CHEMICAL ENGINEERING

Thermodynamics

Hand Notes For GATE, IES, PSUs & Competitive Exam

Hand Notes

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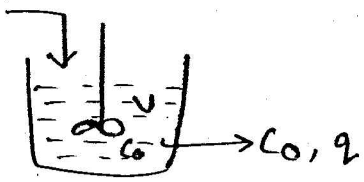
Process Control

Q.) $A \rightarrow B$



$-r_A = KC_A$ (A consumed)

for any material balance

IOGC = Acc
+ − + −

Input − Output + Generation − Consumption = Accumulation

Material balance at unsteady state

$$qC_i - qC_o + \underbrace{0}_{\text{No generation of A}} - \underbrace{KC_oV}_{\text{A consumed in V volume.}} = V \cdot \frac{dC_A}{dt} \quad \text{—(1)}$$

M.B at steady state

$$qC_{is} - qC_{os} - KC_{os}V = 0 = \frac{Vd\cancel{C_{os}}^{\,0}}{dt} \quad \text{—(2)}$$

Substract above equations:—

$$q(C_i - C_{is}) - q(C_o - C_{os}) + KV(C_a - C_{os}) = \frac{Vd}{dt}(C_o - C_{os}) \quad \text{—(3)}$$

Deviation variables

$$\bar{C_i} = (C_i - C_{is})$$

$$\bar{C_o} = (C_o - C_{os})$$

$$q\bar{C_i} - q\bar{C_o} - KV\bar{C_o} = \frac{Vd\bar{C_o}}{dt} \quad \text{—(4)}$$

Formulas of Laplace

$f(t)$	$F(s)$
1	$1/s$
$\frac{dx}{dt}$	$s \cdot f(s) + f(0)$

$f(t) = L^{-1}\{F(s)\}$	$F(s) = L\{f(t)\}$
1	$1/s$
e^{at}	$1/(s-a)$
t^n	$\frac{n!}{s^{n+1}}$
$\sqrt{t}$	$\frac{\sqrt{\pi}}{2s^{1/2}}$
$\sin at$	$\frac{a}{s^2+a^2}$
$\cos at$	$\frac{s}{s^2+a^2}$
$t \cos at$	$\frac{s^2-a^2}{(s^2+a^2)^2}$
$e^{at}\cos bt$	$\frac{s-a}{(s-a)^2+b^2}$
$e^{at}\sin bt$	$\frac{b}{(s-a)^2+b^2}$
$\int_0^t f(t)\,dt$	$F(s)/s$
$\int_0^t f(t-\tau)g(\tau)\,d\tau$	$F(s)\cdot G(s)$
$f(t+T) = f(t)$	$\frac{\int_0^T e^{-sT} f(t)\,dt}{1-e^{sT}}$
$f'(t)$	$sF(s) - f(0)$
$f''(t)$	$s^2F(s) - sf(0) - f'(0)$
$f^n(t)$	$s^nF(s) - s^{n}f(0) - s^{n-2}f'(0) \ldots \ldots sf^{(n-2)}(0) - f^{(n-1)}(0)$

$f(t-\tau)$ $\qquad$ $e^{-\tau s}F(s)$

$$q\bar{C_i} - q\bar{C_o} - kv\bar{C_o} = \frac{v\,d\bar{C_o}}{dt} \quad -(4)$$

Taking Laplace Transform.

$$q\bar{C_i}(s) - q\bar{C_o}(s) - kv\bar{C_o}(s) = vs\,C_o(s) + \cancel{C_o(0)}^{\,0}$$

at $t=0$, $C_o=0$

We have to find $\quad G(s) = \frac{C_o(s)}{C_i(s)}$

$$q\,C_i(s) = C_o(s)\left[q + kv + vs\right)$$

$$= C_o(s)(q+kv)\left[1 + \frac{vs}{q+kv}\right]$$

$$G(s) = \frac{C_o(s)}{C_i(s)} = \frac{\overbrace{\frac{q}{q+kv}}^{R}}{\left\{1 + \underbrace{\frac{vs}{q+kv}}_{\tau}\right\}}$$

$$\boxed{G(s) = \frac{C_o(s)}{C_i(s)} = \frac{R}{1+\tau s}}$$ first order transfer function.

τ = time constant.
= Resistance x Capacitance.

$R \propto 1/\text{cap}$.
$R = \tau \times \frac{1}{\text{cap}}$.

$$\underbrace{\frac{C}{5} = \frac{K-273}{5} = \frac{f-32}{9}}$$

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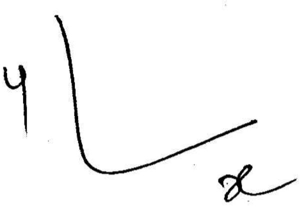
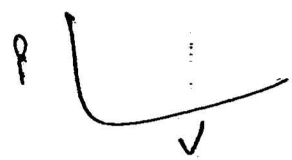
~~Ex~~ tensive
~~In~~ tensive

FM ⇐
HT } ⇐ ✓⇐
Ther
PDC



$\frac{dy}{dx}$ slope
~~Area~~

$y \cdot dx$



Pdv

isobaric : P con $p.dv$ $dv=0$ $w=pdv=0$
✓ Isochoric V con
Isothermal T con
~~Adiabatic~~ Q con.

$PV = nR\cancel{T}$ → const
$PV = \text{Const}$
$PV\cancel{T} = \text{Const}$

* Isenthalpic h const ⇐ Throttling
* Isentropic S const ⇐ adiabadic

$ds = \frac{dq}{T}$

$$\boxed{PV^{\gamma} = \text{Con}}$$

$P_1V_1^{\gamma} = P_2V_2^{\gamma}$ ✓

$\gamma = \frac{C_p}{C_v}$

$C_p > C_v$
$C_p - C_v = R$ ✓

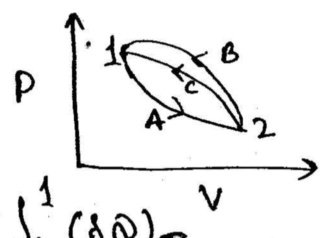
First Law of Thermodynamics :—

In a closed system undergoing any thermodynamic cycle, cycle integral of work & cyclic integral of heat, are proportional to each other, when expressed in their own units & are equal to each other when expressed in the consistent units.

$$\oint \delta W \propto \oint \delta Q$$

kJ   Kcal

$$\oint \delta W = \oint \delta Q$$



(1A2B1) $\int_1^2 (\delta W)_A + \int_2^1 (\delta W)_B = \int_1^2 (\delta Q)_A + \int_2^1 (\delta Q)_B$

(1A2C) $\int_1^2 (\delta W)_A + \int_2^1 (\delta W)_C = \int_1^2 (\delta Q)_A + \int_2^1 (\delta Q)_C$

$$\int_1^2 (\delta W)_A - \int_2^1 (\delta W)_C = \int_2^1 (\delta Q)_B - \int_2^1 (\delta Q)_C$$

$$\int_2^1 (\delta Q)_C - \int_2^1 (\delta W)_C = \int_2^1 (\delta Q)_B - \int_2^1 (\delta W)_B$$

$$\int_2^1 (\delta Q - \delta W)_C = \int_2^1 (\delta Q - \delta W)_C$$

$\underbrace{(\delta Q - \delta W)}$ → Independent of path.

↳ point function.

↳ Thermodynamic property

all pt. functions are perfect differential

Internal energy ← dV = ↵

$$\boxed{\delta Q - \delta W = dV} \rightarrow \text{Process}$$

↳ Non flow energy eqⁿ

$${}_1Q_2 - {}_1W_2 = V_2 - V_1$$

$${}_2Q_3 - {}_2W_3 = V_3 - V_2$$

$${}_3Q_1 - {}_3W_1 = V_1 - V_3$$

$$\oint dQ - \oint dW = 0$$