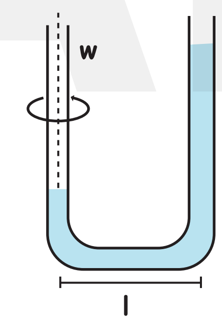


$h = h_1 - h_2$

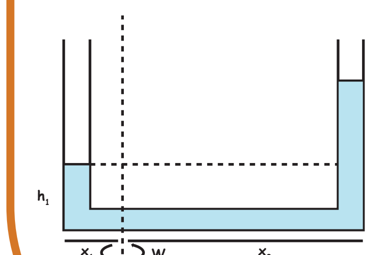
$\frac{h}{L} = \frac{a}{g}$

$\tan\theta = \frac{h}{L} = \frac{a}{g}$

Special case: U - tube rotating



$h = \frac{w^2 l^2}{2g}$



$h_1 = \frac{w^2 x_1^2}{2g}$

$h_2 = \frac{w^2 x_2^2}{2g}$

$h = h_2 - h_1 = \frac{w^2 (x_2^2 - x_1^2)}{2g}$

FLUID MECHANICS 01

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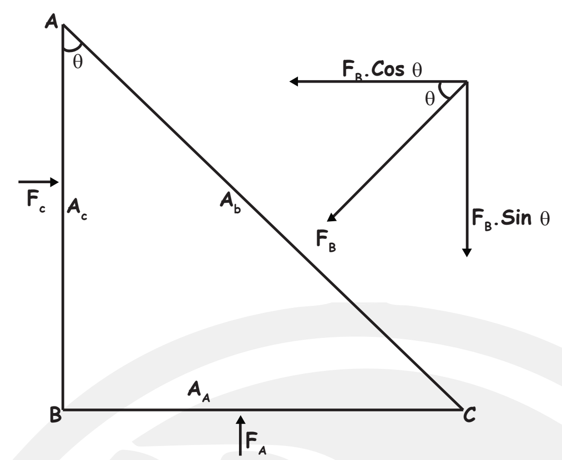
FLUID MECHANICS 02

Pascals Law

If gravity effect is neglected, the pressure at every point of liquid in static equilibrium is same

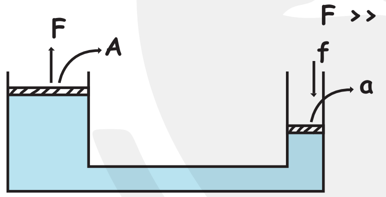


Application

Hydraulic Lift

As A>> a therefore

F >> f



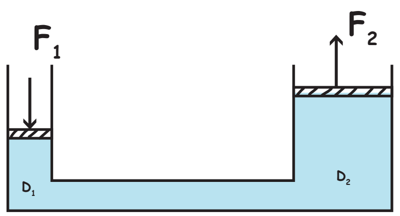
$$\boxed{\frac{F}{A} = \frac{f}{a}}$$

If the cylinders are connected

$$\frac{F_1}{\pi R_1^2} = \frac{F_2}{\pi R_2^2}$$

$$\frac{F_1}{R_1^2} = \frac{F_2}{R_2^2}$$

$$\boxed{\frac{F_1}{D_1^2} = \frac{F_2}{D_2^2}}$$



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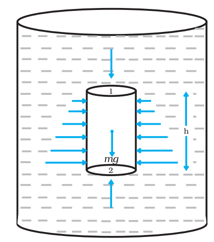
Archimedes principle



upthrust=weight of the liquid displaced=$V\rho g$

Apparent weight=Actual weight-upthrust

$$W_{app}=W_{air}-U$$

$$=W_{air}\left[1-\frac{\sigma}{\rho}\right]$$

net force acting upward=$V \times \rho_L \times g$

Unit of Coefficient of viscosity

1) The CGS Unit of η is dyne s cm^{-2} and is called poise.

2) The SI unit of η is Nsm^{-2} or decapoise or poiseuille

1 poiseuille = 10 poise

Poiseuille's formula

$$Q=\frac{\pi P r^4}{8\eta l}$$

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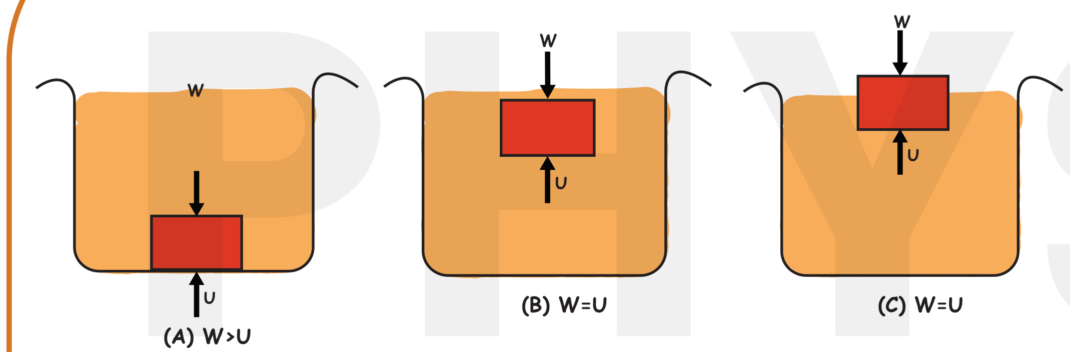
Law of floatation



$\rho_b > \rho_L$ $\quad$ $\rho_b = \rho_L$ $\quad$ $\rho_b < \rho_L$

W ⇒ Weight

U ⇒ Upthrust

Stoke's law

$F=6\eta\pi rv$

F_{net}=Apparent weight-viscous force

Terminal velocity

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

1) If $\rho>\sigma$, the body will attain terminal velocity in the downward direction.

2) If $\rho<\sigma$ the terminal velocity will be negative and the body will move in the upward direction.

3) $\rho=\sigma$, the body remain suspended in the fluid.

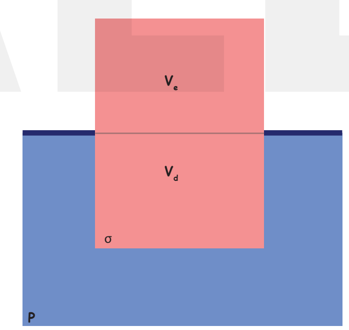
Fractional submerged volume

$$\frac{\text{Displaced volume}(V_d)}{\text{Total volume}(V)} = \frac{\sigma}{\rho} \text{ (submerged fraction)}$$

$$\frac{\text{Exposed volume}(V_e)}{\text{Total volume}(V)} = 1-\frac{\sigma}{\rho} \text{ (Exposed fraction)}$$

Relative density of a solid= $\dfrac{\text{weight of solid in air}}{\text{Loss of weight in water}} = \dfrac{W_a}{W_a-W_w} = \dfrac{\rho_b}{\rho_W}$

Relative density of a liquid= $\dfrac{\text{Loss of weight in liquid}}{\text{Loss of weight in water}} = \dfrac{W_a-W_L}{W_a-W_w} = \dfrac{\rho_L}{\rho_W}$



Critical velocity

Reynold number

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

Significances of Reynold number.

- If R_e lies between 0 and 2000 the folow is stream lined or laminar.
- If R_e>3000, the liquid in turbulent.
- If R_e lies between 2000 & 3000 the flow of liquid is unstable. It may change from laminar to turbulent and vice versa.

Velocity gradient

Velocity gradient= $\dfrac{dv}{dx}$

$F \propto A\dfrac{d_v}{d_x} \Longrightarrow F=-\eta A\dfrac{dv}{dx}$

$\eta=\dfrac{F}{A\,dv/dx} \Longrightarrow$ coefficent of viscosity $\Longrightarrow \eta=\dfrac{F/A}{dv/dx}=\dfrac{F/A}{v/l}=\dfrac{F/A}{\frac{d}{dt}(x/l)}$

$\Longrightarrow \eta=\dfrac{\text{shearing stress}}{\text{strain rate}}$

Equation of continuity

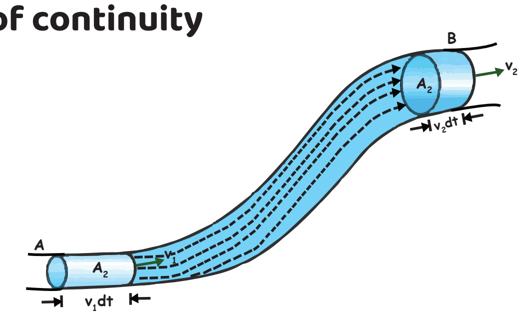
$V_1A_1\Delta t\rho_1=V_2A_2\Delta t\rho_2$

since the liquid is incompressable $\rho_1=\rho_2$

$V_1A_1=V_2A_2$

Av=constant.

$Av=\dfrac{dv}{dt}=Q \Longrightarrow$ Volume rate of flow



Energy of fluid in a study flow

kinetic Energy $= \frac{1}{2} mv^2$

kinetic energy per unit mass $= \frac{1}{2} v^2$

kinetic energy per unit volume $= \frac{1}{2} \rho v^2$

Potential Energy = mgh

Potential energy per unit mass = gh

Potential energy per unit volume = ρgh

Pressure energy = PV

Pressure energy per unit mass $= \frac{P}{\rho}$

Pressure energy per unit volume = P

BERNOULLI'S PRINCIPLE

$P_1V_1 - P_2V_2 = \frac{1}{2} m (v_2^2 - v_1^2) + mg (h_2 - h_1)$

$(P_1 - P_2) V = \frac{1}{2} m (v_2^2 - v_1^2) + mg (h_2 - h_1)$

$(P_1 - P_2) V = \frac{1}{2} \frac{m}{V} (v_2^2 - v_1^2) + \frac{mg}{V} (h_2 - h_1)$

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

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

$\frac{P}{\rho g}$ = pressure head

$\frac{v^2}{2g}$ = velocity head

h = Gravitational head

APPLICATIONS OF BERNOULLI'S PRINCIPLE

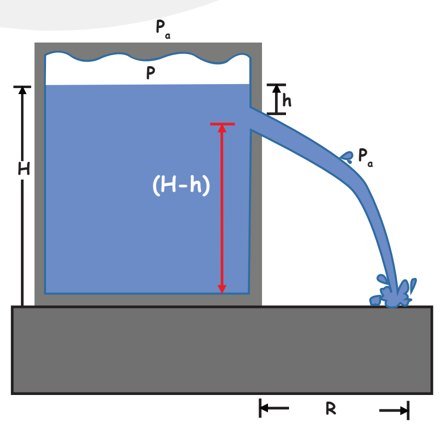
Torricelli's Law of Efflux

$v = \sqrt{\frac{2(P - P_a)}{\rho} + 2gh}$

If tank is open, $P = P_a$

Then $v = \sqrt{2gh}$

Time of fall, $t = \sqrt{\frac{2(H-h)}{g}}$



Range $R = v_x x_t$

$= \sqrt{2gh} \times \sqrt{2(H-h)/g}$

$\Rightarrow R = 2\sqrt{h(H-h)}$

v_x = Horizontal component of velocity

R is max. when $h = \frac{H}{2}$

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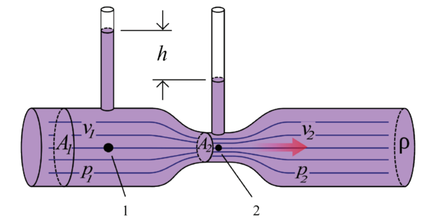
VENTURIMETER

Device to measure the flow of speed of incompressible fluid

$v_1 = \sqrt{\frac{2hg}{(A_1^2/A_2^2) - 1}}$

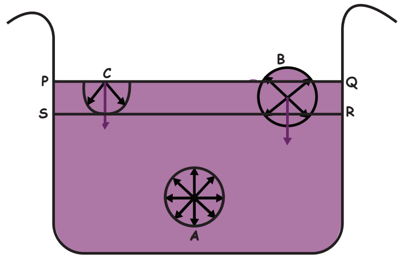


SURFACE TENSION

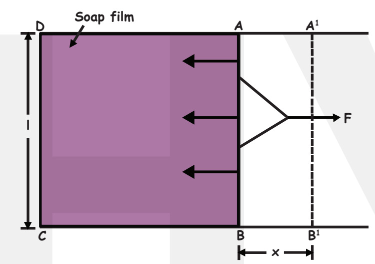
Surface tension $T = \frac{\text{Force}}{\text{Length}} = \frac{F}{l}$

Unit in SI system $= \frac{N}{m}$

Unit in CGS system = dyne / cm



SURFACE ENERGY



Work done W = F × x

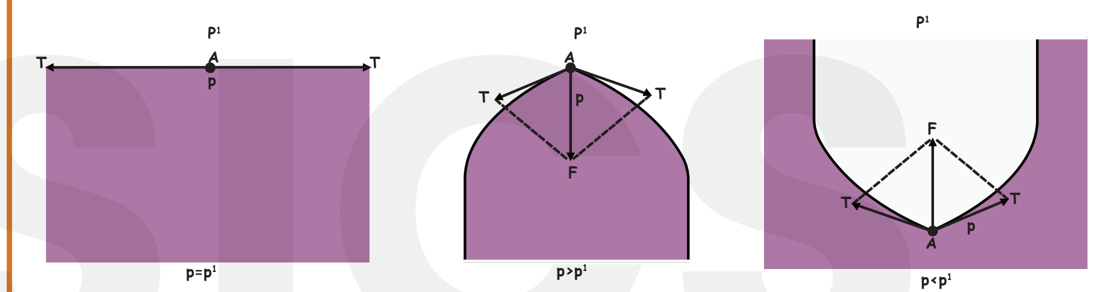
But F = 2TL

$\Rightarrow$ W = 2TL × x

Energy of the additional surface = W = 2TLx

= T (2LX) = $T\Delta A$

PRESSURE DIFFERENCE ACROSS A CURVED LIQUID SURFACE



Pressure on concave side > pressure on convex side

$P_{concave} - P_{convex} = \frac{2T}{R}$

$P_{inside} - P_{outside} = \frac{2T}{R}$ [Liquid drop or air bubble] One surface

$P_{inside} - P_{outside} = \frac{4T}{R}$ [Soap bubble] Two surfaces

Excess pressure inside a liquid drop

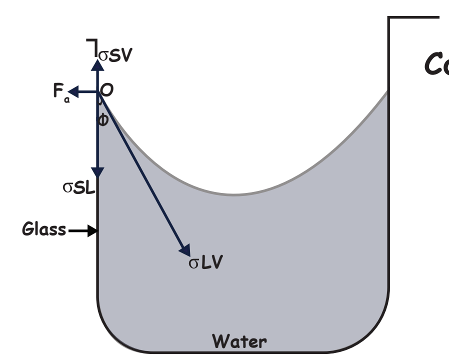
$P_i - P_o = \frac{2T}{R}$

Excess pressure inside a soap bubble

$P_i - P_o = \frac{4T}{R}$

FLUID MECHANICS 03

Shape of liquid meniscus



Consider the equilibrium of at line of contact

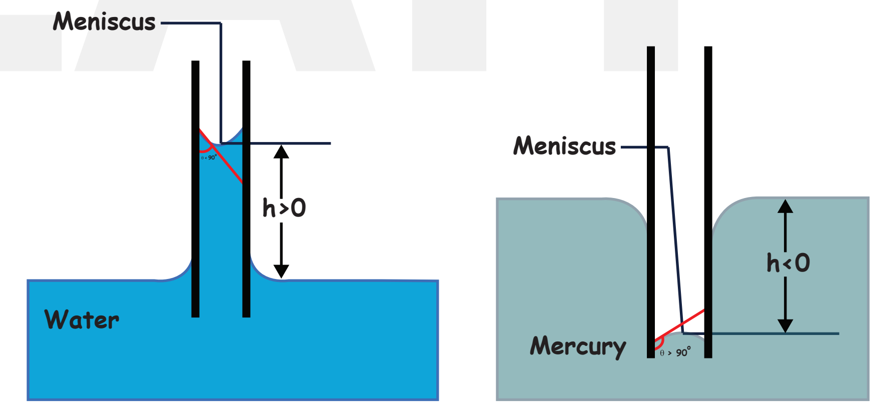
$F_a = \sigma_{LV} \sin\theta$

$\sigma_{SV} = \sigma_{SL} + \sigma_{LV} \cos\theta$

$\cos\theta = \frac{\sigma_{SV} - \sigma_{SL}}{\sigma_{LV}}$

θ = Angle of contact.

Capillarity



Ascent formula:

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

$h > 0 \; (\theta < 90^\circ)$

$h < 0 \; (\theta > 90^\circ)$

$h = \frac{2T\cos\theta}{r\rho g}$