GATE

CHEMICAL ENGINEERING

All-IN-ONE

10 SUBJECTS

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SHORT NOTES

1. Mass Transfer:

Fick's laws, molecular diffusion in fluids, mass transfer coefficients, film, penetration and surface renewal theories; momentum, heat and mass transfer analogies; stage-wise and continuous contacting and stage efficiencies; HTU & NTU concepts; design and operation of equipment for distillation, absorption, leaching, liquid-liquid extraction, drying, humidification, dehumidification and adsorption., membrane separations (micro-filtration, ultrafiltration, nano-filtration and reverse osmosis).

2. Heat Transfer:

Equation of energy, Steady and unsteady heat conduction, convection and radiation, thermal boundary layer and heat transfer coefficients, boiling, condensation and evaporation; types of heat exchangers and evaporators and their process calculations. Design of double pipe, shell and tube heat exchangers, and single and multiple effect evaporators.

3. Chemical Reaction Engineering:

Theories of reaction rates; kinetics of homogeneous reactions, interpretation of kinetic data, single and multiple reactions in ideal reactors, kinetics of enzyme reactions (Michaelis-Menten and Monod models), non-ideal reactors; residence time distribution, single parameter model; non-isothermal reactors; kinetics of heterogeneous catalytic reactions; diffusion effects in catalysis; rate and performance equations for catalyst deactivation

4. Instrumentation and Process Control:

Measurement of process variables; sensors and transducers, P&ID equipment symbols, process modeling and linearization, transfer functions and dynamic responses of various systems, systems with inverse response, process reaction curve, controller modes (P, PI, and PID); control valves; transducer dynamics, analysis of closed loop systems including stability, frequency response, controller tuning, cascade and feed forward control.

5. Thermodynamics:

First and Second laws of thermodynamics. Applications of first law to close and open systems. Second law and Entropy. Thermodynamic properties of pure substances: Equation of State and residual properties, properties of mixtures: partial molar properties, fugacity, excess properties and activity coefficients; phase equilibria: predicting VLE of systems; chemical reaction equilibrium.

6. Fluid Mechanics:

Fluid statics, surface tension, Newtonian and non-Newtonian fluids, transport properties, shell-balances including differential form of Bernoulli equation and energy balance, equation of continuity, equation of motion, equation of mechanical energy, Macroscopic friction factors, dimensional analysis and similitude, flow through pipeline systems, velocity profiles, flow meters, pumps and compressors, elementary boundary layer theory, Turbulent flow: fluctuating velocity, universal velocity profile and pressure drop.

7. Mechanical Operation:

Particle size and shape, particle size distribution, size reduction and classification of solid particles; free and hindered settling; centrifuge and cyclones; thickening and classification, filtration, agitation and mixing; conveying of solids, flow past immersed bodies including packed and fluidized beds.

8. Plant Design and Economics:

Principles of process economics and cost estimation including depreciation and total annualized cost, cost indices, rate of return, payback period, discounted cash flow, optimization in process design and sizing of chemical engineering equipments such as compressors, heat exchangers, multistage contactors.

9. Process Calculation:

Steady and unsteady state mass and energy balances including multiphase, multi-component, reacting and non-reacting systems. Use of tie components; recycle, bypass and purge calculations, Gibb's phase rule and degree of freedom analysis.

10. Chemical Technology:

Inorganic chemical industries (sulfuric acid, phosphoric acid, chlor-alkali industry), fertilizers (Ammonia, Urea, SSP and TSP); natural products industries (Pulp and Paper, Sugar, Oil, and Fats); petroleum refining and petrochemicals; polymerization industries (polyethylene, polypropylene, PVC and polyester synthetic fibers).

Characterization of Solid particle :-

PARTICLE	MEASURED IN
Coarse Particle →	Inches or milimeter
Fine Particle →	Screen Size → Filters
Very fine Particle →	Micro & Nanometer → Cyclone Separator
Ultra fine Particle →	m^2/gm

PARTICLE SHAPE → Sphericity (ϕ_s)

$$\left\{ \phi_s = \frac{\text{Surface area of sphere having same volume that of Particle}}{\text{Surface Area of Particle}} \right\}$$

$$\boxed{\phi_s = \frac{6/D_p}{S_p/V_p}}$$ For a non Spherical Particle

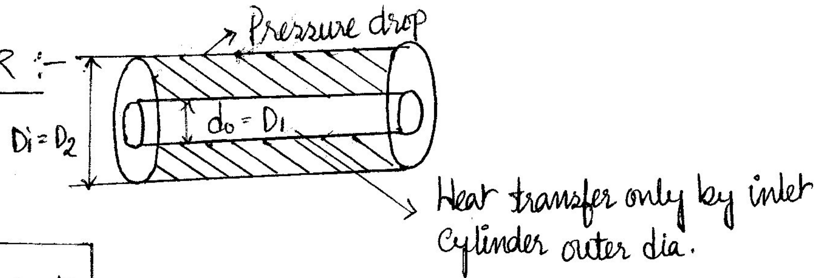
*** For a given volume sphere has the minimum possible surface area.**

Where, D_p = Equivalent diameter or nominal diameter

S_p = Surface area of one particle

V_p = Volume of one particle

* EQUIVALENT DIAMETER :-



$$\boxed{D_e = 4 \times \text{Flow area}/\text{Wetted Perimeter}}$$

* for pressure drop :- Wetted Perimeter = $P = \pi D_1 + \pi D_2$

$= \pi(D_1 + D_2)$

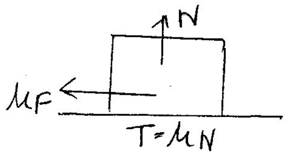
$$\boxed{\text{Hydraulic radius} = A/P}$$

* for Heat transfer :- Wetted Perimeter = πD_1

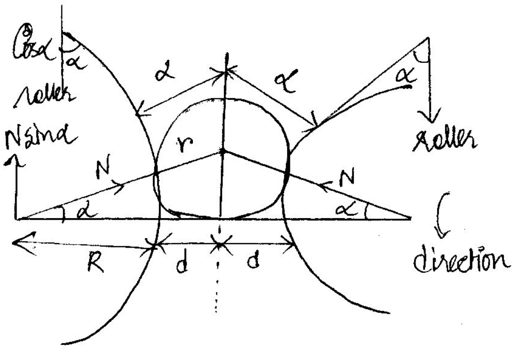
* For pressure drop :- $\boxed{D_e = \dfrac{4\left\{\frac{\pi}{4}D_2^2 - \frac{\pi}{4}D_1^2\right\}}{(\pi D_1 + \pi D_2)}}$ → $D_e = D_2 - D_1$, $\boxed{D_e = (D_2^2 - D_1^2)/D_1}$

** $\phi_s \leq 1$ (always) * for any crushed material ϕ_s is b/w 0.6 & 0.8

3 CRUSHING ROLLS :- (Smooth roll crusher) →



Assumption :- All feed particles are in circular shape



* Condition :- $T \cos\alpha \geq N \sin\alpha$

$\mu N \cos\alpha \geq N \sin\alpha$

$\boxed{\mu \geq \tan\alpha}$

* max^m size of product is approximately equal to 2d.

$$\boxed{\cos\alpha = \frac{R+d}{R+r}}$$

$$\boxed{\begin{gathered}\text{Angle of Nip} = 2\alpha \\ \text{Half of angle nip} = \alpha\end{gathered}}$$

Normally $\alpha = 16$

Where, R = Radius of Roll

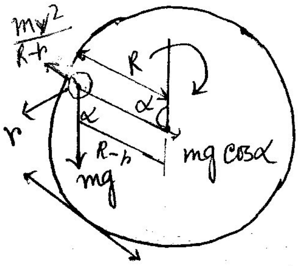
d = Radius of Product Particle

r = radius of feed particle

* Angle of Nip :- Angle of Nip is angle formed by the tangents to the roll faces at the point of contact with a particle to be crushed.

→ To allow unbreakable material to pass through without damaging the machine atleast one roll must be spring mounted.

4. BALL MILL :- $\frac{mv^2}{R-r}$



Gravity force = Centrifugal force

$\cancel{m} g \cos\alpha = \frac{\cancel{m} v^2}{R-r}$

$$\boxed{\cos\alpha = \frac{V^2}{(R-r)g}}$$

$\boxed{V = r\omega}$, $\boxed{\omega = 2\pi N}$

ω = angular speed

N = rotational speed

$$\left\{\cos\alpha\ \frac{[2\pi N (R-r)]^2}{(R-r)g}\right\}$$

* At critical speed ($\alpha = 0$), $\cos\alpha = 1$, $N = N_c$

Critical speed ** $\boxed{N_c = \frac{1}{2\pi}\sqrt{\frac{g}{R-r}}}$

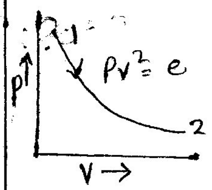
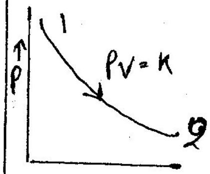
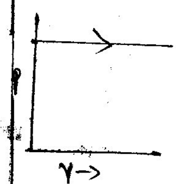
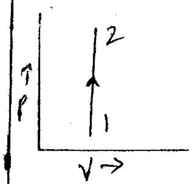
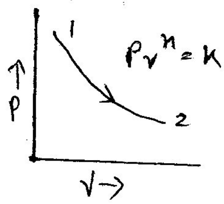
Where, R = radius of ball mill

r = radius of Ball

G-2018 N_c = Independent of particle radius

* Critical Speed :- The minimum rotational speed of ball mill at which the centrifugal condition started (No grinding) is called critical speed of Ball mill.

Optimum Speed ** $\boxed{N_{op} = 50\text{-}75\%\ N_c}$ **Critical angular Velocity** $\boxed{\omega_c = \sqrt{g/R}}$

Process features →	Adiabatic Process	Isothermal Process	Isobaric Process	Isochoric Process	Polytropic Process
P-V-T Relationship	H.T = 0 $PV^{\gamma} = C$ $TV^{\gamma-1} = C$ $\frac{T}{P^{\gamma-1/\gamma}} = C$	T = Constant. PV = Const. $P_1V_1 = P_2V_2$ $P \propto 1/V$ (Boyle's Law)	P = Const. V/T = Const. $V \propto T$ (Charle's law) $\frac{V_1}{T_1} = \frac{V_2}{T_2}$	V = Const. P/T = Const. $P \propto T$	$n < \gamma$ $PV^n = K$ $TV^{n-1} = K$ $\frac{T}{P^{n-1/n}} = K$
Change in Internal energy	$du = C_v dT$	$du = 0$	$du = C_v dT$	$du = C_v dT$	$du = C_v dT$
Work done	${}_1W_2 = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$	${}_1W_2 = P_1V_1 \ln P_1/P_2$ ${}_1W_2 = P_1V_1 \ln V_2/V_1$	${}_1W_2 = P_1(V_2 - V_1)$	$dW = \int P dV$ ${}_1W_2 = 0$	${}_1W_2 = \frac{P_1V_1 - P_2V_2}{n-1}$
Heat transfer	${}_1Q_2 = 0$	${}_1Q_2 = {}_1W_2$	${}_1Q_2 = C_p \Delta T$	${}_1Q_2 = C_v \Delta T$	${}_1Q_2 = \frac{\gamma - n}{\gamma - 1} {}_1W_2$ ${}_1Q_2 = C_n (T_2 - T_1)$ $C_n = \frac{(n C_v - C_p)}{n-1}$
P & V diagram					
Slope.	$\frac{dP}{dV} = \gamma\left(-\frac{P}{V}\right)$	$\frac{dP}{dV} = \left(-\frac{P}{V}\right)$	$\frac{dP}{dV} = \frac{0}{dV} = 0$	$\frac{dP}{dV} = \frac{dP}{0} = \infty$	$\frac{dP}{dV} = n\left(-\frac{P}{V}\right)$
# Polytropic exponent (n) =	$n = \gamma$ $\gamma = C_p/C_v$	PV^n = Const. $n = 1$	$n = 0$	$n = \infty$	$C_n = C_v\left(\frac{n-\gamma}{n-1}\right)$

Open system (kJ/kg)

* **Enthalpy** :- $\boxed{H = U + PV}$ (In open system) at const. P
  $Q = n\Delta H$

* Energy equation, Energy in = Energy out.

$$\boxed{{}_1Q_2 + m_1h_1 + m'U' = {}_1W_{S_2} + m_2h_2 + m''U''}$$

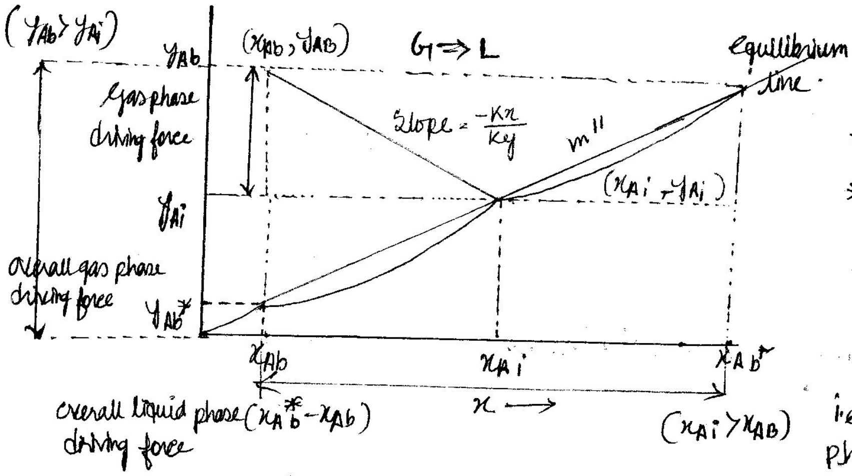
* Work done :- Closed system / Open system

Polytropic or adiabatic Process

$$\boxed{{}_1W_2 = \frac{P_1V_1 - P_2V_2}{n-1}} \qquad \boxed{{}_1W_2 = \frac{n}{n-1}(P_1V_1 - P_2V_2)}$$

[Work done in open system = n (Work done in closed system)]

* In isothermal process work done equal in open & closed system.



* Overall M.T.C
* If there is no gas phase resistance the conc^n in the bulk be same as the conc^n at the interface

$\therefore y_{Ab} = y_{Ai}$

i.e with respect to y_{Ab} some conc^n in liquid phase. It is denoted by x_{AB}^*

$y_A = \phi(x_A)$ (eq^n relationship)

* $\boxed{y_{Ab} = \phi(x_{Ab}^*)}$ To calculate x_{Ab}^* substitute $y_A = y_{Ab}$ in eq^n relation.

<u>Overall gas phase driving force</u> $= (y_{Ab} - y_{Ab}^*)$

* If there is no liquid phase resistance the conc^n in the bulk be same as the conc^n at the interface. $y = \phi(x_A)$

* $y_{Ab}^* = \phi(x_{Ab})$ To calculate y_{Ab}^* substitude $x_A = x_{Ab}$ in eq^m relation

<u>Overall liquid phase driving force</u> $= (x_{Ab}^* - x_{Ab})$

x_{Ab}^* = Equilibrium conc^n corresponding to bulk phase conc^n

y_{Ab}^* = Equilibrium conc^n corresponding to bulk liquid phase conc^n

* <u>Absorption</u> $G \Rightarrow L$ condition $\boxed{\begin{array}{l} * \; y_{Ab} > y_{Ai} > y_{Ab} \\ * \; x_{Ab} > x_{Ai} > x_{Ab} \end{array}}$

$N_A = k_y(y_{Ab} - y_{Ai})$
$N_A = k_x(x_{Ai} - x_{Ab})$
} Based on individual M.T.C

$N_A = K_y(y_{Ab} - y_{AB}^*)$
$N_A = K_x(x_{Ab} - x_{Ab})$
} Based on overall M.T.C

* $\boxed{\frac{1}{K_y} = \frac{1}{k_y} + \frac{m'}{k_x}}$ or * $\boxed{\frac{1}{K_x} = \frac{1}{k_x} + \frac{1}{m'' k_y}}$

* In case equilibrium line is straight line (when Henry's law aplicable)

$m' = m'' = m$

$1/K_y$ = Overall or total resistance based on gas phase

$1/k_y$ = resistance offered by the gas phase

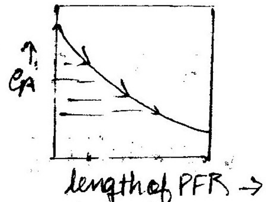
$1/K_x$ = overall or total resistance based on liquid phase

$1/k_x$ = resistance offered by liquid phase

$\frac{1}{m k_y}$ = resistance offered by gas phase

② **Overall yield ($\phi_{R/A}$) of R** or $\overline{\psi}_{R/A}$

$$\phi_{R/A} = \frac{N_R - N_{R0}}{N_{A0} - N_A} = \frac{\text{Total moles of R formed}}{\text{total moles of A Reacted}}$$



* ϕ for PFR → (Overall yield) :—

→ Concⁿ decreases gradually so ψ should very in PFR.

** $$\boxed{\phi_{PFR} = \overline{\psi} = \frac{-1}{C_{A0} - C_{AF}} \int_{C_{A0}}^{C_{AF}} \psi \, dC_A}$$

* for CVRS system

$$\boxed{C_R = C_{R0} - \int_{C_{A0}}^{C_{AF}} \psi_{R/A} \, dC_A}$$

* ϕ for CSTR → for CSTR $\phi = \psi$ because only one concⁿ (C_{AF})

$$\left\{ \phi_{CSTR} = \psi|_{C_A = C_{AF}} = \frac{r_R}{(-r_A)} = \frac{k_1 C_A^{n_1}}{k_1 C_A^{n_1} + k_2 C_A^{n_2}} \right\}$$

$$\boxed{C_R = C_{R0} + \phi_{R/A}(C_{A0} - C_{AF})}$$

$$\boxed{C_P = C_{P0} + \phi_{P/A}(C_{A0} - C_{AF})}$$

Note :- The expression of ψ (fractional yield) remains same for a CSTR as well as PFR.

* Graph for MFR/CSTR

$$A \to R, \quad A \to S \text{ (desired)}, \quad A \to T$$

$$C_S = \cancel{C_{S0}} + \phi_{S/A}(C_{A0} - C_{AF})$$

$$C_S = \phi_{S/A} \; (C_{A0} - C_{AF})$$

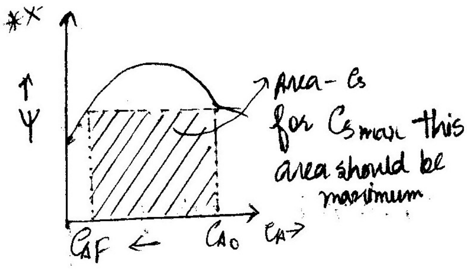
y axis — x axis

* Graph for PFR

$$C_S = \cancel{C_{S0}} - \int_{C_{A0}}^{C_A} \psi_{S/A} \, dC_A$$

$$C_S = \int_{C_A = 0}^{C_{A0}} \psi_{S/A} \, dC_A$$

**



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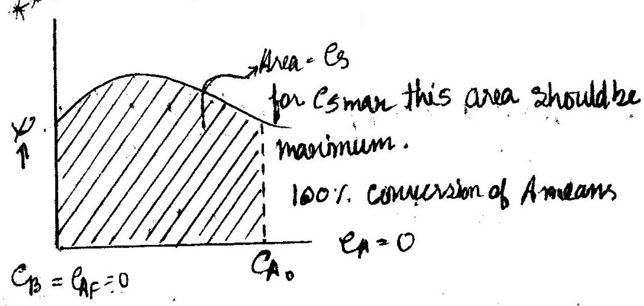
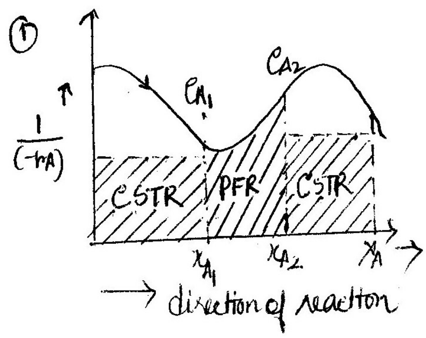


*** Imp Que → Preferred arrangement of reactors :- (PFR's & CSTR)

①



It is a performance curve $\frac{1}{(-r_A)}$ vs x_A

Preferred, CSTR → PFR → CSTR.

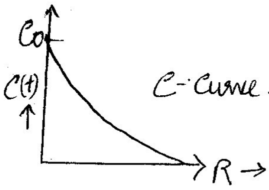
* Relation between $F(\theta)$ & $F(t)$:- $\boxed{F(\theta) = F(t)}$

RTD for ideal reactors for pulse Input →

1. Ideal CSTR :-

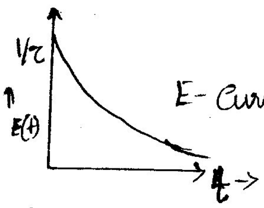
** $\boxed{C = C_0 e^{-t/\tau}}$

* 1st order eqn of RTD



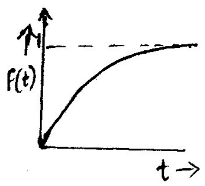
C-Curve for Ideal CSTR

** $\boxed{E(t) = \frac{1}{\tau} \cdot e^{-t/\tau}}$



E- Curve for Ideal CSTR

$\boxed{F(t) = 1 - e^{-t/\tau}}$



F curve for Ideal CSTR

* C, E, F Curve in term of Dimensionless →

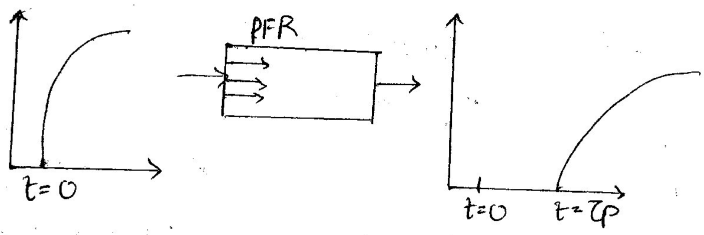
$\boxed{E(\theta) = e^{-\theta}}$, $\boxed{F(\theta) = 1 - e^{-\theta}}$

* for Ideal CSTR $\boxed{E(\theta) + F(\theta) = 1}$

2. RTD for Ideal PFR →

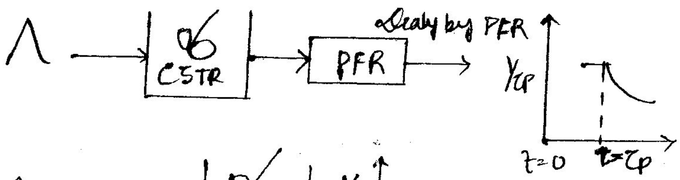
Imp $\boxed{\begin{matrix} \theta = 1 \\ \sigma_\theta^2 = 0 \end{matrix}}$

variance of RTD

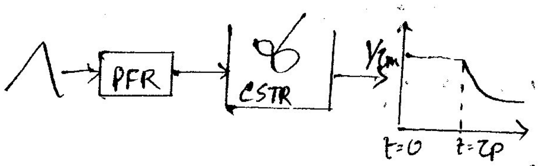


* RTD for Ideal Reactor in series :- (Pulse input)

(1) **



(2)



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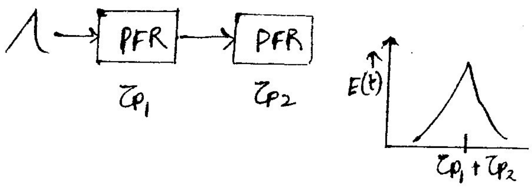
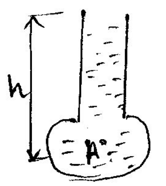


1. **Pizometer :-** (straight transparent glass tube) one end is open to atmosphere and other end is connected to gauge point.



→ Can't measure excess pressure than atmosphere. (1 atm)

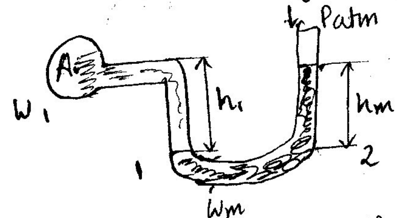
→ Can't measure negative gauge pressure

→ Can't measure the pressure of gaseous fluid.

$\boxed{P_A = \rho g h_A}$

2. **U-Tube Manometer :-** Transparent glass tube in U-shape. One end is open to atmosphere and other end is connected to gauge point.

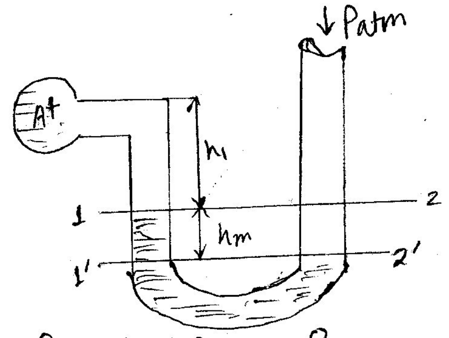
Case I measurement of +ve gauge present



$P_A + w_1 h_1 = w_m h_m$

$w = \rho g$
weight density

$\boxed{P_A = w_m h_m - w_1 h_1}$



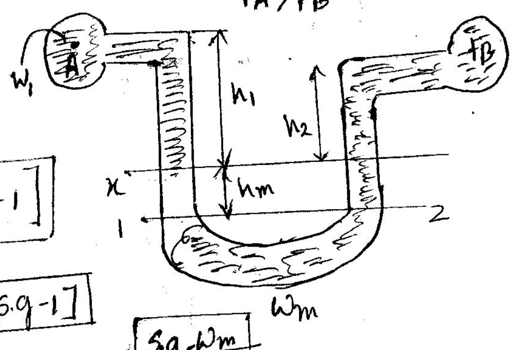
$P_A + w_1 h_1 + w_m h_m = 0$

$\boxed{P_A = -(w_1 h_1 + w_m h_m)}$

3. **U tube differential Manometer :-** It is used to calculate the difference in pressure between two gauge Pressure of a pipe or container or two different pipes or container.

① **Up-right U-tube differential manometer :-**

$P_A > P_B$



$P_A + w_1 h_1 + w_1 h_m = P_B + w_2 h_2 + w_m h_m$

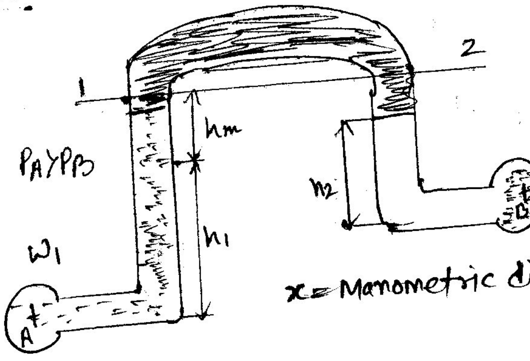
$\Rightarrow \boxed{P_A - P_B = w_2 h_2 - w_2 h_1 + w_m h_m - w_1 h_m}$

Case I If $h_1 - h_2 = h$ $\quad w_1 = w_2 = w_w$ $\quad$ ** $\boxed{h = x\left[\frac{S.g_m}{S.g_w} - 1\right]}$

$P_A - P_B = w_m h_m - w_w h_m$ $\quad \boxed{\Delta P = P_A - P_B = w_w h_m [S.g - 1]}$

$\boxed{Sg = \frac{w_m}{w_w}}$

II. **Inverted U-tube differential Manometer**



$P_A - w_1 h_1 - w_1 h_m = P_B - w_2 h_2 - w_m h_m$

$P_A - w_1 h_1 - w_1 h_m + w_m h_m + w_2 h_2 = P_B$

$\Delta P = P_A - P_B = -\cancel{w_2} h_2 - w_m h_m + \cancel{w_1} h_1 + w_1 h_m$

If $h_1 = h_2 = h$ $\quad w_1 = w_2 = w_3$ $\quad \boxed{h = x\left[1 - \frac{Sg_m}{Sg_w}\right]}$

x = Manometric difference

$\boxed{Nu = \frac{hL}{k}} = \frac{h\delta_t}{k}$ $\boxed{\frac{h\delta_t}{k} = 3/2}$

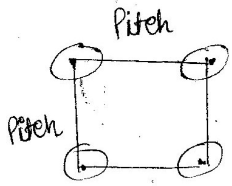
* In shell & tube heat exchanger, baffles are mainly used to deflect the flow in desired direction
* for Condenser $C_{max} = \infty$ $C_T = 0$ $\boxed{\epsilon = 1 - \exp(-NTU)}$
* The maximum possible heat transfer (Q_{max}) between the two fluid is = $C_{min} \times (\Delta T)_{max}$
* The value of Biot No. is very small (< 0.01)

When the conductive resistance of solid is negligible

$$\left[B_i = \frac{hL}{k} = \frac{L/kA}{1/hA} = \frac{\text{Conductive resistance of solid}}{\text{Convective resistance of fluid}} \right]$$

* $\left\{ \frac{T - T_\infty}{T_i - T_\infty} = e^{\frac{-haT}{\rho V c}} \right\}$ Lumped heat capacity system.

Rectengular Pitch



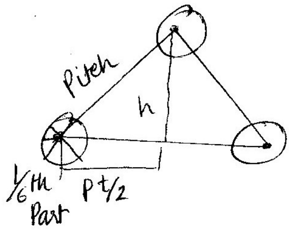
$De = 4r_H$

$De = 4A/P = 4\left(\frac{\text{Cross sectional Area}}{\text{Wetted Perimeter}}\right)$

* $\boxed{Deq = \frac{4\{\text{Pitch}^2 - \frac{\pi}{4} d_o^2\}}{\pi d_o}}$ $A = \text{Area} - 4\{\frac{\pi}{4} d_o^2\}$

$P \Rightarrow 4 \cdot (\frac{\pi D_o}{4}) = \pi D_o$

Triangular Pitch



$h = \sqrt{Pt^2 - Pt^2/4}$

$h = \sqrt{3Pt^2/4}$

Area of $\Delta = 1/2 \times Pt \times \sqrt{\frac{3Pt^2}{4}} = \sqrt{3/4}\, Pt^2$

$D_{qH} = 4 \cdot r_H = 4\, A/P$

* $Deq = 4\left\{\frac{\frac{\sqrt{3}Pt^2}{4} - \frac{\pi d^2}{8}}{\pi d_o/2}\right\}$

Area subtract,

$= 3\left(\frac{\pi d^2}{4}\right)\left(\frac{1}{6}\right) = \frac{\pi d^2}{8}$

Perimeter,

$P = 3 \times \left(\frac{60}{360}\right) \times \pi d_o = \frac{\pi d_o}{2}$

If $\Delta T_1 = \Delta T_2 = \Delta T$ Constant

dT/dz Constant.

then $\frac{d^2 T}{dz^2} = 0$ the temp profile satisfy $\left(\frac{d^2 y}{dz^2} \leq 0\right)$

For liquid Metal (Hg) $P_r < 1$

$\left(P_r = \frac{C_p \mu}{k}\right)$

Since, $\boxed{\text{Prandtl No}, \frac{\delta}{\delta t} = (P_r)^{1/3}}$

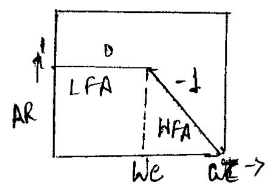
Since, $\frac{L_t}{L_H} = \frac{\text{Thermal entry length}}{\text{Hydrodynamic entry length}} = P_r$ $L_t < L_H$

* SUMMARY :-

Process	Transfer function G(S)	Amplitude Ratio (AR)	Phase shift ϕ
1. First Order	$G(s) = K_p/(\tau_p s+1)$	$AR = K_p/\sqrt{1+\tau_p^2\omega^2}$	$\phi = \tan^{-1}(-\tau_p\omega)$
2. Pure capacitive	$G(s) = K_p/s$	$AR = K_p/\omega$	$\phi = -\pi/2$
3. Pure dead time	$G(s) = e^{-\tau_d s}$	$AR = 1$	$\phi = -\tau_d\omega$
4. Second order Process	$G(s) = \frac{1}{(\tau_1 s+1)(\tau_2 s+1)}$	$AR = 1/\sqrt{(1+\tau_1^2\omega^2)(1+\tau_2^2\omega^2)}$	$\phi = \tan^{-1}(-\tau_1\omega)+\tan^{-1}(-\tau_2\omega)$
5. First order plus dead time	$G(s) = \frac{K_p e^{-\tau_d s}}{(\tau_p s+1)}$	$AR = \frac{K_p}{\sqrt{1+\tau_p^2\omega^2}} \cdot 1$	$\phi = \tan^{-1}(-\tau_p\omega)+(-\tau_d\omega)$
Second order process	$G(s) = K_p/(\tau^2 s^2+2\zeta\tau s+1)$	$AR = K_p/\sqrt{(1-\tau^2\omega^2)^2+(2\zeta\tau\omega)^2}$	$\phi = \tan^{-1}\left(\frac{-2\zeta\tau\omega}{1-\tau^2\omega^2}\right)$
6. P-Controller	$G(s) = K_c$	$AR = K_c$	$\phi = 0$
7. PI Controller	$G(s) = K_c(1+\frac{1}{\tau_I s})$	$AR = K_c\sqrt{1+\frac{1}{\tau_I^2\omega^2}}$	$\phi = \tan^{-1}(-\frac{1}{\tau_I\omega})$
8. PD Controller	$G(s) = K_c(1+\tau_D s)$	$AR = K_c\sqrt{1+\tau_D^2\omega^2}$	$\phi = \tan^{-1}(\tau_D\omega)$
9. PID Controller	$G(s) = K_c(1+\frac{1}{\tau_I s}+\tau_D s)$	$AR = K_c\sqrt{1+(\tau_D\omega-\frac{1}{\tau_I\omega})^2}$	$\phi = \tan^{-1}(\tau_D\omega-\frac{1}{\tau_I\omega})$

BODE PLOTS :-

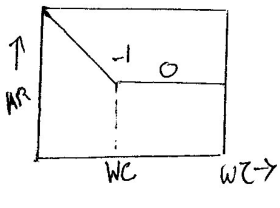
① First Order



Corner frequency $\phi = -\pi/4$

$[-\pi/2, 0]$

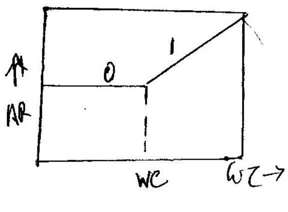
② PI Controller



Corner frequency $\phi = -\pi/4$

$[-\pi/2, 0]$

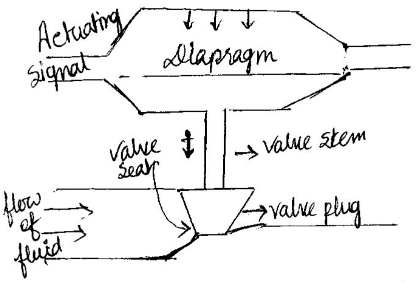
③ PD-Controller



Corner frequency $\phi = \pi/4$

$[0, \pi/2]$

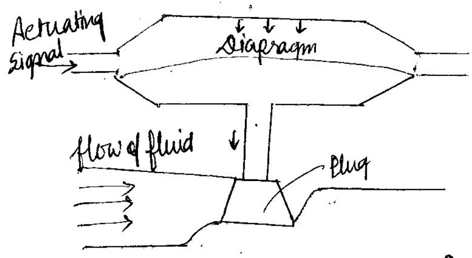
Control valve characteristic :-



Air to close (fail-open valve)

Signal ↑, flow ↓

Direct acting valve



Air to open (fail close value)

Signal ↑, flow ↑

Indirect acting valve

* Controller :-

(1) Direct acting controller :- Process variable ↑, controller output ↑

(2) Indirect acting controller :- Process variable ↑, Controller output ↓
(Reverse acting)

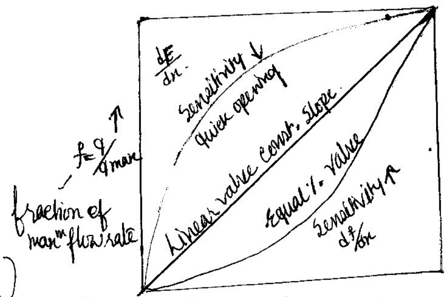
* Note :- the valve and the controller always work in opposite function.

* Inherent valve characteristics :-

→ Ideal valve characteristics that depends upon sensitivity only.

* Sensitivity of a valve :- It is defined as the slope of curve

$$\boxed{\text{Slope} = \frac{df}{dx} = \text{Sensitivity}}$$



1) Linear valve :- $\frac{df}{dx} = \alpha$ $\alpha = 1$, $F = x$

2) Equal Percentage valve :- $\boxed{\frac{df}{dx} = BF}$, $\boxed{F = F_0 \cdot e^{Bx}}$

$\beta = \ln(1/F_0)$

3) Quick opening Valve :- $\frac{df}{dx} = \frac{r}{F}$ $f = \sqrt{x}$

$(F = q/q_{max}$, $f_0 = \frac{q_{min}}{q_{max}}$ fraction of steam position $x = L/L_{max}$.

* Rangeability / Turndown Ratio of valve :-

$R, T = \frac{\text{max. flow rate}}{\text{Min flow rate}}$ $R = 1/f_0$ $f_0 = \frac{q_{min}}{q_{max}}$.

Fertilizer Industry :- < Nitrogen Industry > { Commercial aqueous Ammonia – 28% NH_3 }

> Ammonia (NH_3) :- ** Haber Process

Ammonia Synthesis gas) : $N_2 + 3H_2 \underset{\substack{100-1000\ atm \\ 400-500^\circ C}}{\overset{Fe\ oxide}{\rightleftharpoons}} 2NH_3$ exothermic Reaction

* Promoted with Alkalioxide (KOH)

K_2O (1-2%) :

25 mPa (150-250 atm)

Haber Process :- High Pressure
High temperature

(NH_3 Product
8-30% Conversion
13-14% Per Pass)

* Catalyst :- Fe Iron oxide
$Fe_2O_3 \rightarrow$ feric oxide

* NH_3 used for making Urea (NH_2CONH_2), Ammonia nitrate, and HNO_3

* Raw material $\rightarrow$ N_2 from Air, H_2 from synthesis gas

* { Haber Process :- Moderate Pressure (200-300 atm) }
* { Claude Process :- Very high Pressure (900 – 1000 atm) }

* Promoter of oxide $\rightarrow$ Oxides of aluminium, zirconium or silicon at 3% $conc^n$.

* Ammonium Phosphate :- fire retarding agent for wood, paper and cloth.

* UREA : (NH_2CONH_2) :-

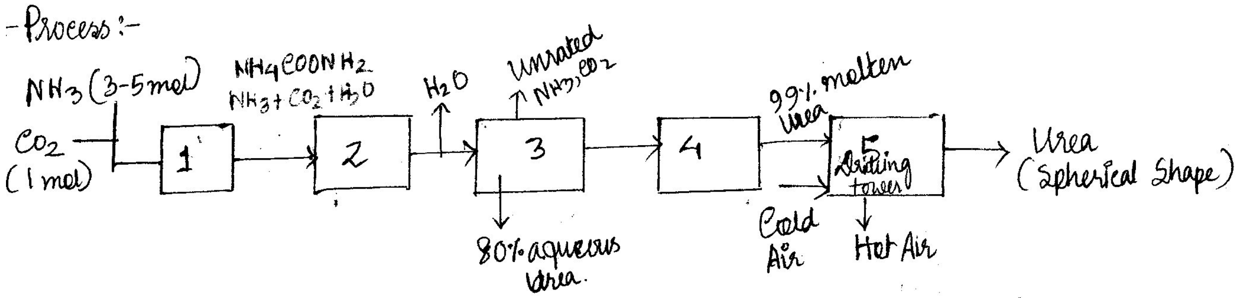
> Contain 40-42% Nitrogen (N_2), used as nitrogen fertilizer

> Also used to make Urea formaldehyde resin.

* Raw material :- Ammonia — from Ammonia plant
from synthesis gas

$$\boxed{2NH_3 + CO_2 \longrightarrow \underset{Urea}{NH_2CONH_2} + H_2O}$$

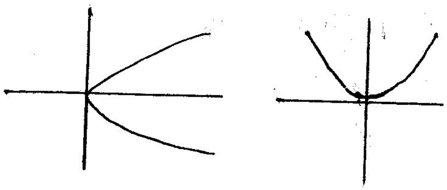
- Process :-



* Eqn of Circle :- $\boxed{(x-h)^2+(y-k)^2 = r^2}$

Or $x^2+y^2=r^2$, Centre $(0,0)$

* Parabola :- $\boxed{y^2=4ax}$ $\boxed{x^2=4ay}$



* Ellipse

$$\boxed{\frac{x^2}{a^2}+\frac{y^2}{b^2}=1}$$

* Hyperbola

$$\boxed{\frac{x^2}{a^2}-\frac{y^2}{b^2}=1}$$

3. Linear First order D.E :-

* $\boxed{\frac{dy}{dx}+Py=Q}$

P & Q are function of x or constant

* Integrating factor (IF)

$\boxed{I.F = e^{\int P.dx}}$

* Solution

* $\boxed{y.(I.F) = \int Q.(I.F)dx + c}$

$\boxed{\frac{dx}{dy}+P'x = Q'}$

P' & Q' are function of y or constant

* Integrating factor (IF)

$\boxed{I.F = e^{\int P'.dy}}$

* Solution

$\boxed{x.(I.F) = \int Q'.(I.F).dy + c}$

4. Bernoulli's D.E → (Reducible to linear first order D.E)

$\boxed{\frac{dy}{dx}+Py = Qy^n} \Rightarrow \frac{1}{y^n}\frac{dy}{dx}+Py^{1-n} = Q$

$\boxed{\frac{1}{(1-n)}\frac{dz}{dx}+P.z = Q}$ This is linear D.E of first order

Put $y^{-n} = z$

$(1-n)y^{-n}\frac{dy}{dx} = \frac{dz}{dx}$

$\frac{1}{y^n}\frac{dy}{dx} = \frac{1}{(1-n)}\frac{dz}{dx}$

5. Exact D.E :- $\boxed{M.dx + Ndy = 0}$

or $\boxed{\frac{dx}{dy}+P'x = Q'x^n}$

Imp: $\frac{\delta M}{\delta y}\Big|_{x=Const} = \frac{\delta N}{\delta x}\Big|_{y=Const}$

Solution of D.E $= \boxed{\int_{y=Const} M dx + \int N dy = c}$ should consist of only the part which not having x