CE-261

22-03-23

Fluid Mechanics (3 crc hrc) Prof. Jahid sirc

chapter-1

Textbook: Fluid Mechanics (Franzini)

Ref: - Subramanya
- Modi
- Shaum Series.

1) static → Pressure ও force নিয়ে
2) dynamics
3) kinematics



Franzini

- chapter 1 : Defn
- chapter 2 : Properties
- chapter 3 : Static
- chapter 8 : Pipe flow
- chapter 5 : Bernoulli's
- chapter 4 : kinematics
- chapter 6 : Momentum

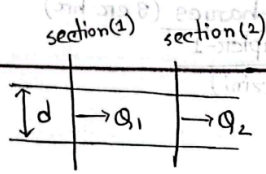
First 7 weeks, Last 7 weeks → Jahid sirc

Tirtho sirc

① continuity Eqn: Q = eos constant [Q → discharge (m^3s^{-1})]

1 sec এ যত m^3 volume এর পানি pass করে।

Q = Area × velocity
(m^2) (m/s)



Pipe চেপে ধরলে Area কমে যাবে ও পানির velocity বেড়ে যাবে।

$Q = \text{const.}$

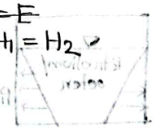
$Q_1 = Q_2$

$\Rightarrow A_1V_1 = A_2V_2$

② Bernoulli's Equⁿ/Energy equⁿ: Energy = constant

~~$E_1 = E$~~

$H_1 = H_2$ ✓



③ Momentum equⁿ; $\Sigma mV = \text{constant}$

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Definition:

Mechanics is the oldest physical science with both stationary and moving bodies under the influence of forces.

Fluid — liquid
Gas

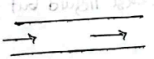
specific density, $S = \frac{\rho}{\rho_w}$

$S_{Hg} = 13.6$ (পানির চেয়ে 13.6 গুন ভারী)

$S = 0.8$ (" " 0.8 " হালকা)
↓
কেরোসিন

Kinematic: where pressure forces are not considered

Dynamic: " " are



pipe এ পানি flow হচ্ছে কোনো force apply করা হচ্ছে (kinematics)



pipe inclined থাকলে পানি নিজে থেকে উপরে উঠতে পারে না force apply করা লাগে → Dynamic

hydrodynamics: The study of motion of fluids that are practically incompressible

hydraulics: which deals with liquid flows in pipes and open channels.

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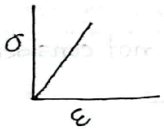
Aerodynamics:

Deals with the flow of gases.

* A solid can resist an applied shear stress by deforming
* a fluid deforms under the influence of shear stress.



Solid stress is proportion to strain



liquid: Incompressible. Shear force তিলে more বহে liquid but solid এ deformation হয়।



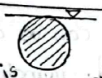
(intermolecular bonding strong weak weak)

Gas: Free surface থাকে না। Intermolecular bonding অনেক weak থাকায় container এ ছড়িয়ে থাকে। compressible.

~~shear force তিলে না~~

Q: Differences between solid vs Fluid

" " liquid vs Gas.

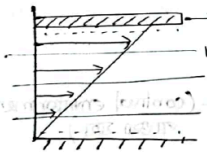


This is a pipe flow.
velocity + pressure



This is open channel flow (OCF).
Pressure নেই।

* পানি যাহাতে flow করে কিন্তু মধু / Mercury যাহাতে flow করে না তাহাকে পানির viscosity ~~কমা~~ বলা।



পানির উপরের object টা যদি move করি তাহলে, উপরে পানির molecule move করবে।

নিচের পানি static থাকবে।

Viscosity → resistance of flow. পানির viscosity বলা।

* Fluid
  Fluid vs solid
  liquid vs Gas
  Viscous vs inviscid
  Region of flow.

* Natural / unforced: Naturally flow হয়।

* forced flow : pump, pipe flow

05-04-23

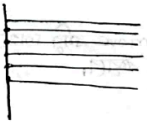
Compressible: Gas. Density ~~remains constant~~ can be changed.

Incompressible: liquid. Density ~~can be changed~~. remains constant.

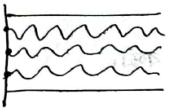
water → 210 atm ⟶ 1% density change

Gas ⟶ 0.01 atm ⟶ 1% density change.

Laminar vs Turbulent



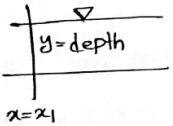
pathline parallel and smooth ⟶ Laminar (control environment ও পাওয়া যায়)



Turbulent (most of the flows are turbulent)

Transition: In between Laminar and turbulent.

Steady Vs. unsteady:



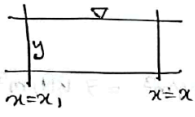
$t_1 = y_1$, $t_2 = y_2$ | $y_1 \neq y_2$

$\frac{dy}{dt} = \frac{du}{dt} = \frac{dQ}{dt} = 0$ → steady for a ~~particle~~ fixed location (x)

$\frac{dy}{dt} = \frac{du}{dt} = \frac{dQ}{dt} \neq 0$ ⟶ unsteady

uniform Vs non-uniform :

$\frac{dy}{dx} = \frac{du}{dx} = \frac{dQ}{dx} = 0$ for a particular time ⟶ uniform



$\frac{dy}{dx} = \frac{du}{dx} = \frac{dQ}{dx} \neq 0$ ⟶ non-uniform

chapter-2
Fluid properties

mass density / Density, ρ (rho) : $\rho = \frac{\text{Mass}}{\text{volume}}$ $\left[\frac{kg}{m^3} \text{ or } \frac{gm}{cm^3}\right]$

γ or ω, specific weight / weight density:

γ or $\omega = \frac{wt}{\text{volume}} = \frac{\text{Mass} \times g}{\text{volume}} = \rho \times g$

(γ : kN/m^3)

Pressure, Temp., mass, volume ⟶ common characteristics of fluid

ρ_w ⟶ 1 gm/cm^3 or $1000\ kgm^3$

Density, $\rho \propto P$

$\rho \propto \frac{1}{T}$

specific volume: sp. $vol^m = \frac{Vol^m}{mass} = \frac{1}{\rho}$ (m^3/kg) ⟶ reciprocal of mass density (ρ)

relative Density / Sp. Gravity, $S = \frac{\rho}{\rho_w} / \frac{\gamma}{\gamma_w}$ [unitless]

- S = 0.8 (পানির চেয়ে 0.8 গুন হালকা)
  = 1.36 (" " 1.36 " ভারী)
- S_{Hg} = 13.6 (পারদ)

$\gamma \rightarrow kNm^{-3}$

Specific wt, density and specific gravity of 1 litre liquid whose wt 7N.

soln:

$$\text{Volume} = 1\,L = \frac{1}{1000}\ m^3$$

$$\gamma = \frac{wt}{Vol^m} = \frac{7N}{1/1000} = 7000\ N/m^3 = 7\ kN/m^3$$

$$\gamma = \rho g$$

$$\Rightarrow \rho = \frac{\gamma}{g} = \frac{7\ kN/m^3}{9.81\ ms^{-2}} = \frac{7000\ N/m^3}{9.81}$$

$$= 713.5\ kgm^{-3}$$

$$S = \frac{\rho}{\rho_w} = \frac{713.5}{1000} = 0.713.$$

Density, sp. wt and weight of 1L petrol whose sp. Grr = 0.7

soln:

$$\text{Sp. Gravity} = \frac{\rho}{\rho_w}$$

$$\Rightarrow \rho = 0.7 \times 1000 = 700 kgm^{-3}$$

$$V = \frac{1}{1000}\ m^3$$

$$m = V\rho$$

$$\Rightarrow m = 0.7\ kg$$

$$\Rightarrow \frac{w}{g} = 0.7$$

$$w = 6.867\ N$$

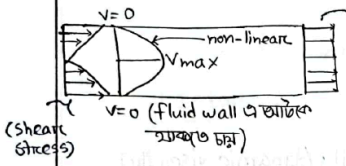
$$\text{sp. wt}, \gamma = \frac{wt}{Vol^m} = \frac{6.867}{\frac{1}{1000}} = 6860.7\ N/m^3$$

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Shear force:

Steady flow তে shear force develop করে না।



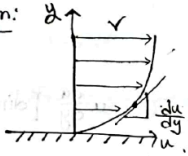
[Shear stress নেই]

* Shear stress pattern linear
* velocity pattern linear/non-linear

যেখানে velocity = 0 সেখানে shear stress maximum
যেখানে velocity = max " " " minimum (0) .

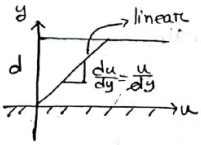
* fluid যেদিকে flow হয় তার opposite এ shear stress এর direction.

velocity pattern:



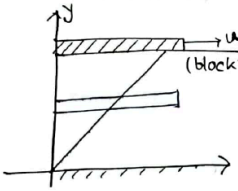
$y = mx + c$
$y = mx^2 + nx + c$ [2°]

River/canal flow



non-linear হলে slope constant.

Viscosity: resistance of flow



(block টা move করলে উপরের পানির molecule তাকে move করাবে)

contact area → A
velocity gradient → $\frac{u}{y}$

plate/block কে move করানোর জন্য force লাগবে F

$F \propto A$

$F \propto \frac{u}{y}$

$F = \frac{\text{stress}}{\text{area}} = \frac{\tau}{A} \quad \tau A$

$F \propto \frac{Au}{y}$

$\therefore F = \mu \frac{Au}{y}$ [$\mu \rightarrow$ viscosity /dynamic viscosity]

$\Rightarrow \frac{F}{A} = \mu \frac{u}{y}$

$\Rightarrow \boxed{\tau = \frac{\mu U}{y}}$ [$F = \tau A$]

↳ linear

$\boxed{\tau = \mu \times \frac{du}{dy}}$ → non-linear

Newton's Law of viscosity, $\tau = \mu \times \frac{du}{dy}$ / $\tau = -\mu \frac{du}{dy}$ [direction]

$\therefore \mu = \frac{\tau}{\frac{du}{dy}}$

$\frac{du}{dy}$ → velocity gradient / rate of shear strain

unit :

$\mu = \frac{\tau}{\frac{du}{dy}} = \frac{F/A}{\frac{L}{T} \cdot \frac{1}{L}} = \frac{N/m^2}{\frac{1}{S}} = \boxed{Ns/m^2}$

$= \boxed{Pa\text{-}s}$

1 poise = 0.1 Pa-S

1 centi-poise = 10^{-2} poise

Kinematic viseosity: (ν)

$$\nu = \frac{\text{viseosity}}{\text{Density}} = \frac{\mu}{\rho}$$

Unit $\rightarrow m^2/s$

$\boxed{1 \text{ stoke} = 1 cm^2/s}$

যেসব fluid Newton's law মেনে চলে $\rightarrow$ Newtonian-fluid

মেনে চলে না $\rightarrow$ Non- " " (viseosity change হয়)

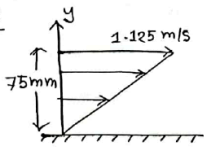
* viseosity decreases with temperature.

but the viseosity of gases increases with increase of temp. because of cohesive force.

Q: Differences between Newtonian and Non-Newtonian fluid.

Ideal plastic fluid $\longrightarrow$ toothpaste

Problem -1 :



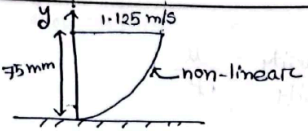
Question এ কিছু বলা না থাকলে linear ধরে নিব।

$\mu = 0.048$ Pa-S

$\tau_{y=0} = ?$

Soln : $\tau = \mu \times \frac{u}{d} = 0.048 \times \frac{1.125}{75 \times 10^{-3}}$ [linear]

$= 0.72$ Pa $= 0.72$ N-m^2

② 

$\mu = 0.048$ Pa-s

$\tau_{y=0} = ?$

Soln:

Let, $u = ay^2 + by + c$

at, $y = 0$, $u = 0$

$\therefore c = 0$

at, $y = 0.075\,m$, $u = 1.125\,m/s$

$\therefore 1.125 = a(0.075)^2 + b \times (0.075) \quad \ldots\ldots (i)$

at, $y = 0.15\,m$, $u = 0$

$\therefore \quad 0 = a(0.15)^2 + b \times (0.15) \quad \ldots\ldots (ii)$

$a = -200$

$b = 30$

$\therefore u = -200y^2 + 30y$

$\therefore \frac{du}{dy} = -400y + 30$

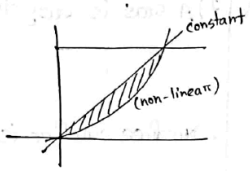
$\tau_{y=0} = \mu \times \left[\frac{du}{dy}\right]_{y=0}$

$= 0.048 \times (-400 \times 0 + 30)$

$= 1.44$ Pa.

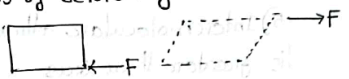
দুইটা mathematical relation, linear এ $\tau \rightarrow$ ধ্রুবক

non- " এ $\tau \rightarrow$ বেশি।



$y=0$ থেকে উপরে velocity বাড়লে, shear stress কমবে।

Introduction

Fluid	Solid
1) A fluid deforms continuously under the influence of shear stress, no matter how small.	1) A solid can resist an applied shear stress by deforming. 
2) In fluids stress is proportional to strain rate.	2) strain.
3) Fluids have no shape.	3) have a definite shape.
4) Fluid has a dynamic state	4) static or quasi-static state.
5) Attractive forces between the molecules are larger therefore more closely packed.	5) are smaller therefore more loosely packed.
6) A solid can may regain partly or fully its original shape when the tangential stress is removed.	6) fluid can never regain its original shape, once it has been distorted by the shear stress.

solid

Liquid	Gas
1) A liquid is difficult to compress and often regarded as being incompressible	1) A Gas is easy to compress.
2) Free surface space is formed.	2) No free surface is formed.
3) A given mass of liquid occupies a given volume and will take the shape of the container.	3) Gas has no fixed volume, it changes volume to expand to fill the containing vessel.
4) They have more intermolecular space.	4) They have the most intermolecular space than solid and liquid.
5) Intermolecular attraction is greater than Gas.	5) lowest intermolecular attraction.

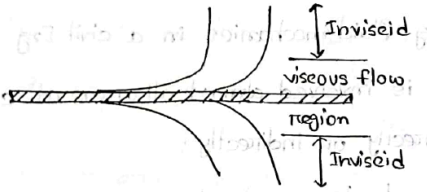
Steady	Unsteady
1) Defn	1) Defn
2) $\frac{\delta v}{\delta t} = \frac{\delta Q}{\delta t} = \frac{\delta T}{\delta t} = \frac{\delta p}{\delta t} = 0$	2) $\neq 0$
3) Ex:	

*Why are we studying fluid mechanics in a civil Eng. courrse?

Ans: fluid mechanics is involved almost all areas of civil Engineering either directly or indirectly:

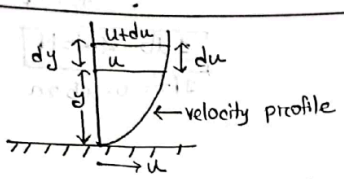
1) Hydraulic design of water/sewege treatment works
2) Dams, Embankments, spillways.
3) Irrigation (सिंचन)
4) pumps and turbines
5) water retaining structures
6) flow of air around buildings
7) Bridge piers in rivers.

Viscous	Inviscid regions of flow
1) They are usually close to solid surfaces.	1) not close to solid surfaces.
2) flows in which the frictional effects are significant.	2) In many flows of practical interest, there are regions where viscous forces are negligibly small compared to inertial or pressure forces.



Viscosity:

When two fluid layers move relative to each other, a friction force develops between them and the slower layer. Viscosity is defined as the property of a fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of the fluid.



when two layers of a fluid, a distance dy apart move one over the other at diff. velocities i.e u and u+du as shown in fig, then there will occure resistance to the movement of flows which is called viscosity.

The top layer causes a sheare stress on the adjacent lower layer while the lower layer causes " " on " " top " .

This sheare stress is proportional to the rate of change of velocity wrt y.

$$\tau \propto \frac{du}{dy} \quad \therefore \tau = \mu \frac{du}{dy}.$$

Q: why the viscosity of gases increases with the increase of temp and " " " liquids decreases " " " " ?

Ans:

For gases, viscosity is due to collision between gas molecules. With increase in temp, gas molecules attain more kinetic energy and the rate of collision is more. Because, gas molecules move faster at higher temp.

When temp. of liquid increases, the average kinetic energy of molecules increases. As a result, the molecules overcome the intermolecular attractive forces between them.

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= 0.454 kg

1 lb = 4.45 N

1 ft = 0.305 m

Excercise :

2.3.1

$\gamma = 52\ lb/ft^3$

$\gamma = \rho g$

$\Rightarrow \rho = \frac{52}{32.2} = 1.615\ \frac{lb/ft^3}{ft\,s^{-2}} = 1.615\ \frac{lb\,ft^{-1}\,s^2/ft^3}{slug}$

$= 1.615\ slug/ft^3$

2.3.2

$\gamma = 8.1\ kN/m^3$

$= 8100\ N/m^3$

$\rho = \frac{\gamma}{g} = \frac{8100}{9.81} = 825.688\ kgm^{-3}$

2.3.3

specific volume $= 375\ ft^3/slug$

$\gamma = ?$

$\therefore \rho = \frac{1}{375} = 2.67 \times 10^{-3}\ slug/ft^3$

$\gamma = \rho g$

$\gamma = 0.086\ lb/ft^3$

at $60^\circ F$, $\gamma = 62.37\ lb/ft^3$

2.3.54

Sp. V $= 0.70\ m^3 kg^{-1}$

$\rho = \frac{1}{0.70} = 1.4286\ kg/m^3$

$\gamma = \rho g$

$= 14.014\ N/m^3$

2.3.5

$\gamma = 16\ N/m^3$

$\rho = ?$

Sp. V $= ?$

$w/s = ?$

air $= 12\ N/m^3$

$\gamma = \rho g$

$\therefore \rho = 1.63\ kg/m^3$

Sp. volume $= \frac{1}{\rho} = 0.613\ m^3/kg$

$S = \frac{\rho}{\rho_{air}} = 1.33$

2.3.6

$\gamma = 78.6\ lb/ft^3 = 12.33\ kN/m^3$

$\therefore \rho = \frac{\gamma}{g} = 2.44\ slug/ft^3$

Sp. gravity $= \frac{\rho}{\rho_w} = 1.255$

$1\ slug = 14.594\ kg$

2.11

① specific Gravity = 0.680

Kinematic viscosity, $\nu = ?$

$$S = \frac{\rho}{\rho_w} \gamma_w \rightarrow 62.37$$

$$\Rightarrow \gamma_{gasoline} = 42.41 \text{ lb/ft}^3$$

$$\gamma_g = \rho_g \times g$$

$$\Rightarrow \boxed{\rho_g = 4.32 \text{ slug/ft}^3} \rightarrow \text{BG unit}$$

$$\rho_g = \frac{4.32 \times 0.454}{(0.305)^3} = 99.216 \text{ kg/m}^3 \longrightarrow \text{SI unit.}$$

$$\nu = \frac{\mu}{\rho}$$

④ $A = 0.15 \text{ m}^2$

$\mu = 0.85 \text{ N-S/m}^2$

$V = 1.2 \text{ m/s}$

$dy/t = 0.6 \times 10^{-3} \text{ m}$

$$\tau = \mu \frac{du}{dy}$$

$$\Rightarrow \tau = 1700 \text{ Pa}$$

$$\tau = \frac{F}{A}$$

$$\therefore \boxed{F = 255 \text{ N}}$$

⑤ $A = (2 \times 3) = 6 \text{ ft}^2$

$\mu = 0.024 \text{ lb-sec/ft}^2$

$V = 4 \text{ ft/sec}$

$t = 0.025 \text{ in} = \frac{0.025}{12} \text{ ft}$

$$\tau = \mu \frac{V}{t}$$

$$\Rightarrow \tau = 46.08 \text{ lb-ft}^2$$

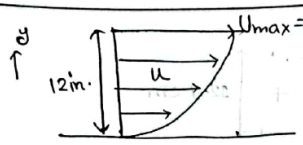
$$\tau = \frac{F}{A}$$

$$\therefore \boxed{F = 276.48 \text{ lb}}$$

CamScanner

absolute viscosity → dynamic viscosity

(11)



$u = ay^2 + by + c$

at, $y = 0, u = 0$

$\therefore c = 0$

at, $y = 12\,in / 1\,ft$, $u = 10\,ft/s$

$\therefore 10 = a + b + 0$

$\therefore a + b = 10 \quad \cdots (i)$

and, $y = 2\,ft$, $u = 0$

$\therefore 0 = 4a + 2b \quad \cdots (ii)$

$\therefore a = -10$

$b = 20$

$u = -10y^2 + 20y$

$\frac{du}{dy} = 20 - 20y$

$\therefore \tau = \mu \frac{du}{dy}$

$\Rightarrow \tau_{y=0} = 0.6 \times (20 - 20 \times 0) = 12 \text{ Pa}$

$\tau_{y=3} = 0.6 \times (20 - 20 \times 3) = -24 \text{ Pa}$

$\mu = 600\,cp$

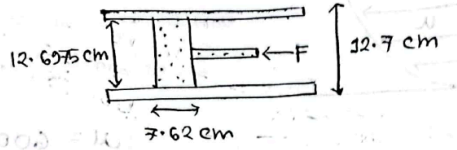
$= 600\,centipoise$

$= 600 \times 10^{-2}\,poise$

$= 0.6\,Pa\text{-}s$

CamScanner

Ex-4 (slide)



$\mu = 0.5$ Poise $= 0.05$ Pa-s

$du = 6.1$ m/s

$dy / t = 7.62 \times 10^{-2}$ m

~~Area~~ $= (12.7 - 12.6975)$ cm $= \frac{2.5 \times 10^{-5}\ m}{2} = 1.25 \times 10^{-5}$ m.

Area $= \pi r^2 =$ ~~$1.96 \times 10^{-5}\ m^2$~~ ~~$+.5625 \times 10^{-10}\ m^2$~~ $4.9 \times 10^{-10}\ m^2$

$\tau = \mu \frac{du}{dy}$

$= 4$ Pa

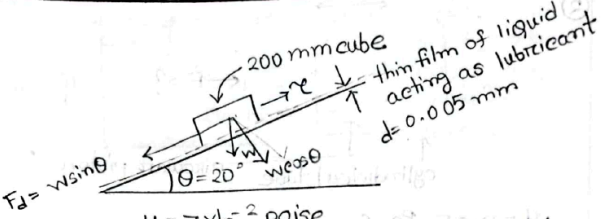
$\therefore \tau = \frac{F}{A}$

$\therefore F = \tau \times A =$ ~~7.845×10^{-5} N.~~ 1.96×10^{-3} N

স্থির অবস্থায় কোনো τ নেই।

03-05-23

① Math



$\mu = 7\times10^{-2}$ poise

$W = 1$ kN, $\theta = 20°$

After a long period of time, $V_T = ?$

Solution:

Driving force, $F_d = W\sin\theta$

Resistive force, $\tau = F_R = \tau \times A$

Object টা ছেড়ে দেয়ার পর একসময় constant velocity তে move করবে acceleration নেই। এই velocity কে V_T বলে। ∴ Terminal velocity

$\Sigma F = 0$

$\Rightarrow F_d = F_R$

$\Rightarrow W\sin\theta = \tau \times A$

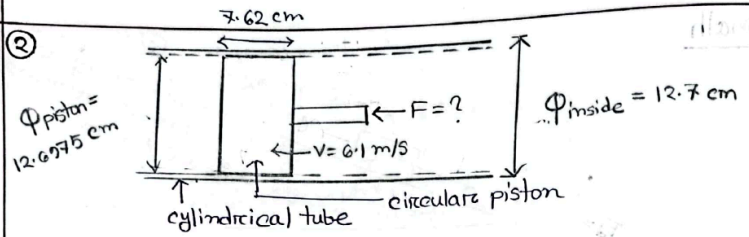
$\Rightarrow 1000\times\sin(20°) = \mu \times \frac{V_T}{d} \times A$

$\Rightarrow 1000\times\sin 20° = \frac{7\times10^{-2}}{10} \times \frac{V_T}{0.005\times10^{-3}} \times (200\times10^{-3}\times200\times10^{-3})$

$V_T = 6.1$ m/s

$\phi \rightarrow$ dia

②



$\mu = 0.05$ Pa-S

$F = ?$



$$d = \frac{(12.7 - 12.6975) \times 10^{-2}}{2} = 1.25 \times 10^{-5} \text{ m}$$

$$A = 2\pi \times d$$

$$= 2\pi \times \frac{12.6975 \times 10^{-2}}{2} \times 7.62 \times 10^{-2}$$

$$= 0.03 \text{ m}^2$$

$$\tau = \mu \times \frac{u}{d}$$

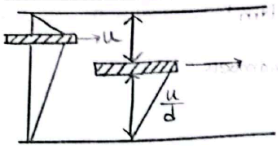
$$\Rightarrow F \cancel{\times A} = \mu \times \frac{u}{d} \times A$$

$$F = \frac{\mu \times u \times A}{d \cancel{\times A}}$$

$$= \cancel{-741.67 \text{ N}}$$

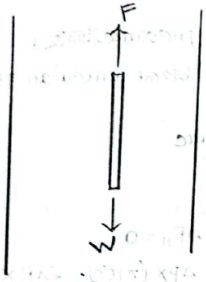
$$= 732 \text{ N}$$

③



centre দিয়ে gap both side distance equal. otherwise equal হবে না। তখন দুই side এর area আলাদাভাবে বের করতে হবে।

④

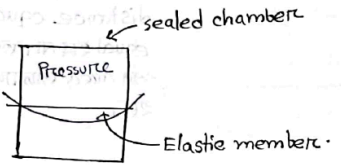


যদি a দেয়া থাকে।

$\Sigma F = \theta = ma$

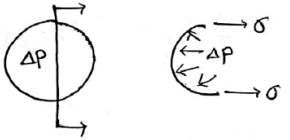
09-05-23

Surface tension (σ) Nm^{-1}



circular হওয়া মানে ভিতরে excess pressure আছে।
যদি দুইপাশে pressure same হয় তাহলে circular হবে না.

P_a ($P_a+\Delta P$) ΔP = excess pressure



$\Delta F_H = 0$

$\Delta P \times (\pi r^2) = 2\pi R \times \sigma$ ← surface tension

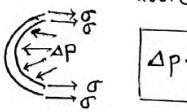
↓

excess pressure জন্য কারণে যে force

$$\Delta P = \frac{2\sigma}{R}$$

* Bubble এ double layer থাকে। Air (air) liquid

Bubble



cross section করলে

$$\Delta P = \frac{4\sigma}{R}$$ for bubble.

Temp ↑, surface tension ↓

* air drop inside liquid ⟶ coke

① * Two liquid drops $\Delta P_1 = 10\ Pa$, $\Delta P_2 = 1\ kPa$, $\sigma = 0.021\ N/m$

ϕ_1 and $\phi_2 = ?$ [$\phi \rightarrow$ dia]

Soln:

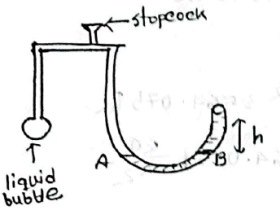
$$\Delta P = \frac{2\sigma}{R} = \frac{2\sigma}{D/2} = \frac{4\sigma}{D}$$

$$\therefore D_1 = \frac{4 \times 0.021}{10} = 8.4 \times 10^{-3}\ m$$

$$D_2 = \frac{4 \times 0.021}{10^3} = 8.4 \times 10^{-5}\ m$$

So, the smaller dia gives higher pressure.

* coke এর বোতলে নিচের দিকে p বেশি তাই কম তাপে ছোটের bubble এর size বড় হয়।

② 

bubble, $r = 1\ cm$

$h = 1.4\ mm$

$\rho_{liquid} = 0.8$

$\sigma = ?$

Soln: Interface এ Pسame

$P_A = P_B$

$\Rightarrow P_A = \rho g h$

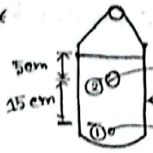
$\Rightarrow \frac{4\sigma}{R} = \rho g h$

$\Rightarrow \sigma = \frac{\rho g h R}{4} = \frac{800 \times 9.8 \times 1.4 \times 10^{-3} \times 10^{-2}}{4}$

[bubble এর pressure = P_A]

$= 0.02744\ Nm^{-1}$

*



$\sigma = 0.075\ N/m$

$S = 1.15$

$\rho = S\rho_w = 1.15 \times 1000$

$\gamma = \rho g = 1.15 \times 1000 \times 9.8$

$= 11281.5\ N/m^3$

$\Delta P_1 = \frac{2\sigma}{R_1} = 2142.857\ Pa$

$P_1(\text{outside}) = \gamma h_1 = 11281.5 \times 0.2\,m = 2256.3\ Pa$

$P_1(\text{inside}) = P_1(\text{outside}) + \Delta P_1 = 4399.16\ Pa$

$V_1 = \frac{4}{3}\pi(r_1)^3 = 1.437 \times 10^{-12}\,m^3$

$P_2(\text{outside}) = \gamma h_2 = 11281.5 \times 5 \times 10^{-2} = 564.075\ Pa$

$P_2(\text{inside}) = P_2(\text{outside}) + \Delta P_2 = 564.075 + \frac{2\sigma}{r_2}$

$V_2 = \frac{4}{3}\pi r_2^3$

According to Bowel's law,

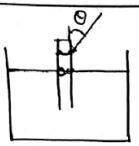
$P_1V_1 = P_2V_2$

$\Rightarrow 4399.16 \times \frac{4}{3}\pi \times 1.437 \times 10^{-12} = \left(564.075 + \frac{2\sigma}{r_2}\right) \times \frac{4}{3}\pi r_2^3$

$\Rightarrow \boxed{r_2 = 0.000087\,m}$

16-05-23

Capilarity:



[Tube insert করা হয়েছে]

কেশোলিন হলে উপরে উঠবে

(mercury) → cohesive force বেশি
surface tension strong

এই rise কে বলে → capilarity.

$$h = \frac{4\sigma\cos\theta}{\rho g d} \quad [\theta \neq 90^\circ]$$

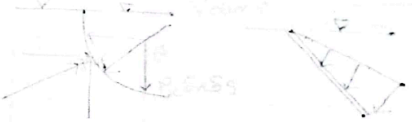
for water $\theta \approx 0$

$$h_{water} = \frac{4\sigma}{\rho g d}$$

$$h_{Hg} = \frac{4\sigma\cos\theta}{\rho g d}$$

for water, adhesive force > cohesive.
for mercury, cohesive " > adhesive force. (surface tension অনেক বেশি)

Math:



Dia = 2.5 mm
$\sigma_w = 0.0725$ N/m
$\sigma_{Hg} = 0.52$ N/m
$S_{Hg} = 13.6$
$\theta = 130^\circ$

$$h_w = \frac{4\sigma}{\rho g d} = \frac{4 \times 0.0725}{1000 \times 9.81 \times 2.5 \times 10^{-3}} = 0.018 \text{ m}$$

$$= 1.18 \text{ cm}$$

CamScanner

(b) for mercury,

$$h = \frac{4\sigma\cos\theta}{\rho g d} = -0.004\ m$$

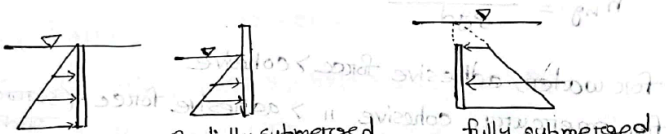
* Dimensional Analysis: velocity → LT^{-1}
acceleration → LT^{-2}

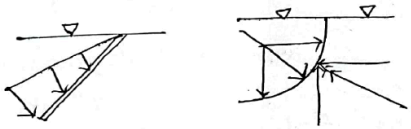
Chapter-3

Fluid statics → fluid at rest

Fluid static → shear stress থাকবে না, শুধু pressure দিবে থাকবে।

Pressure is similar to normal stress (solid mechanics)





বিভিন্ন ধরনের surface থাকলে (inclined, curve)।

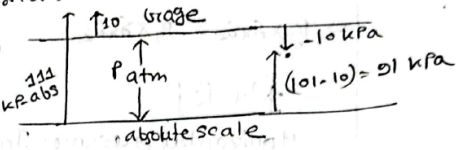
1 bar = 105 Pa = 0.1 MPa = 100 kPa

1 atm = 101,325 Pa = 101.325 kPa = 1.01325 barg.

Pressure মেপে বহুল scale দুইটি,

1) Gage (+/neg. Pressure হয়)

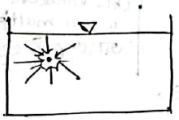
2) absolute scale (always positive)



P = 10 kPa-gage

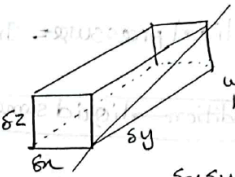
= 10 + 101 = 111 kPa-abs

*** * Pressure at any point in a fluid at rest is equal in all directions ⟶ Pascle's law

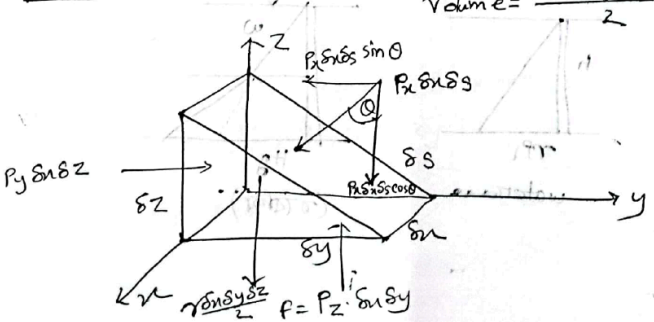


fluid rest এ থাকলে যেকোনো direction এ pressure একই same.





Volume = $\frac{\delta x \delta y \delta z}{2}$ (half)



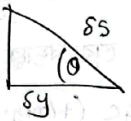
weight এর = $\gamma \times$ volume

$\gamma = \frac{mg}{V} = \frac{\rho V g}{V} = \rho g$ (w)

$\Sigma F_x = \Sigma F_y = \Sigma F_z = 0$

$\Sigma F_y = 0 \longrightarrow$

$P_y \times \delta x \delta z = P_s \times \delta x \delta s \sin\theta$



$\Rightarrow P_y \times \delta x \delta z = P_s \times \delta x \delta z$

$\boxed{P_y = P_s}$

Horizontal pressure = Inclined pressure.

$\Sigma F_z = 0 \uparrow$

$P_z \delta x \delta y = P_s \delta s \frac{\delta x}{\delta y} \cos\theta + \gamma \times \frac{\delta x \delta y \delta z}{2}$ (0)

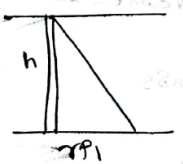
$\Rightarrow P_z \delta x \delta y = P_s \times \delta x \delta y$

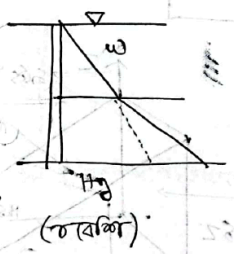
$\boxed{P_z = P_s}$

Vertical pressure = Inclined pressure.

$\delta x = 0.01$
$\delta y = 0.02$
$\delta z = 0.03$
$\delta x \delta y \delta z = 0.00006$
ছোট value এর সাথে
" " multiply করলে
আরও ছোট হয়.

condition → liquid same

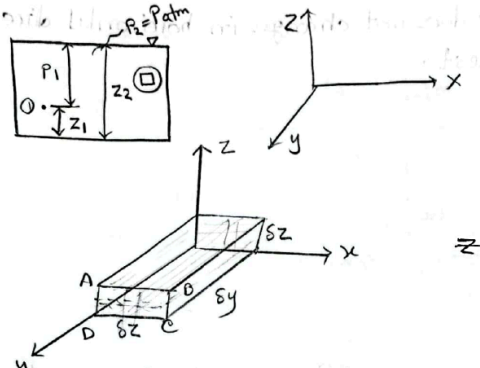




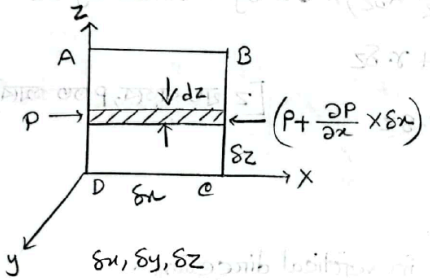
17-05-23

Vertical

Variation of pressure in static fluid:



Z-41



$\delta x, \delta y, \delta z$

$P = P(x, y, z)$

$\Sigma F_x = 0$ → change of P in x direction.

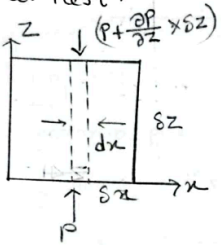
$$\Rightarrow P \times \frac{dz \cdot \delta y}{\text{Area}} = \left(P + \frac{\partial P}{\partial x} \times \delta x\right) \times dz \cdot \delta y$$

$$P = P + \frac{\partial P}{\partial x} \times \delta x$$

$$\frac{\partial P}{\partial x} \times \delta x = 0$$

Since, $\delta x \neq 0$, $\frac{\partial p}{\partial x} = 0$

Pressure does not change in horizontal direction if it is at rest.



$\Sigma F_z = 0$

$\Rightarrow p \times dx\,\delta y = \left(p + \frac{\partial p}{\partial z} \times \delta z\right) \times dx \cdot \delta y + \gamma \times dx \cdot \delta y \cdot \delta z$

$\Rightarrow p = p + \frac{\partial p}{\partial z} \times \partial z + \gamma \cdot \delta z$

[z যত বাড়বে, p তত কমবে]

$\frac{\partial p}{\partial z} \times \partial z = -\gamma \cdot \delta z$

$$\boxed{\frac{\partial p}{\partial z} = -\gamma}$$

Change of pressure in vertical direction:

$\frac{\partial p}{\partial z} = -\gamma$

$\Rightarrow \partial p = -\gamma\, \partial z$

$\Rightarrow \int_{p_1}^{p_2} \partial p = -\gamma \int_{z_1}^{z_2} \partial z$

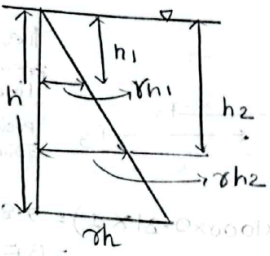
$\Rightarrow p_2 - p_1 = -\gamma(z_2 - z_1)$

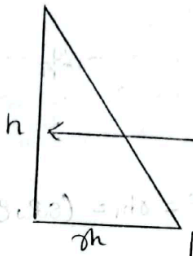
$p_2 - p_1 = -\gamma h$

$\therefore \boxed{p_1 = p_2 + \gamma h}$

$p_1 \rightarrow$ surface এ আছে

$P_g = P_{atm} + \gamma h$





thickness

$F = P \times A$

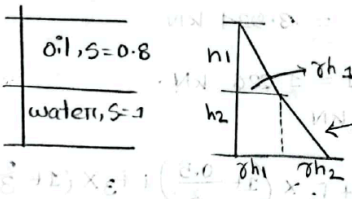
$= \frac{1}{2} \times \gamma h \times h \times b$ (A)

$= \gamma \times \frac{h}{2} \times A$

$F = \gamma h_{cg} \cdot A$

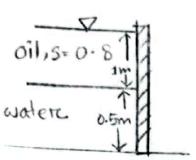
Area of the pressure diagram

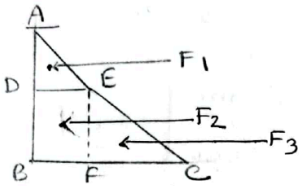
thickness না থাকলে, b=1



Variation of pressure with depth.

Math:





Pressure per m = ?
Result line of action = ?
Resultant force কোথায় কাজ করে।

$DE = \gamma h_1 = (S\rho_w g)h = (0.8 \times 1000 \times 9.81 \times 1) = 7.85\ kN/m^2$
$= BF$

$FC = \gamma h_2 = 1000 \times 9.81 \times 0.5 = 4.91\ kN\,m^{-2}$

$F_1 = \left(\frac{1}{2} \times 7.85 \times 1\right) \times \underbrace{1\ m}_{b} = 3.924\ kN$

$F_2 = (7.85 \times 0.5) \times 1 = 3.924\ kN$

$F_3 = \left(\frac{1}{2} \times 4.91 \times 0.5\right) \times 1 = 1.226\ kN.$

$F = F_1 + F_2 + F_3 = 9.074\ kN$

$\Sigma M_A = 0$

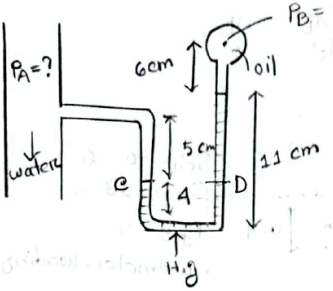
$\Rightarrow F \times \bar{h} = \left(F_1 \times \frac{2}{3} \times 1\right) + F_2 \times \left(1 + \frac{0.5}{2}\right) + F_3 \times \left(1 + \frac{2}{3} \times 0.5\right)$

$\Rightarrow \bar{h} = 1\ m$

CamScanner

Gas এর P সকল chamber এ same থাকে।
liquid এর ক্ষেত্রে যত depth এর সাথে P বাড়ে।

Math: P-83 +Book (white)



γ_{water} = 9.79 kN/m3
γ_{Hg} = 133.1 kN/m3
γ_{oil} = 8.72 kN/m3

~~Pressure Gauge B = ?~~

Same level liquid এর Pressure সমান।
(Interface খুঁজে বের করতে হবে)

P_A = ?

Pressure at C = Pressure at D

নিচের দিকে গেলে pressure বাড়বে γh পরিমান।

$$P_C = P_D$$

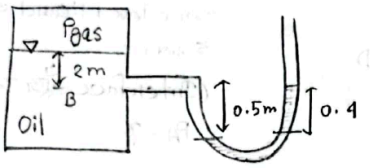
$$\Rightarrow \left(P_A + \gamma_w \times \frac{5}{100}\right) = 87 + \left(\gamma_{oil} \times \frac{6}{100}\right) + \left(\gamma_{Hg} \times \frac{7}{100}\right)$$

$$P_A = 96.35 \text{ kPa}$$

$P = \gamma h = \rho g h$

$\Delta p = \rho g \cdot \Delta h \Rightarrow \Delta h = \frac{\Delta P}{\rho g} = \frac{\Delta P}{\gamma}$.

*



$S_{oil} = 0.86$

$S_{Hg} = 13.6$

$P_{gas} = ?$

manometer reading = 0.4

$P_C = P_D$

$\Rightarrow P_{gas} + \frac{0.86 \times 1000 \times 9.81}{1000} \times 2.5 = 0 + \frac{13.6 \times 1000 \times 9.81}{1000} \times 0.4$

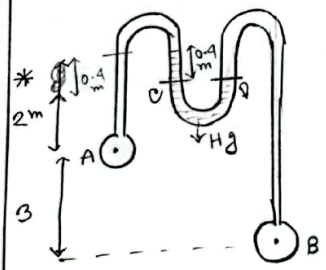
$P_{gas} = 32.27$ kPa (gage scale).

$= 101 + 32.27$ kPa (abs ").

$= 133.27$ kPa (abs)

Ques এ বলা না থাকলে gage scale এ বসাবে।

*



$\gamma_A = 8.4$ kN/m3

$\gamma_B = 12.3$ kN/m3

$S_{Hg} = 13.6$

$P_B = 200$ kN/m^2 — abs

$P_A = ?$

$P_C = P_D$

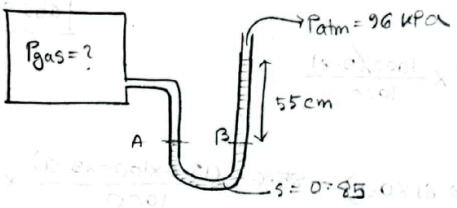
$\Rightarrow P_A - (8.4 \times 2.4) + \underbrace{\frac{13.6 \times 1000 \times 9.81}{1000}}_{\gamma_{Hg}} \times 0.4 = P_B - (12.3 \times 5)$ (200 ↑)

$\therefore P_A = 105.29$ kN/m² – abs

Glass tube এর dia বেশি হলে capillary rise is negligible.

ET ✓✓

Example:



$P_A = P_B$

$\Rightarrow P_A = P_{atm} + \frac{0.85 \times 1000 \times 9.81}{1000} \times 0.55$

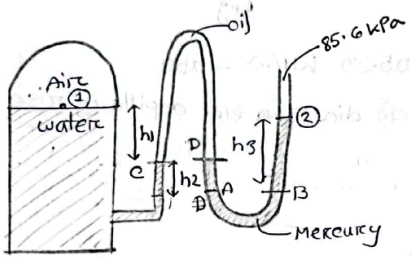
$= 96 + \dots$

$P_A = 100.586$ kPa – abs.

Multi fluid manometer:

pipeline এ leak হলে সেখানে P drop হয়।

Ex-2



$h_1 = 0.1\ m$
$h_2 = 0.2\ m$
$h_3 = 0.35 m$

$P_1 = ?$

abs scale

$P_1 = P_2$ ✓

$\Rightarrow P_1 - 0.1 \times \frac{1000 \times 9.81}{1000}$ ~~$- 0.2$~~

$P_C = P_D$

$\Rightarrow P_{Air} + (9.81 \times 0.1) = 85.6 + \frac{(13.6 \times 1000 \times 9.81)}{1000} \times 0.35 - \left(\frac{0.85 \times 1000 \times}{1000}\right.$

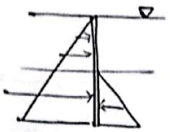
$P_{Air} = 129.6469$

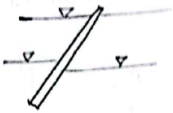
অথবা,

$P_A = P_B$

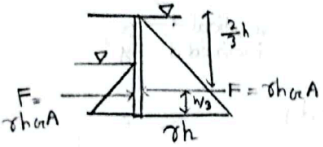
$\Rightarrow P_{Air} + (\gamma_w \times 0.1) + (0.2 \times \gamma_{oil}) = 85.6 + (\gamma_{Hg} \times 0.35)$

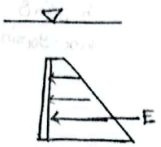
P_{Air}

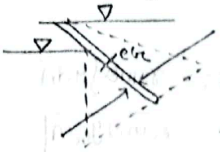




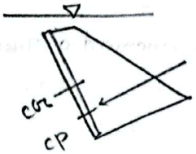
২৭-05-23



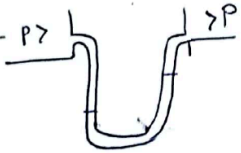




cg এর নিচে pressure centre থাকে।

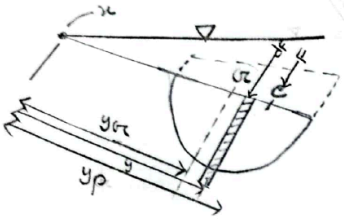


Ex. 2

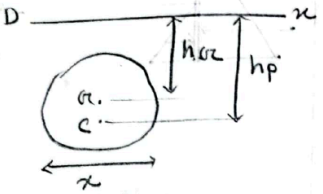


Derivation → imp

centre of pressure on plane submerged area:



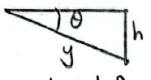
dA = dy × x



vertical d → h
inclined d → y

dF = force on $dA = p \times dA = \gamma h \times dA$

$= \gamma \times y \sin\theta \cdot dA$



$h = y \sin\theta$

$h_G = y_G \sin\theta$

$$\int dF = \int_A \gamma y \sin\theta \, dA = \gamma \sin\theta \int y \, dA$$

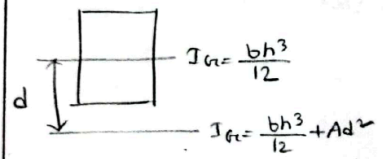
$$\therefore \boxed{F = \gamma \sin\theta \, y_G \cdot A}$$

$$\boxed{F = \gamma h_G A} \checkmark \quad \text{[vertical/inclined for both case]}$$

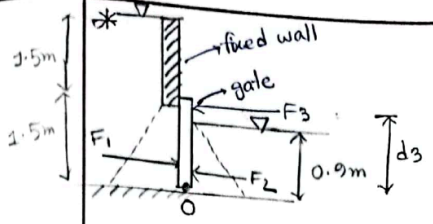
$$y_p = y_G + \frac{I_G}{y_G A}$$

[I_G → moment of Inertia]

গড়ের সাথে প্রযুক্ত লম্ব চাপ P.



Math → Plane surface, inclined, curve surface + Manometer math



কি পরিমান force F_3 apply করলে gate off থাকবে ?

width of the gate = 1.2

Solⁿ:

$$F_1 = \gamma h_{cr} \times A = 9.81 \frac{kN}{m^3} \times \left(1.5 + \frac{1.5}{2}\right) \times (1.5 \times 1.2)$$

$$= 39.73 \text{ kN}$$

$$F_2 = \gamma h_{cr} \times A = 9.81 \frac{kN}{m^3} \times \frac{0.9}{2} \times (0.9 \times 1.2) = 4.77 \text{ kN}$$

$$y_{p_1} = y_{cr} + \frac{I_{cr}}{y_{cr} A} = \left(1.5 + \frac{1.5}{2}\right) + \frac{1.2 \times \frac{1.5^3}{12}}{2.25 \times (1.5 \times 1.2)}$$

$$= 2.33 \text{ m}.$$

$$d_1 = (3 - 2.33)\text{m} = 0.67 \text{ m}$$

$$d_2 = \frac{0.9}{3} = 0.3$$

or, $y_{p_2} = y_{cr_2} + \frac{I_{cr}}{y_{cr_2} A}$

$$= 0.45 + \frac{1.2 \times \frac{(0.9)^3}{12}}{0.45 \times (0.9 \times 1.2)}$$

$$= 0.6$$

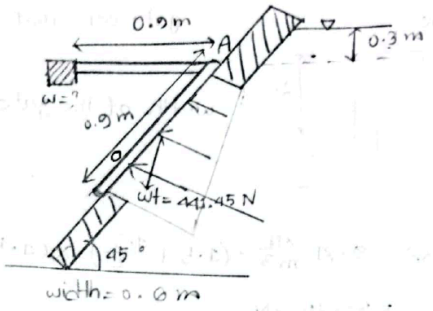
$\Sigma M_o = 0$

$F_1 d_1 = F_2 d_2 + F_3 d_3$ → 1.5

$\Rightarrow \boxed{F_3 = 16.8 \text{ kN}}$

$y_G, h_G \rightarrow$ free water level থেকে হিসাব করবো।

30-05-23



$\Sigma M_A = 0$

$\Rightarrow F \times OA = \omega_1 \times 0.45\cos 45° + W \times 0.9$ —(1)

$F = \gamma h_G A = 9.81 \times (0.3 + 0.45\sin 45) \times (0.9 \times 0.6)$

$= 3.275\ kN$

$y_p = y_G + \frac{I_G}{y_G A}$

$= 0.45 \underbrace{\left(\frac{0.3}{\sin 45} + 0.45\right)}_{0.874} + \frac{0.6 \times 0.9^3}{12} \times \frac{1}{0.874 \times (0.9 \times 0.6)}$

$= 0.951$

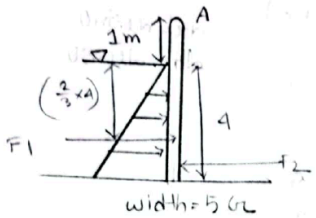
$\therefore OA = 0.951 - \frac{0.3}{\sin 45} = 0.5272\ m$

(1) $\Rightarrow$

$3.275 \times 0.5272 = 441.45 \times \ldots + W \times 0.9$

$\therefore W = 1.7623\ kN$

ข้อ



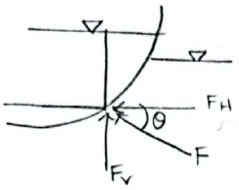
$F_1 = \gamma h_G A = 9.81 \times \frac{4}{2} \times (4 \times 5) = 392.4$ N.

$\Sigma M_A = 0$

$F_1 \times (1 + \frac{8}{3}) = F_2 \times 5$

$F_2 = \cancel{444.72}$ 287.76 N.

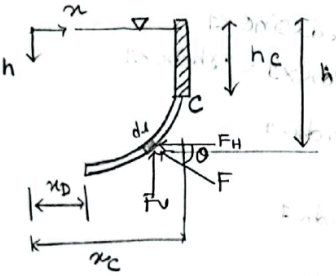
ข้อ

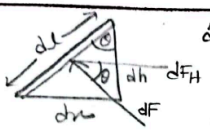


$F = \sqrt{F_H^2 + F_V^2}$

$\theta = \tan^{-1} \frac{F_V}{F_H}$

ข้อ





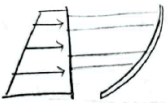
$dA = dl \times 1$

$dx = dl \sin\theta$

$dh = dl \cos\theta$

$$dF_H = dF\cos\theta = (P \times dA)\cos\theta$$
$$= P \times (dl \times 1) \times \cos\theta$$
$$= P \cdot dl\cos\theta = P \cdot dh$$
$$= P_{(h)} \times dh \quad [\because P(h) \rightarrow \text{variation of pressure along } h \text{ direction}]$$

$$\int dF_H = \int_{hc}^{hp} P(h) \times dh \times 1$$



Area of the pressure diagram

$F_H = \gamma h_{cg} A_P$ — Projected Area

$$dF_V = dF\sin\theta = (P \times dA)\sin\theta$$
$$= P \times dl\sin\theta \times 1$$
$$= P \times dx \times 1 = \gamma h dx \times 1$$

$$\int_A dF_V = \int_{xc}^{xp} \gamma h\, dx \cdot 1$$
$$= \gamma \int_{xc}^{xp} h \cdot dx \cdot 1$$

$F_V = \gamma \times \text{volm}$

= wt of the liquid vertically above the curved surface.

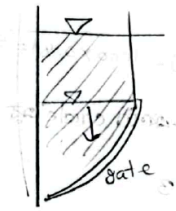
$F_H = \gamma h_{cg} A_p$

$F_V = \gamma \times volm$

$F = \sqrt{F_H^2 + F_V^2}$

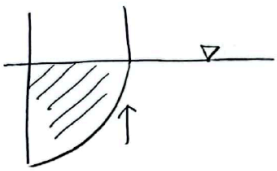
$\theta = \tan^{-1} \frac{F_V}{F_H}$

*



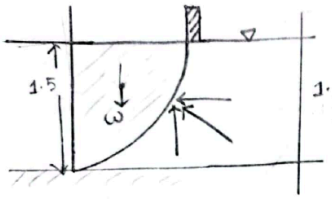
gate বরাবর vertically উপরে extend করবে।

*



31-05-23

Ex-1:



$F_H = \rho g h_{CG} A_P$

$= 9.81 \times \frac{1.5}{2} \times (1.5 \times 3)$ $[\gamma = \rho g = 1000 \times 9.81 = 9.1\ kN/m^3]$

$= 33.108\ kN$

$F_V = \gamma \times Vol^m = 9.81 \times \frac{1}{4}\pi\left(\frac{1}{2}.5\right)^2 \times 3$ → একটা circle এর $\frac{1}{4}$ ভাগ

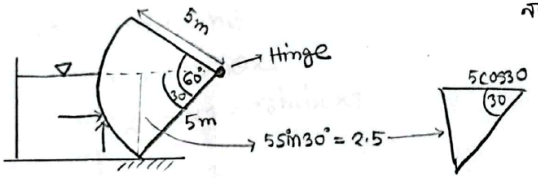
$= 52\ kN$

$F = \sqrt{F_H^2 + F_V^2} = 61.64\ kN$

$\theta = \tan^{-1}\left(\frac{F_V}{F_H}\right) = 57.5°$

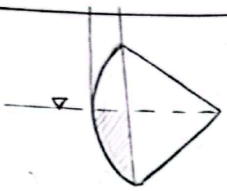
thickness = 1
না দেয়া থাকলে ধরে নিতে হবে

②



$F_H = 9.8 \times \frac{2.5}{2} \times (2.5 \times 1) = 30.656\ kN$

$F_V = \gamma \times Vol^m$



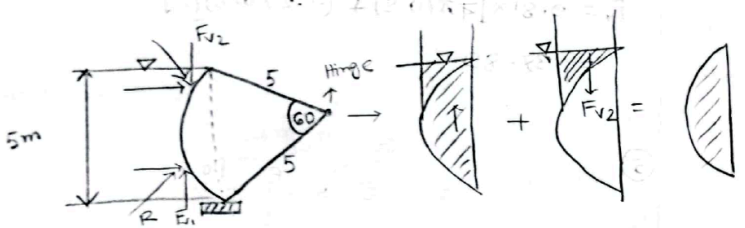
$\frac{30}{360} \times \pi r^2$

$F_V = \gamma \times Vol^m = 9.81 \times \left[\frac{30}{360}\pi(5)^2 - \frac{1}{2} \times 5\sin 30° \times 5\cos 30°\right] \times 1$

circular — triangular — [Thickness 1 অনুমান করা হলো]

$= 11.108$ kN

③

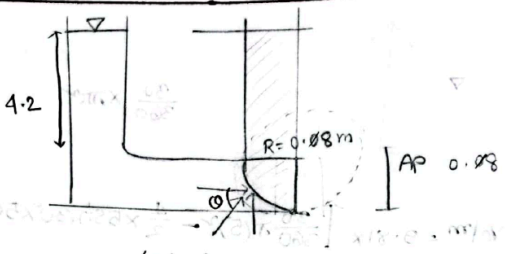


$F_H = 9.81 \times \frac{5}{2} \times (5 \times 1) =$

$F_V = 9.81 \times \left[\frac{60}{360}\pi(5)^2 - \frac{1}{2} \times 5 \times 5\cos 30\right] \times 1$

$= 22.216$ kN

④

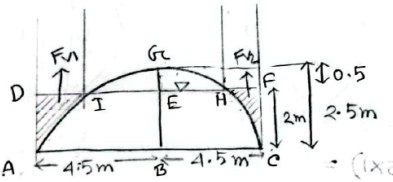


$F_H = \gamma h_G A = 9.81 \times \left(\frac{4.2 + \frac{0.8}{2}}{2}\right) \times 0.8 \times 1 = 3.1392\ kN = 36.1\ kN$

$F_V = 9.81 \times \left[\frac{1}{4}\pi (0.8)^2 + (4.2 \times 0.8)\right] \times 1$

$= 37.89$

⑤



$y = kx^2$ [Parabola]

$\Rightarrow 2.5 = k(9)^2 (4.5)^2$

$\therefore k = 0.123456$

$\therefore y = 0.1235 x^2$

$y = 0.1235 x^2$

$\Rightarrow 0.5 = 0.1235 \times (EH)^2$

$EH = 2.012$

AGC, $\frac{2}{3} \times 4.5 \times 2.5 = 15\ m^2$

IGH, $\frac{2}{3} \times 4.024 \times 0.5 = 1.34\ m^2$

AIEHC $= 13.6587\ m^2$

ADI + CFH $= 18 - 13.66 = 4.34\ m^2$

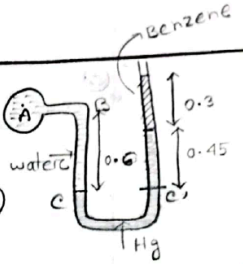
$\therefore F_V = \gamma . Vol^m = 9.81 \times 4.34 \times 6 = 255.53\ kN$

$F_H = 0\ kN$

CT-1

① $S_{Hg} = 13.6$

$S_{water} = 1$, $S_{Benzene} = 0.88$



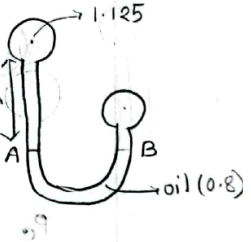
$P_C = P_{C'}$

$\Rightarrow P_A + (\gamma_{water} \times 0.6) = (\gamma_{Benzene} \times 0.3) + (\gamma_{Hg} \times 0.45)$ (Sp.wt)

$\Rightarrow P_A = \frac{0.88 \times 10^3 \times 9.81 \times 0.3}{1000} + \frac{13.6 \times 10^3 \times 9.81 \times 0.45}{1000} - 9.81 \times 0.6$

$= 56.74 \text{ kN/m}^2$

② The pressure between two points A and B in a pipe conveying oil of specific gravity 0.8 is measured by an inverted U-tube. The column connected to point B stands 1.6m higher than that at point A. A commercial pressure gage attached directly to the pipe A reads 1.125 kg (f)/cm², Determine the reading when attached directly to the pipe at B.

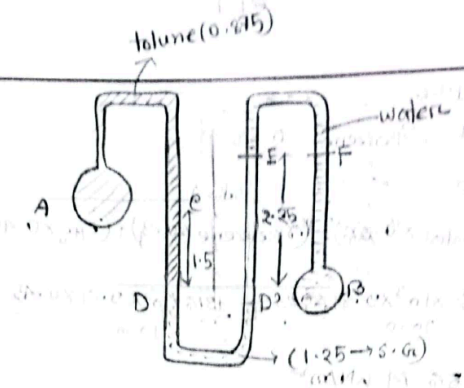


$P_A = P_B$

$\Rightarrow \frac{1.125 \times 10}{1000} (\text{kN/m}^2) = P_B + (0.8 \times 9.81) \times 1.6$

$P_B = \frac{1.125 \times 10}{1000} + (0.8 \times 9.81 \times 1.6)$

③



$P_B - P_A = ?$

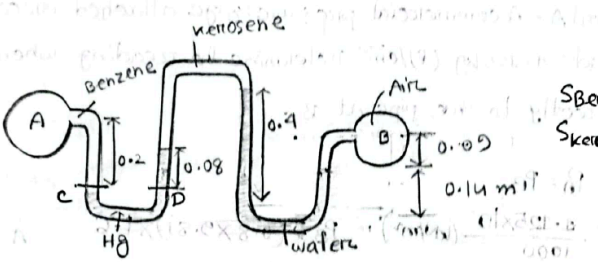
Soln:

$P_z = P_{z'}$

$\Rightarrow P_A + (0.875 \times 9.81 \times 1.5) = P_B + (2.25 \times 9.81 \times 1) + (2.25 \times 9.81 \times 1.25)$

$\therefore P_B - P_A = 7.3575 \text{ kN/m}^2$

④



$S_{Benzen} = 0.876$

$S_{kerosen} = 0.786$

$P_C = P_D$

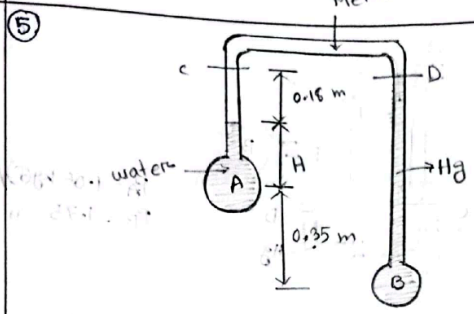
$\Rightarrow P_{BA} + (0.876 \times 9.81 \times 0.2) = P_B + (9.81 \times 0.14) - (9.81 \times 0.4) + (0.786 \times 9.81 \times 0.32) + (13.6 \times 9.81 \times 0.08)$

$P_A + 1.7187 = P_B + 10.59$

$P_A - P_B = 8.87 \text{ kPa}$

CamScanner

⑤



$P_B - P_A = 97\ kPa$

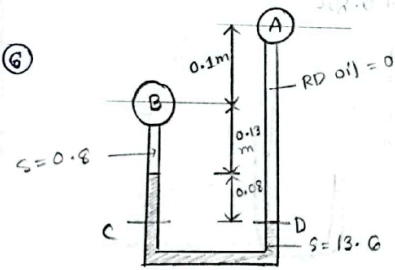
$H = ?$

$P_C = P_D$

$\Rightarrow P_A - (9.81 \times H) - (0.827 \times 9.81 \times 0.18) = P_B - \{13.6 \times 9.81 \times (0.53 + H)\}$

$H = 0.22\ m = 22.45\ cm$

⑥

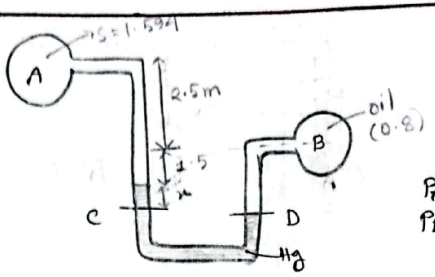


$P_C = P_D$

$\Rightarrow P_B + (0.8 \times 9.81 \times 0.13) + (13.6 \times 9.81 \times 0.08) = P_A + (0.7 \times 9.81 \times 0.3)$

$P_A - P_B = 0.56475\ kPa$

(7)



$P_A = 1.05\ kg(f)/cm^2$

$P_B = 1.75$ "

$x = ?$

$P_C = P_D$

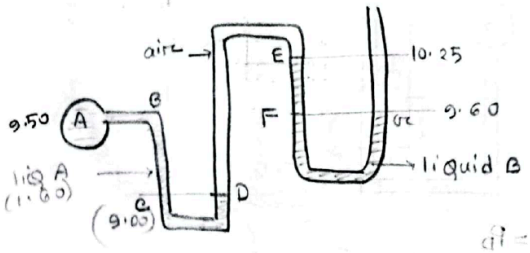
$\Rightarrow P_A + \frac{1.05\times10^4\times9.81}{1000} + (1.594\times9.81\times4) + (13.6\times9.81\times x) = \frac{1.75\times10^4\times9.81}{1000} + (0.8\times9.8\times(1.5+x))$

$\Rightarrow 10.5 + 62.55 + 6.376 + 13.6x = 17.5 + 1.2 + 0.8x$

$\Rightarrow 16.876 + 13.6x = 18.7 + 0.8x$

$x = 0.1425\ m$

(8)



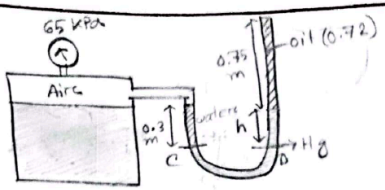
$P_C = P_D$

$\Rightarrow P_A + (1.60\times9.81\times0.5) = -8\times9.81\times0.65$

$\left(-\frac{0.15\times10^4\times9.81}{1000}\right)$

$\therefore S = 1.077$

(9)



h = ?

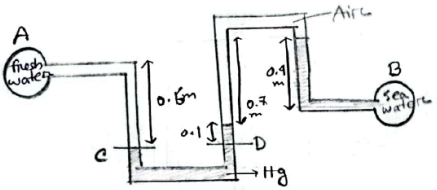
Soln:

$P_C = P_D$

$\Rightarrow 65 + (9.81 \times 0.3) = (0.72 \times 9.81 \times 0.75) + (13.6 \times 9.81 \times h)$

$h = 0.4695 \text{ m}$

(10)



$\gamma_{sea\ water} = \rho g$

$= \frac{1035 \times 9.81}{1000}$

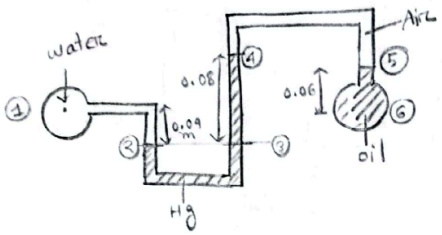
$= 10.15 \text{ kN/m}^3$

$P_C = P_D$

$\Rightarrow P_A + (9.81 \times 0.6) = P_B - (10.15 \times 9.81 \times 0.4) + (13.6 \times 9.81 \times 0.1)$

$P_A - P_B = 3.3956 \text{ kPa}$

(11)



$S_{oil} = 0.86$

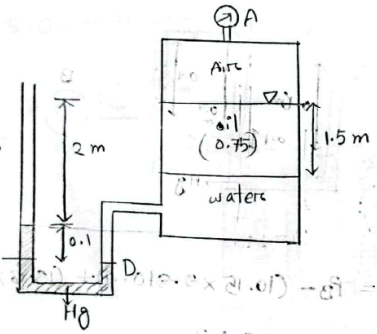
$S_{Hg} = 13.6$

$P_2 = P_3$

$\Rightarrow P_{water} + (9.81 \times 0.04) = P_{oil} - (0.86 \times 9.81 \times 0.06) + (13.6 \times 9.81 \times 0.08)$

$P_{water} - P_{oil} = 9.7747$ kPa

(12)



$P_C = P_D$

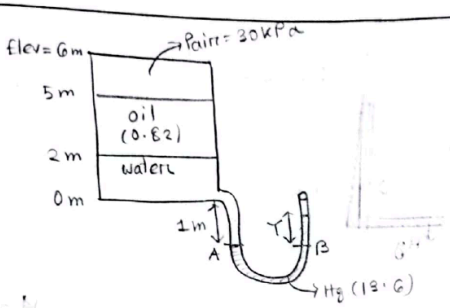
$\Rightarrow (13.6 \times 9.81 \times 0.1) = P_A + (0.75 \times 9.81 \times 1.5) + (9.81 \times 0.5) + (9.81 \times 0.1)$

$P_A = -3.58$ (gage scale)

$= 101 - 3.58$ (abs)

$= 97.42$ kPa-abs

(13)

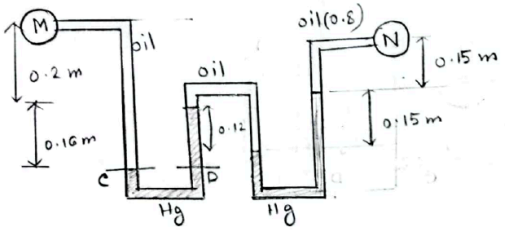


$P_A = P_B$

$\Rightarrow 30 + (0.82 \times 9.81 \times 3) + (9.81 \times 2) + (9.81 \times 1) = (13.6 \times 9.81 \times Y)$

$\therefore Y = 0.626\ m$

(14)

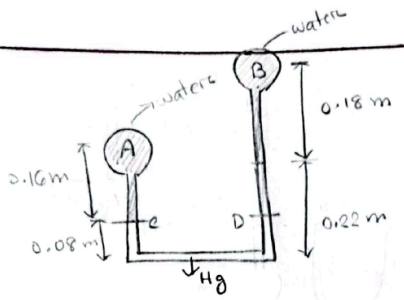


$P_C = P_D$

$\Rightarrow P_M + (0.8 \times 9.81 \times 0.36) = P_N + (0.8 \times 9.81 \times 0.15) + (13.6 \times 9.81 \times 0.15) - (0.8 \times 9.81 \times 0.12) + (13.6 \times 9.81 \times 0.16)$

$P_M - P_N = 38.769\ kPa$

(15)



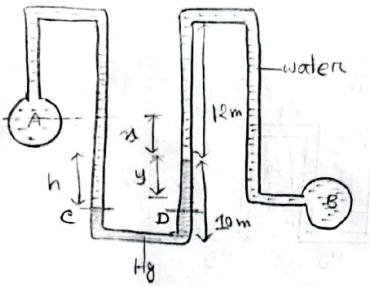
$P_C = P_D$

$\Rightarrow P_A + (9.81 \times 0.16) = P_B + (9.81 \times 0.18) + (13.6 \times 9.81 \times 0.32)$

$P_A \downarrow 200$

$P_B = 181.126$ kPa

(15)

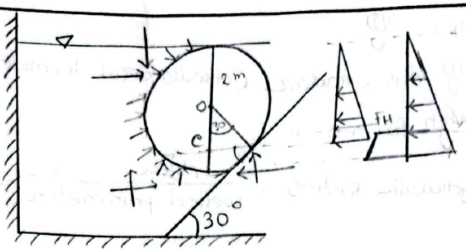


$P_C = P_D$

$\Rightarrow 274.68 + (9.81 \times (x+y)) = 137.34 - (9.81 \times y) + (13.6 \times 9.81 \times$

06-06-23

Ex-3

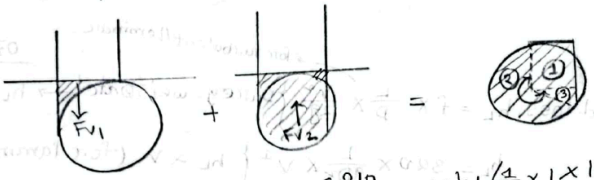


$\Phi = 4\,m$, F_H and $F_V = ?$

$OC = 2\cos 30^\circ = 1.732\,m$, $Cf = 2\sin 30^\circ = 1\,m$

$F_H = \gamma h_{cg} A_p = 9.81 \times \left(\frac{2+1.732}{2}\right) \times [(2+1.732) \times 1]$

$= 68.31\ kN$



$F_V = \gamma \times Vol^m = 9.81 \times \left[(2\times1) + \left\{\frac{210}{360} \times \pi \times 2^2\right\} + \left(\frac{1}{2} \times 1 \times 1.732\right)\right] \times 1$

↓ thickness

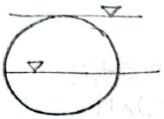
=

Reor $N_R = \frac{VD}{\nu}$

$N_R = \frac{VD}{\nu}$ for circular (circular-হলে diameter নিব)

$= \frac{V R_h}{\nu}$ for non-"

$R_h \rightarrow$ hydraulic radius $= \frac{\text{Area}}{\text{wetted perimeter}}$ (যেপার্টে পানি আছে)



R_h (full) $= \frac{\frac{\pi}{4}(D)^2}{2\pi r}$

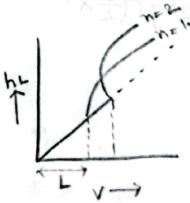
$= \frac{\pi r^2}{2\pi r} = \frac{r}{2} = \frac{D}{4}$

R_h (half) $= \frac{\frac{1}{2}\pi r^2}{\frac{1}{2} \times 2\pi r} = \frac{r}{2} = \frac{D}{4}$.

07-06-23

head loss, $h_L = f \times \frac{L}{D} \times \frac{V^2}{2g}$ } Darcy-weisbatel (for turbulent/Laminar) $\rightarrow h_L \propto V^n [n=2]$

$h_L = 32\nu \times \frac{L}{gD^2} \times V^1$ } $h_L \propto V$ (for laminar)



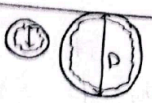
$f \times \frac{L}{D} \times \frac{V^2}{2g} = 32\nu \frac{L}{gD^2} \times V$ → for laminar

$\boxed{f = \frac{64}{N_R}}$ for laminar

$f = f\left(\frac{e}{D}, N_R\right)$



→ pipe এর imperfection/ (e or ε)
perturbation



$f = f\left(\frac{e}{D}, N_R\right)$ (N_R depends on V, D)

Example: $Q = 300\ l/s$

$\nu = 1.007 \times 10^{-6}\ m^2/s$

$D = 300\ mm = 0.3\ m$

$$V = \frac{Q}{A} = \frac{Q}{\frac{\pi}{4}(D)^2} = 4.244\ m/s$$

$$N_R = \frac{VD}{\nu} = \frac{4.244 \times 0.3}{1.007 \times 10^{-6}} = 1.264 \times 10^6 \longrightarrow \text{so flow is turbulent.}$$

FX: $\nu = 1.15 \times 10^{-6}\ m^2/s$

$D = 30mm = 0.03mm$

calculate largest flow rate for which laminar flow can be maintained?

$$N_R = \frac{VD}{\nu}$$

$$\Rightarrow 2000 = \frac{V \times 0.03}{1.15 \times 10^{-6}}$$

$$\therefore V = 0.0767\ m/s$$

$$Q = VA = \frac{\pi}{4} \times (0.03)^2 \times 0.0767 = 5.42 \times 10^{-5}\ m^3/s$$

smallest होगा, $N_R \rightarrow 0.01 / 0.1 / 1$

Ex: $\rho = 62.42\ lb/ft^3$

$\mu = 1.038 \times 10^{-3}$, $D = 0.010\ ft$, $L = 30\ ft$, $V = 3\ ft/s$

$h_L = ?$

$\nu = \frac{\mu}{\rho} =$

$Re / N_R = \frac{VD}{\nu} = \frac{3 \times 0.01}{\frac{\mu}{\rho}} = 1803 < 2000$ (Laminar)

(যেহেতু laminar তাই h_L এর যেকোনো formula use করা যাবে)

$f = \frac{64}{N_R} = \frac{64}{1803} = 0.0355$

$h_L = f \frac{L}{D} \times \frac{V^2}{2g}$

Fully turbulent এর ক্ষেত্রে f, $(\frac{e}{D})$ ratio এর উপর depend করে।

$h_L = ?$
$Q = ?$
$D = ?$
} এই ধরনের problem থাকবে।

Ex: (solve for h_L)

$h_L = ?$

$Q = 140\ l/s = 0.14\ m^3/s$

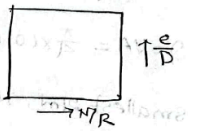
$\nu = 0.00001\ m^2/s$

$L = 400\ m$

$D = 200\ mm = 0.2\ m$

$e = 0.25\ mm$

Moody's diagram



$\frac{e}{D} = \frac{0.25}{200} = 0.00125$

$N_R = \frac{VD}{\nu} = 8.912 \times 10^4 \approx 9 \times 10^4$

$f = 0.028$ from Moody diagram.

$h_L = f \times \frac{L}{D} \times \frac{V^2}{2g} =$

Ex: (soln for Q)

$D = 300\ mm = 0.3\ m$

$L = 300\ m$

$h_L = 6\ m$

$e = 3\ mm$

$\nu = 1.13 \times 10^{-6}$

$Q = ?$

$Q = A \times V$

$h_L = f \times \frac{L}{D} \times \frac{V^2}{2g}$ [f depends on $\frac{e}{D}$, N_R]

Assume fully turbulent,

$\frac{e}{D} = \frac{3}{300} = 0.01$

assume, $f = 0.04$

Ex: (soln for D)

$h_L = 25m$

$\nu = 1.0 \times 10^{-5}\ m^2/s$

$e = 0.04\ mm$

$Q = 250\ l/s = 0.25\ m^3/s$

$L = 3000\ m$

$D = ?$

$\Rightarrow$

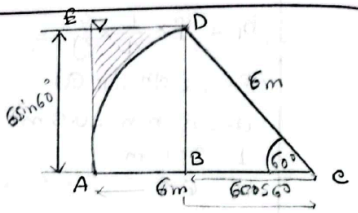
$Q = AV$

$h_L = f \times \frac{L}{D} \times \frac{V^2}{2g}$

① $F_H = \gamma h_G A_p$

$= 9.81 \times \frac{6\sin 60}{2} \times 6\sin 60^\circ \times 9$ t

$= 1191.915$ kN



$F_V = \gamma \times Vol^m = 9.81 \times \left[\frac{60}{360}\pi(6)^2 - \right.$

Vol^m,

ABD, $\frac{60}{360}\pi(6)^2 - \frac{1}{2} \times 6\cos 60^\circ \times 6\sin 60^\circ = 11.055$

AED = ABDE − ABD

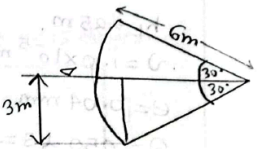
$= (6\sin 60 \times (6 - 6\cos 60)) - 11.055$

$= 4.53$

$F_V = \gamma \times AED = 9.81 \times 4.53 \times 9 = 400.26$ kN

② $F_H = \gamma h_G A_p$

$= 9.81 \times \frac{3}{2} \times 3 \times 0.5 = 22.07$ kN



$F_V = \gamma \times Vol^m$

$= 9.81 \times 1.63 \times 0.5 = 7.99$ kN

Area $= \frac{30}{360}\pi(6)^2 - \frac{1}{2} \times 3 \times \sqrt{6^2 - 3^2}$

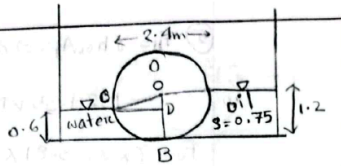
$= 1.63\ m^2$

$\theta = \tan^{-1}\left(\frac{F_V}{F_H}\right) = 19°55'$ with the horizontal.

③ P_H = (component of AB to left − component of CB to right)

$= \left[0.75\times0.81\times\frac{1.2}{2}\times1.2 - 9.81\times0.6\times\frac{0.6}{2}\right]$

$= 3.531$ kN to left

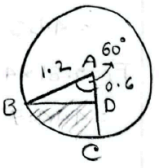


$R_V = \gamma \times V_{olm}$

Area of ABCD,

$\cos\angle BAD = \frac{0.6}{1.2}$

$\angle BAD = 60°$



Area BDC $= \frac{60}{360}\pi(1.2)^2 - \frac{1}{2}\times0.6\times\sqrt{(1.2)^2-(0.6)^2}$

$= 0.4422$

$= 4.338\ m^2$

$\therefore P_V = \gamma \times V = 4.338$ kN upward

$P_V = 0.75\times0.81\times\frac{1}{4}\pi(1.2)^2 + 9.81\times0.4422$

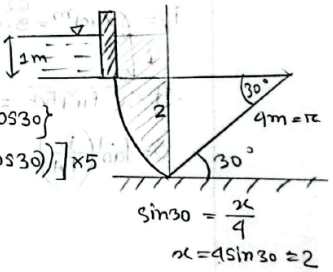
$= 12.659$ kN (UP)

Net downward force to hold the cylinder in place = (12.659 − 2) kN (weight)

$= 10.659$ kN (down)

④ $F_H = \gamma h_g A_p$

$= 9.81\times\left(1+\frac{2}{2}\right)\times2\times5 = 196.2$ kN



$F_V = \gamma \times V = 9.8\times\left[\left\{\frac{30}{360}\pi(4)^2 - \frac{1}{2}\times4\sin30\times4\cos30\right\} + (1\times(4-4\cos30))\right]\times5$

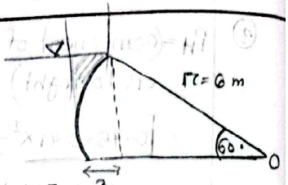
$= 61.83$

$F = \sqrt{F_H^2+F_V^2} = 205.713$ kN

$\theta = \tan^{-1}\left(\frac{F_V}{F_H}\right) = 17°29'$ with horizontal.

⑤ $F_H = \gamma h_G A_p = 9.81 \times \frac{6\sin 60}{2} \times 6\sin 60 \times 10$ ← length of gate

$= 1324.35\ kN$



$F_V = \gamma \times V = 9.81 \times V$

$A = (6\sin 60 \times 3) - \left[\frac{60}{360}\pi(6)^2 - \frac{1}{2} 6\sin 60 \times 6\cos 60\right]$

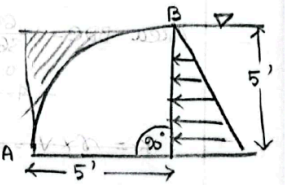
$= 4.53\ m^3$

$F_V = 9.81 \times 4.53 \times 10$

$= 444.7\ kN$

⑥ $F_H = \frac{62.4}{9.81} \times \frac{5}{2} \times 5 \times 8$ ← length

$= 6240\ lb$

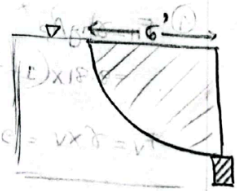


$F_V = \gamma \times V = 62.4 \times \left[5 \times 5 - \frac{90}{360}\pi(5)^2\right] \times 8$

$= 2678.23\ lb$

⑦ $F_H = \gamma h_G A_p = 62.4 \times \frac{6}{2} \times 6 \times 1 = 1123\ lb$

$F_V = \gamma \times Vol^m = \frac{62.4}{9.81} \times \frac{\pi}{4} \times (6)^2 \times 1 = 1769\ lb$



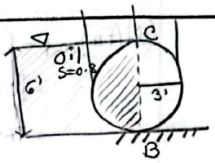
$\therefore F = \sqrt{F_H^2 + F_V^2} =$

$\theta = \tan^{-1}\left(\frac{F_V}{F_H}\right)$

⑧ $F_H = \gamma h_c A_p$

$= (0.8 \times 62.4) \times \frac{6}{2} \times (6 \times 5)$ ← L

$= 4493$ lb



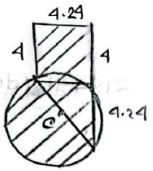
$F_V = \gamma \times V = (0.8 \times 62.4) \times \frac{\pi}{2} (3)^2 \times 5$

$= 3529$ lb (upward)

$W \rightarrow 5000$ lb

reaction at B $= (5000 - 3529)$ lb $= 1471$ lb (upward)

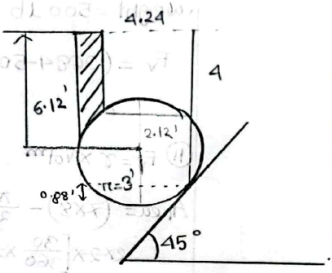
⑨ $F_V = \gamma \times V$



$A = (4.24 \times 4) + \frac{1}{2} \times 4.24 \times 4.24 + \frac{\pi}{2}(3)^2$

$= 40.0859$ ft²

$F_V = 62.4 \times A \times 1 = 2501.36$ lb



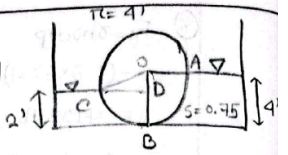
$F_H = 62.4 \times \left(6.12 + \frac{3 - 0.88}{2}\right) \times (3 - 0.88) \times 1$

$= 949.8$ lb

(10) $(F_H)_{net} = (F_H)_1 - (F_H)_2$ (1 ↑)

$= [0.750 \times 62.4 \times \frac{4}{2} \times 4 \times 3 - 62.4 \times 1 \times 2 \times 3]$

$= 748.8$ lb (left)



$(F_V)_{net} = {}^{0.750\times}_{\wedge} 62.4 \times \frac{\pi}{4} \times (4)^2 \times 3 + 62.4 \times 3 \times \left[\frac{60}{360} \times \pi 4^2 - \frac{1}{2} \times 2 \times 4 \cos 60 \overset{\sin}{}\right]$

$= 2684$ lb (up)

weight = 500 lb

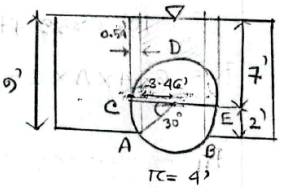
$F_V = (2684 - 500)$ lb $= 2184$ lb (down).

(11) $F_V = \gamma \times Vol^m$

Area $= (7 \times 8) - \frac{\pi}{2}(4)^2 - (0.54 \times 7) \times 2 -$

$2 \times 2 \times \left[\frac{30}{360} \times \pi \times (4)^2 - \frac{1}{2} \times 3.46 \times 2\right]$

$= 21.849$ ft²

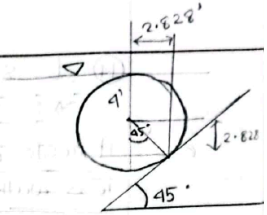


$F_V = 62.4 \times A \times 3 = 4090.26$ lb

~~$F_H = \gamma h_G \times A = 62.4 \times (3 + \frac{8}{2}) \times (3 + \frac{4}{2}) \times 3 = 4680$ lb~~ 7488 lb

$F_H = 0$ lb

(12)



$F_H = \gamma h_{cg} A_p$

$= 9 \times 62.4 \times \left(\frac{4+2.828}{2}\right) \times (4+2.828) \times 5$

$= 7273 \text{ lb}$

$F_V = \gamma \times \text{Volm}$

$= 62.4 \times V \quad \cdots (i)$



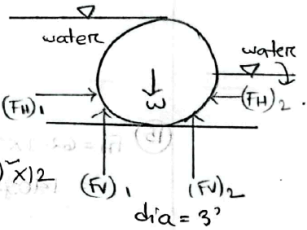
$\text{Area} = (2.828 \times 4) + \frac{1}{2} \times 2.828 \times 2.828 + \frac{225}{360}° \times \pi (4)^2$

$= 46.726 \text{ ft}^2$

$(i) \Rightarrow$

$F_V = 62.4 \times A \times 5 = 14579 \text{ lb}.$

(13)



$(F_H)_{net} = (F_H)_1 - (F_H)_2$

$= 62.4 \times \frac{3}{2} \times 3 \times 12 - 62.4 \times \frac{1.5}{2} \times 1.5 \times 12$

$= 2527.2 \text{ lb} \quad (\quad)$

$(F_V)_{net} = 62.4 \times \frac{\pi}{2} \times (1.5)^2 \times 12 + 62.4 \times \frac{\pi}{4} \times (1.5)^2 \times 12$

$= 3969.7 \text{ lb}$

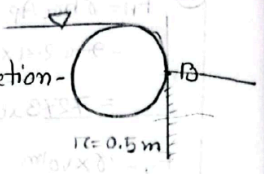
$W \rightarrow 842 \text{ lb}$

$F_V = 3969.7 - 842 = 3127.7 \text{ lb} \quad (\quad)$

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(14) $t = 8\ m$

$s = ?$



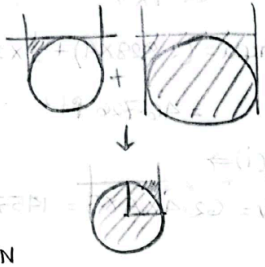
it rests in static equilibrium against a friction-less wall at pt B.

Soln:

$F_H = \gamma h_G A_P = 9.81 \times$

$F_V = \gamma \times Vol^m = 9.81 \times 8 \times \pi \times (0.5)^2$

$= 61.512\ kN$



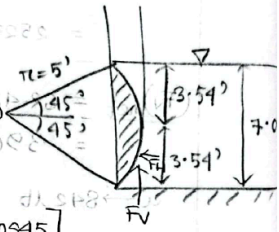
$Area = \frac{270}{360}\pi(0.5)^2 + (0.5 \times 0.5)$

$= 0.839\ m^2$

$\therefore F_V = 9.81 \times 8 \times 0.839 = 65.85\ kN$

(15) $F_H = 62.4 \times 3.534 \times 7.07 \times 9$ ← width

$= 14075\ lb.$

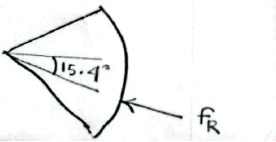


$F_V = \gamma \times Vol^m$

$= 62.4 \times 9 \times \left[\frac{90}{360}\pi(5)^2 - \frac{1}{2} \times 7.07 \times 5\cos 45\right]$

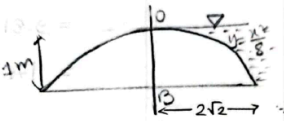
$= 4008\ lb$

$F_{resultant} = \sqrt{F_H^2 + F_V^2} = 14015.3\ lb$ passes through pt O at an angle $\theta = \tan^{-1}\frac{F_V}{F_H} = 15.9°$.



(16) $F_H = \gamma h_{CG} A = 9.20 \times \frac{1}{2} \times (1) \times 4.5 = 20.70\,kN$

~~$9.20 \times = 0$ kN~~



$L = 4.5\,m$

$\gamma = 9.20\,kN/m^3$

$F_V = 9.20 \times Vol\,m$

$= 9.20 \times Area \times 4.5$

$Area = (2\sqrt{2} \times 1) - \frac{2}{3}(2\sqrt{2}) \times 1$ / $\Box, \frac{1}{3} \times bh$

$= 0.9428\,m^2$ / $= \frac{1}{3} \times \sqrt{8} \times 1$

$\therefore F_V = 39.03\,kN$

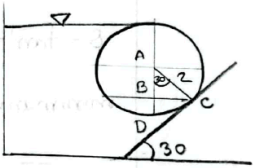
$y = \frac{x^2}{8}$

$y = 1, x = 2$

$x = 2\sqrt{2}$

(17) $\sin 30 = \frac{BC}{2}$

$\therefore BC = 1\,m$



$r = 2\,m$

$AB = \sqrt{2^2 - 1^2} = 1.732\,m$

$F_H = \gamma h_{CG} A_P = 9.81 \times \left(\frac{2+1.732}{2}\right) \times (2 \times 1.732) \times 1$

$= 68.2\,kN$ (right)



$F_V = \gamma \times Vol\,m$

$A = (1 \times 2) + \frac{1}{2} \times 1 \times 1.732 + \frac{210}{360} \pi (2)^2$

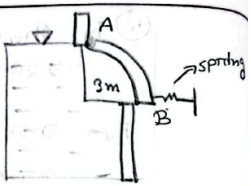
$= 10.19\,m^2$

$F_V = 100.03\,kN$ (UP)

(18) $F_H = \gamma h_G A_p$ → width

$= 9.81 \times \frac{3}{2} \times (3) \times 4$

$= 176.58\ kN$



$F_V = \gamma \times Vol^m$

$Area = (3\times3) - \frac{\pi}{4}(3)^2$

$= 1.93\ m^2$



$\therefore F_V = 9.81 \times 1.93 \times 4 = 75.79\ kN$

$F_R = \sqrt{F_H^2 + F_V^2} = 192.157\ KN$

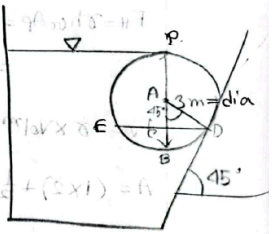
$\theta = \tan^{-1}\frac{F_V}{F_H} = 23.2^\circ$

minimum spring force = ?

(19) ΔACD, $\sin 45^\circ = \frac{CD}{1.5}$

$\Rightarrow CD = 1.06\ m$

$AC = 1.06\ m$



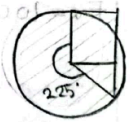
$PC = (1.5 + 1.06) = 2.56\ m$

$F_H = \gamma h_G A_p = 9.81 \times \frac{2.56}{2} \times 2.56 \times 10$

$= 321.454$

$Area = (1.06 \times 1.5) + \frac{1}{2} \times 1.06 \times 1.06 + \frac{225}{360}\pi(1.5)^2$

$= 6.57\ m^2$



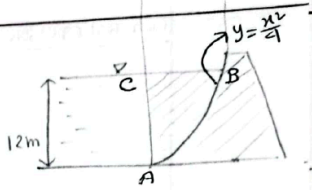
$F_V = 9.81 \times A \times 10 = 644.484\ KN$

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(20) $F_H = \gamma h_G A_P$

$= 9.81 \times \frac{12}{2} \times 12$

$= 706.32\ kN$



$F_V = \gamma \times Vol^m$

$AB = \frac{12}{12} m$, $BC = x$

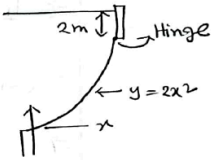
$y = \frac{x^2}{4}$

$\Rightarrow x = \sqrt{4y} = \sqrt{4 \times 12} = 4\sqrt{3}\ m$

Area of $ABC = \frac{2}{3} bh = 32\sqrt{3}\ m^2$

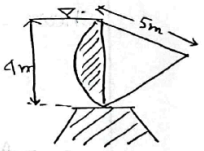
$F_V = 9.81 \times Area \times 1 = 543.725\ kN$

(21)



(22) $F_H = \gamma h_G A_P = 9.81 \times \frac{4}{2} \times 4 \times 1$

$= 78.48\ kN$



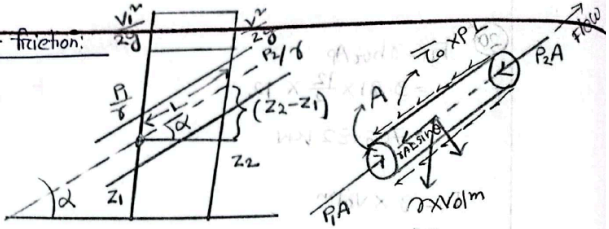
$F_V = \gamma \times Vol^m = 9.81 \times \left[\frac{2 \times 23.578}{360} \pi (5)^2 - \frac{1}{2} \times 4 \times 5 \cos 23.578\right]$

$= 11.01\ kN$



$\theta = 23.578°$

General eqn for conduit friction:



Steady $\longrightarrow a = 0$

$\Sigma F = ma = 0$

x-cross section, constant, $V = 0$

$\Rightarrow (P_1A - P_2A) - \gamma AL\sin\alpha - \tau_0 PL = 0$ —(i)

$\sin\alpha = \frac{z_2 - z_1}{L}$

(i) $\Rightarrow$

$$\frac{P_1A - P_2A}{\gamma A} - L \cdot \frac{z_2 - z_1}{L} = \frac{\tau_0 PL}{\gamma A}$$ [Divided by γA]

$$\Rightarrow \frac{P_1 - P_2}{\gamma} - z_2 + z_1 = \frac{\tau_0 PL}{\gamma A}$$

$$\Rightarrow \left(z_1 + \frac{P_1}{\gamma}\right) - \left(z_2 + \frac{P_2}{\gamma}\right) = \frac{\tau_0 L}{\gamma (A/P)}$$

$$\Rightarrow h_L = \frac{\tau_0 L}{\gamma R_h}$$ [R_h = hydraulic radius]

$$\boxed{\tau_0 = \frac{\gamma h_L R_h}{L}}$$

$H_1 = H_2 + h_L$

$\Rightarrow \left(z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g}\right) - \left(z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g}\right) = h_L$

Shear stress depend করে $\longrightarrow$

$$\tau_0 = f(R_h, \rho, \mu, V)$$

$$\Rightarrow \tau_0 = k \cdot R_h^a \cdot \rho^b \cdot \mu^c \cdot V^n$$

$R_h = \frac{A}{P} = \frac{L^2}{L} = L$

$V = LT^{-1}$

$\rho = FT^2L^{-4}$

$\mu = FTL^{-2}$

$\tau_0 = FL^{-2}$

$\tau_0 = k \cdot L^a \cdot (FT^2L^{-4})^b \cdot (FTL^{-2})^c \cdot (LT^{-1})^n$

$(FL^{-2})^1 = kL^a (FT^2L^{-4})^b \cdot (FTL^{-2})^c \cdot (LT^{-1})^n$

F: $1 = b+c$

L: $-2 = a-4b-2c+n$

T: $0 = 2b+c-n$

} Equiting exponents

$a = n-2, \quad b = n-1, \quad c = 2-n$

$\tau_0 = k (R_h)^{n-2} \cdot \rho^{n+1} \cdot \mu^{2-n} \cdot V^n$

$= k (R_h)^{n-2} \cdot (\rho)^{n+1} \cdot (\mu)^{-(n-2)} \cdot V^n$

$= 2k \left(\frac{R_h \rho V}{\mu}\right)^{n-2} \times \frac{1}{2} \rho V^2$

$= (2k \times N_R^{n-2}) \times \frac{1}{2} \rho V^2 = C_f \times \frac{1}{2} \rho V^2$

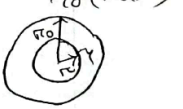
$= \frac{\gamma h_L R_h}{L}$

$\nu = \frac{\mu}{\rho}$

$N_R = \frac{VD}{\nu} = \frac{VR_h}{\nu}$

$$\boxed{h_L = f \frac{L}{D} \frac{V^2}{2g}}$$

Show that sheare stress varries lineardy with radius :



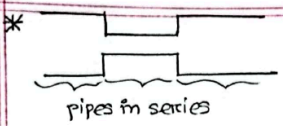
$h_L = \frac{\tau_0 L}{\gamma R_h} = \frac{\tau_0 \times 2L}{\gamma \times r_0}$

$\Rightarrow \tau_0 = \frac{\gamma h}{2L} \times r_0$

$\Rightarrow \tau_0 = \frac{\gamma h_L}{2L} \times r_0$

$\Rightarrow \tau = \frac{\gamma h_L}{2L} \times r$

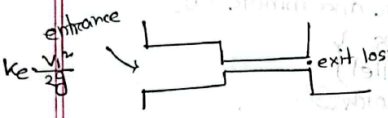
$$\boxed{\frac{\tau}{\tau_0} = \frac{r}{r_0}}$$



pipes in series

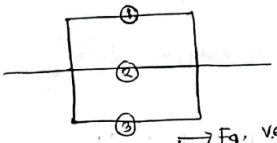
$h_L = f \cdot \frac{l}{D} \cdot \frac{v^2}{2g}$

Assumption: Flow (Q) is continuous



[exit का ke normally 1 होता
entrance " " 0.5 "]

Pipes in parallel



Assumption: $h_{L1} = h_{L2} = h_{L3}$

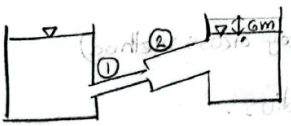
two methods → Eq. velocity method
→ Equivalent length method.

$Q_1 = Q_2$

$\Rightarrow A_1 v_1 = A_2 v_2$

$\Rightarrow \frac{\pi}{4} D_1^2 \times v_1 = \frac{\pi}{4} D_2^2 \times v_2$

$\boxed{v_2 = \left(\frac{D_1}{D_2}\right)^2 v_1}$ → eq. velocity method.



$z_1 + \frac{p_1}{\gamma} + \frac{v_1^2}{2g} = z_2 + \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + h_L$

$\# h_L = 6m$

$h_L = \underbrace{0.5 \times \frac{v_1^2}{2g}}_{\text{Major loss}} + \underbrace{f_1 \frac{l_1}{D_1} \cdot \frac{v_1^2}{2g}}_{\text{Minor}} + 1 \cdot \frac{(v_1 - v_2)^2}{2g} + f_2 \frac{L_2}{D_2} \frac{v_2^2}{2g} + 1 \cdot \frac{v_2^2}{2g}$

$$V_2 = \left(\frac{D_1}{D_2}\right)^n V_1$$

final

* viscosity ✓*
  surface Tension } একসাথে 1টা আসবে
  capilarity
* Manometer ✓
  plane surface ✓
  Inclined ✓
  curved ✓

h_1, Q, D ✓
Major and minor loss
series }
parallel }
Network ✓

Theory

i) viscosity (ছোট derivation / derivation)
ii) S.T → derivation
iii) surface tension → defn + characteristics + derivation
iv) capilarity derivation আসবে না
v) Pascal's law, (derivation)
   $F = \gamma h_{cg} A$ → inclined
   F_H and F_V → curved
vi) D-W }
    H-P } derivation
    H-C → Network এর জন্য (hardy cross method)
vii) Shear stress varies with radius.
viii) major and minor loss defn.

compulsory:

CO-PO

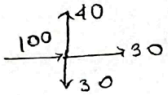
CO1 → properties + static

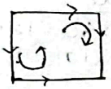
5 → Pipe

pipe network ★ (আজকের) 21-06-23

conditions

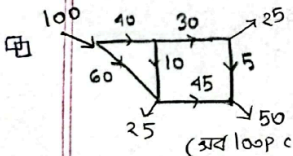
1) Σ In flow = Σ outflow, at any junction.



ii)  h_L(clockwise) = h_L(counter clockwise)

$$h_L = f\cdot\frac{L}{D}\cdot\frac{V^2}{2g} = f\cdot\frac{L}{D}\cdot\left(\frac{4Q}{\pi D^2}\right)^2\times\frac{1}{2g} = \underbrace{\left(f\cdot\frac{L}{D^5}\cdot\frac{8}{\pi^2 g}\right)}_{k}Q^2$$

$$\boxed{h_L = kQ^n} \quad [n=2]$$



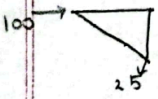
(সব loop close হবে)

[correction করব loopwise]

Q_0 → initial

$Q = Q_0 + \Delta Q$ → (+/−)

loop-1



$$\Sigma h_L = \Sigma kQ^n = \Sigma k(Q_0+\Delta Q)^n = \Sigma k\left(Q_0^n + nQ_0^{n-1}\Delta Q + \frac{n(n-1)}{2!}Q_0^{n-2}\Delta Q^2 + \dots\right)$$

(small value → 0)

$$\Sigma h_L = \Sigma kQ_0^n + \Sigma knQ^{n-1}\Delta Q$$ [main target $h_L = 0$ করানো]

$$\Rightarrow 0 = \text{''}$$

$$\Rightarrow \boxed{\Delta Q = \frac{-\Sigma kQ_0^n}{|\Sigma knQ_0^{n-1}|}} \quad \text{(correction)}$$

CamScanner

Steps :

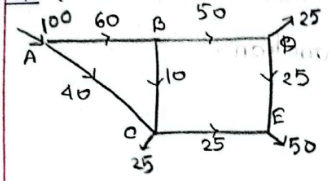
i) Initial assumption

ii) Correction বের করব

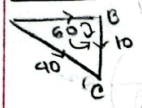
iii) " যোগ-বিয়োগ করব

iv)

Ex (Hanzini)

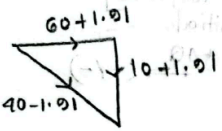


loop-1



	kQ^n	knQ^{n-1}	knQ^{n-1}
AB →	$1\times60^2=3600$		$1\times2\times60=120$
BC →	$4\times10^2=400$		$4\times2\times10=80$
	4000 ↻		
AC →	$3\times40^2=4800$ ↺		$3\times2\times40=240$
	800 ↺		440

$\Delta Q = \frac{800\circlearrowleft}{440} = 1.91\ \circlearrowleft$ → Add to clockwise



Ex :

