Fluid dynamics

Fluid - Liquid & gas

dynamics - branch of physics which deals with motion of fluid and forces acting upon it.

Unit operations - Mass transfer, Heat transfer, mechanical operation.

Raw material → unit operations + unit process → desired product.

All the unit operations and unit process generally takes place in fluid medium because we get better transfer rates

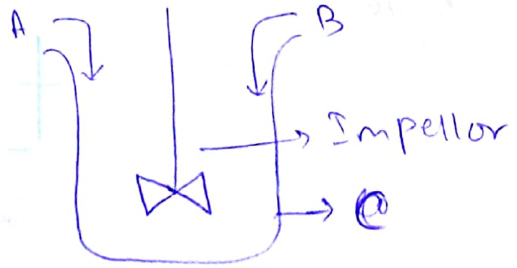
eg diffusion rate
heat transfer rate
rate of chemical reaction.

Applications of F.D :-

① Flow measurement : quality & quantity control.

② Design - complex network of pipelines, valves, joints etc, pumps, compressor blower.

③ Reactor -



→ depending on the properties of fluid, impeller is designed.
→ power consumption.

Reynolds Apparatus :-

To find out the Reynold's no and determine the type of flow.

Reynolds no is a dimensionless no $= \frac{DV\rho}{\mu}$

D - diameter of pipe
V - velocity of liquid in pipe.
ρ - density of liquid
μ - Viscosity of liquid

Reynolds no can be defined as $\frac{\text{inertial forces}}{\text{viscous forces}}$

$$= \frac{DV\rho}{\mu} = \frac{L^1 \times L^1T^{-1} \times M^1L^{-3}}{M^1L^{-1}T^{-1}} = \frac{M^1L^{-1}T^{-1}}{M^1L^{-1}T^{-1}} = M^0L^0T^0$$

Laminar flow for Re < 2000 (straight flow)

Transition flow 2000 < Re < 4000 (zigzag flow)
(laminar + turbulent)

Turbulent zone Re > 4000 (wave flow)

Low critical Re no
Upper critical Re no

Units

1. S.I units - It is international units which is accepted every where.

Fundamental quantities - These are those from which other quantities are derived.

Mass (m), Length (L), Time (T), Temp (K), mole

2. MKS unit - Metre Kg second
3. FPS unit - foot pound second
4. CGS unit - cm gram second

$F = ma = M^1 L^1 T^{-2}$

MKS - $Kg\ m\ s^{-2}$

FPS - Pound $ft\ s^{-2}$

CGS - gram $cm\ s^{-2}$

1 Kg Force $= 9.8\ Kg\ m\ s^{-2}$

1 lb force $= 9.8 \times \cancel{2.2705} \times 3.281 ft \times s^{-2}$

$= \cancel{70.0849}$ pound $ft\ s^{-2}$

$= 32.15$

$1 Kgf = 9.8\ Kg\ m\ s^{-2}$ $1\ Kg = 2.204\ lb$

$1 \times 2.204\ lb\ f = 9.8 \times 2.204\ lb \times 3.28\ ft\ s^{-2}$

$\Rightarrow 1 lb f = 9.8 \times 3.28\ lb\ ft\ s^{-2} = 32.15\ lb\ ft\ s^{-2}$

Q1. Calculate factors for converting atmosphere to pounds force per sq. inch.

Q2. Newton to pound force.

Q1 =) Pressure = $\frac{\text{Force}}{\text{Area}} = \frac{M^1L^1T^{-2}}{L^2} = M^1L^{-1}T^{-2}$

$1 \text{ atm} = 101325 \text{ Pa}$

$= 101.325 \text{ KPa}$

$1 \text{ KPa} = 0.145 \text{ lbf/in}^2$

$101.325 \text{ KPa} = 0.145 \times 101.325 \text{ lbf/in}^2$

$= 14.696 \text{ lbf/in}^2$

Q2. $1 \text{ N} = \frac{1}{9.8} \text{ kgf}$

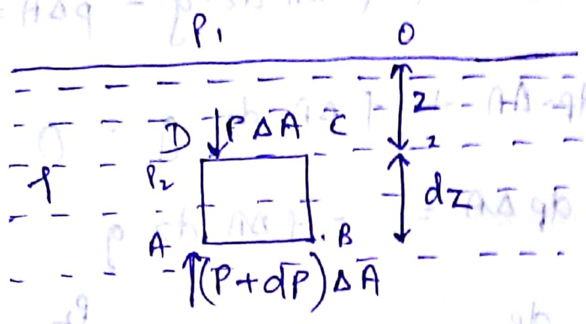
$= \frac{1}{9.8} \times 2.204 \text{ lbf}$

$= 0.224 \text{ lbf}$

FLUID STATICS

Study of fluid at rest.

Hydrostatic equilibrium :-



Force acting on DC = $P \Delta A$

Force acting on AB = $(P+dP)\Delta A$

weight = $\rho V g$ (V = volume)

$= \rho \times \Delta A \times dz \times g$

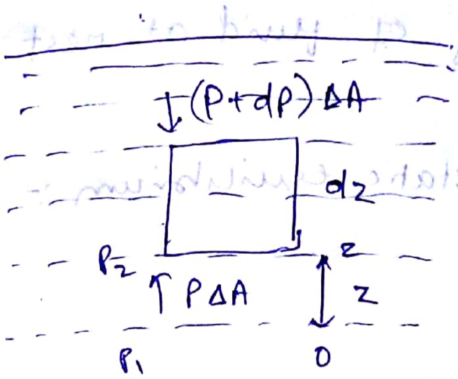
$$P\Delta A + \rho \cdot \Delta A \cdot dz \cdot g - (P+dP)\Delta A = 0$$

$$\Rightarrow -dP\,\Delta A + \rho \cdot \Delta A \cdot dz \cdot g = 0$$

$$\Rightarrow \frac{dP}{dz} = \rho g$$

$$\Rightarrow \int_{P_1}^{P_2} dP = \rho g \int_{0}^{z} dz$$

$$\Rightarrow P_2 = P_1 + \rho g z$$



$$(P + dP)\Delta A + \rho \cdot \Delta A \cdot dz \cdot g - P\Delta A = 0$$

$$\Rightarrow dP \cdot \Delta A + \rho \cdot \Delta A \cdot dz \cdot g = 0$$

$$\Rightarrow dP\,\Delta A = -\rho\,\Delta A \cdot dz\, g$$

$$\Rightarrow \frac{dP}{dz} = -\rho g \quad \Rightarrow \int_{P_1}^{P_2} dP = -\rho g \int_0^z dz$$

$$\Rightarrow P_2 = P_1 - \rho g z$$

$$\Rightarrow P_1 = P_2 + \rho g z$$

So it is concluded that pressure increases when we go from top to bottom of liquid.

Incompressible & compressible fluid :-

Those fluids whose density varies w.r.t temp and pressure are known as compressible fluids. eg- gases.

Those fluids whose density don't change much with respect to temp & pressure are known as incompressible fluids. eg- liquid.

$\frac{dP}{dz} = -\rho g$ is the hydrostatic equilibrium law.

$PV = nRT$ - ideal gas eq.^{n}

For an ideal compressible gas, ρ changes with P.

So $\rho = \frac{PM}{RT}$

$\Rightarrow \frac{dP}{dz} = -\frac{PM}{RT} g$

$\Rightarrow \int_{P_1}^{P_2} \frac{dP}{P} = -\frac{Mg}{RT} \int_0^z dz$

$\Rightarrow \boxed{\ln \frac{P_2}{P_1} = -\frac{Mgz}{RT}}$

Q. The temp of earths atmosphere drops about 5°C for every 1000 m of elevation above the earth surface. If air temp at ground is 15°C and the pressure is 760 mm Hg, at what elevation is the pressure 380 mmHg. Assume the air to be ideal. (M=29)

$\Rightarrow \frac{dT}{dz} = \frac{-5+273}{1000}$

$\Rightarrow \int_{15+273}^{T} dT = \frac{268}{1000} \int_0^z dz$

$\Rightarrow T - 288 = 0.268\,z$

$\Rightarrow T = 288 + 0.268\,z$

$\frac{dP}{dz} = -\frac{PMg}{RT} \Rightarrow \int_{760}^{380} \frac{dP}{P} = -\frac{Mg}{RT} \int_0^z dz$

$\Rightarrow \ln \frac{380}{760} = \frac{-29 \times 981}{8314 \times 288 + 0.268\,z} \times z$

$\Rightarrow 0.69 = 29 \times 981 \times z$

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$\Rightarrow 0.69 \times (8314 \times (288 + 0.2682z)) = 28449\,z$

$\Rightarrow \cancel{288 + 0.2682z = 9.9}$

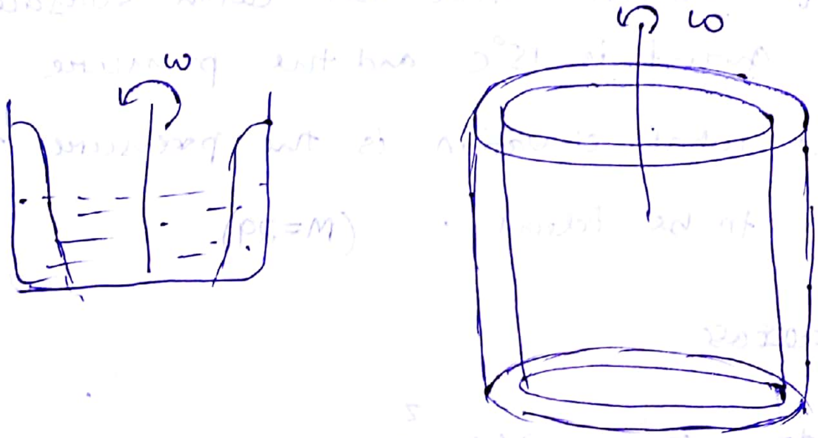
$\Rightarrow 5736.66\,(288 + 0.2682z) = 28449\,z$

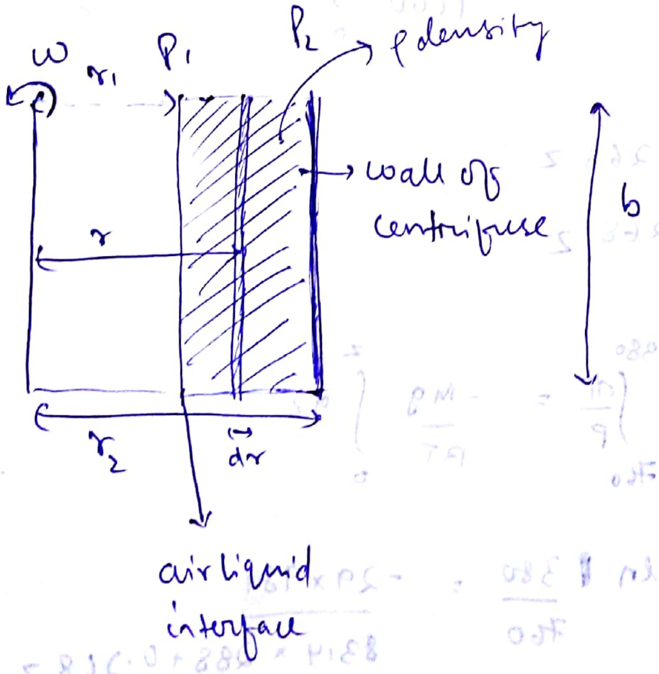
$\Rightarrow 1652158.08 + 1537.42\,z = 28449\,z$

$\Rightarrow \dfrac{1652158.08}{26911.58} = z$

$\Rightarrow z = 61.$

Hydrostatic equilibrium in a centrifugal field :-





$dF = dm\,\omega^2 r$ (Centrifugal force on dm)

$dm = (2\pi r \cdot dr)\, b \times 1$

$$dP = \frac{dF}{A} = \frac{2\pi r \cdot \omega^2 \cdot b \cdot dr \times \rho}{2\pi r b}$$

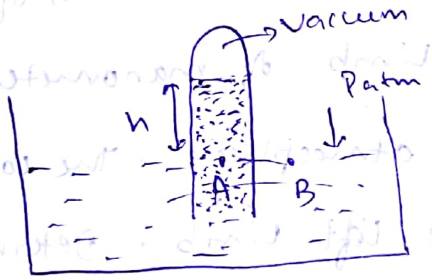
$$\Rightarrow \int_{P_1}^{P_2} dp = \omega^2 \rho \int_{r_1}^{r_2} r \cdot dr$$

$$\Rightarrow P_2 - P_1 = \frac{\omega^2 \rho}{2}\left(r_2^2 - r_1^2\right)$$

$$\Rightarrow \boxed{P_2 = P_1 + \frac{\omega^2 \rho}{2}\left(r_2^2 - r_1^2\right)}$$

Pressure measurement :-

Pressure exerted by air at sea level is measured by a barometer.



$P_A = P_B$

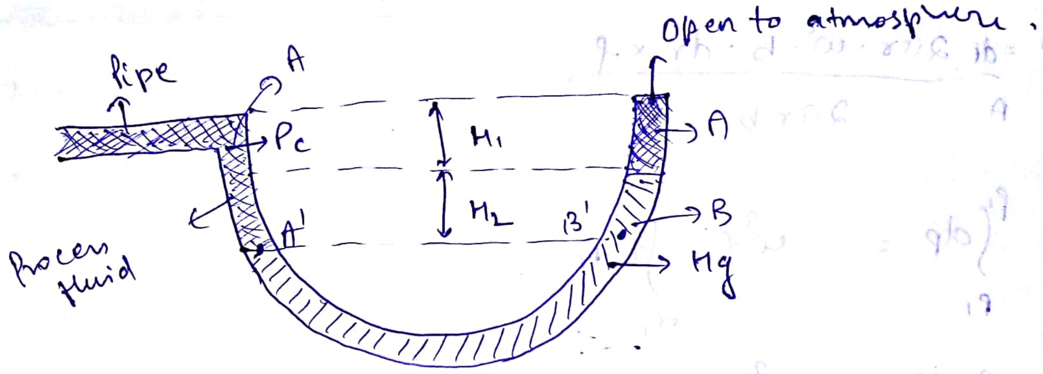
$\Rightarrow \underset{\text{(vacuum)}}{0} + h\rho g = P_{atm}$

$\Rightarrow 0.76\,m \times \underset{\text{density of Hg}}{13.6 \times 10^3} \times 9.8 = P_{atm}$

$\Rightarrow P_{atm} = 1.013 \times 10^5$ Pascal

$$\boxed{\frac{P}{\rho g} = h}$$

U-tube - manometer :-



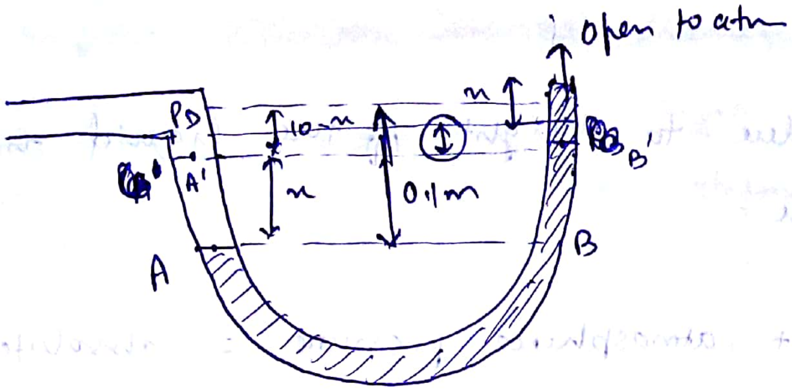
$$P_{A'} = P_{B'}$$

$$\Rightarrow P_c + (H_1 + H_2)\rho_A g = P_{atm} + H_1 \rho_A g + H_2 \rho_B g$$

$$\Rightarrow \boxed{P_c = P_{atm} + H_2(\rho_B - \rho_A) g}$$

Q. A u-tube manometer is used to ~~prepo~~ measure the pressure of water in a pipeline, which is in excess of atmospheric pressure. The right limb of manometer contains mercury and is opened to atmosphere. The contact betn water and mercury is in the left limb. Determine the pressure of water in the pipeline if the difference in level of mercury in the limbs of U-tube manometer is 10cm and the free surface of the mercury is in level with centre of pipe containing water. If the pressure of water in pipeline is reduced to 9810 N/m^2. Calculate the new difference in the level of mercury.

=)



$$P_B = \cancel{P_{atm}}^{\,0} + 0.1\,(\rho_B - \rho_A)\,g$$

$$= 0.1\,(13600 - 1000) \times 9.8$$

$$= 13328 \text{ Pascal}$$

$$P_A = 0.1 \times \rho_A \times g + P_D$$

$$= 0.1 \times 1000 \times 9.8 + P_D$$

$$= 980 + P_D$$

So $P_D + 980 = 13328$

$$\Rightarrow P_D = 12348 \text{ Pascal}.$$

$$P_{A'} = P_{B'}$$

$$\Rightarrow P_D + \left(\frac{10-x}{100}\right) \times 1000 \times 9.81 = \frac{10-2x}{100} \times 13.6 \times 10^3 \times 9.81$$

$$\Rightarrow 9810 + (10-x) \times 98.1 = (10-2x) \times 13.6 \times 98.1$$

$$\Rightarrow 9810 + 981 - 98.1x = (10-2x) \times 1334.16$$

$$\Rightarrow x = 0.99$$

So difference $= 10 - 1.98 = 8.01$ cm.

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Pressure acting due to height of the liquid is called as gauge pressure.

Gauge pressure + atmosphere pressure = absolute pressure.

Q. Find the gauge pressure and absolute pressure at a point 3m below the free surface of the liquid having a density

$\rho = 1.53 \times 10^3 \ kg/m^3$

$P_{atm} = 750 \ mm$ of Hg

S.g of Hg = 13.6

⇒ At. pressure = $\rho g h$ = $13.6 \times 1000 \times 9.81 \times 0.75$ = $100062 \ N/m^2$

Pressure at the depth of 3m = $1.53 \times 10^3 \times 9.81 \times 3$

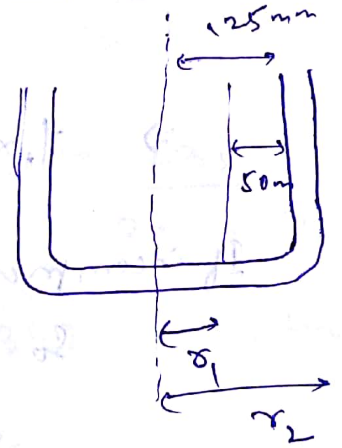
= $45028 \ N/m^2$

Absolute pressure = $145090 \ N/m^2$

Q. Find out the height of water which exerts pressure of $100062 \ N/m^2$

⇒ $z = \frac{P}{\rho g} = \frac{100062}{1000 \times 9.81} = 10.2 \ m$

Q. A centrifuge 250 mm internal diameter is turning at 4000 rev/min. It contains a layer of chlorobenzene 50 mm thick. If the density of chlorobenzene is 1109 kg/m³ and the pressure at the liquid is atm. pressure, what gauge pressure is exerted on the walls of centrifuge.



$r_1 = 75$ mm

$r_2 = 125$ mm

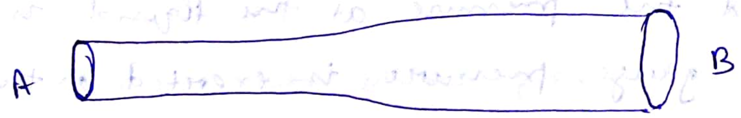
⇒ $\omega = 2\pi \times \frac{4000}{60} = 418.6$ rad/sec

$$P_2 - P_1 = \frac{\omega^2 \rho (r_2^2 - r_1^2)}{2}$$

$$= \frac{418.6^2 \times 1109 (0.125^2 - 0.075^2)}{2}$$

$$= 971627.94 \text{ N/m}^2$$

Equation of continuity:-



$\dot{m}_A = \dot{m}_B$ ($\dot{m}_A$ = mass flow rate of liquid coming out of 'A')

$\Rightarrow \rho_A \times A_A \times V_A = \rho_B \times A_B \times V_B$

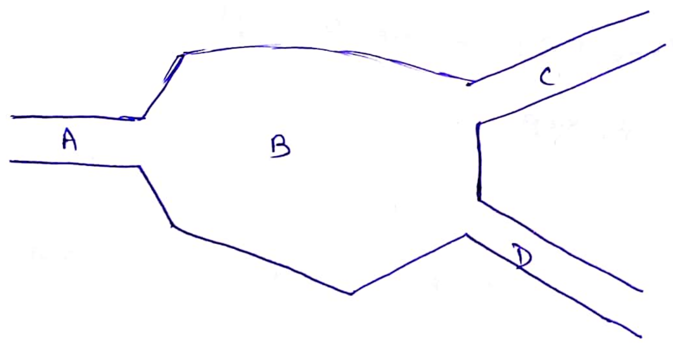
ρ - density
A - area
V - velocity

If incompressible $\rho_A = \rho_B$ so cancel out.

So $A_A \times V_A = A_B \times V_B$

$\Rightarrow Q_A = Q_B$ ($\because$ Q = Volumetric flow rate)

Q.



Crude oil, $\rho = 55.3\ lb/ft^3$, flows through the piping system as shown below.

$A_A = 0.22\ ft^2$
$A_B = 0.051\ ft^2$
$A_C = 0.014\ ft^2$
$A_D = 0.014\ ft^2$

Dia of A = 2 inches = 0.166 ft
Dia of B = 3 inches = 0.25 ft
$Q_A = 235\ ft^3/hr$

Calculate $\dot{m}_A, \dot{m}_B, \dot{m}_C, \dot{m}_D$ & Q_B, Q_C, Q_D

$\Rightarrow \cancel{\dot{m}_A = \dot{m}_B = 2\dot{m}_C}$

$\dot{m}_A = \dot{m}_B = 2\dot{M}_C$

$Q_A = Q_B = 2Q_c$

$\Rightarrow A_A \times V_A = A_B \times V_B = 2A_c \times V_c$

$\Rightarrow 0.22 \times V_A = 2 \times 0.014 \times V_c = 0.057 \times V_B$

$Q_A = A_A \times V_A$

$\Rightarrow 235 = 0.22 \times V_A$

$\Rightarrow V_A = 1068.18$ ft/hr

$V_c = V_D = \dfrac{235}{2 \times 0.014}$

$= 8392.8$ ft/hr

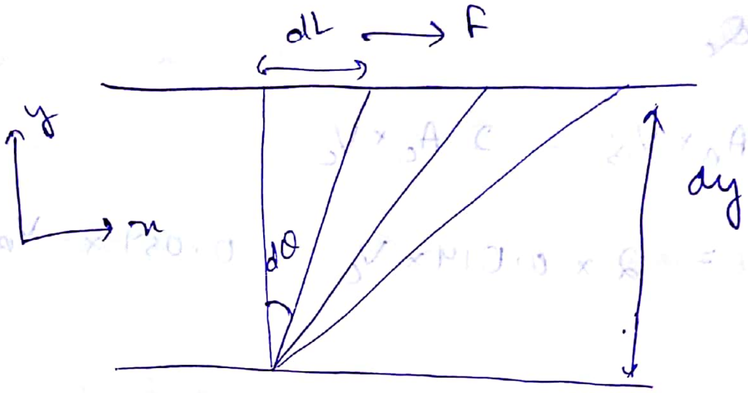
$V_B = 4607.8$ ft/hr.

$\dot{m}_A = 12995.5$ lb

$\dot{m}_B = 12995.5$ lb

$\dot{m}_C = \dot{m}_D = 6497.75$ lb.

Fluid dynamics :-



Shear stress $\propto$ Rate of shear strain

$(\tau_{yx}) \propto \frac{d\theta}{dt}$

$x \to$ direction of force

$y \to$ unit normal perpendicular to area vector. (velocity gradient dir.n)

Any quantities which is represented with two or more directions is known as tensor quantity.

$\tan d\theta = \frac{dL}{dy}$ (∴ as $d\theta$ is very small so $\tan\theta \sim \theta$)

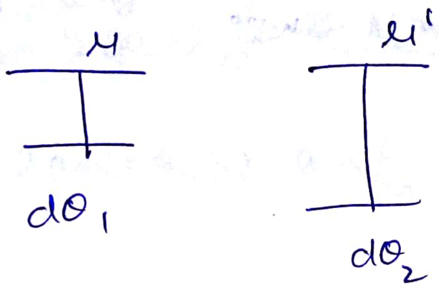
$\Rightarrow d\theta = \frac{dL}{dy}$ (length of deformation)

So $\tau_{yx} \propto \frac{dL}{dy\,dt}$

$\Rightarrow \tau_{yx} \propto \frac{du_x}{dy} \Rightarrow \tau_{yx} = \mu \frac{du_x}{dy}$ (Newton's law of viscosity)

$\mu \to$ dynamic viscosity.

Newtonian fluid – Air, water, honey



if $\mu < \mu'$

then $d\theta_1 > d\theta_2$

$$\tau_{yx} = \mu \frac{du_x}{dy}$$

$$\Rightarrow \frac{\text{Force}}{\text{Area}} = \mu \frac{du_x}{dy} \quad \frac{m/s}{m}$$

$$\Rightarrow \frac{\text{Force} \times \text{Time}}{\text{Length}^2} = \mu$$

S.I $= \frac{Ns}{m^2}$ C.G.S $= \frac{\text{dyne sec}}{cm^2}$ (poise)

$\frac{\mu}{\rho} \rightarrow$ kinamatic viscosity

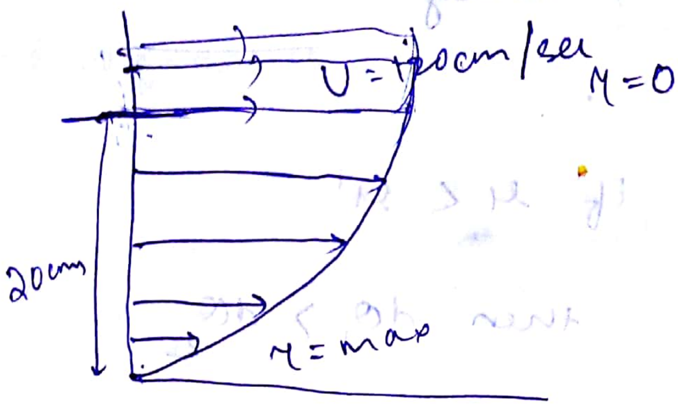
$$= \frac{M^1 L^1 T^{-2} \times T}{L^2} \div \frac{M}{L^3}$$

$$= \frac{M^1 L^1 T^{-1}}{L^2} \times \frac{L^3}{M}$$

$$= \frac{L^2}{T}$$

S.I $= \frac{m^2}{}$ C.G.S $= \frac{cm^2}{}$ (stokes)

Q.



$\frac{du}{dy} = 2ay + b$

$u = 120$

Calculate velocity gradient $\left(\frac{du}{dy}\right)$ and shear stresses (τ) at 0, 10, 20 cms from the plate if $\mu = 8.5$ poise.

eq.ⁿ is parabola. $U = ay^2 + by + c$

$\Rightarrow \boxed{\frac{du}{dy} = 2ay + b}$

$U_{20} = 120$ cm/sec

$U_0 = 0$ cm/sec.

$400a + 20b + c = 120$

$c = 0$

$\Rightarrow 400a + 20b = 120$

$\Rightarrow \boxed{20a + b = 6}$

$900a + 30b = 120$

$\Rightarrow \boxed{30a + b = 4}$

$60a + 3b = 18$

$60a + 2b = 8$

(-) (-) (-)

$\boxed{b = 10}$

$30a + 10 = 4$

$\Rightarrow 30a =$

$$\left.\frac{du}{dy}\right]_{\substack{u=120 \\ y=20}} = 2ay + b = 0 \Rightarrow 40a + b = 0$$

$$\cancel{20a = 6 \Rightarrow a = \frac{6}{20}}$$

$$20a + b = 6$$

$$40a + b = 0$$

$$(-) \quad (-) \quad (-)$$

$$-20a = 6$$

$$\Rightarrow a = \frac{-6}{20} = -0.3$$

$$b = 12$$

$$\left(\frac{du}{dy}\right)_{y=0} = 12 \qquad \tau = \mu \times 12 =$$

$$\left(\frac{du}{dy}\right)_{y=10} = 6 \qquad \tau = \mu \times 6 =$$

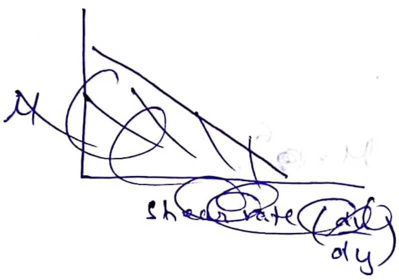
$$\left(\frac{du}{dy}\right)_{y=20} = 0 \qquad \tau = \mu \times 0 = 0$$

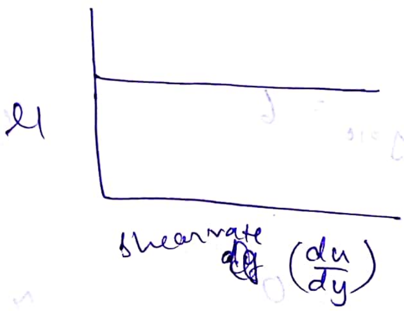
Types of fluids :-

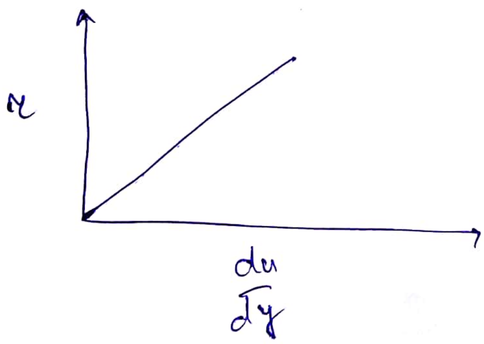
(i) Real fluids - These are those fluids which posses certain viscosity $\mu \neq 0$

(ii) Ideal fluids - These are fluids which are incompressible in nature and posses zero viscosity. These types of fluids are imaginary. $\mu = 0$, $Re = \infty = \frac{DV\rho}{\mu}$

(iii) Newtonian fluids - $\tau = \mu \frac{du}{dy}$ which obeys Newton's law of viscosity are newtonian fluids.
eg- air, water, glycerine.







(iv) Non-newtonian fluids - These are those fluids which don't obey viscosity law.

→ Dilatant fluids.

$$\tau = K\left(\frac{du}{dy}\right)^n, \quad n > 1, \text{ shear thickening fluids}$$

K = apparent viscosity

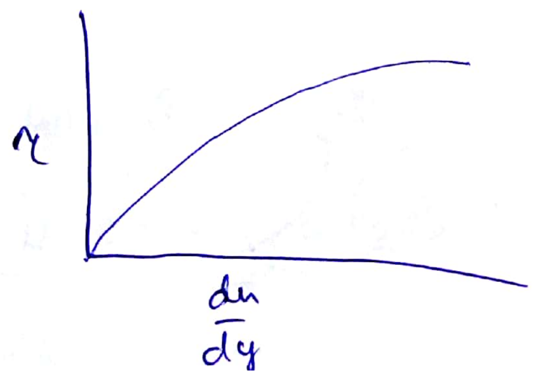
n = flow behaviour index. (n > 1) always.

eg:- starch, Sand suspension, colloids.

→ Pseudoplastic fluids -

$$\tau = K\left(\frac{du}{dy}\right)^n, \quad n < 1, \text{ shear thinning fluids}$$

eg- paints, polymer Latex. Rubber solⁿ

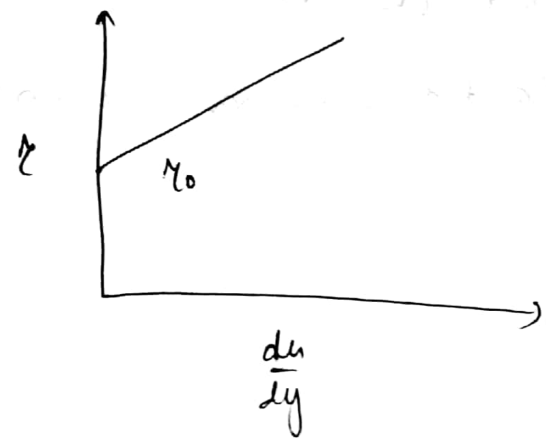


→ Bingham plastic -

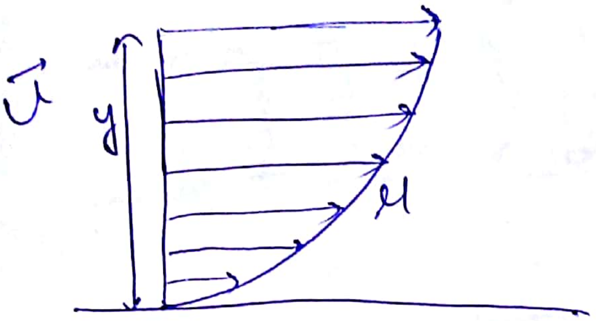
$$\tau = \tau_0 + \mu \frac{du}{dy}$$

↓
initial
stress

eg- Toothpaste, tar sol^n etc.



Boundary layer formation :-



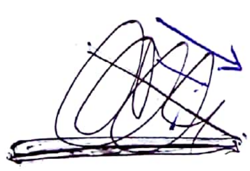
$\frac{du}{dy}$ will exist till 'y'

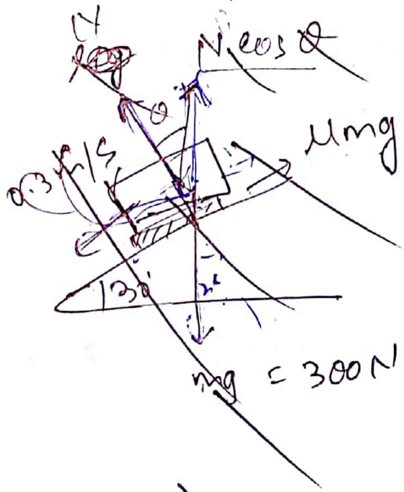
solid wall or plate

velocity profile of a liquid in pipe.

Q. Calculate the dynamic viscosity of an oil which is used for lubrication bet^n a sq. plate of size (0.8 m × 0.8 m) and an inclined plane with an angle of inclination 30°. The weight of sq. plate is 30 kg and is slides down the inclined plane with a uniform velocity of 0.3 m/s. The thickness of oil film is 1.5 mm

⇒



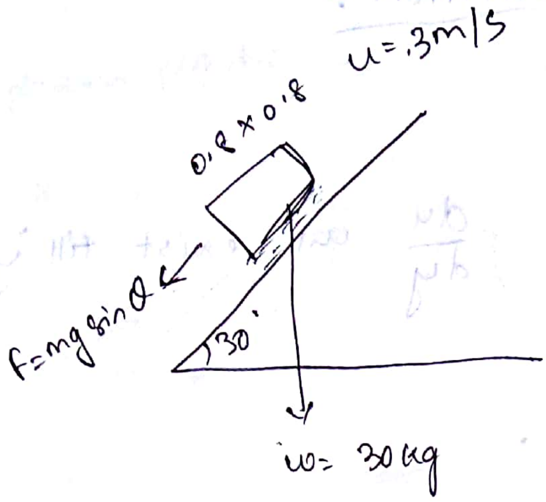


$f = \mu N$

$\mu g\cos\theta = 300$

⇒ $\mu \times 10 \times \frac{\sqrt{3}}{2} = 300$

⇒



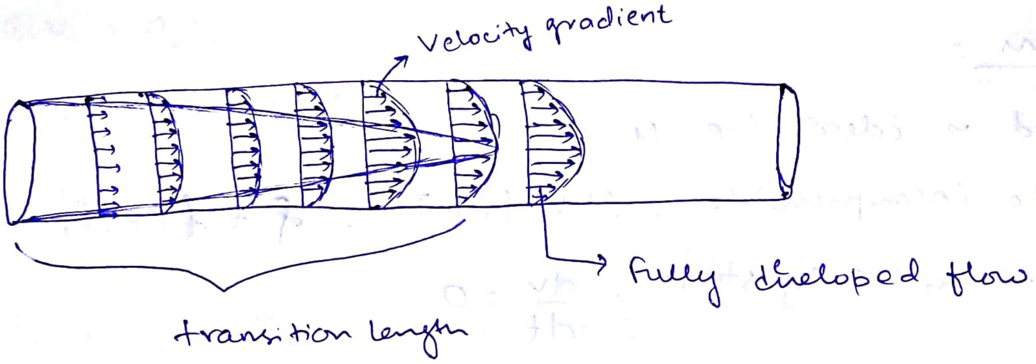
$$\tau = \frac{F}{A} = \frac{mg \sin\theta}{0.64\,m^2} = \cancel{100}\ 234.37 = \mu \frac{du}{dy}$$

$$= \mu \times \frac{0.3}{1.5\times10^{-3}}$$

$$\Rightarrow \mu = \frac{234.37 \times 1.5\times10^{-3}}{0.3}$$

$$= 1.17$$

Boundary layer formation in straight pipes



Velocity gradient increases as we move towards inner of the pipe.

Transition length :- The length after which fully developed flow is attained in the pipe.

Fully developed flow :- The uniform velocity profile which is attained at transition length is known as fully developed flow.

Boundary layer separation :-

1) whenever there is sudden change in velocity of fluid either in magnitude or direction, boundary layer separation will occur.

how to avoid boundary layer separation :-

(i) Streamline the body.

(ii) Gradually increasing or decreasing the angle of inclination

Berenoulli's eq.ⁿ for ideal fluid :-

Assumptions :-

(i) The fluid is ideal i.e $\mu = 0$
(ii) Fluid is incompressible, $\mu \neq f(P,T)$, $\rho \neq f(P,T)$
(iii) Fluid is in steady state, $\frac{dv}{dt} = 0$

$$\frac{P}{\rho g} + \frac{v^2}{2g} + z = \text{constant.} \quad - \text{mechanical head}$$

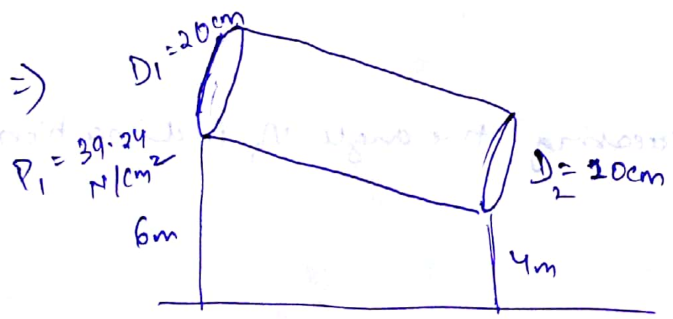
$$\frac{P}{\rho} + \frac{v^2}{2} + zg = \text{constant} \quad - \text{mechanical energy}$$

$\frac{v^2}{2} \rightarrow$ J/kg

$\frac{1}{2}mv^2$ = Joule

$\frac{v^2}{2}$ = Joule/kg

Q. Water is flowing through a pipe having dia 20cm and 10cm at section 1 & 2 respectively. The rate of flow through the pipe is 35 lit/s. The section ① is 6 m above datum line and section ② is 4 m above datum line. If the pressure at section ① is 39.24 N/cm². Find the pressure at section ②. Consider the fluid to be ideal.

=> 

$39.24 \frac{N}{cm^2} = 39.24 N$

$Q = 35$ litre/sec $= 0.035\ m^3/s$

$Q = a_1 v_1 = a_2 V_2$

$0.035 = 0.00785\ v_1$

$\Rightarrow V_2 = 4.45\ m/s$ $\qquad v_1 = 1.114\ m/s$

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

$$\Rightarrow \frac{39.24 \times 10^4}{10^3 \times 10} + \frac{(1.114)^2}{2 \times 10} + 6 = \frac{P_2}{10^4} + \frac{(4.45)^2}{20} + 4$$

$P_2 = 40.27\ N/cm^2$

$\Rightarrow 39.24 \times 10^{-8} + 0.06 + 6 = \frac{P_2}{10^4} + 0.99 + 4$

$\Rightarrow P_2 = 40.31\ N/cm^2$

Q. Water is flowing through a pipe having dia 300 mm and 400 mm at the bottom and upper end respectively. The intensity of pressure at bottom end is 24.525 N/cm² and the pressure at upper end is 9.81 N/cm². Determine the difference in potential head if the flow rate through the pipe is 40 l/s.

$$\Rightarrow \frac{P_1}{\rho g} + \frac{v_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

$Q = 0.04\ m^3/s$

$v_1 = 2.8 \times 10^{-3} = 0.0028\ m/s$

$V_2 = 0.32\ m/s$

$\Rightarrow \frac{24.525 \times 10^4}{10^4} + 3.92 \times 10^{-7} + Z_1 = 9.81 + 5.12 \times 10^{-3} + Z_2$

$\Rightarrow Z_1 - Z_2 = 14.7\ m$

Bernoulli's eq.^{n} for real fluid

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

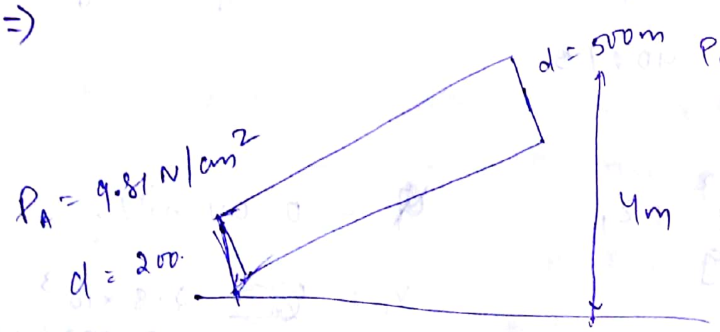
h_L - frictional energy losses

Skin friction

form friction

Q. A pipeline carrying oil of specific gravity 0.87 changes in diameter from 200 mm at position A to 500mm dia at pos.^{n} B which is 4m at a higher level. If pressure at point A and B are 9.81 N/cm^2, 5.886 N/cm^2 respectively and discharge is 200 litre / sec. Determine the loss of head and direction of flow.

=>



Q = 200litre/sec

$Q = a_1 v_1 = a_2 v_2$

$0.2 = 0.0314 \times v_1 \Rightarrow v_1 = 6.36 \text{ m/s}$

~~oozla~~ $v_2 = 0.19 \text{ m/s}$

$$s.g = \frac{\rho_{liq}}{\rho_{water}} \Rightarrow \rho_{liq} = 0.87 \times 1000 = 870$$

$$A := \frac{P_A}{\rho g} + \frac{v_1^2}{2g} + Z_A = \frac{9.81 \times 10^4}{8700} + 2.02 + 0$$

$$= 13.29 \text{ m}$$

$$B := \frac{P_B}{\rho g} + \frac{v_2^2}{2g} + Z_B = \frac{5.886 \times 10^4}{8700} + 1.805 \times 10^{-3} + 4$$

$$+ h_L' = 10.76 \text{ m} + 2.64 \text{ m}$$

Dir.ⁿ of flow is point A to B

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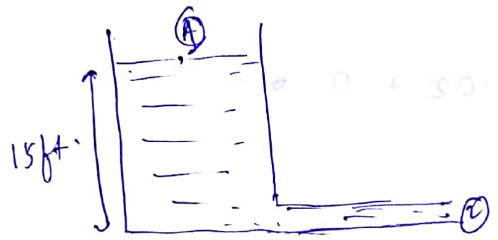
Q Brine sol.ⁿ of s.g = 1.15 is draining from the bottom of an open tank from a 2 inches drainage pipe. Drained pipe ends at a point 15 ft below the surface of the brine sol.ⁿ in the tank. Calculate the velocity of the discharge point. Neglect frictional losses and atmospheric pressure. Drainage pipe is also open to atmosphere

=)



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

due to large open tank $V_1 = 0$

$\frac{Q}{A} \approx 0$ ($\because$ A is very large)

P_1 & P_2 are open to atmosphere so no pressure head

=) 4.572 = $\frac{V_2^2}{20}$

=) $V_2^2 = 91.44$ =) $V_2 = 9.56$ m/s

if point ② is closed then pressure will be $p = h\rho g$ due to water in the tank.