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دفتر

فلويد

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* محاضرة رقم (1)

ch 2 properties of Fluids
خصائص

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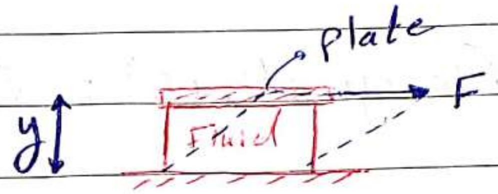
def

Fluid: Is a substance whose molecules move freely pust each other, or it's a substance that deforms continuously when subjected to shear stress



Fluid
- liquids: take the shape of the containar. وعاء
- Gases: expand to fill a closed containar. بتنتشر

2.1 properties involving mass and weight

1. Density (ρ): mass per unit volume

$$\rho = \frac{mass}{volume} = \frac{Kg}{m^3}$$

$$\rho_{water}\Big|_{4c^\circ} = 100\ Kg/m^3$$

$$\rho_{Air}\Big|_{4c^\circ} = 1.27\ kg/m^3$$

2- specific weight (γ): The weight per unit volume

$$\gamma = \rho g$$

g: accelerating gravity = 9.8 m/s^2

ρ: density

$$= \frac{kg}{m^3} \cdot \frac{m}{s^2} \; N$$

$$= \frac{N}{m^3}$$

3- specific gravity (S): SG

The ratio of the specific weight of a given fluid to the specific weight of water at the standard temp 4°C.

$$S = \frac{\gamma_{fluid}}{\gamma_{water}} = \frac{\rho_{fluid} * g}{\rho_{water} * g} = \frac{\rho_{fluid}}{\rho_{water}}$$ unitless

4- specific volume (v): $v = \frac{volume}{mass} = \frac{1}{\rho}$ $\frac{m^3}{kg}$

2.2 Ideal gas law

$$P\forall = n R_u T$$

P: absolute pressure

$\forall$: volume m^3

R_u: universal gas const. $= 8.314\ KJ/Kmol.K$

n: # of moles

T: absolute Temp (K)

$$P = \underbrace{\frac{nM}{\forall}}_{\rho} \left(\frac{R_u}{M}\right) T$$

$\frac{R_u}{M}$ → gas const (R)

M → moleculer weight

$$P = \rho R T \qquad P\forall = m R T$$

m → mass

2.3 Properties involving thermal energy

1- Specific Heat (C) :- The amount of thermal energy that must be transfered to a unit mass of a substance to raise its temprature by one degree. $C_{water} = 4.186\ KJ/Kg.°C$ or $KJ/Kg.K$

C_P: specific heat at const pressure

C_V:- " " ratio $\Rightarrow K = \frac{C_P}{C_V}$

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محاضرة ح (2)

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2- Internal energy (U) or specific energy (u)

↳ expressed of the molcular activity in the substance:

U: J

u: J/kg

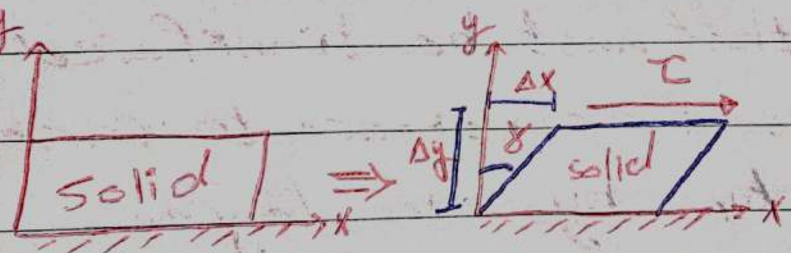
2- Enthalpy (h)

$h = u + Pv$ → specific volume

or $h = u + \frac{P}{\rho}$

~~[illegible]~~ * u and h as function of temp

2.4 Viscosity (μ) :- absolute viscosity or dynamic viscosity is a measure of a fluids resistance to deformation under shear stress.

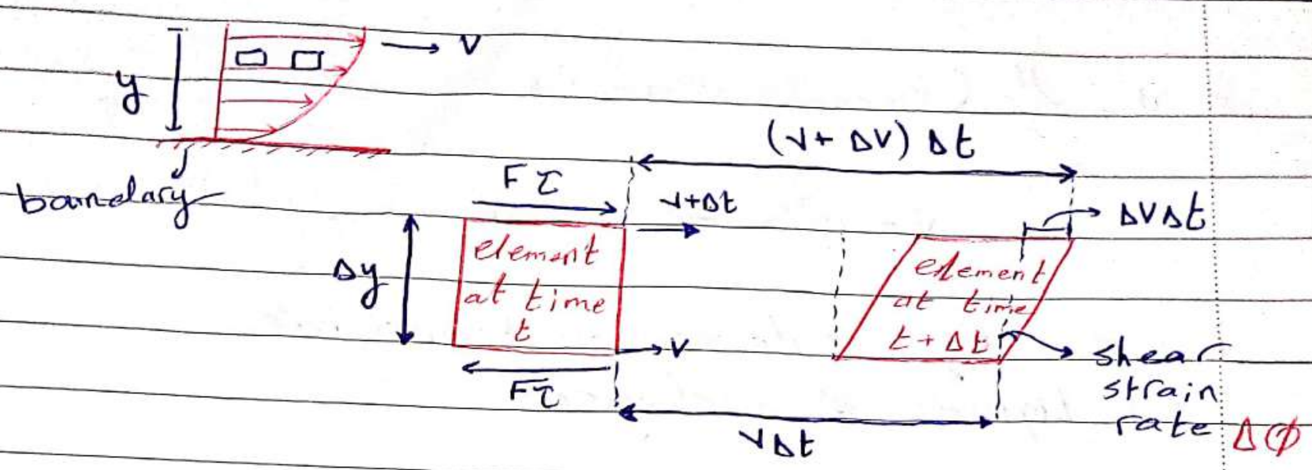


γ: shear strain

$\tau \propto \gamma$

shear stress ← $\tau = G\gamma$ → shear strain

G: modulus of rigidity



$\tau \propto \Delta\phi$

$$\tau = \mu . \Delta\phi$$

Shear strain rate

$$\Delta\phi = \frac{\Delta v . \Delta t}{\Delta y}$$

$$\frac{\Delta\phi}{\Delta t} = \frac{\Delta v}{\Delta y}$$

$$\phi = \frac{dv}{dy} \Rightarrow \boxed{\tau = \mu \frac{dv}{dy}}$$

$\frac{dv}{dy}$: velocity gradient

* The velocity of the fluid is zero at the boundary (No - slip condition) and Maximum shear stress.

unit $\tau = \mu \frac{dv}{dy} \Rightarrow \mu = \frac{\tau}{dv/dy}$

$$\mu = \frac{N/m^2}{\frac{m}{s} \cdot \frac{1}{m}} = \frac{N.S}{m^2}$$

* other unit for viscosity
$\Rightarrow$ 1 poise $\rightarrow 0.1 \frac{N.S}{m^2}$

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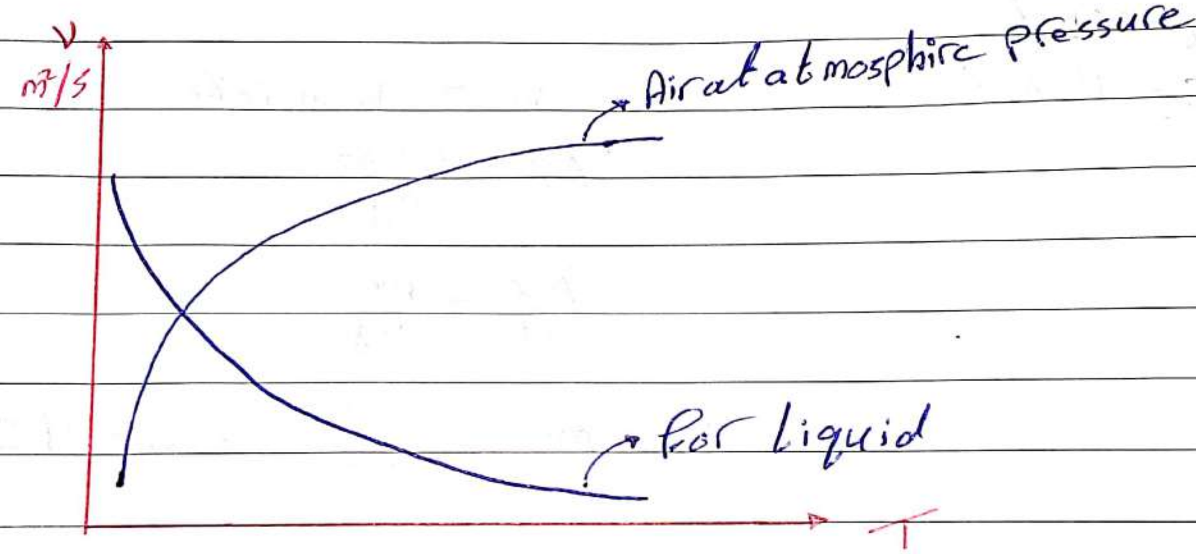
* $\nu = \frac{\mu}{\rho}$ (kinematic viscosity) $\frac{N \cdot s}{m^2} \cdot \frac{m^3}{kg}$

$\nu = m^2/s \Rightarrow cm^2/s \rightarrow 1$ stoke

* Viscosity is depend on temperature for liquids & and gases.



* for liquid $\mu = Ce^{b/T}$ wher C, b are constant.
T: Temperature in kelvin
* $T_K = T_{C} + 273$

* for gases (Sutherlands equation)

$$\frac{\mu}{\mu_0} = \left(\frac{T}{T_0}\right)^{3/2} \cdot \frac{T_0 + S}{T + S}$$

μ_0: viscosity at Temp T_0 kelvin

S: Sutherlands constant (table A.2)

محاضرة (3)
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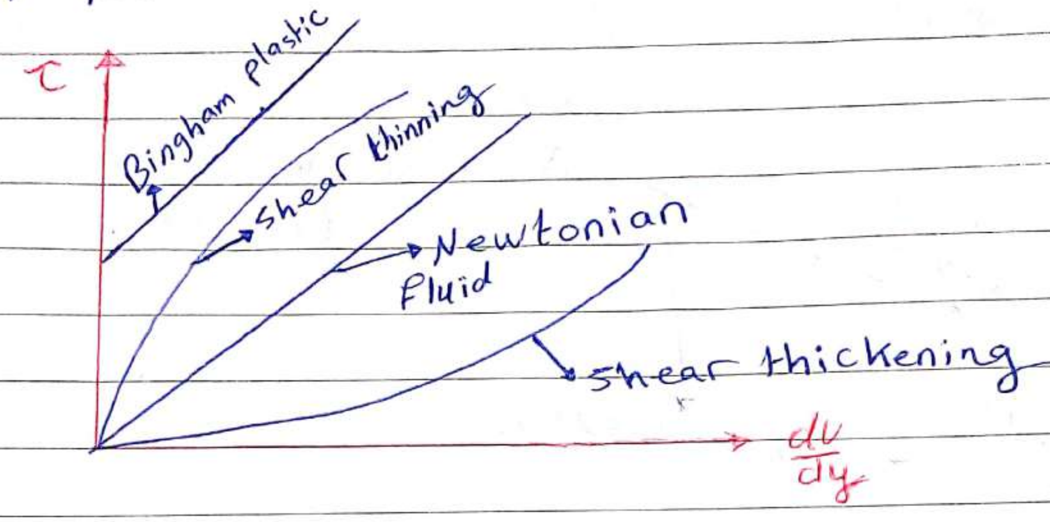
* Newtonian versus non-Newtonian Fluids.
مقابل

↳ Fluids for which the shear stress is directly proportinal to the rate of strain.



Ex2.2 Find the viscosity of water at 30°C if the viscosity of water at 20°C,

$\mu|_{20°} = 1.0 \times 10^{-3} \frac{N.s}{m^2}$ (Pa.s), $\mu|_{40°} = 6.53 \times 10^{-4}$ N.s/m²

Sol $\mu = c e^{b/T}$

$\ln \mu = \ln (c e^{b/T})$

$\ln \mu = \ln c + \ln e^{b/T}$

* $\ln \mu = \ln c + b/T$

at 20°C $\Rightarrow -6.908 = \ln c + 0.00341 b$ --(1)

at 40°C $\Rightarrow -7.334 = \ln c + 0.00319 b$ —(2)

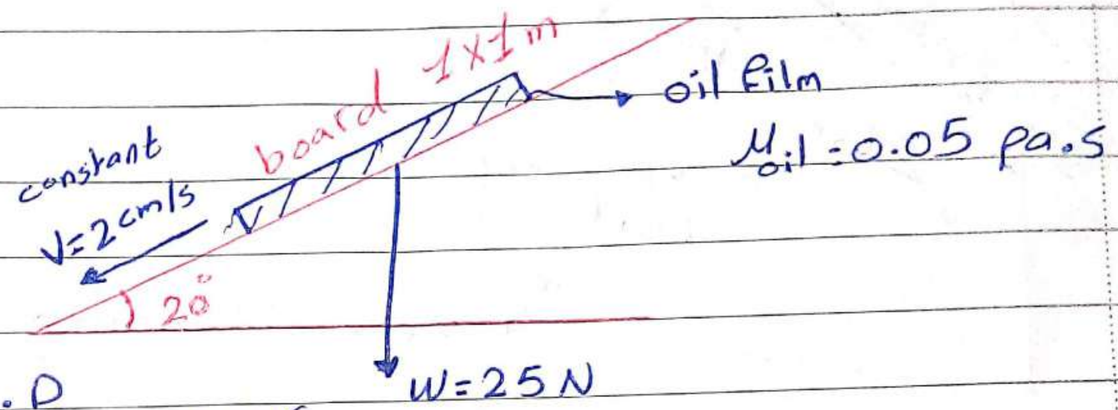
$c = 1.357 \times 10^{-6}$, $b = 1936$

$$\rightarrow \mu = 1.357 * 10^{-6} * e^{1936/(273+30)}$$

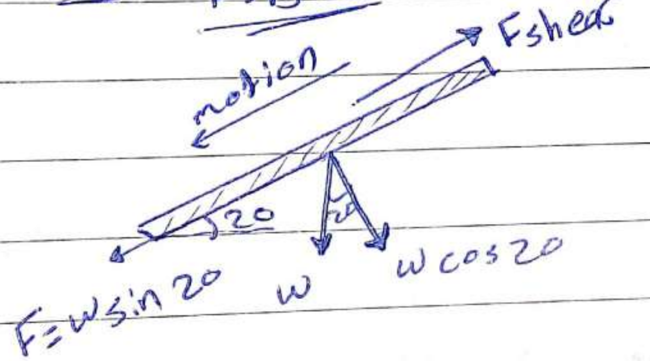
$$\mu = 8.08 * 10^{-4} \ pa.s$$

Ex 2.3 Find the film thickness of oil.

dy ?!



sol F.B.D



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

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

$$\Sigma F = \overset{zero}{ma}$$

$$W \sin 20 - F_{shear} = 0$$

$$W \sin 20 - \tau A = 0$$

$$W \sin 20 - \mu \frac{v}{y} * A = 0$$

$$y = \frac{0.05 * 2 * 10^{-2} * 1 * 1}{25 \sin 20} = 0.000117 m \text{ or } 0.117 mm$$

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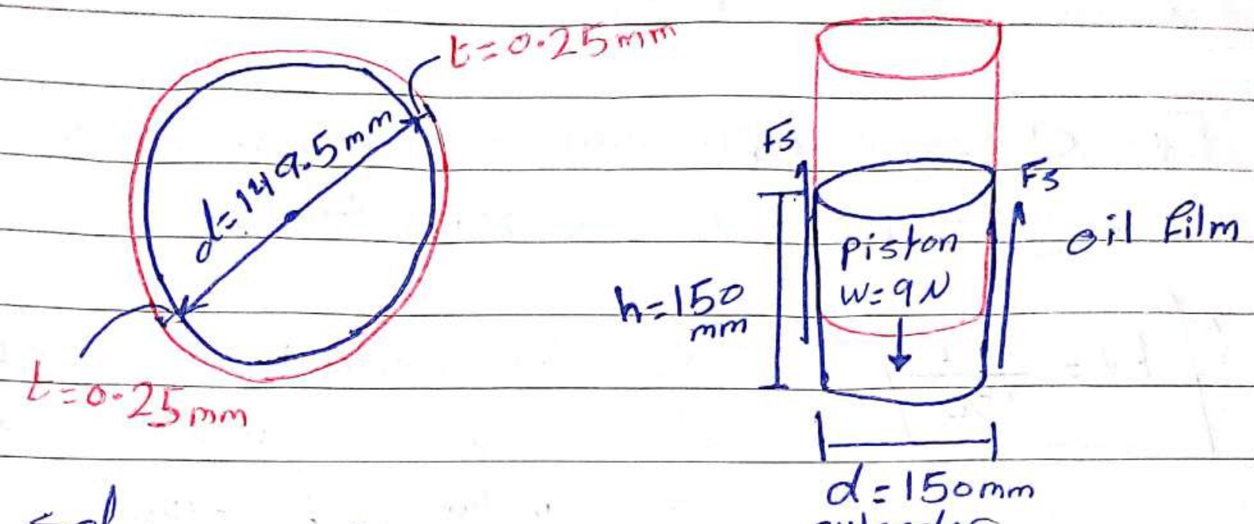
Ex The piston with weight 9N fall at constant $V = 46\ mm/s$, find the viscosity of the oil?



Sol

$+\uparrow \sum F = m\underbrace{a}_{zero}$

$F_s - W = 0$

$\tau * A - W = 0$

$\mu \cdot \frac{V}{y} * A - W = 0$

المساحة الجانبية للاسطوانة* $= 2\pi r L$

$= \pi d L$

$$\mu = \frac{W \cdot y}{V \cdot A} = \frac{9 * 0.25 * 10^{-3}}{46 * 10^{-3} * \pi * 149.5 * 10^{-3} * 150 * 10^{-3}}$$

$\mu = 0.694\ N.s/m^2$

* first exam → 27/2/2019 11-12 wednesday

* second exam → 25/3/2019 11-12 Monday

محاضرة رقم (4)
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2.5 Bulk Modulus of elasticity ~~compressibility~~ (compersssibilty)

E_v: changes in pressure to changes in volume e.g' (expansion & contraction)
التوسع الانكماش

إشارة السالب لأن الضغط يسبب تناقص بالحجم.

$$\boxed{E_v = \frac{-dP}{d\forall/\forall}}$$

dp:- differential pressure change
$d\forall$: " volume "
$\forall$: volume of fluid

$M = \rho\forall$

mass

$dM = 0$

$dM = \rho\, d\forall + \forall\, d\rho = 0$ *الكتلة لا تتغير

$$\boxed{\rho\, d\forall = -\forall\, d\rho} \rightarrow \frac{d\rho}{\rho} = \frac{-d\forall}{\forall}, \quad E_v = \frac{dP}{d\rho/\rho} \quad \frac{N}{m^2} = Pa$$

* for water 1 Mpa in pressure to change 0.05% in volume.

* for ideal gas at constant temp

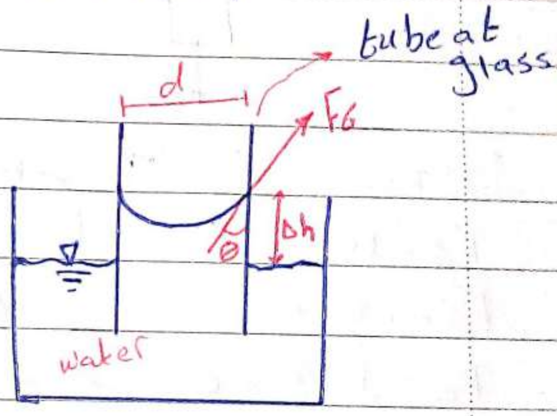
$$P = \rho RT \Rightarrow \frac{dP}{d\rho} = RT$$

$$E_v = \rho \frac{dP}{d\rho} \Rightarrow E_v = \rho RT \Longrightarrow E_v = P$$

* For adiabatic process $E_v = kP$

2.6 Surface tension (σ) (التوتر السطحي)

↳ The effect of surface tension is illustrated for the case of capillary action.



تماسك

* Cohesive forces :-

↳ Forces between like molecules.

تلاصق

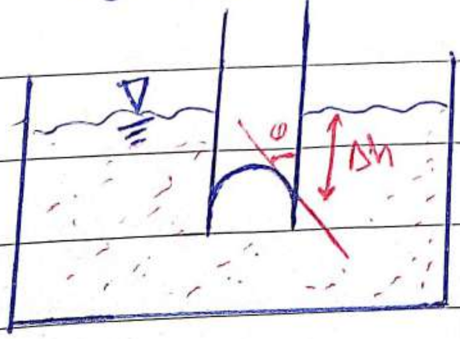
* Adhesive forces :-

↳ Forces between unlike molecules such as water & glass.

θ : constant angle

$\theta_{water} = \text{zero}$

$F_\sigma = \sigma L$



σ: surface tension coefficient

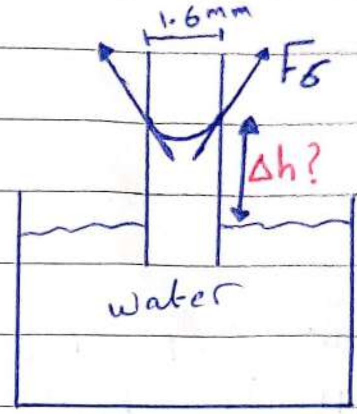
L: The length over which the surface tension acts. تمثل محيط الأنبوب

* $\sigma_{water} = 0.073$ N/m at room temp. ↳ Table A.5

* Unit $\sigma = \frac{F}{L}$ $\left\{\frac{N}{m}\right\}$

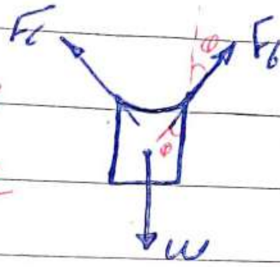
EX What the height above the reservoir level will water 20°C rise in glass tube, if inside diameter of tube is 1.6 mm ??

خزان



Sol

F.B.D



* عند التحليل نتعامل مع قوة واحدة فقط

$\Sigma F = 0$

$F_\sigma \cos\phi - w = 0$

$F_\sigma - w = 0$

γ: specific weight

$\uparrow \Sigma F = 0$

$F_\sigma - W = 0$

$F_\sigma - mg = 0$

$F_\sigma - \rho V g = 0$

الحجم

$$F_\sigma - \rho \frac{\pi}{4} d^2 \Delta h \, g = 0$$

$$\sigma L - \gamma \frac{\pi}{4} d^2 \Delta h = 0$$

$$\sigma \pi d = \gamma \frac{\pi}{4} d^2 \Delta h$$

$$* \ \Delta h = \frac{4\sigma}{\gamma d} \cos\phi$$

$$\Delta h = \frac{4 * 0.073}{9790 * 1.6 * 10^{-3}} = 18.6 * 10^{-3} \, m = 18.6 \, mm$$

$\sigma_{water} = 0.073 \, N/m$

$\gamma|_{20°C} = 9790 \, N/m^3$

→ From Table A.5

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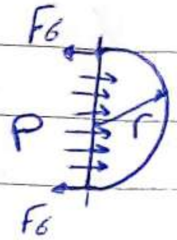
* Surface tension forces for several different cases.

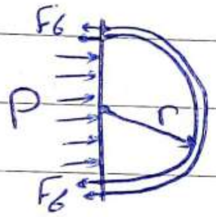
a) spherical droplet

$$\boxed{P = \frac{2\sigma}{r}}$$



b) spherical bubble

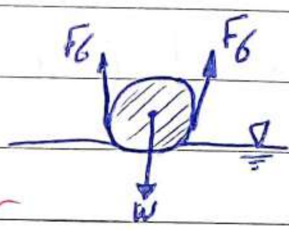
$$\boxed{P = \frac{4\sigma}{r}}$$



c) cylinder supported by surface tension

$W = 2F_\sigma$

$\boxed{W = 2\sigma L}$ → length of cylinder



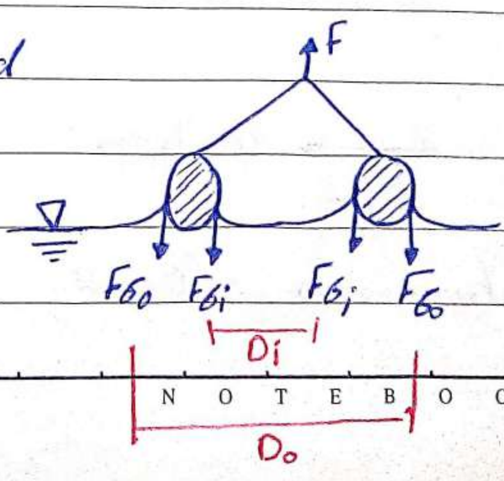
d) Ring pulled out of liquid

(liquid wet the ring)

* يهمل الوزن

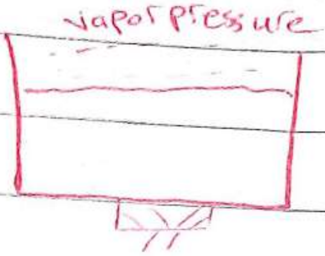
$F_\sigma = F_{\sigma i} + F_{\sigma o}$

$\boxed{F_\sigma = \pi\sigma(D_i + D_o)}$



N O T E B O O K

2.7 Vapor pressure



The pressure which a liquid will vaporize or boil, at give temp.

CH.3 Fluid statics.

↳ pressure : normal force exerted by a fluid per unit area.

$P = \frac{F}{A} = \frac{N}{m^2}$ (pa), other units [bar, mmHg, atm, Torr, kgf/cm^2, Ibf/in^2 (psi)]

→ P_{atm} = 101.3 kpa
sea level

→ 1 bar = → 100 kpa

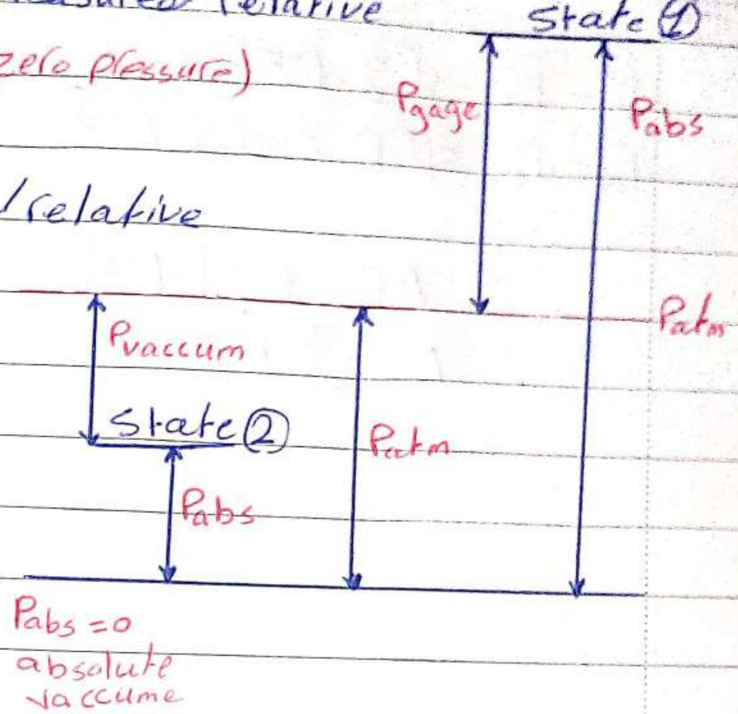
→ 1 atm → 760 mmHg

N O T E B O O K

* Absolute Pressure : it is measured relative to absolute vaccum (zero pressure)

* Gage pressure : measured relative to local atmospheric pressure.

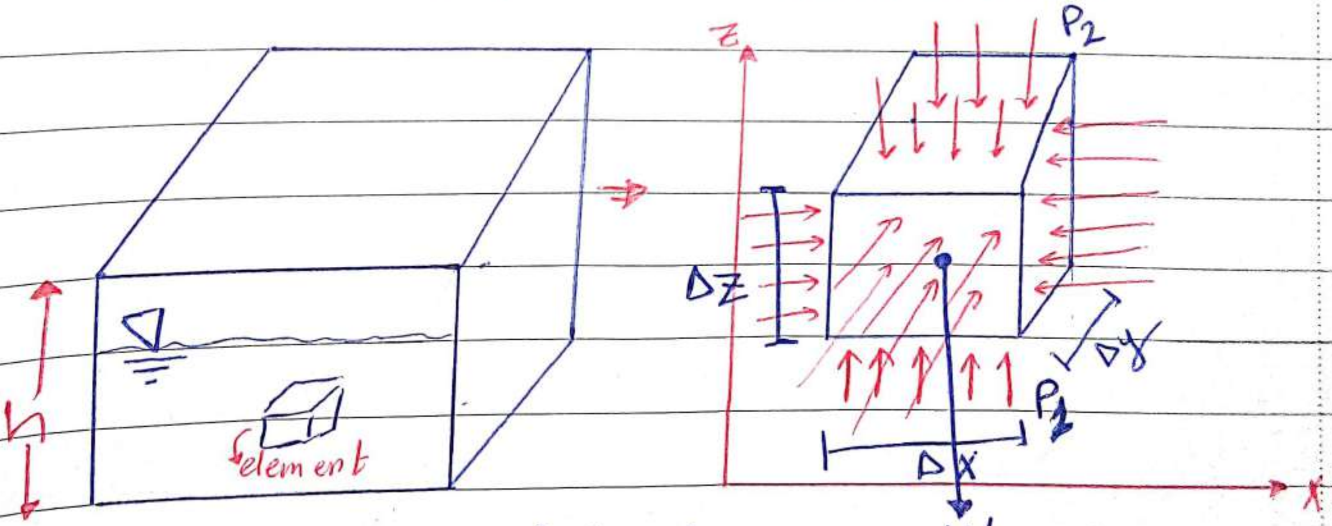
* Vaccum pressure : pressure less than atmospheric.



$$\boxed{P_{gage} = P_{abs} - P_{atm}}$$

$$\boxed{P_{vaccum} = P_{atm} - P_{abs}}$$

* Variation of pressure with elevation



$$W = mg = \rho \forall g$$

$$\uparrow \sum F_z = 0 \Rightarrow P_1 \cdot A - P_2 A - W = 0$$

$$P_1 \Delta x \cdot \Delta y - P_2 \Delta x \cdot \Delta y - \rho \forall g = 0$$

$$P_1 \Delta x \cdot \Delta y - P_2 \Delta x \cdot \Delta y - \rho \Delta x \cdot \Delta y \cdot \Delta z\, g = 0$$

$\Rightarrow$

$$P_1 - P_2 - \rho g . \Delta Z = 0$$

$$P_2 - P_1 = \boxed{\Delta P = -\rho g \Delta Z}$$

$$\Delta P = \rho g |-\Delta Z|$$

$$\boxed{\Delta P = \gamma \Delta Z}$$

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$\Rightarrow$

$$P_1 - P_2 - \rho g \cdot \Delta Z = 0$$

$$P_2 - P_1 = \boxed{\Delta P = -\rho g \Delta Z}$$

$$\Delta P = \rho g |-\Delta Z|$$

$$\boxed{\Delta P = \gamma \Delta Z}$$

محاضرة رقم (6)

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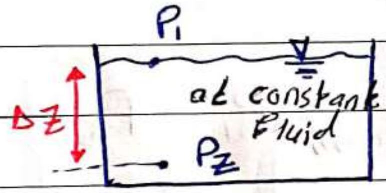


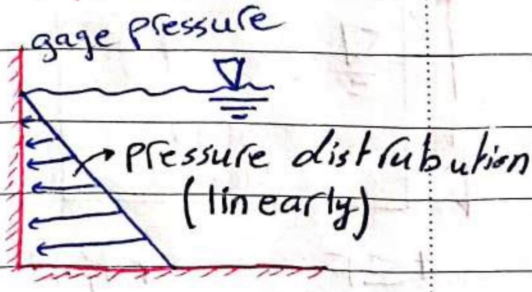
* الضغط يتغير مع الارتفاع
ولا يتغير في نفس المستوى .

$$\Delta P = -\gamma \Delta Z$$

$\Delta P = \gamma |-\Delta Z|$ Hydrostatic pressure equation.

$$P_1 - P_Z = -\gamma \Delta Z$$

$\boxed{P_Z = P_1 + \gamma \Delta Z}$ (piezometric pressure) {pa}

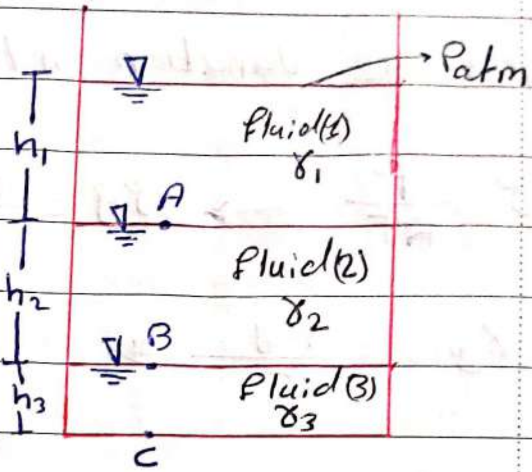


$$\boxed{\frac{P_Z}{\gamma} = \left(\frac{P_1}{\gamma} + \Delta Z\right) = h}$$

(head pressure (m))

* For different density fluid with elevation.

$$\boxed{\Delta P = \int_1^2 -\gamma \, dZ}$$



* $P_A = P_{atm} + \gamma_1 h_1$ (absolute pressure)

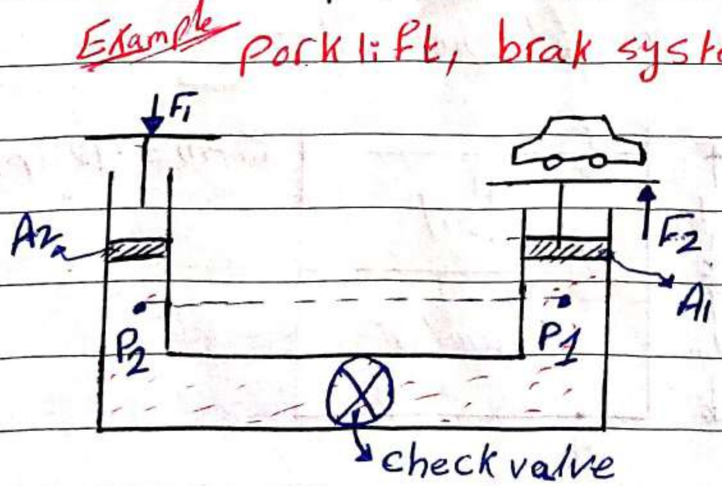
* $P_B = P_A + \gamma_2 h_2$ (")

* $P_C = P_B + \gamma_3 h_3$ (")

[*] Hydraulic machines.

↳ used to lifiting (رفع) of large weight by a small force by the application of pascal's law.

Example: Pork lift, brak system, power steering system } * أمثلة ع الهايدروليك ماشينز.



$P_2 = P_1 \Rightarrow \frac{F_2}{A_2} = \frac{F_1}{A_1}$

↳ $F_2 = F_1 \left(\frac{A_2}{A_1}\right)$

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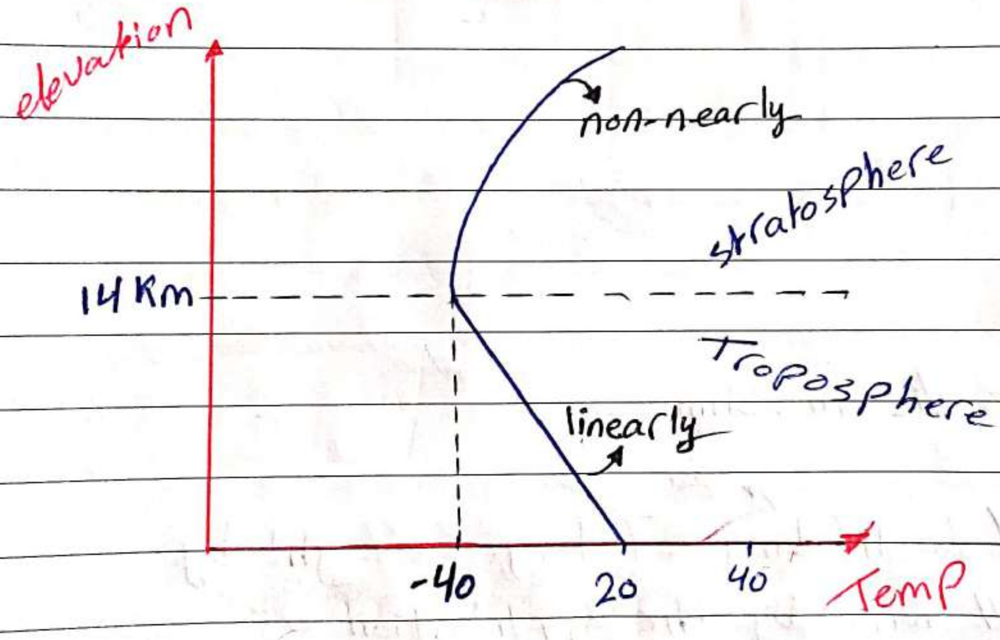
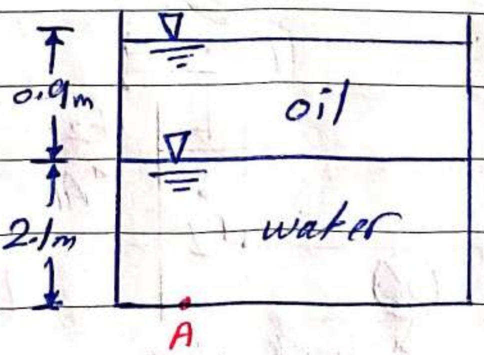
* pressure Variation in the atmosphere

$\rho = \frac{P}{RT} \longrightarrow \rho g = \frac{Pg}{RT}$

$\gamma_{gas} = \frac{Pg}{RT} \Rightarrow \gamma_{gas} = f(P,T) \rightarrow$ function of (P,T)



Ex what is the gage pressure at the bottom of the tank ?!



$S_{oil} = 0.8$, $\gamma_{water} = 9810 N/m^3$

$\hookrightarrow \gamma = \rho_{water} \times g = 1000 \times 9.81$

$S = \frac{\gamma_{oil}}{\gamma_{water}}$

$\rightarrow \gamma_{oil} = \gamma_{water} \times S_{oil} = 7848 N/m^3$

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Sol

$$\gamma = \rho g$$

$$P_A = \gamma_{water}\,\Delta z_{water} + \gamma_{oil}\,\Delta z_{oil}$$

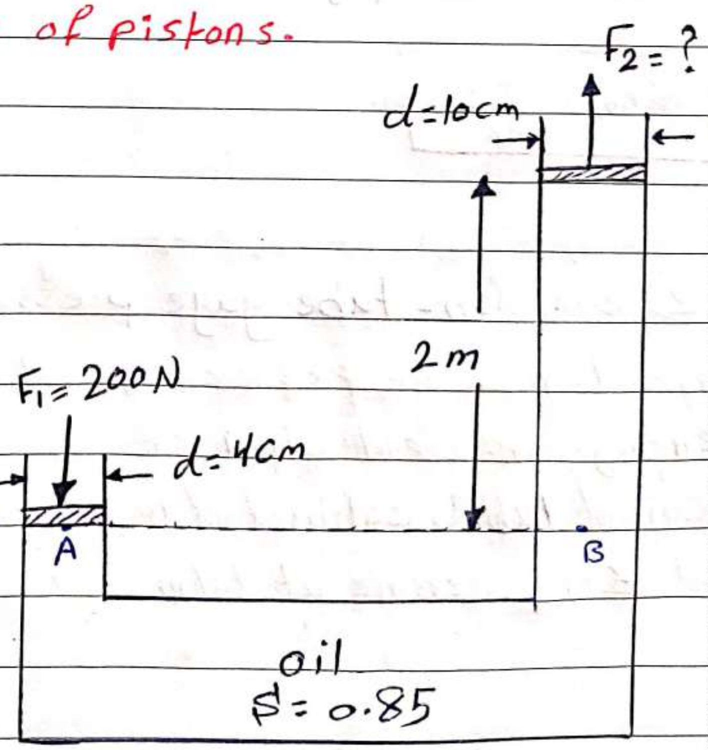
$$P_A = 9810 * 2.1 + 7848 * 0.9$$

$$P_A = 27.66 * 10^3 \text{ pa}$$

$$= 27.66 \text{ Kpa}$$

Ex If a 200N force F_1 is applied to a piston with the 4cm diameter, what is the magnitude of the force F_2 that can be resisted by the piston with the 10cm diameter ?!

* Neglect the weights of pistons.



Sol $P_A = P_B$

$$\frac{F_1}{A_1} = P_2 + \gamma_{oil} h$$

$$\frac{200}{\frac{\pi}{4}(0.04)^2} = \frac{F_2}{\frac{\pi}{4}(0.1)^2} + \gamma_{oil} h$$

$$\frac{200}{\frac{\pi}{4}(0.04)^2} = \frac{F_2}{\frac{\pi}{4}(0.1)^2} + 0.85 * 1000 * 9.81 * 2$$

$$F_2 = 1118.98 N$$

$$= 1.119 KN$$

N O T E B O O K

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محاضرة ع (7)

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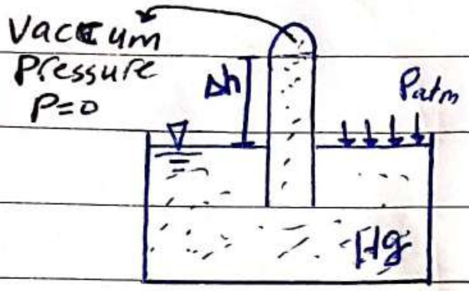
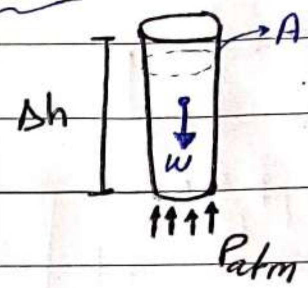
3.3. pressure measurment

① Barometer :- used to measure atmospheric pressure.



⇒ F.B.D



$\uparrow \Sigma F = 0$

$P_{atm} * A - W = 0$

$P_{atm} * A - \rho \forall g = 0$

$P_{atm} * A - \rho A \Delta h g = 0$

$$\boxed{P_{atm} = \gamma_{Hg} \Delta h}$$

1 atm ⟶ 760 mmHg

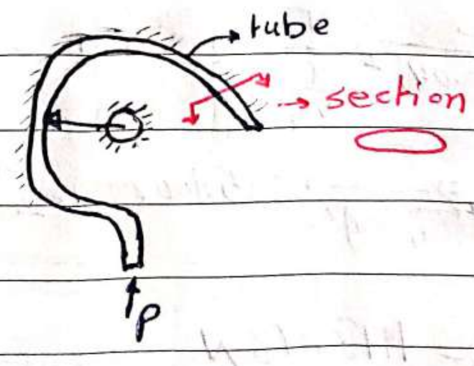
$\rho_{Hg} = 13600 \ Kg/m^3$

$S = 13.6$

$\gamma = 133416 \ N/m^3$

② Bourdon- tube gage pressure :

→ used to measure pressure by sensing the deflection of a coiled tube, culibrated to read zero pressure at 1atm.



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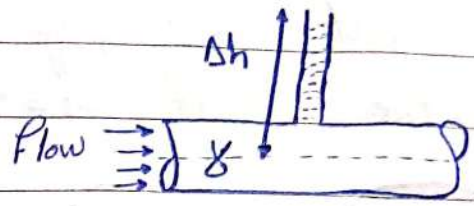
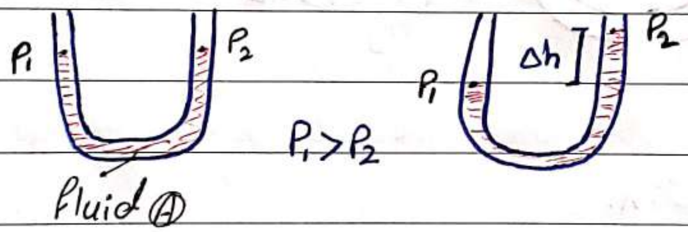
(3) Piezometer:

↳ A vertical tube usually made by glass or plastic, in which a liquid rise in response to a positive gage pressure (used to law pressure)



$$\boxed{P = \gamma \Delta h}$$

(4) Manometer: U-shape made by glass or plastic, with one or more fluids, used to measured pressure difference.

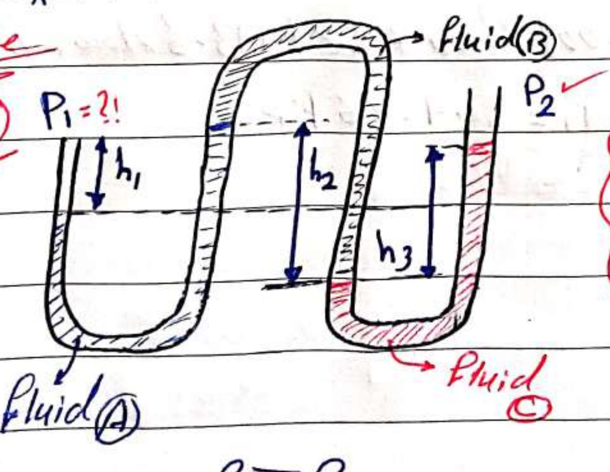


$$\boxed{\Delta P = \gamma_f \Delta h}$$

* for multi manometer attached each other.

like

Type (1)



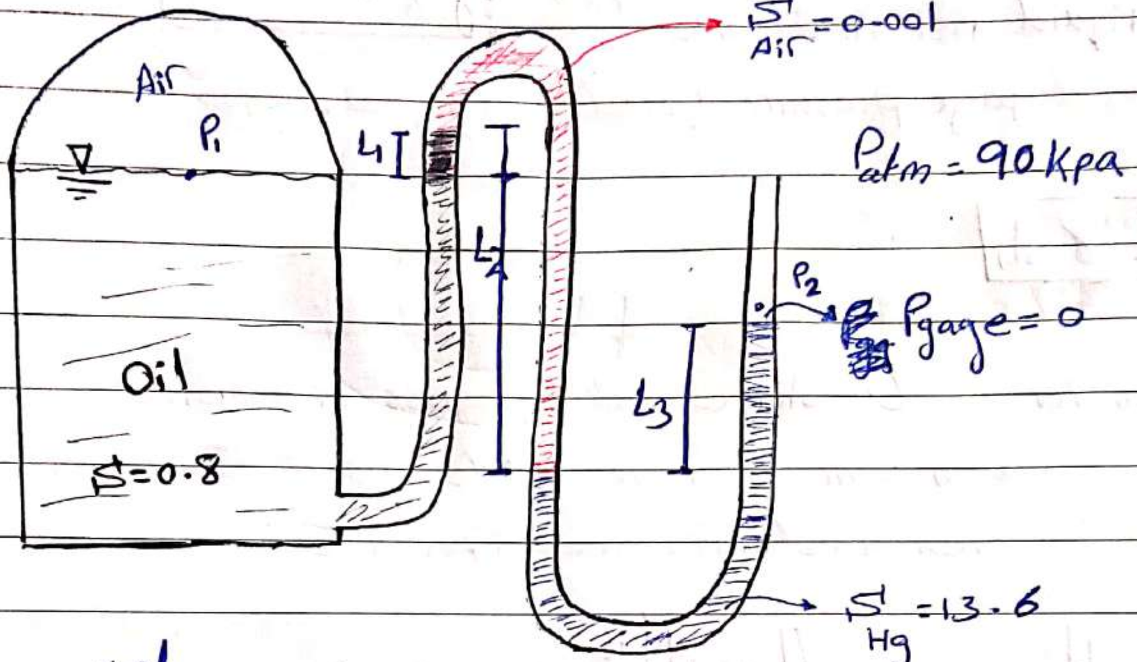
$$P_1 = P_2 + \sum_{down}^{n} \gamma_i h_i - \sum_{up}^{n} \gamma_i h_i$$

$P_1 > P_2$

Ex

محاضرة رقم (8)
7/2

What is the gage pressure of the air in the tank if $L_1 = 40cm$, $L_2 = 100cm$, $L_3 = 80cm$?!



sol

$$P_2 = P_1 + \sum_{down}^{n} \gamma_i h_i - \sum_{up}^{n} \gamma_i h_i$$

$$0 = P_1 - \gamma_{oil} L_1 + \gamma_{air} L_2 - \gamma_{Hg} L_3$$

$$P_1 = 0.8 * 1000 * 9.81 * 0.4 - 0.001 * 1000 * 9.81 + 13.6 * 1000 * 9.81 * 0.8$$

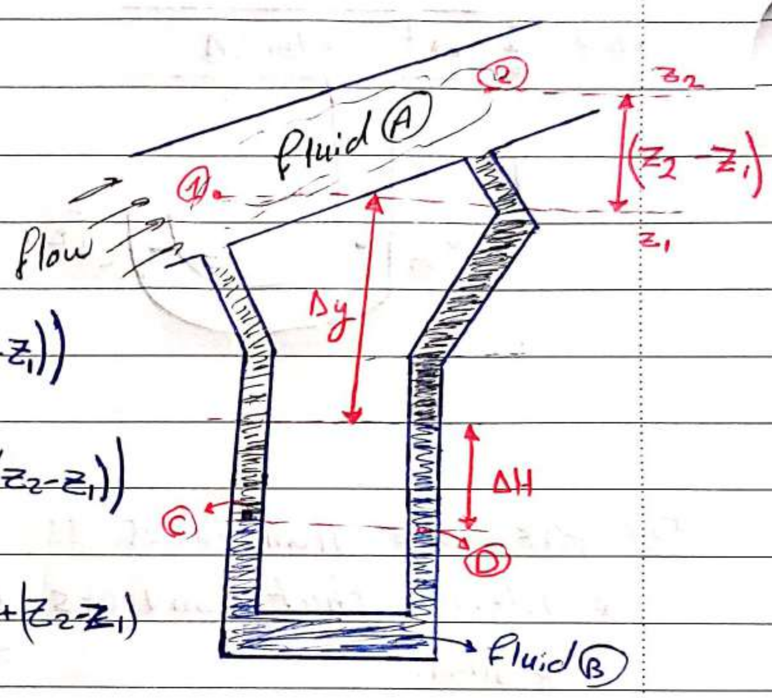
$P_1 = 109.86 * 10^3 Pa$ or $P_1 = 109.86 Kpa$

N O T E B O O K

Subject Date No.

Type (2) Differential Manometers.

used to mesure the pressure difference between two points in a pipe flowing fluid.



$P_C = P_D$

$P_C = P_1 + \gamma_A (\Delta y + \Delta H)$

$P_D = P_2 + \gamma_B \Delta H + \gamma_A (\Delta y + (z_2 - z_1))$

$P_1 + \gamma_A (\Delta y + \Delta H) = P_2 + \gamma_B \Delta H + \gamma_A (\Delta y + (z_2 - z_1))$

$$\frac{P_1}{\gamma_A} + \Delta y + \Delta H = \frac{P_2}{\gamma_A} + \frac{\gamma_B}{\gamma_A}\Delta H + \Delta y + (z_2 - z_1)$$

$$\left(\frac{P_1}{\gamma_A} + z_1\right) - \left(\frac{P_2}{\gamma_A} + z_2\right) = \frac{\gamma_B}{\gamma_A}\Delta H - \Delta H$$

$$\boxed{\left(\frac{P_1}{\gamma_A} + z_1\right) - \left(\frac{P_2}{\gamma_A} + z_2\right) = \Delta H\left(\frac{\gamma_B}{\gamma_A} - 1\right)}$$

$$\boxed{h_1 - h_2 = \Delta H\left(\frac{\gamma_B}{\gamma_A} - 1\right)}$$

h_1 :- Pizeometeric pressure at point (1)

h_2 : " " " (2)

N O T E B O O K

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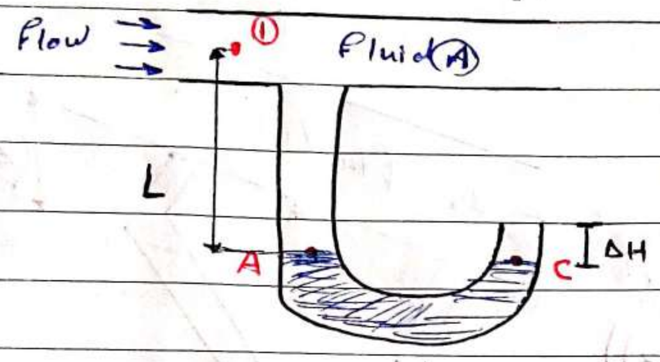
Type (3)

↳ used to measure the static pressure in the pipe flowing fluid.



$P_A = P_C$

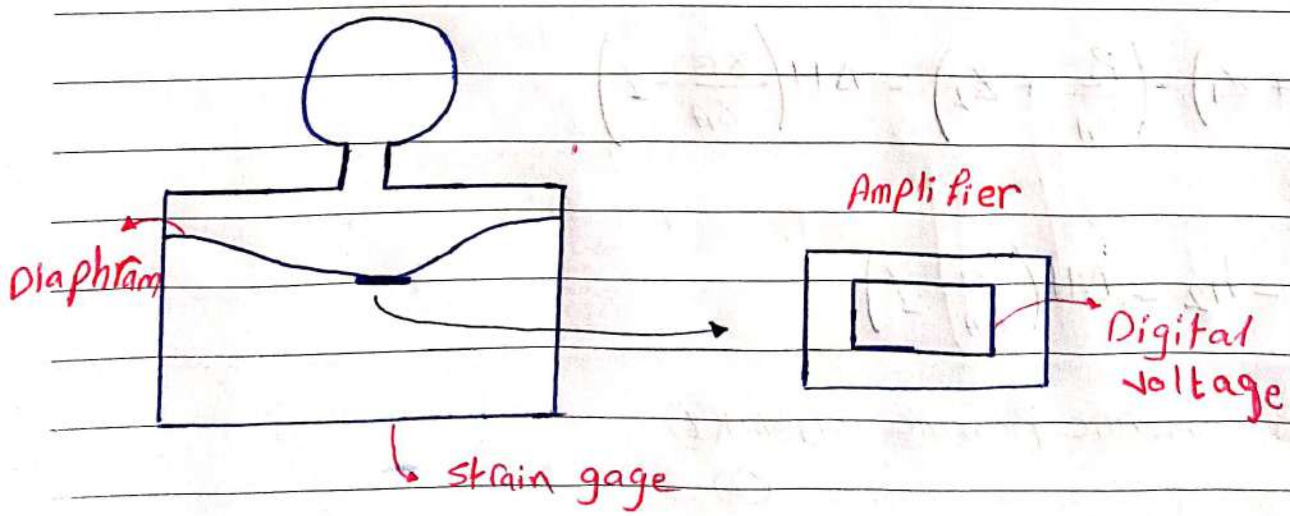
$P_1 + \gamma L = \gamma_B \Delta H$

$P_1 = \gamma_B \Delta H - \gamma L$

(5) pressure Transducer

* A device that converts pressure to an electrical signal.

- strain gage transducers.
- piezoelectric transducers.

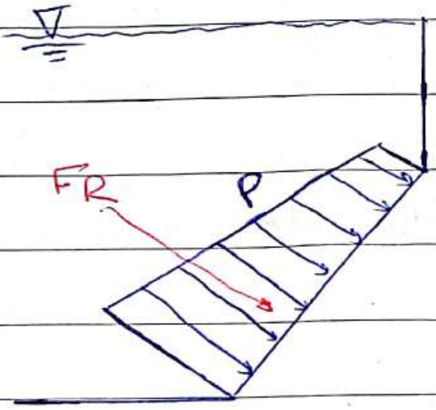


محاضرة رقم (9)

10/2

3.4

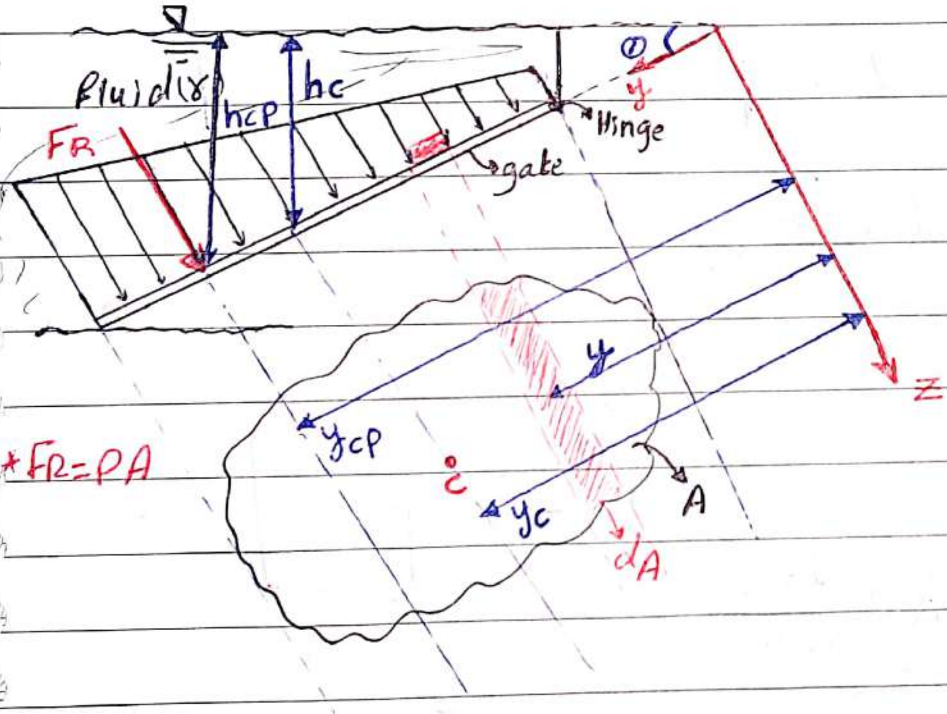
Hydro static forces on plane surface.

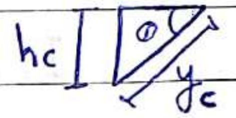


$F_R = P.A$

$\int_A dF = \int_A P\,dA$

$F = P.A$





$h_c = y\sin\theta$

* pressure at any where on the plane

$\boxed{P = \gamma h = \gamma y \sin\theta}$

* $F_R = PA$

⇒ The differential is :-

$dF = P\,dA$

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

$F_R = \gamma \sin\theta \int_A y\,dA$ → first moment of inertia or (area)

$\boxed{y_c A = \int_A y.dA}$

$$\boxed{\begin{aligned} F_R &= \gamma y_c A . \sin\theta \\ F_R &= \bar{P}_{avg} A . \sin\theta \end{aligned}}$$

*Where does the force act?! (location of Resultant force)

$+\uparrow \Sigma M_o = 0$

$$F_R \, y_{cp} = \int_A y P \, dA \Rightarrow F_R \, y_{cp} = \int_A y \cdot \gamma y \sin\theta \cdot dA$$

$$F_R \, y_{cp} = \gamma \sin\theta \int_A y^2 \cdot dA$$ → second moment of inertia or (area) $I_{o,x}$

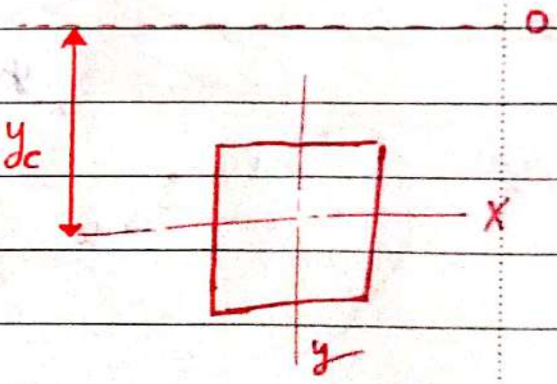
$$F_R \, y_{cp} = \gamma \sin\theta \cdot I_{o,x}$$ from $F_R = \gamma y_c A \cdot \sin\theta$

$$\gamma y_c A \sin\theta \cdot y_{cp} = \gamma \sin\theta \cdot (I_x + A y_c^2)$$

$$y_c \cdot y_{cp} A = I_x + A y_c^2$$

$$y_{cp} \cdot A = \frac{I_x}{y_c} + A y_c$$

$$y_{cp} = \frac{I_x}{y_c \cdot A} + y_c \Rightarrow \boxed{y_{cp} = y_c + \frac{I_x}{y_c A}}$$



$$I_{x,o} = I_x + A y_c^2$$

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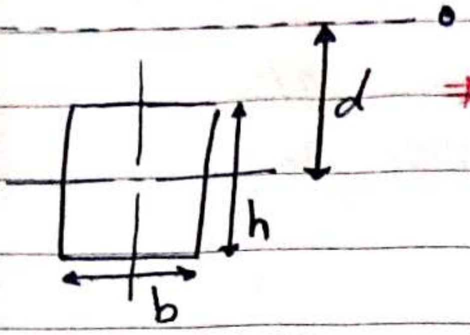
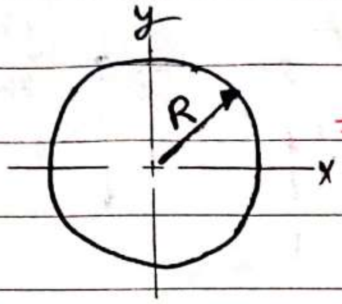


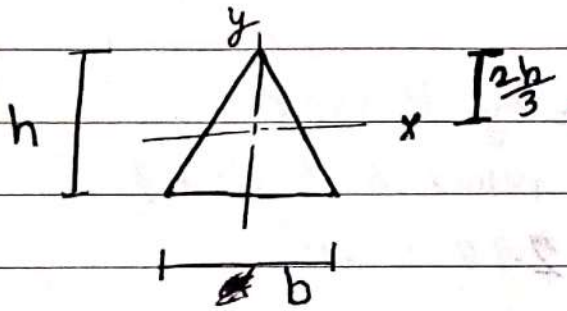
$$I_{x,o} = I_x + \overbrace{A}^{b*h} \cdot d^2$$

$$I_x = \frac{1}{12} b h^3$$



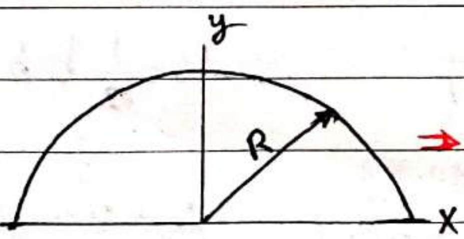
$$I_x = I_y = \frac{\pi}{4} R^4$$

$$A = \pi R^2$$



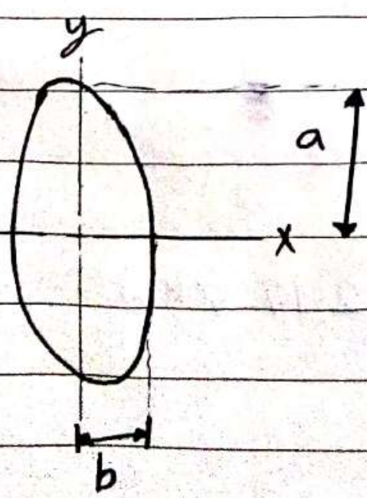
$$I_x = \frac{b h^3}{36}$$

$$A = \frac{bh}{2}$$



$$I_x = \frac{\pi}{8} R^4$$

$$A = \frac{\pi}{2} R^2$$



$$I_x = \frac{\pi a^3 b}{4}$$

$$A = \pi a b$$

محاضرة رقم (١٠).

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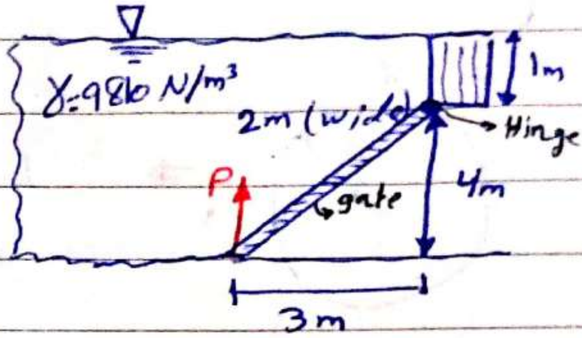
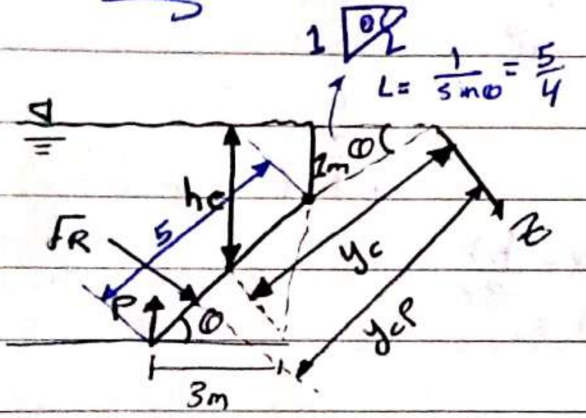
Example:

* Determine (P) necessary to just start opening the 2m Wide gate?



Sol

F.B.D



$$F_R = \gamma y_c A \sin\theta$$

$$= 9810 * 3.75 * 10 * \frac{4}{5}$$

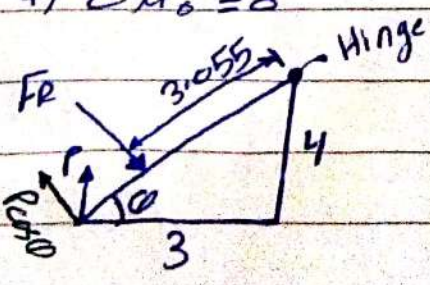
$$F_R = 294.3 * 10^3 N$$

$$y_{cP} = y_c + \frac{I_x}{y_c A} \qquad I_x = \frac{1}{12} b h^3 = \frac{2*5^3}{12}$$

$$y_{cP} = 3.75 + \frac{20.83}{3.75*(2*5)} \qquad I_x = 20.83 m^4$$

$$y_{cP} = 4.305 m$$

$+\circlearrowleft \Sigma M_o = 0$

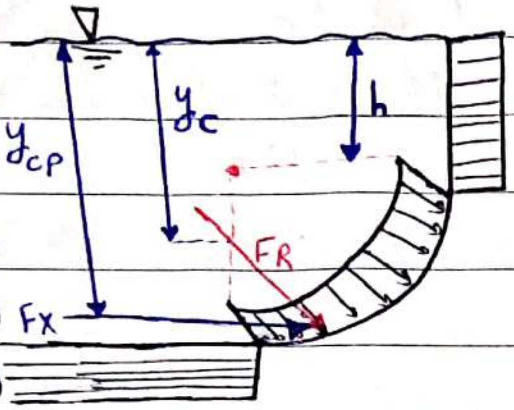


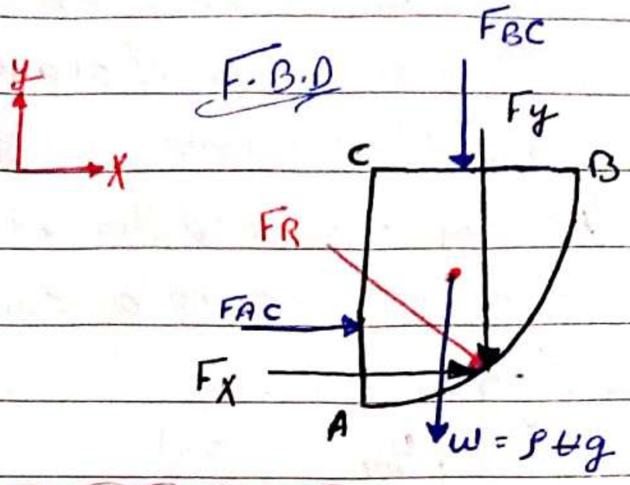
294.3 kN

$$\cancel{F_R} * 3.05 - P\cancel{\cos\theta}_{3/5} * 5 = 0$$

$$P = 299.7 KN$$

3.5 Hydrostatic force on curved surface.





$$\boxed{F_{AC} = F_x = \gamma y_c A_{AC}}$$

$$\boxed{F_{BC} = \gamma h A_{BC}}$$

$$\boxed{F_y = F_{BC} + W}$$

$$\boxed{F_R = \sqrt{F_x^2 + F_y^2}}$$

Notes:
1. The line of action for the force F_{AC} is through the C.O.P for side AC.
2. The line of action for the force F_{BC} is through the centroide of surface BC.
3. The weight acts through the center of gravity of the free body.

Subject

Date محاضرة رقم (11) No.

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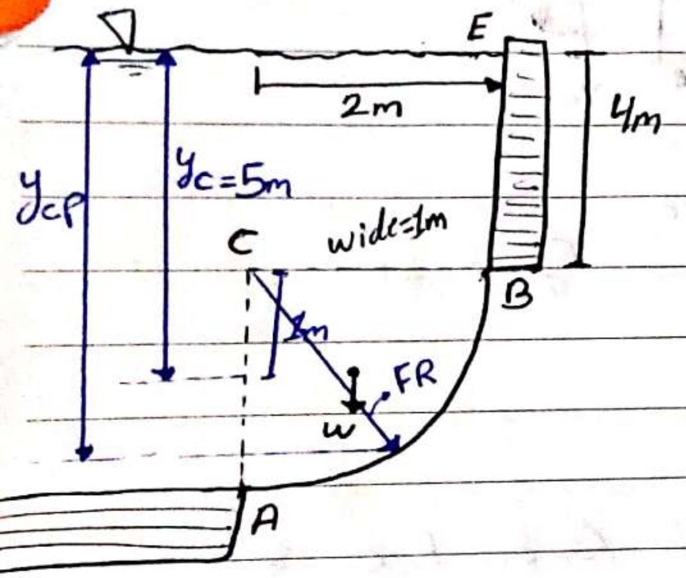
Example 3.11 surface AB is a circular arc with radius of 2m, and wide of 1m into the paper. The distance EB is 4m. The fluid above surface AB is water. Find the magnitude and line of action of the hydrostatic force acting on surface AB.



Sol

$$F_X = F_{AC} = \gamma y_c A_{AC}$$
$$= 9810 * 5 * 2 * 1$$
$$F_{AC} = 98.1\ KN$$

$$F_{CB} = \gamma h A$$
$$= 9810 * 4 * 2 * 1$$
$$F_{CB} = 78.5\ KN$$

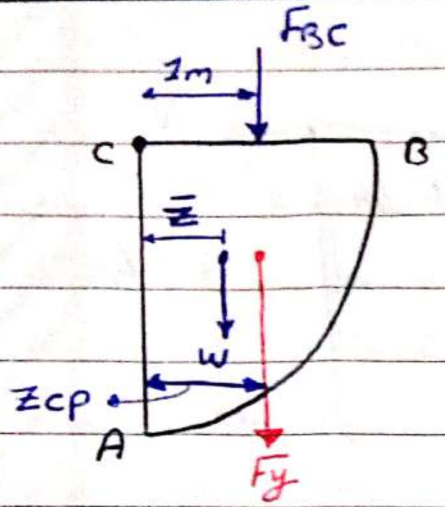
$$W = \rho * g$$
$$= \gamma V$$
$$= 9810 \left(\frac{\pi}{4} * 2^2 * 1\right)$$
$$W = 30.8\ KN$$

$$F_y = 78.5 + 30.8$$
$$F_y = 109.3\ KN$$

$$F_R = \sqrt{F_x^2 + F_y^2}$$

$$F_R = \sqrt{98.1^2 + 109.3^2} = 146.9\ KN$$

$$y_{cP} = y_c + \frac{I_x}{y_c A} = 5 + \frac{\frac{1}{12}(1)(2)^3}{5 * 2 * 1} = 5.067\ m$$



$$+\!\uparrow \sum M_c = 0$$

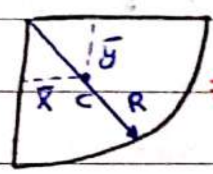
$$F_y \, Z_{cp} = F_{BC} * 1 + W \bar{z}$$

$$\therefore \; 109.3 * Z_{cp} = 78.5 + 30.8 * 0.8488$$

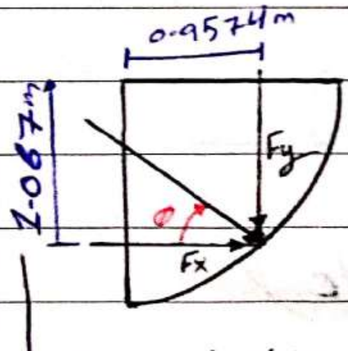
$$Z_{cp} = 0.9574 \text{ m}$$

$$\boxed{\bar{z} = \frac{4}{3} * \frac{2}{\pi} \qquad \bar{z} = 0.8488}$$

*



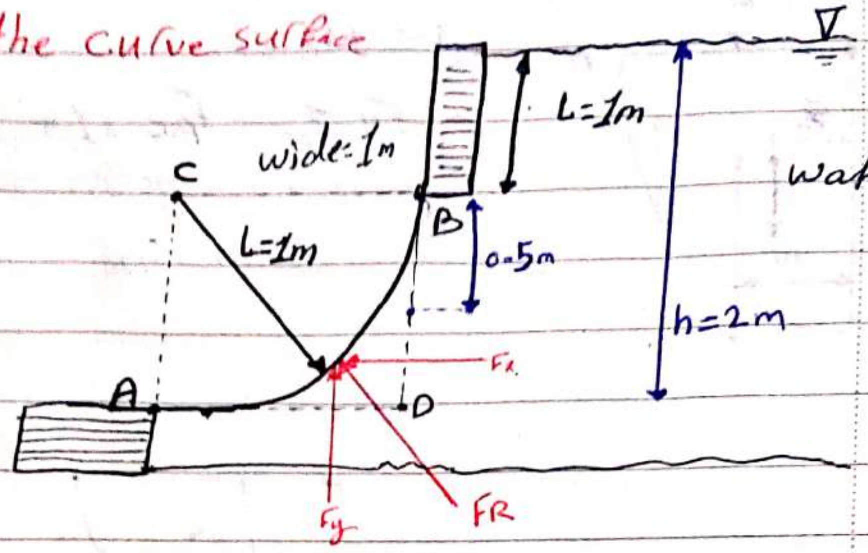
$$\bar{x} = \bar{y} = \frac{4}{3} * \frac{R}{\pi}$$



$$\tan\theta = \frac{F_y}{F_x} \rightarrow \theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = 48^\circ$$

$y_{cp} - 4 = 1.067$m

Example Find the Resultant force and the direction on the curve surface AB.

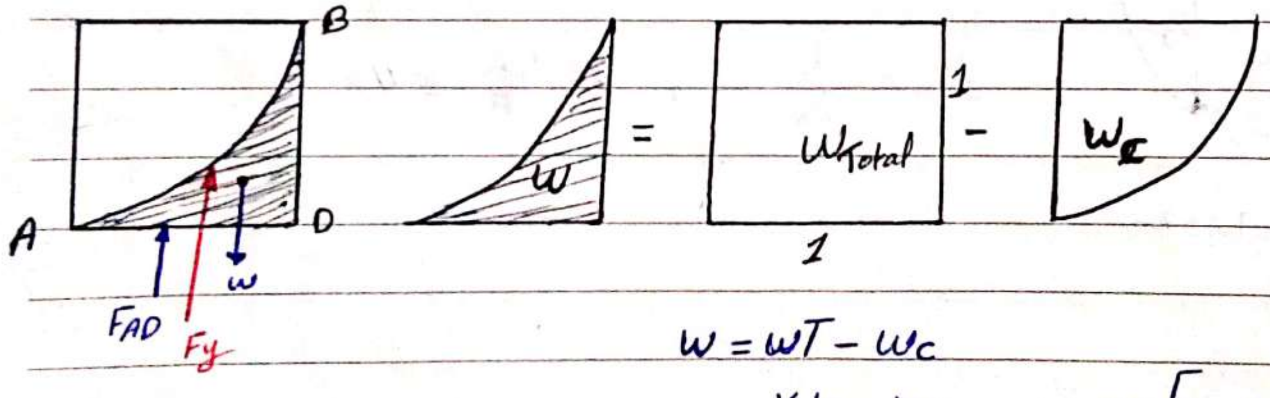


Sol $F_{BD} = \gamma\, y_c\, A$

$= 9810 * 1.5 * (1*1) = 14.715\ KN$

$F_{AD} = \gamma\, h\, A$

$= 9810 * 2 * (1*1) = 19.62\ KN$



$W = W_T - W_c$

$= \gamma\, \forall_T - \gamma\, \forall_c \Rightarrow W = 9810\left[(1*1*1) - \left(\frac{\pi}{4} * 1^2 * 1\right)\right]$

$w = 2.105\ KN$

$F_y = F_{AD} - w$

$= 19.62 - 2.105 = 17.51\ KN$

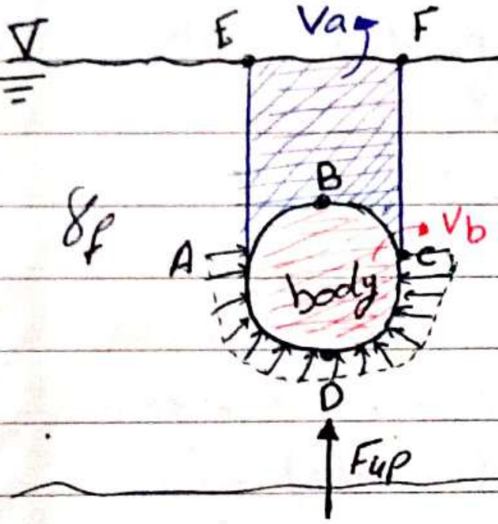
$F_R = \sqrt{F_x^2 + F_y^2} = 22.87\ KN$

$y_{cp} = y_c + \frac{I_x}{y_c A} = 1.5 + \frac{\frac{1}{12}(1)(1)^3}{1.5(1*1)}$

$y_{cp} = 1.555\ m$

3.6 Buoyancy الطفو

A buoyant force is the upward force that is produced on a body that is totally or partially submerged in a fluid when the fluid is in a gravity field.



*Lower surface (ADC)

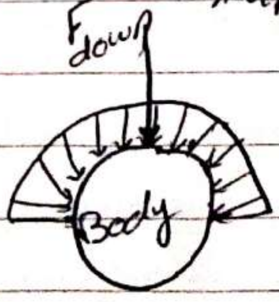
$$F_{up} = \gamma_f (\forall_b + \forall_a)$$

where:-

$\forall_b$:- The volume of body

$\forall_a$:- The volume of fluid above body ($\forall_{ABCFE}$).

*upper surface (ABC)



$$F_{dwon} = \gamma_f (\forall_a)$$

$$F_{net} = F_{\substack{buoyant\\force}} = F_{up} - F_{down}$$

$$= \gamma_f(\forall_b + \forall_a) - \gamma_f \forall_a$$

قوة الطفو $\boxed{F_B = \gamma_f \forall_b}$

$$\rightarrow F_B = \gamma_f \forall_D$$

* Note The line of action of the buoyant force passes through the centroid of displaced volume.

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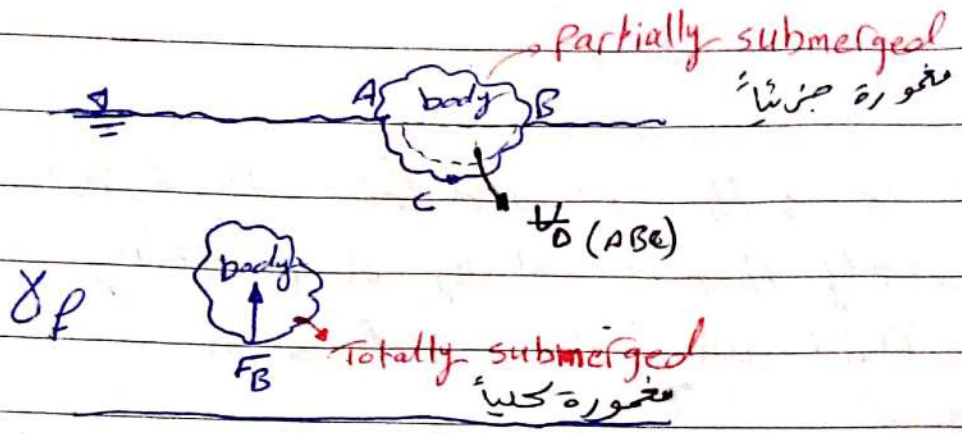
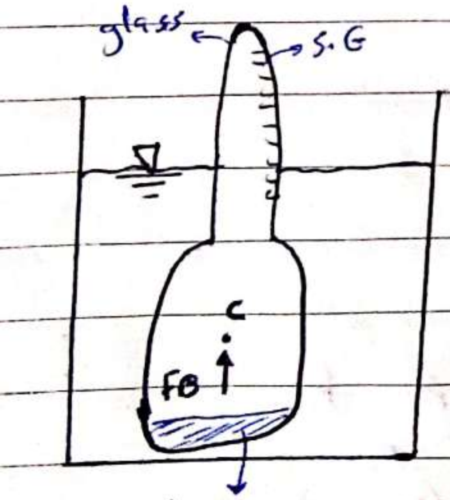


مبدأ

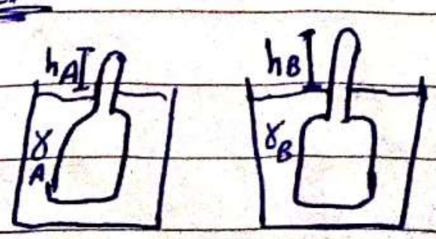
④ **Archimedes Principle:** for an object partially or completly submerged in a fluid, there is a net upward force (buoyant force) equal to the weight of the displaced fluid.

⇒ **The Hydrometer:** a measurement device used to measure the specific gravity of fluid (density).



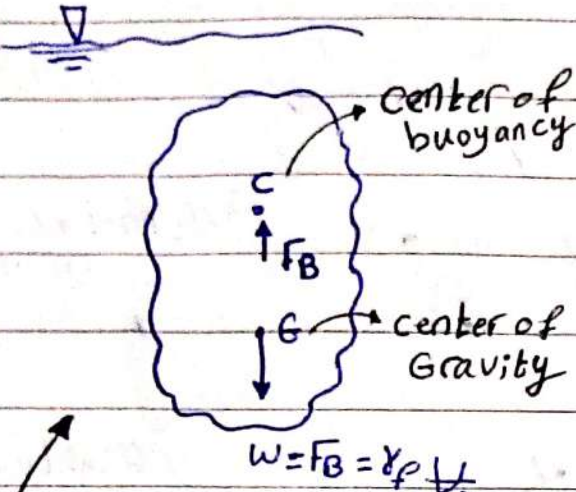
* يستخدم لحساب الـ S.G للفلويد.

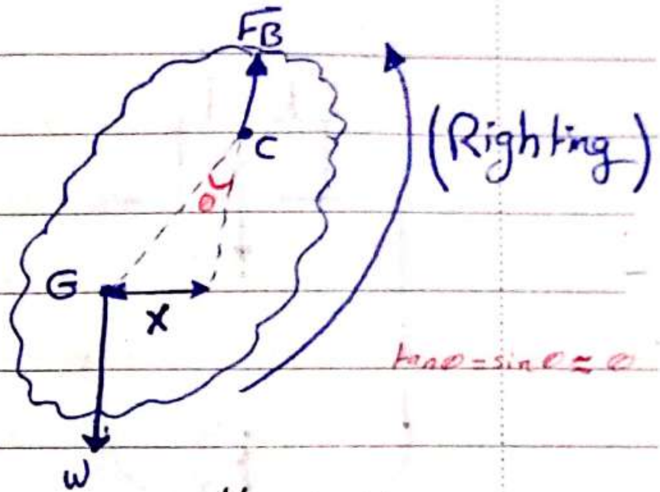
Ex



$h_A > h_B \Rightarrow S.G_A > S.G_B$

stability of submerged bodies.





$\tan\theta = \sin\theta \approx \theta$

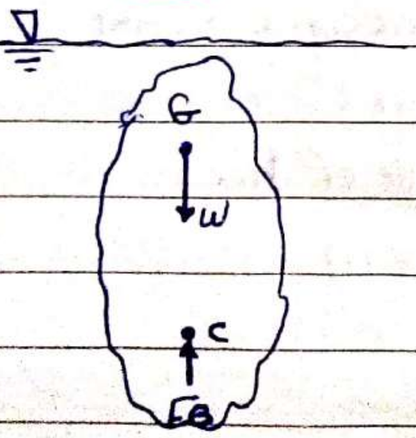
stable body

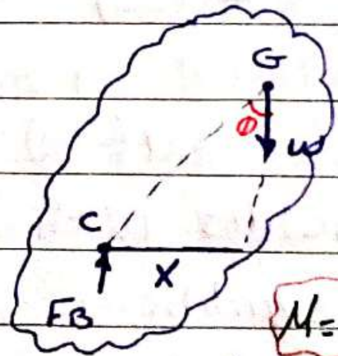
$M = W * X$

$\boxed{M = W * \overline{CG}\,\theta}$

Rad بال ϕ *

unstable



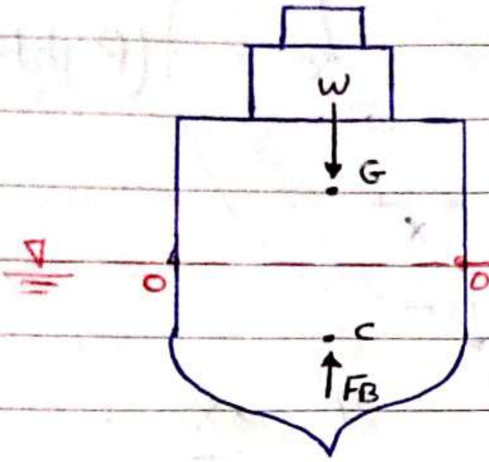


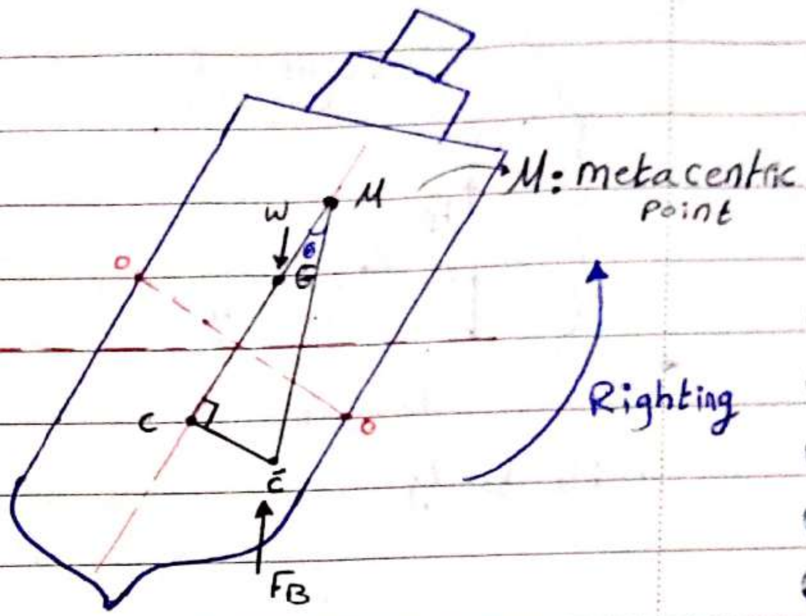
$\boxed{M = W * \overline{CG} * \theta}$

(over turning)

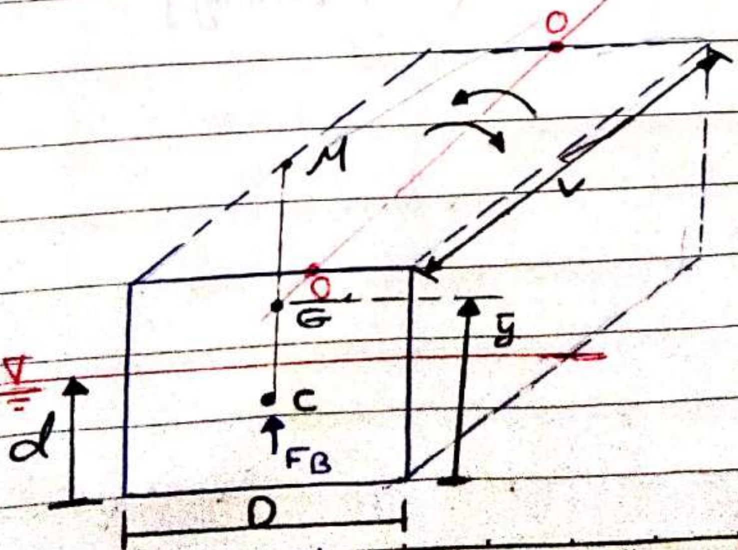
Newtral

* Stability of floating bodies:





* If M lies above (G) a righting moment ($W * \overline{CG} * \theta$), stable GM (+ve) GM: metacentric height
* If M lies below (G), an overturning moment ($W * \overline{CG} * \theta$), unstable GM (−ve) θ: angle of heel
* If M coincides with (G), the body is in neutral equilibrium



$$GM = CM - CG$$

$$GM = \frac{I_{o\text{-}o}}{V_D} - \left(\bar{y} - \frac{d}{2}\right)$$

$$I_{o\text{-}o} = \frac{LD^3}{12}, \quad V_D = dDL$$

* see Example 3.13 in Book

NOTEBOOK

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محاضرة رقم (13)

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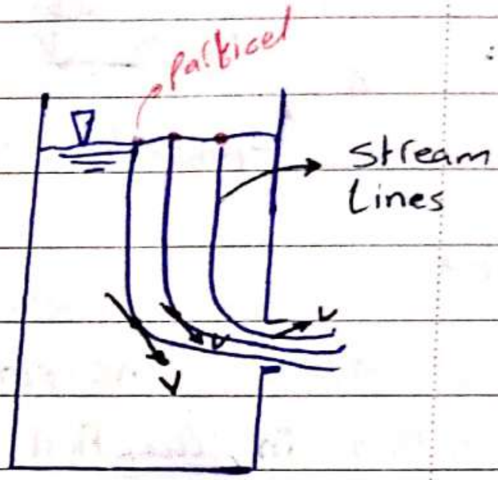
CH.4 Flowing fluids & pressure variation.

4.1 Description of fluid motion.

* stream lines :-

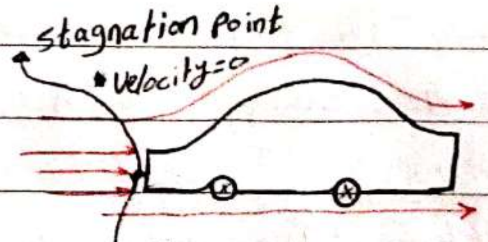
↳ stream lines are lines drawn through the flow fluid so that the velocity vector at each & every point on the stream lines is tangent to the stream lines at that instant.



* كل ما كانت الـ stream lines أقرب من بعضها تكون السرعة أعلى.

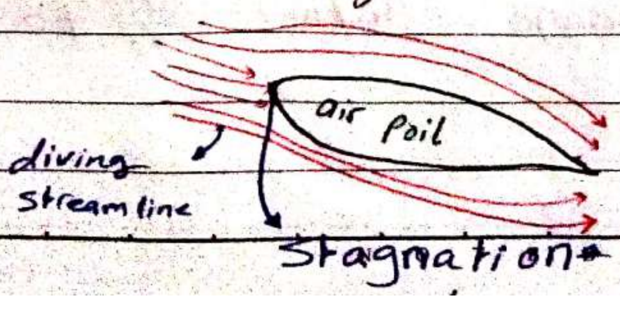
* Groups of stream lines [flow patterns]

* Stream lines are very effective in illustrating the geometry of the fluid flow or even the speed of flow.



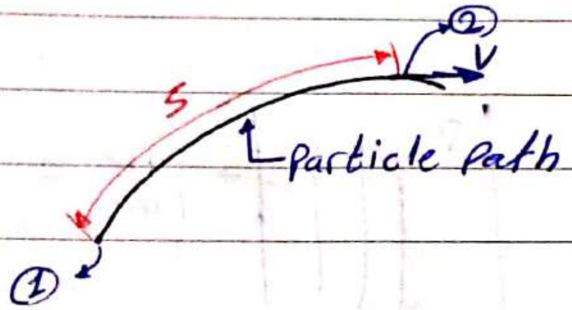
Note

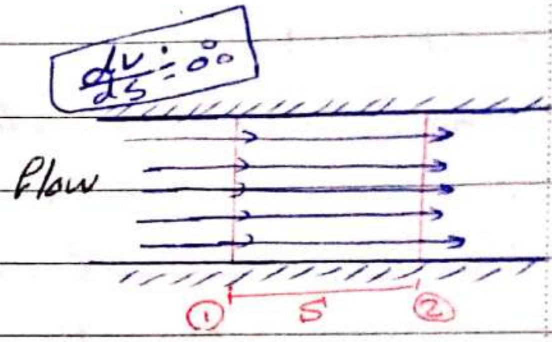
The speed is inversely proportional to the spacing between the stream lines.



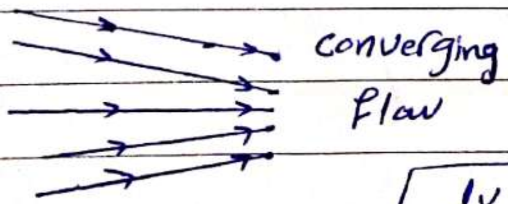
* flow classification {uniform, Non-uniform, steady, unsteady}

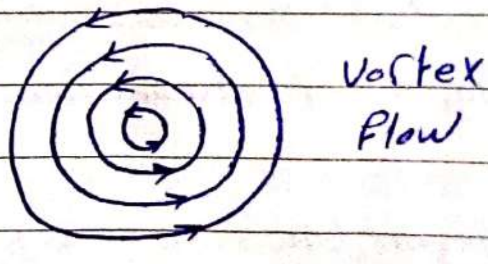
*uniform:- The velocity does not change a long fluid path.





* Non-uniform:- The velocity changes along the stream lines. either in direction or magnitude





* Steady flow:- The velocity at a given point on a fluid path does not change with time $\frac{dv}{dt} = 0$

* unsteady flow:- The velocity at a given point on a fluid path change with time $\frac{dv}{dt} \neq 0$

محاضرة رقم (14)

Laminar & Turbulent Flow

21/2

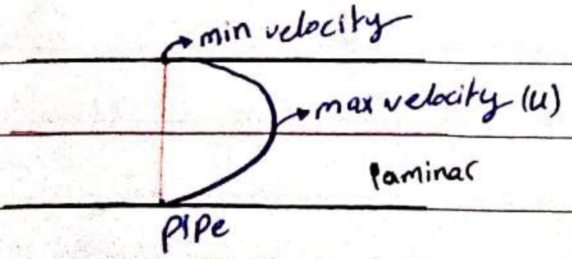
* laminar flow: Fluid layers ~~move~~ move smoothly with respect to each other.
  - No mixing between layers.
  - low velocity (Steady Flow).
  - common in thick fluids (honey, syrup القطر)

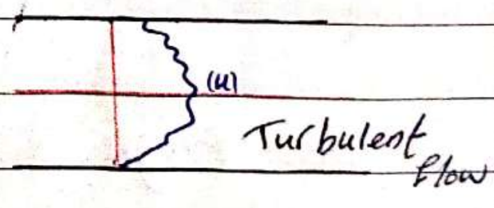
* Turbulent Flow: mixing between layers
  fast velocity, (Unsteady flow)

* Based on Reynolds number can be classified flow.

$$Re = \frac{\text{inertia force}}{\text{Viscous force}} = \frac{\rho V D}{\mu} \quad (\text{dimentionless})$$

(V: velocity)





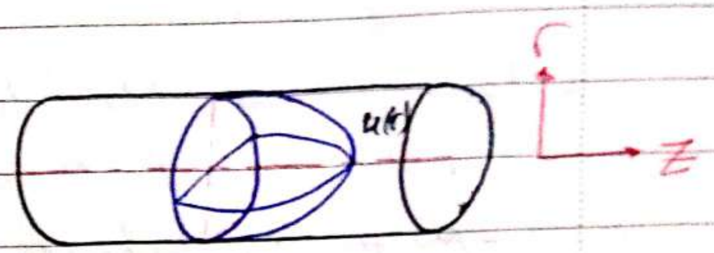
$Re < 2000 \longrightarrow$ laminar

$2000 < Re < 4000 \longrightarrow$ Transiet

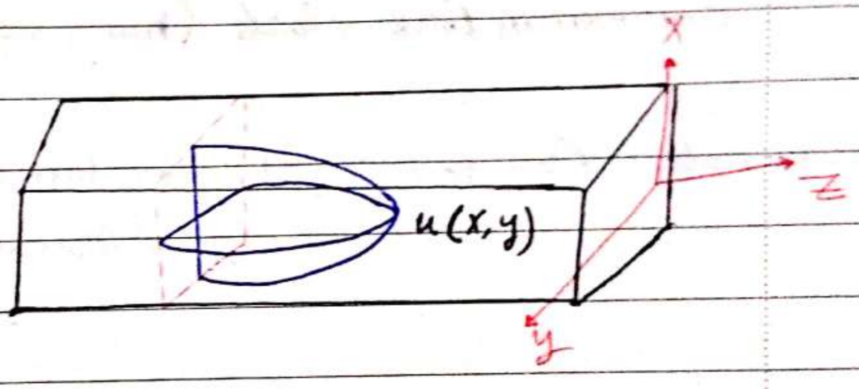
$Re > 4000 \longrightarrow$ Turbulent

Dimensionality of flow field.

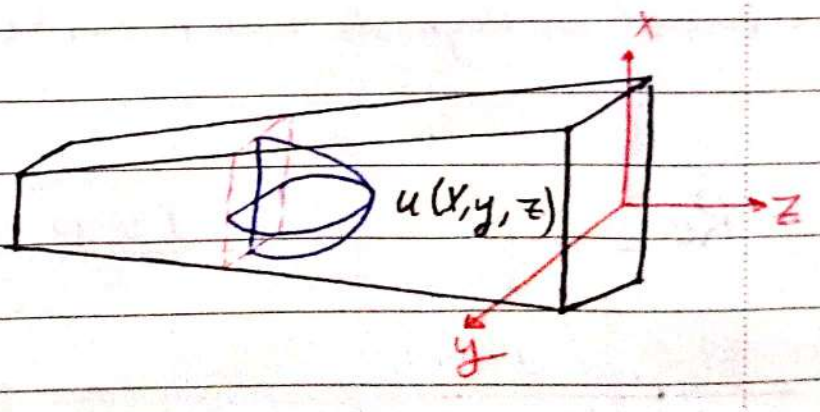
1-D flow
uniform in
circular pipe duct



2-D flow
uniform flow
in a squre duct.



3-D flow
uniform in
an expanding
squre duct.



* see page 83 in book.

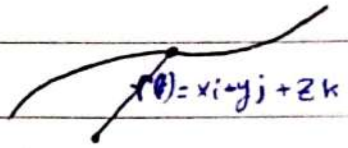
* Two Approach to decribe the velocity of flow field.

[1] lagrangiun approach:

→ based on recording the motion of aspecific fluid particle at all time.

position of particles:

↳ $r(t) = xi + yj + zk$



$$\boxed{v(t) = \frac{dx}{dt}i + \frac{dy}{dt}j + \frac{dz}{dt}k} \quad \text{or} \quad \boxed{v(t) = ui + vj + wk}$$

velocity

[2] Eulerian approach.

→ fouces on a certian point in space & describes the motion of fluid particles passing this point.

⇒ The velocity of fluid particles ~~with~~ will be decribed depending on the location of the point in passing throgh it in space & time.

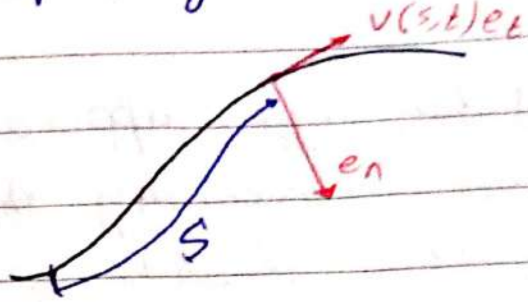
$u = f_1(x, y, z, t)$

$v = f_2(x, y, z, t)$

$w = f_3(x, y, z, t)$

* The velocity can be expressing for this approach as

$$\mathbf{v} = v(s,t)\,e_t$$



4.2) Acceleration

The rate of change of all particles velocity with time.

$$\cancel{a = \frac{dv}{\partial t} = \frac{\partial v(s,t)e_t}{\partial t}}$$

$$a = \frac{dv}{dt} = \frac{dv(s,t)e_t}{dt} = \left(\frac{dv}{dt}\right)e_t + v\left(\frac{de_t}{dt}\right)$$

$$\boxed{\frac{dv}{dt} = \frac{\partial v}{\partial s}\cdot\frac{ds}{dt} + \frac{\partial v}{\partial t}} \quad , \quad \boxed{\frac{de_t}{dt} = \frac{v}{r}\,e_n}$$

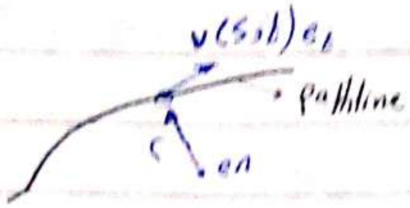
$$a = \left[\left(\frac{\partial v}{\partial s}\cdot\frac{ds}{dt}\right) + \frac{\partial v}{\partial t}\right]e_t + v\left(\frac{v}{r}\right)e_n$$

$$\boxed{a = \left(v\frac{\partial v}{\partial s} + \frac{\partial v}{\partial t}\right)e_t + \frac{v^2}{r}\,e_n}$$

(15) L ciple

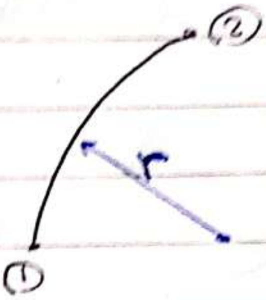
24/2

Acceleration



$$a = \frac{dv}{dt} = \frac{dv}{dt} e_t + v \frac{de_t}{dt}$$

e_t → tangentional unit vector



$$\frac{dv}{dt} = \underbrace{\frac{\partial v}{\partial s} \cdot \frac{\partial s}{\partial t} + \frac{\partial v}{\partial t}}_{}$$ Tangentional accelerational

v → $v(s,t)$

$$\frac{\partial e_t}{\partial t} = \frac{v}{r} e_n$$

e_n → normal unit vector

r → radius of curveture

$$\boxed{a_t = \left(v \frac{\partial v}{\partial s} + \frac{\partial v}{\partial t}\right) e_t + \left(\frac{v^2}{r}\right) e_n}$$

$\frac{\partial v}{\partial t}$: local accelerational (m/s^2) (if flow is steady state $\frac{\partial v}{\partial t} = 0$)

$v \frac{\partial v}{\partial s}$: convective acceleration (depends on the variation of the velocity along the path line). if flow uniform $\frac{\partial v}{\partial s} = 0$

$\frac{v^2}{r}$: centripetal acceleration (Normal to the path line & directed toward the center of rotation) ubject

Ex
Prop. [4.17]

The velocity along the pathline is given by $V(s,t) = s^2 t^{1/2}$, the raduis of curvature is 0.5m, Evalute the acceleration along & normal to the pathline at $S = 2m$, $t = 0.5 sec$

sol

$$a_t = \left(V \frac{\partial v}{\partial s} + \frac{\partial v}{\partial t}\right) e_t + \frac{V^2}{r} e_n \quad , \quad \text{at } \begin{array}{l} s = 2m \\ t = 0.5 sec \end{array}$$

$$V(s,t) = s^2 t^{1/2} , \quad V(2, 0.5) = 2^2 * 0.5^{1/2} = 2.828 m/s$$

$$\frac{\partial v}{\partial s} = 2 s t^{1/2} , \quad \left.\frac{\partial v}{\partial s}\right|_{\substack{s=2m \\ t=0.5}} = 2 * 2 * 0.5^{1/2} = 2.828 m/s$$

$$\frac{\partial v}{\partial t} = \frac{s^2}{2} t^{-1/2} , \quad \left.\frac{\partial v}{\partial t}\right|_{\substack{s=2m \\ t=0.5}} = \frac{2^2}{2} * 0.5^{-1/2} = 2.828 m/s$$

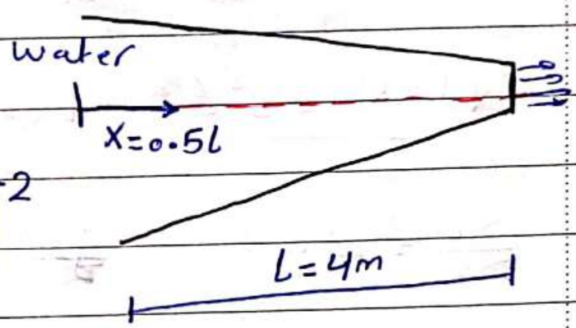
$$\left.\frac{V^2}{r}\right|_{\substack{s=2 \\ t=0.5}} = \frac{(2^2 * 0.5^{1/2})^2}{0.5} = 16 \ m/s^2$$

$$a_t = (2.828 * 2.828 + 2.828) e_t + 16 e_n$$

$$\boxed{a_t = 10.82 e_t + 16 e_n}$$

Example The velocity of water flow in the nozzle is given by $V = 2t/(1-\frac{0.5x}{L})^2$,
X := distance along the nozzle,
L := length of nozzle 4m, when $X = 0.5L$ & $t = 3$ sec
What is the local acceleration along the centerline?
What is the convetive acceleration??

sol



$$V = \frac{2t}{(1-\frac{0.5x}{L})^2},$$

$$V(s,t) = \frac{2t}{(1-\frac{0.5s}{L})^2} = 2t\left(1-\frac{0.5s}{L}\right)^{-2}$$

$$a_L = \frac{\partial v}{\partial t}\bigg|_{\substack{x=0.5L \\ t=3sec}} = \frac{2}{(1-\frac{0.5x}{L})^2} = \frac{2}{(1-\frac{0.5*0.5L}{L})^2} = 3.56\,m/s^2$$

$$a_c = V\frac{\partial v}{\partial s}, \quad \frac{\partial v}{\partial s} = 2t*(-2)*\left(1-\frac{0.5s}{L}\right)^{-3} * \frac{(-0.5)}{L}$$

$$\frac{\partial v}{\partial s} = \frac{2t}{L(1-\frac{0.5s}{L})^3}$$

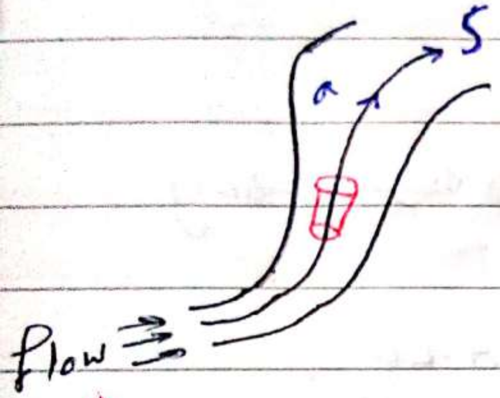
$$a_c\bigg|_{\substack{s=0.5L \\ t=3sec}} = \frac{2t}{(1-\frac{0.5s}{L})^2} \cdot \frac{2t}{L(1-\frac{0.5s}{L})^3} = \frac{4t^2}{L(1-\frac{0.5s}{L})^5}$$

$$a_c = \frac{4*3^2}{4(1-\frac{0.5*0.5L}{L})^5} = 37.9\,m/s^2$$

NOTEBOOK

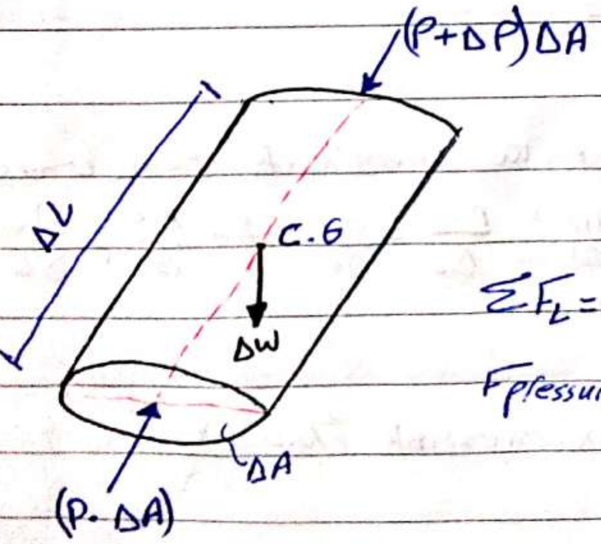
محاضرة رقم (16)
26/2

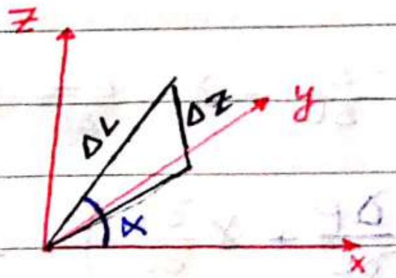
4.4 Euler's equation of motion



بتأثير
pressure

* if a fluid mass accelerations in the certain direction, this means that is a net force in the direction of acceleration
* assume the viscous is zero (shear force = 0)
* applying second law of Newton's
* acceleration in the (L) direction.





$$\Sigma F_L = m a_L$$

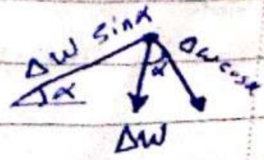
$$F_{pressure} + F_{gravity} = m a_L$$

⇒ Net forces due to pressure in the direction of motion (L-direction)

$$F_{pressure} = P \cdot \Delta A - (P + \Delta P)\Delta A = -\Delta P \cdot \Delta A$$

⇒ gravity force in the direction of motion.

$$F_{gravity} = -\Delta W \cdot \sin\alpha$$



$\Sigma F_L = m a_L \Rightarrow F_{pressure} + F_{gravity} = m a_L$

$\hookrightarrow \quad -\Delta P \cdot \Delta A - \Delta W \sin\alpha = m a_L$

where ① $\Delta W = m \cdot g \rightarrow \Delta W = \rho \cdot \forall \cdot g \rightarrow \boxed{\Delta W = \rho \cdot \Delta A \cdot \Delta L \cdot g}$

② $\boxed{\sin\alpha = \frac{\Delta Z}{\Delta L}}$ ③ $m = \rho \cdot \forall \rightarrow \boxed{m = \rho \cdot \Delta A \cdot \Delta L}$

$-\Delta P \cdot \Delta A - \rho \Delta A \Delta L g \cdot \frac{\Delta z}{\Delta L} = (\rho \cdot \Delta A \cdot \Delta L) a_L \quad / \; \Delta A \cdot \Delta L$

$\cancel{\Rightarrow -\Delta P \cdot \Delta A - \rho \Delta A \cdot \Delta L g \cdot \frac{\Delta z}{\Delta L} =}$

$\Rightarrow \quad \frac{-\Delta P}{\Delta L} - \gamma \cdot \frac{\Delta z}{\Delta L} = \rho \cdot a_L$ → take the limit to $\Delta L \to 0$

$\lim_{\Delta L \to 0} \frac{\Delta P}{\Delta L} = \frac{\partial p}{\partial L}$, $\lim \frac{\Delta z}{\Delta L} = \frac{\partial z}{\partial L}$

$-\left(\frac{\partial P}{\partial L} + \gamma \frac{\partial z}{\partial L}\right) = \rho \cdot a_L$

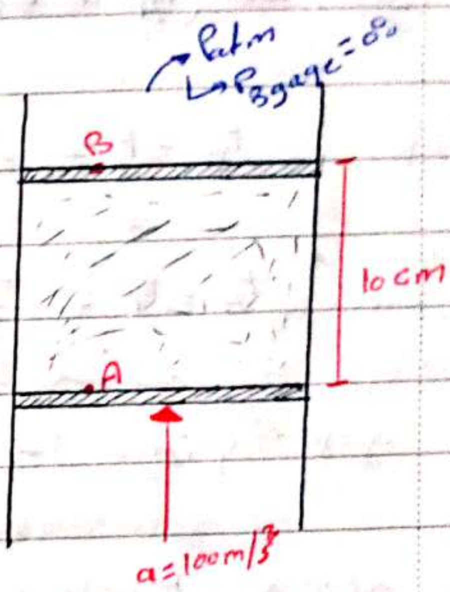
$\boxed{\frac{-d}{dL}(P + \gamma z) = \rho a_L}$ for incompressible flow (γ is const)

* It shows that the acceleration is equal to the change in piezometric pressure with distance & the minus sign means that the acceleration is in the direction of decreasing piezometric pressure

N O T E B O O K

4.4 Euler's equation of motion.

Ex A colum water in vertical tube is being accelerated by a piston in the vertical direction at $100\,m/s^2$, The depth of water colum is 10 cm. find the gage pressure on the piston.



Sol (vertical direction)

$$-\frac{d}{dL}\left(P + \gamma z\right) = \rho \cdot a_L$$

$$-\int_A^B d\left(P + \gamma z\right) = \int_0^{0.1} \rho \cdot a_L \, dL$$

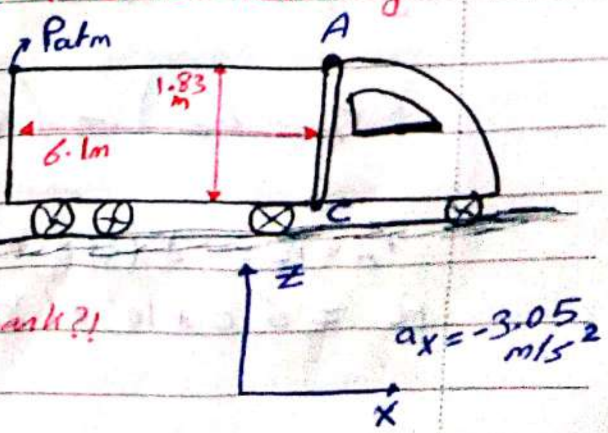
$$-\left[\left(\overset{0}{P_B} + \gamma \overset{0.1}{z_B}\right) - \left(P_A + \gamma \cancel{\overset{0}{z_A}}\right)\right] = \rho a_L * 0.1$$

محاضرة رقم (17)
28/2

Example (4.3) The Tank on a trailer truck is filled completely with gasoline, which has a specific weight of $6.6\,KN/m^3$. The truck is decelerating at a rate of $3.05\,m/s^2$.

[a] if the pressure at the top rear end is atmospheric. what is the pressure at the top front ?!

[b] what is the maximum pressure in the tank ?!



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Subject Date No.

Sol $\frac{d}{dL}(P+\gamma z) = -\rho a_L$, $z=0$ (No elevation)

$$\int_{P_1}^{P(A)} d(P+\gamma z) = -\int_{1}^{A} \rho . a_L . d_L$$

$$\cancel{P_A}\ (P_A + \gamma \cancel{z_A}^{0}) - (P_1 + \cancel{\gamma z_1}^{0}) = -\rho . a_L . L_{1A}$$

$$P_A - P_1 = -\rho a_L L_{1A}$$

gage pressure ← $P_A - \cancel{P_1}^{0} = \frac{-6.6*10^3}{9.81} * -3.05 * 6.1$

gage ← $\boxed{P_A = 12.5*10^3 \text{ Pa}}$

atm ← $\boxed{P_A = 12.5*10^3 + 101.3*10^3 = 113.8 \text{ KPa}}$

* $\frac{d}{dL}(P+\gamma z) = -\rho \cancel{a_L}^{0}$

$$\int_{C}^{A} d(P+\gamma z)$$

$$(P_A + \gamma z_A) - (P_C + \gamma z_C) = 0$$

$$P_A - P_C = -\gamma(z_C + z_A)$$

$P_C = 6.6*10^3 * 1.83 + 113.8*10^3 = \boxed{125.87 \text{ KPa}}$ atm

$= \boxed{24.57 \text{ KPa}}$ gage

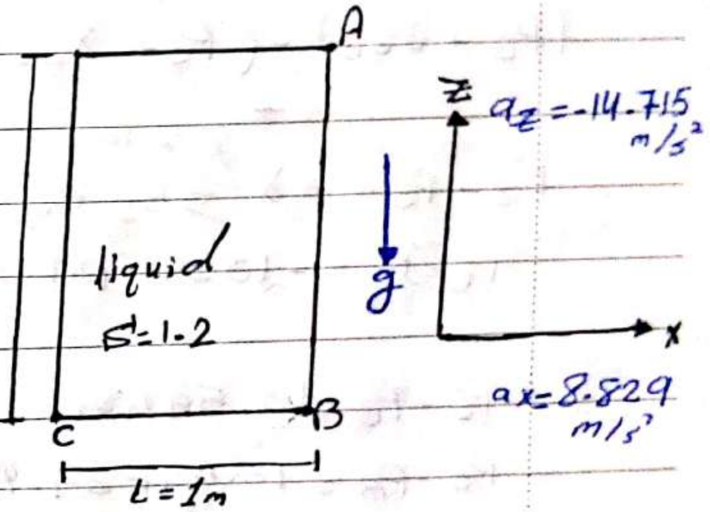
N O T E B O O K

Problem :- 4.37 The closed tank, which is full liquid is accelerated downward at 1.5g & to the right at 0.9g. The specific gravity of the liquid is 1.2, Determine pressure difference between points C & A, B & A

sol

① $P_C - P_A$

② $P_B - P_A$



$P_C - P_A = (P_C - P_B) + (P_B - P_A)$

$(P_A - P_B)$

$$\frac{d}{dL}(P + \gamma z) = -\rho a_L$$

$$\int_A^B d(P + \gamma z) = -\rho a_L \int_A^B dL$$

$$(P_B + \gamma z_B) - (P_A + \gamma z_A) = -\rho a_L \Delta L_{AB}$$

$$P_B - P_A + \gamma(\overset{5}{\cancel{z_B - z_A}}) = -1.2 * 1000 * -14.715 * 5$$

$$P_B - P_A = 1.2 * 1000 * 14.715 * 5 - 1.2 * 9810 * 5 = 29430 (Pa)$$

$$P_B - P_A = 29.43\ KPa$$

C to B

$$\frac{d}{dL}(P+\gamma z) = -\rho a_x$$

$$\int_C^B d(P+\gamma z) = -\rho a_x \int_C^B dL$$

$$(P_B + \gamma z_B) - (P_C + \gamma z_C) = -\rho a_x L_{CB}$$

$$P_B - P_C + \gamma \underbrace{\cancel{(z_B - z_C)}}_{zero} = -1.2 * 1000 * 8.829 * 1$$

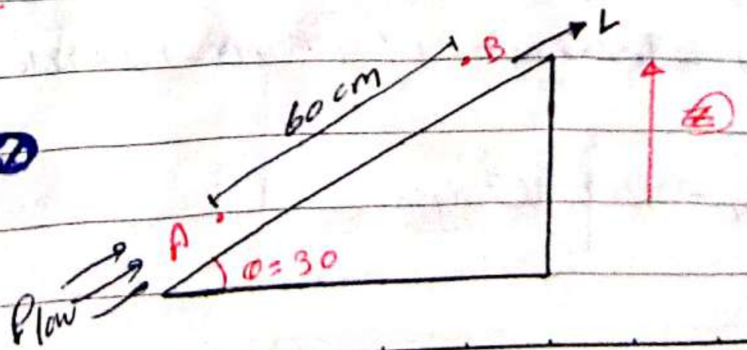
$$P_B - P_C = -10590 \text{ pa} \Rightarrow 10.59 \text{ KPa}$$

$$P_C - P_B = 10.59 \text{ KPa}$$

$$P_C - P_A = 10.59 + 29.43 = \boxed{40.02 \text{ KP}}$$

Problems:- A liquid with a specific weight of 15717 N/m^3 in the conduit. This is a special kind of liquid that has zero vicosity. The pressure at points A & B 9kpa, 5kpa. What is the acceleration of flow?

$$\frac{\Delta z}{\Delta L} = \sin \theta$$



Sol

$\frac{d}{dl}(P + \gamma z) = -\rho a_l$

$$\frac{dP}{dl} + \gamma \frac{dz}{dl} = -\rho a_l$$

$$\frac{(9-5)\times 10^3}{0.6} + 15717 \times \sin 30 = \frac{-15717}{9.81} \times a_l$$

$$\boxed{a_l = -0.744\, m/s^2}$$

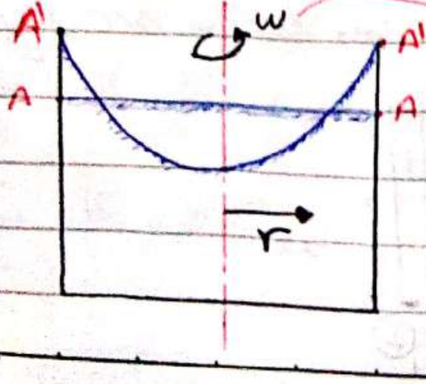
4.4 Pressure distribution in rotating flow

⇒ one common application is the centrifugal seperator.

⇒ Applying euler in the direction normal to streamline & outward from the center of rotation.

$$\frac{-d}{dl}(P + \gamma z) = \rho a_l \text{ → Normal direction}$$

$$\frac{-d}{dr}(P + \gamma z) = \rho a_r \quad , \text{where } a_r = \frac{v^2}{r}$$



→ angular velocity

$$\frac{-d}{dr}(P + \gamma z) = \rho . \frac{w^2 r^2}{r}$$

$$\frac{-d}{dr}(P + \gamma z) = \rho . w^2 . r$$

$$-d(P + \gamma z) = \rho w^2 \int r . dr$$

const

$$\boxed{P + \gamma z = \rho w^2 \frac{r^2}{2} + C} \; , \; \boxed{\frac{P}{\gamma} + z - \frac{w^2 r^2}{2g} = C}$$

محاضرة رقم (١٩)

~~Ex~~ 5/3

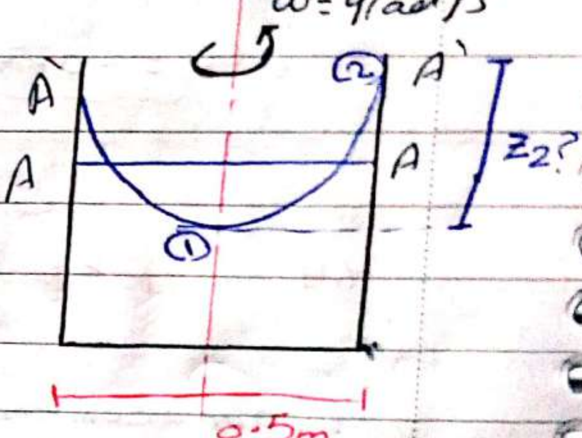
Ex A cylindrecal tank liquid is rotating at a rate of 4 rad/s the tank diameter is 0.5m, find the elevation difference between the liquid at the center & the wall ~~during~~ during rotation.

sol

$$\cancel{\frac{P_1}{\gamma}} + \cancel{z_1}^{\,0} - \cancel{\frac{w_1^2 r_1^2}{2g}}^{\,0} = \cancel{\frac{P_2}{\gamma}} + z_2 - \frac{w_2^2 r^2}{2g}$$

$$z_2 = \frac{+w_2^2 r^2}{2g} = \frac{4^2 * 0.25^2}{2 * 9.81}$$

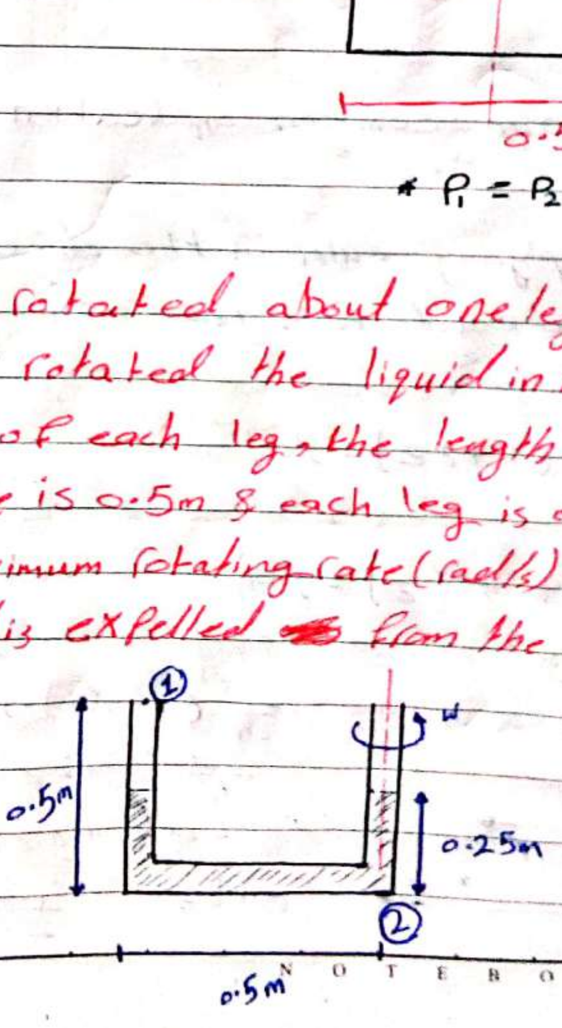
$$z_2 = 0.051\,m$$



* $P_1 = P_2 = P_{atm}$

Ex A U-tube is rotated about one leg. Before being rotated the liquid in the tube fill 0.25m of each leg, the length of the base of the tube is 0.5m & each leg is 0.5m long. what would be the maximum rotating rate (rad/s) to ensure that no liquid is expelled from the other leg?

* $P_1 = P_2 = P_{atm}$



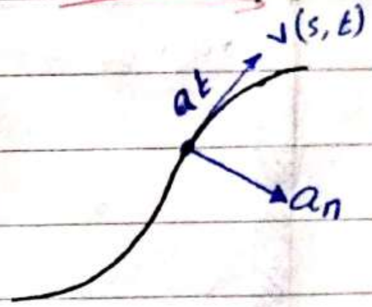
sol $\frac{P_1}{\gamma} + Z_1 - \frac{\omega_1^2 r^2}{2g} = \frac{P_2}{\gamma} + Z_2 - \frac{\omega_2^2 r^2}{2g}$

$$Z_1 = \frac{\omega_1^2 r^2}{2g} \longrightarrow \omega_1 = \sqrt{\frac{0.5 * 2 * 9.81}{0.5^2}}$$

$$\boxed{\omega_1 = 6.26 \text{ rad/s}}$$

اخر محاضرة رقم (20) 7/3

4.5 The Bernolli equation along stream line



$$a_{total} = a_t + a_n$$

$$a_{total} = v \frac{\partial v}{\partial s} + \frac{\partial v}{\partial t} + \frac{v^2}{r}$$

Applying Eular's equation

$$\frac{-d}{dL}(P + \gamma z) = \rho a_t \text{ , flow is steady } \frac{dv}{dt} = 0$$

$$\frac{-d}{ds}(P + \gamma z) = \rho v \frac{dv}{ds} \text{ , } \frac{-d}{ds}(P + \gamma z) = \rho v \frac{dv}{ds}$$

$$\frac{d}{ds}(P + \gamma z) = -\rho \frac{d}{ds}\left(\frac{v^2}{2}\right)$$

$$\frac{d}{ds}\left(P + \gamma z + \rho \frac{v^2}{2}\right) = 0 \text{ , } \boxed{\left(P + \gamma z + \rho \frac{v^2}{2}\right) = C}$$ Bernolli equ

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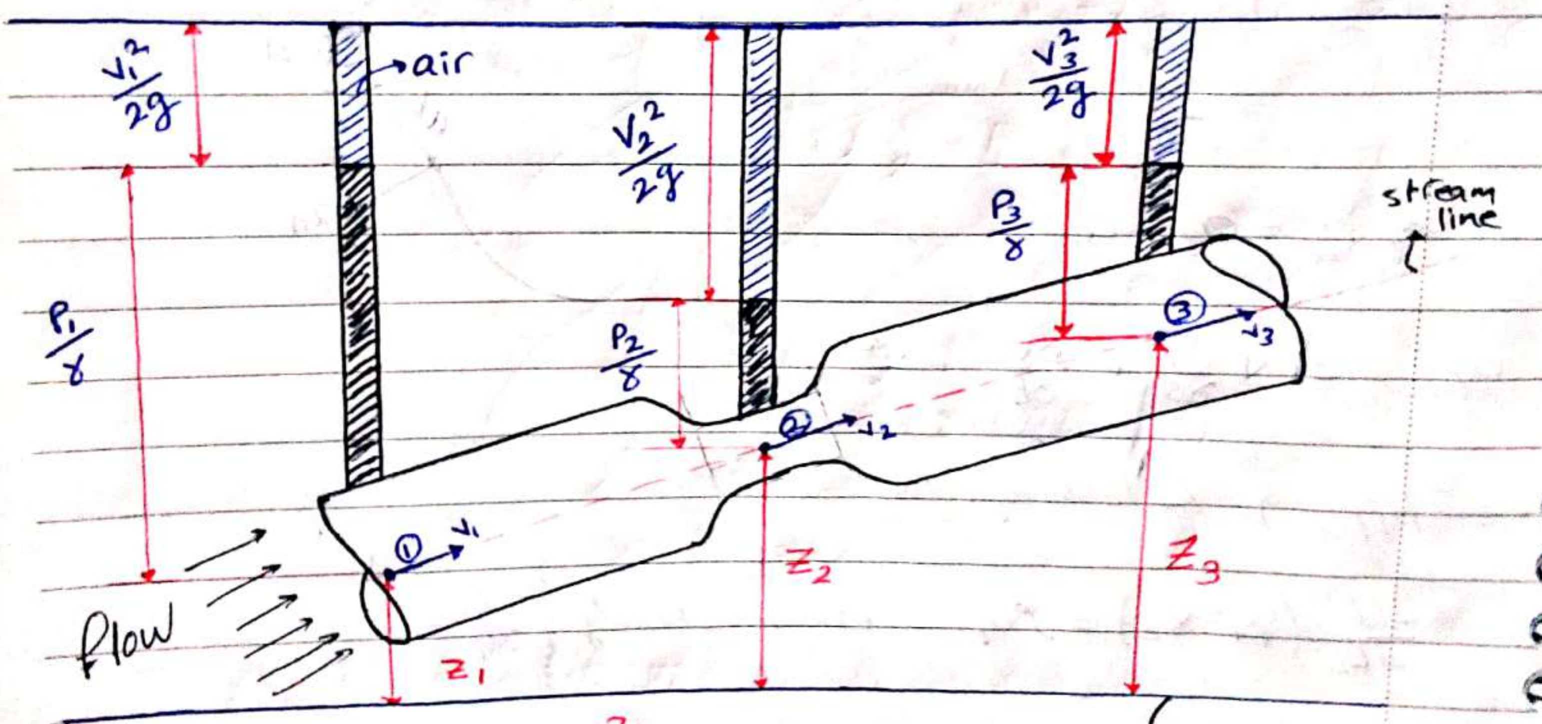
⇒ which mean the sum of pizometric pressure $(P+\gamma z)$ & Kinetic pressure $(\rho \frac{v^2}{2})$ is constant along stream line for steady flow of an incompressible inviscid fluid.

$$\boxed{\frac{P}{\gamma} + Z + \frac{V^2}{2g} = C} \longrightarrow \boxed{h + \frac{V^2}{2g} = C}$$

h → pizometric (head)

$\frac{V^2}{2g}$ → velocity head



{ Venturi section }

$$\left(\frac{P_1}{\gamma}\right) + (Z_1) + \left(\frac{V_1^2}{2g}\right) = \left(\frac{P_2}{\gamma}\right) + (Z_2) + \left(\frac{V_2^2}{2g}\right) = \left(\frac{P_3}{\gamma}\right) + (Z_3) + \left(\frac{V_3^2}{2g}\right)$$

$\frac{P_1}{\gamma}$ → pressure head

Z_1 → elevation head

$\frac{V_1^2}{2g}$ → velocity head

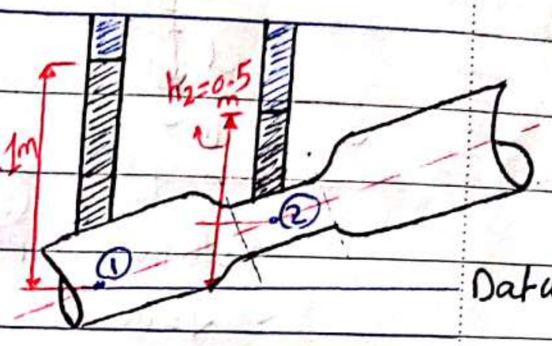
* Application of Bernolli equation.

[1] Venturi section: is used to measure the velocity of flo[w]

Ex 4.6

* velocity of throat area twice of large area.

$\boxed{V_2 = 2V_1}$, find the velocity of throat area ?!



sol: $h_1 + \frac{V_1^2}{2g} = h_2 + \frac{V_2^2}{2g}$ — eq(1)

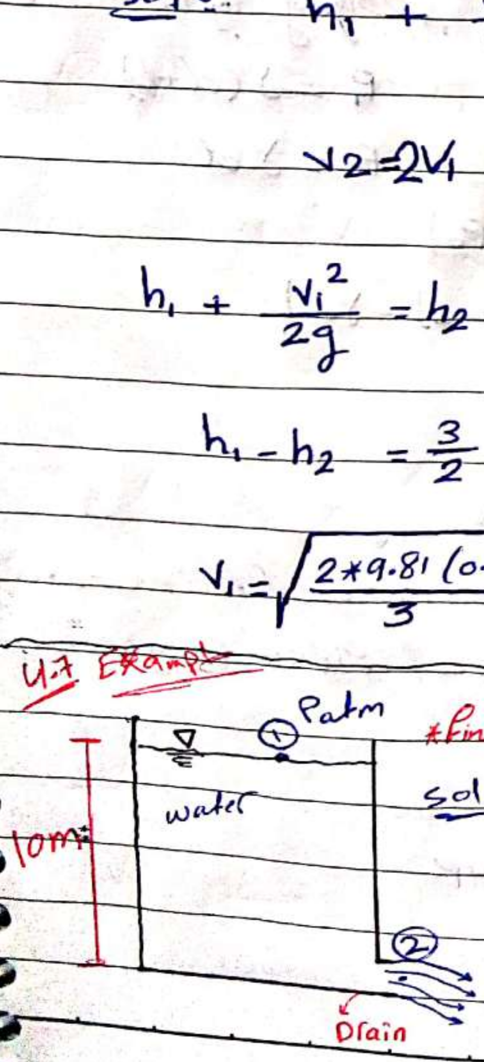
$V_2 = 2V_1$ — eq(2)

$$h_1 + \frac{V_1^2}{2g} = h_2 + \frac{4V_1^2}{2g} \Rightarrow h_1 - h_2 = \frac{2V_1^2}{g} - \frac{V_1^2}{2g}$$

$$h_1 - h_2 = \frac{3}{2}\frac{V_1^2}{g} \Rightarrow V_1 = \sqrt{\frac{2g}{3}(h_1 - h_2)}$$

$$V_1 = \sqrt{\frac{2*9.81(0.5)}{3}} = 1.808 \text{ m/s} \qquad V_2 = 2*V_1 = 3.62 \text{ m/s}$$

4.7 Example



* Find the velocity of flow of the Drain?!

sol $P_1 = P_2 = P_{atm}$ ~ zero

$$\cancel{\frac{P_1}{\gamma}} + Z_1 + \frac{V_1^2}{2g} = \cancel{\frac{P_2}{\gamma}} + \cancel{Z_2} + \frac{V_2^2}{2g}$$

$$Z_1 = \frac{V_2^2}{2g} \Rightarrow V_2 = \sqrt{2gZ_1} = \sqrt{2*9.81*10} = \boxed{14 \text{ m/s}}$$

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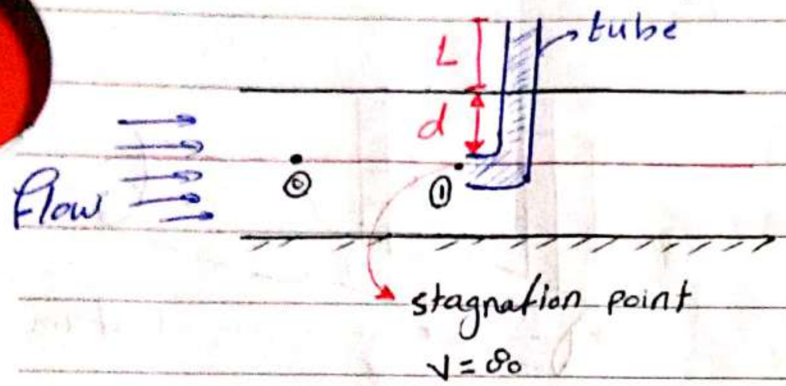
[2] Stagnation tube: an instrument can be used for measuring the velocity of the flow (open channel)



$$P_1 + \gamma Z_1 + \frac{\rho V^2}{2} = C$$

$$P_0 + \gamma \cancel{Z_0} + \frac{\rho V_0^2}{2} = P_1 + \cancel{\gamma Z_1} + \cancel{\rho \frac{V_1^2}{2}}$$

$$P_0 + \rho \frac{V_0^2}{2} = P_1$$ Applying hydrostatic

$$P_1 = \gamma (d+L)$$

$$P_0 = \gamma d$$

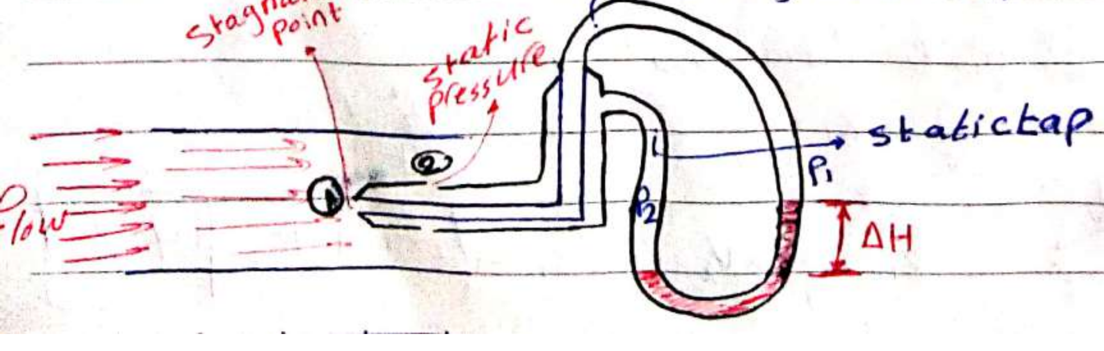
$$\hookrightarrow V_0^2 = \frac{2}{\rho} (P_1 - P_0)$$

$$V_0^2 = \frac{2}{\rho} (\gamma * (d+L) - \gamma d)$$

$$V_0^2 = \frac{2}{\rho} \gamma L$$

$$\boxed{V_0 = \sqrt{2gL}}$$

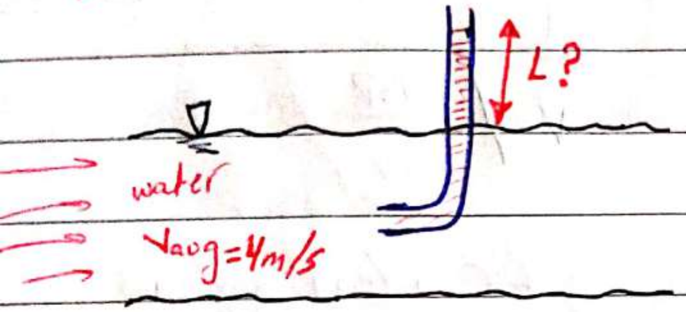
[3] pitot - static tube an instrument can be used for measuring the velocity of the flow, usefull in pressurized pipes for gases.



$$P_1 + \gamma z_1 + \rho \frac{V_1^2}{2} = P_2 + \gamma z_2 + \rho \frac{V_2^2}{2}$$

$$P_1 = P_2 + \frac{\rho V_2^2}{2} \Longrightarrow V_2 = \sqrt{\frac{2(P_{stagnation} - P_{static})}{\rho_{fluid}}}$$

Example

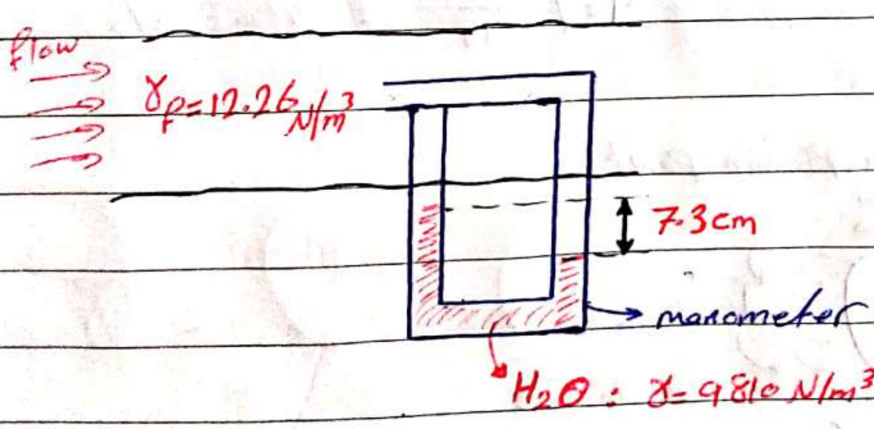


Sol

$$V_o = \sqrt{2gL}$$

$$4^2 = 2 * 9.81 * L \Rightarrow \boxed{L = 0.815 m = 81.5 cm}$$

Example. Find the velocity of flow.



$$* \Delta P = \gamma \Delta H$$

$$\Delta P = 9810 * 7.3 * 10^{-2}$$

$$\Delta P = 716.13 KPa$$

$$V = \sqrt{\frac{2(716.13 * 10^3)}{(12.26/9.81)}}$$

$$\boxed{V = 33.85 m/s}$$

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Example

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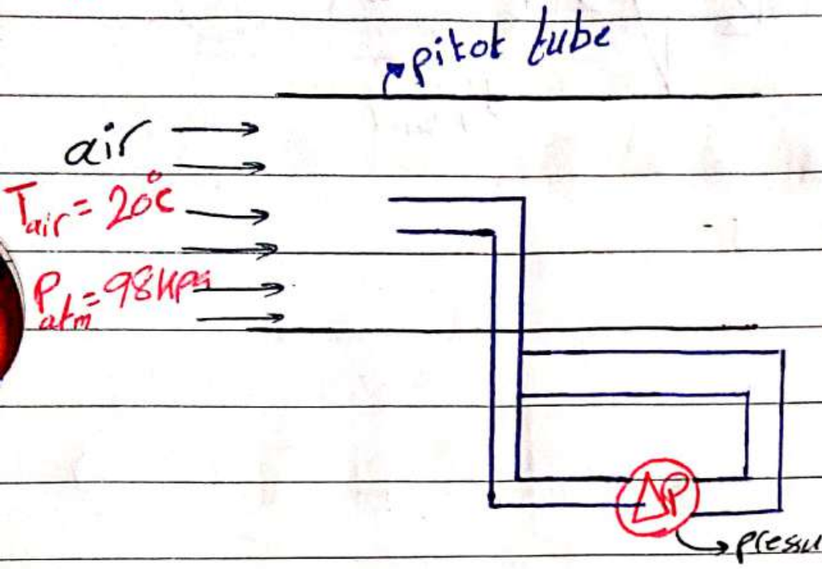


$\Delta P = 730\ pa$

* find the velocity of air inside the wind channal ?!

sol

$$V = \sqrt{\frac{2\Delta P}{\rho_{air}}}$$

for ideal gas law

$$P = \rho R T$$

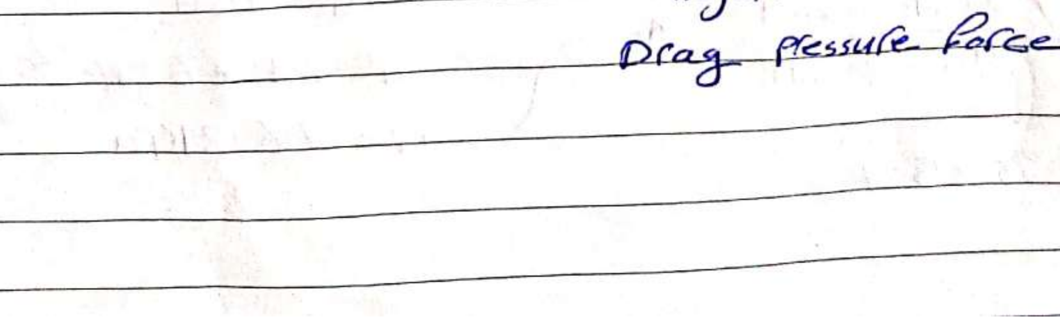
$$R_{air} = 287\ J/kg.K$$

$$98 * 10^3 = \rho * 287 * (20 + 273)$$

$$\rho = 1.17\ Kg/m^3$$

$$V = \sqrt{\frac{2 * 730}{1.17}} = 35.3\ m/s$$

4.8 sepration



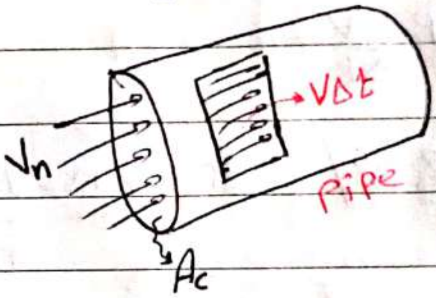
CH-5 : Control volume Approach & continuity equation

5-1 Rate flow

* Discharge (volume flow rate) $(\dot{Q})(Q)(\dot{\forall})$

The volume of fluid that passes through an area per unit time

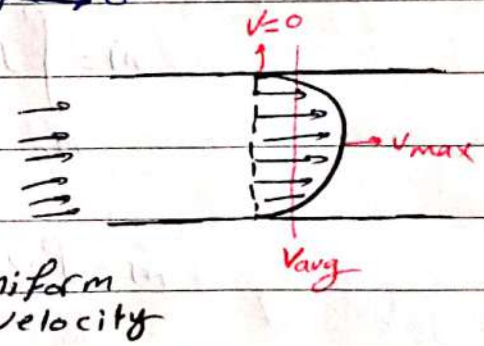
(m^3/s) or (L/s) or (gal/s)



$$\Delta\forall = A_c \underbrace{V}_{\text{velocity}} \underbrace{\Delta t}_{\text{change of time}}$$

$\frac{\Delta\forall}{\Delta t} = A_c V$ ⟶ take limit $\Delta t \to 0$

$$\lim_{\Delta t \to 0} \frac{\Delta\forall}{\Delta t} = Q = V_n \cdot A_c$$

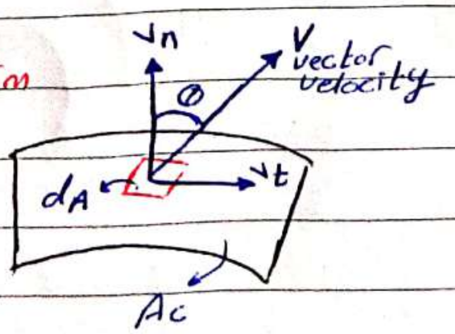


$$\boxed{Q = V_n \cdot A_c}$$

This equ based on a constant velocity over the cross section area.

$Q = V_{avg} \cdot A_c$, $V_{avg} = \frac{1}{A_c} \int_{A_c} V_n \cdot dA$

* In general form



* $V_n \cdot dA = |V| \cos(\theta) \cdot d_A = V \cdot A_c$

$\boxed{Q = V \cdot A_c}$ → Dot product

④ Mass flow rate ($\dot{m}$)

* The mass of fluid passing through across sectional area per unit time (kg/s).

$$\Delta m = \rho \Delta V$$

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

$$\boxed{\dot{m} = \rho . \dot{V}} \quad \text{or} \quad \boxed{\dot{m} = \rho . V_n . A_c}$$

Ingeneral form :-

$$\boxed{\dot{m} = \int_{A_c} \rho V . dA}$$

* constant density.

$$\boxed{\dot{m} = \rho . V_{avg} . A_c}$$

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$Q = \int_{A_c} V_n \cdot dA$, $Q = V_{avg} \cdot A$

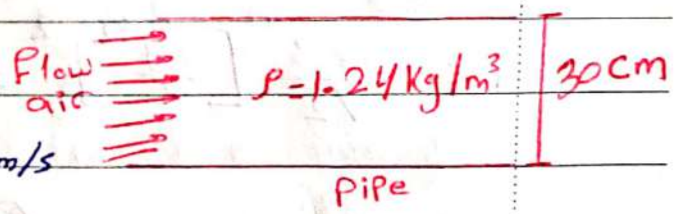
$V_{avg} = \frac{1}{A_c} \int_{A_c} V \cdot dA$, $Q = V \cdot A$

$\dot{m} = \rho Q \Rightarrow \dot{m} = \rho \int V \cdot dA$, where ρ is constant

$\boxed{\dot{m} = \rho V_{avg} A_c}$

Example $\rho_{air} = 1.24\ kg/m^3$, $\dot{m} = 3\ kg/s$

what are the mean velocity & discharge in this pipe?!



sol

$V_{avg} = \frac{Q}{A}$

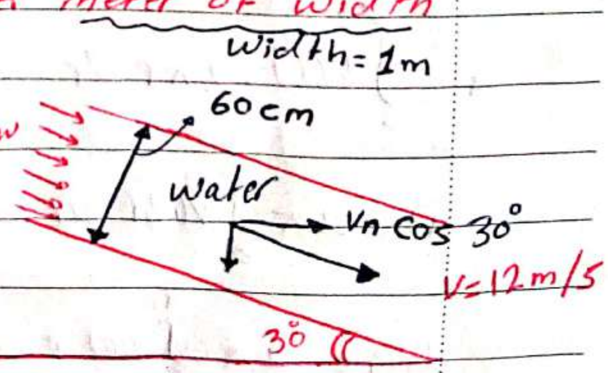
$V_{avg} = \frac{\dot{m}}{\rho A} = \frac{3}{1.24 * \frac{\pi}{4}(0.3)^2} = 34.2\ m/s$

$Q = V_{avg} \cdot A$

$= 34.2 * \frac{\pi}{4}(0.3)^2 = 2.42\ m^3/s$

$\dot{m} = \rho \cdot Q \Rightarrow Q = \frac{\dot{m}}{\rho} = \frac{3}{1.24} = 2.42\ m^3/s$

Example what is the direction per meter of width of the channel ?!



sol

$Q = V \cdot A$

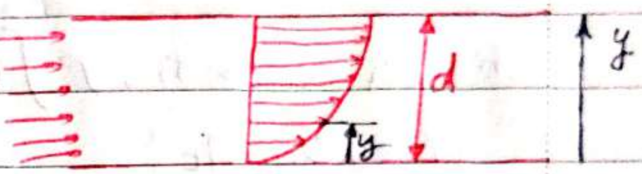
$Q = V \cos 30° \cdot (0.6 * 1)$

$Q = 12 * \frac{\sqrt{3}}{2} (0.6) = 6.24\ m^3/s$

per meter wide

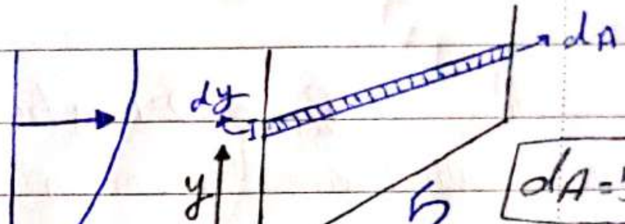
Example ~~The~~ The water velocity in the channel equal $\frac{u}{u_{max}} = \left(\frac{y}{d}\right)^{1/2}$, what is the discharge in the channel if the water is 2m deep, the wide of channel is 5m if the maximum velocity 3m/s??

Sol



$$Q = \int_{A_c} u \cdot dA$$

$$Q = \int_{A_c} u_{max} \left(\frac{y}{d}\right)^{1/2} \cdot dA$$



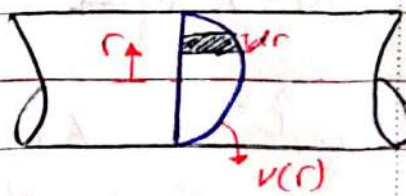
$\boxed{dA = 5dy}$

$$Q = \frac{5\, u_{max}}{\sqrt{d}} \int_0^2 y^{1/2} \cdot dy$$

$$Q = \frac{5 * 3}{\sqrt{2}} \left[\frac{2y^{3/2}}{3}\right]_0^2 = \frac{5*3}{\sqrt{2}} * \frac{2}{3} * 2^{3/2} = 20\ m^3/s$$

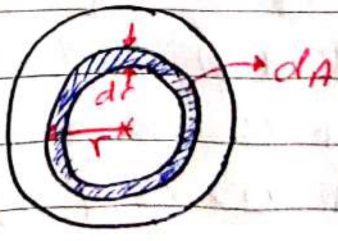
* Special case:- Flow in pipe

$$Q = \int_A v \cdot dA$$



$$Q = \int_0^{r_o} v(r) \cdot 2\pi r\, dr$$

$$Q = 2\pi \int_0^{r_o} v(r)\, r\, dr$$



$$V_{avg} = \frac{2\pi \int_0^{r_o} v(r) \cdot r \cdot dr}{A_c}$$

$\boxed{dA = 2\pi\, dr}$

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Exampl Prob 5.24 — The velocity $\frac{V}{V_c} = \left(1-\left(\frac{r}{r_0}\right)^2\right)^n$, where

V_c the velocity at centerline,

r_0: radius of pipe, r: radial distance from the center line

n: exponent → $\boxed{n=1}$ → lamener
→ غير ذلك → turbinet

is general of is chosen to fit agiven profile ($n=1$ for laminar flow). Determine the mean velocity as a function of V_c & n ??

Sol $V_{avg} = \frac{2\pi}{A_c}\int_0^{r_0} v(r) \cdot r \cdot dr$

$V_{avg} = \frac{2\pi}{A_c}\int_0^{r_0} r \cdot V_c\left(1-\left(\frac{r}{r_0}\right)^2\right)^n dr$

$V_{avg} = \frac{2\pi V_c}{A_c}\int_0^{r_0} r\left(1-\left(\frac{r}{r_0}\right)^2\right)^n \cdot dr$ * let $x = 1-\left(\frac{r}{r_0}\right)^2$

$dx = \frac{-2r}{r_0^2} dr$

$V_{avg} = \frac{2\pi V_c}{A_c}\int_1^0 x^n \cdot \frac{-r \cdot r_0^2}{2r} \cdot dx$ $r=0 \rightarrow x=1$

$r=r_0 \rightarrow x=0$

$V_{avg} = \frac{-\pi V_c}{A_c} \cdot r_0^2 \int_1^0 x^n \cdot dx$

$V_{avg} = \frac{-\pi V_c \cdot r_0^2}{A_c}\left[\frac{x^{n+1}}{n+1}\right]_1^0 = \frac{-\pi V_c r_0^2}{A_c}\left[0 - \frac{1}{n+1}\right]$

$V_{avg} = \frac{\pi V_c r_0^2}{A_c(n+1)} = \frac{\pi V_c r_0^2}{\pi r_0^2(n+1)} = \boxed{\frac{U_c}{n+1}}$ #

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(24) محاضرة رقم

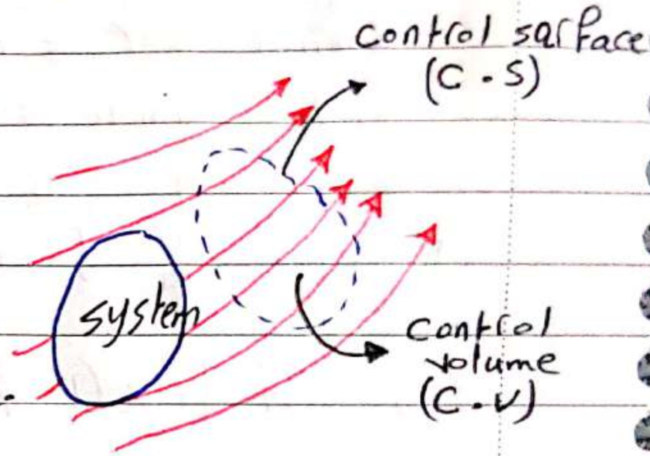
5.2 :- control volume approach

17/3

<u>def</u> A control volume is a volume located in space and through which matter can pass.

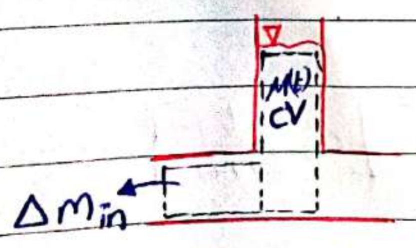
{ System pass control volume }

- it can deform with time
- it can move and rotate
- The mass of the control volume can change with time.



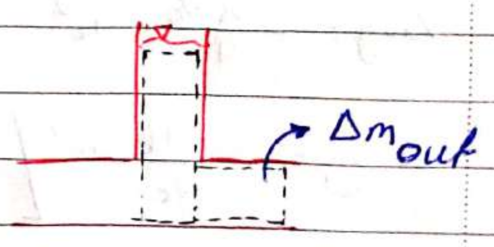
⇒ system: is a continous mass of fluid that always contions the same matter.

→ control surface :- boundary of the C.V



The system at time (t)

$M_{system}(t) = M_{cv}(t) + \Delta m_{in}$



The system at time

$M_{system}(t+\Delta t) = M_{cv}(t+\Delta t) + \Delta m_{out}$

From the conservation of mass

$= M_{cv}(t+\Delta t) - M_{cv}(t)$

$M_{sys} = M_{sys}(t+\Delta t)$

ΔM_{cv}

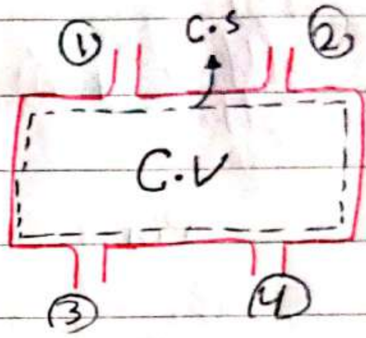
$M_{cv}(t) + \Delta m_{in} = M_{cv}(t+\Delta t) + \Delta m_{out}$

$\{\Delta M_{cv} + \Delta M_{out} - \Delta m_{in} = 0\}$ divided by Δt

$\frac{\Delta M_{cv}}{\Delta t} + \frac{\Delta m_{out}}{\Delta t} + \frac{\Delta m_{in}}{\Delta t} = 0$, limit $\Delta t \to 0$

$\lim_{\Delta t \to 0} \frac{\Delta M_{cv}}{\Delta t} + \lim_{\Delta t \to 0} \frac{\Delta M_{out}}{\Delta t} + \lim_{\Delta t \to 0} \frac{\Delta m_{in}}{\Delta t} = 0$

$\frac{dM_{cv}}{dt} + \dot{m}_{out} - \dot{m}_{in} = 0$



$$\boxed{\frac{dM_{cv}}{dt} + \sum_{C.S} \dot{m}_{out} - \sum_{C.S} \dot{m}_{in} = 0}$$

The rate from of continusly equation principle

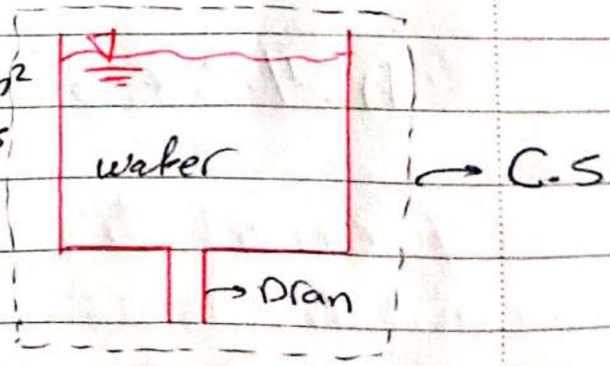
[the acceleration rate of mass in the control volume] + [The net flow rate of the mass through the control volume] = 0

Example what the value is water accumulation in the tank?

$V = 7\,m/s$

$A = 0.0025\,m^2$

$Q = 0.003\,m^3/s$



sol

$\frac{dM_{cv}}{dt} + \sum_{C.S} \dot{m}_{out} + \sum_{C.S} \dot{m}_{in} = 0$

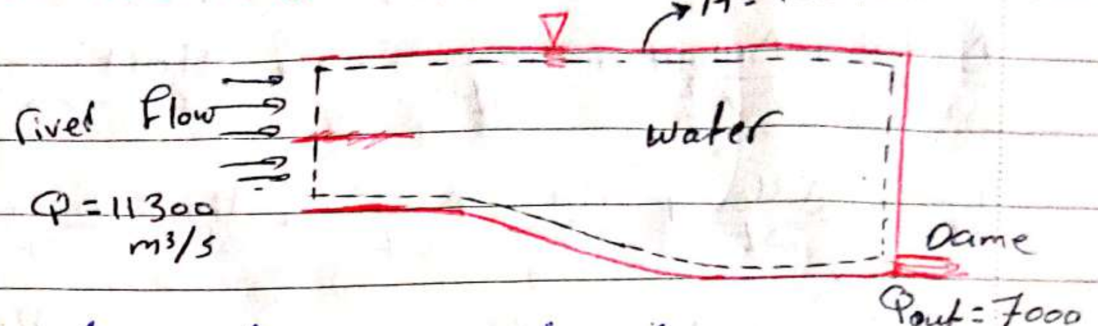
$\dot{m}_{in} = \rho V A = 1000(7)(0.0025)$

* $\dot{m}_{in} = 17.5\,Kg/s$

* $m_{out} = \rho Q = 1000 * 0.003 = 3\,Kg/s$

$\frac{dM_{cv}}{dt} = 17.5 - 3 = \{14.5\,Kg/s\}$

Example What is the rate of rise of water in the Dame?



sol

$$\text{zero} \leftarrow \frac{dM_{cv}}{dt} + \dot{m}_{out} - \dot{m}_{in} = 0 \Rightarrow \dot{m}_{in} = \dot{m}_{out}$$

$$Q_{in} = Q_{out} + Q_{rise}$$

$$\rho Q_{in} = \rho Q_{out} + \rho Q_{rise}$$

$$\dot{m}_{in} = \dot{m}_{out} + \rho(h * A)$$

$$11300(1000) = 7000(1000) + 100(h * 100 * 10^{6})$$

$$h = 4.3 * 10^{-5}\ m/s$$

$$h = 4.3 * 3600 = 0.155\ m/hr$$

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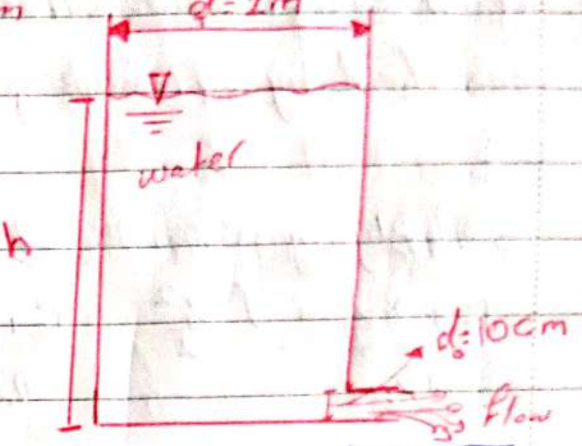
19/3/2019

Example

* How long will take for water surface in the tank to drop from $h_o = 2m$, $h_f = 0.5m$?!



$\hookrightarrow V = \sqrt{2gh}$

$* \ \dot{m} = \rho V A_o$

$\dot{m}_o = \rho A_o \sqrt{2gh}$

sol

$$\frac{dM_{cv}}{dt} + \sum_{c.s} \dot{m}_{out} - \sum_{c.s} \dot{m}_{in} = 0$$

$$dM_{c.v} = \rho \, d\forall \quad . \; d\forall = A_T \, dh$$

$$dM_{cv} = \rho A_T \, dh \Rightarrow \frac{dM_{cv}}{dt} = \rho A_T \frac{dh}{dt}$$

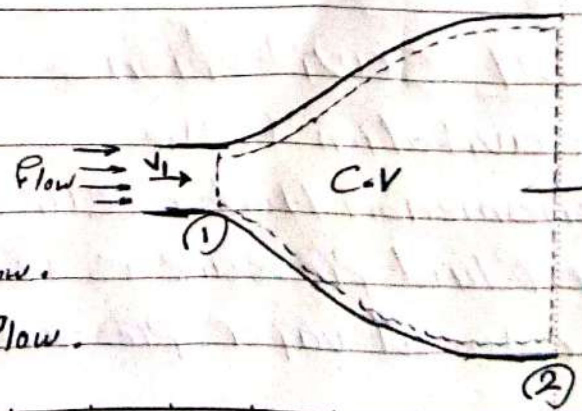
$$\rho A_T \frac{dh}{dt} = -\rho A_o \sqrt{2gh}$$

$$\int_{h_o}^{h_f} \frac{-A_T}{A_o\sqrt{2gh}} \cdot dh = \int_0^t dt \Rightarrow \frac{-A_T}{A_o\sqrt{2g}} \int_{h_o}^{h_f} \frac{1}{\sqrt{h}} \cdot dh = t$$

$$\frac{-A_T}{A_o\sqrt{2g}} \Big[2\sqrt{h} \Big]_2^{0.5} = t \Rightarrow \frac{-2\left(\frac{\pi}{4}(1)^2\right)}{\frac{\pi}{4}(0.1)^2\sqrt{2 \times 9.81}} \left(\sqrt{0.5} - \sqrt{2}\right) = t$$

$$t = 31.9 \text{ sec}$$

* continuity eq for flow in pipe.



$$\frac{dM_{c.v}}{dt} = 0 \;, \; \dot{m}_{in} = \dot{m}_{out} \;, \; \dot{m}_1 = \dot{m}_2$$

$\dot{m} = \rho V_1 A_1 = \rho V_2 A_2$ for compressible flow.

$V_1 A_1 = V_2 A_2$ for incompressible flow.

$$Q_1 = Q_2$$

NOTEBOOK

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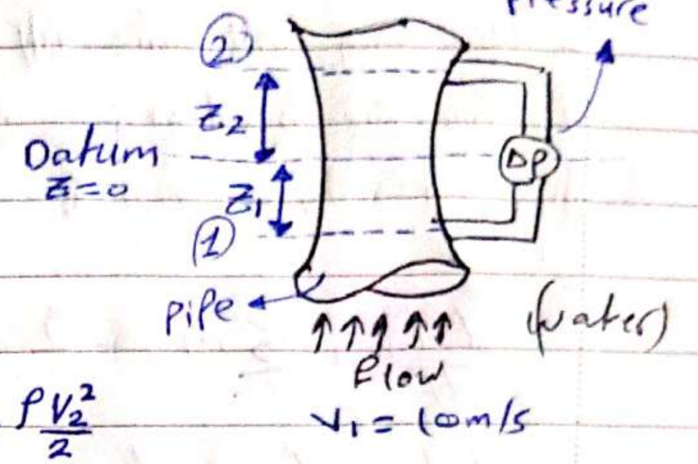
Example $\frac{A_{throat}}{A_{pipe}} = 0.5$



* Find the pressure difference recorded by pressure gage.

Sol

⇒ Applying Bernolli eq

$$\underbrace{P_1 + \gamma z_1}_{P_{z_1}} + \rho \frac{V_1^2}{2} = \underbrace{P_2 + \gamma z_2}_{P_{z_2}} + \rho \frac{V_2^2}{2}$$

$$P_{z_1} - P_{z_2} = \frac{\rho}{2}(V_2^2 - V_1^2)$$

* Applying continuity

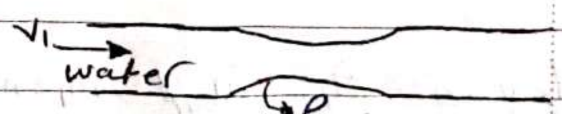
$$A_1 V_1 = A_2 V_2 \Rightarrow \boxed{V_2 = \frac{A_1}{A_2} V_1}$$

$$P_{z_1} - P_{z_2} = \frac{\rho}{2}\left(\left(\frac{A_1}{A_2}\right)^2 V_1^2 - V_1^2\right)$$

$$P_{z_1} - P_{z_2} = \frac{\rho V_1^2}{2}\left(\left(\frac{A_1}{A_2}\right)^2 - 1\right)$$

$$P_{z_1} - P_{z_2} = \frac{1000 \times 10^2}{2}(2^2 - 1) = 150 \times 10^3 \, Pa \text{ or } 150 \, KPa$$

5.4 Cavitation:-



$P_{sat} = 101.3 \, KPa$

$T_{sat} = 99.8 \, C^\circ$

* Cavitation is the phenomenon that occurs when the fluid pressure is reduced to the local vapor pressure and boiling occurs.

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under this condition vapor bubbles from in the liquid and then collapse, producing shock waves. noise and dynamic effects, that lead to decrease equipment performance and equipment failure.

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CH-6 :- Momentum principle

6.1 Momentum eq. derivation

* considering Newton's 2^{nd} law for a fluid particles.

$$\Sigma F = ma \quad or \quad \Sigma F = \frac{d(m.v)}{dt}$$

$$\Sigma F = \frac{d(Mom)_{sys}}{dt} \text{ for groups of particles}$$

* Reynolds transport theorem.

{Rate of change of property (B) of the system} = {Rate of change of property (B) in control volume} + {Net out flow of property (B) through the control surface}

B :- extensive property (dependent on mass)
b :- intensive property (independent of mass)

$$b = \frac{B}{m}$$

$$\frac{dB_{sys}}{dt} = \frac{d}{dt}\int_{C.V} b \rho \, d\forall + \int_{C.S} b \, \rho . V . dA$$

* Applying Mom_{sys} , $b = v$ (velocity) , $B = mv$

$$\frac{d\,Mom_{sys}}{dt} = \frac{d}{dt}\int_{C.V} v . \rho . d\forall + \int_{C.S} \underline{v} . \rho . \underline{V} . dA \text{ ------ eq (1)}$$

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