Revision Booster WORKSHOP for NEET & JEE Main

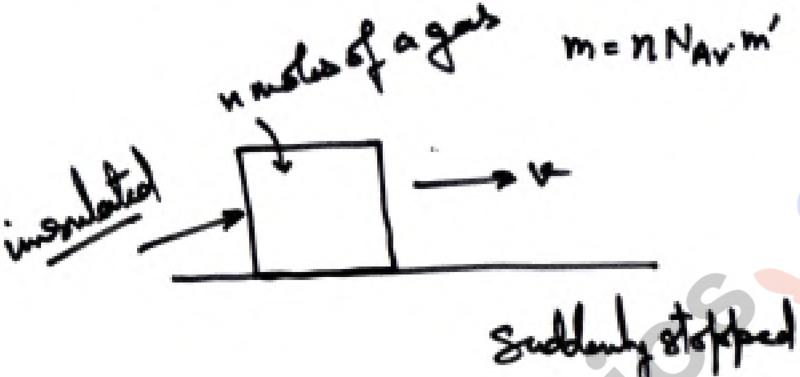
Heat and Thermodynamics

Notes of Revision Booster Workshop for JEE Main & NEET

Questions Based on

Stopping of a Moving Container

$m = n N_{Av} \cdot m'$



$KE = \frac{1}{2} m v^2 = \frac{3}{2} k \Delta T$

$T_2 - T_1 = \Delta T = ----$

$\frac{P_1}{T_1} = \frac{P_2}{T_2} \longrightarrow P_2 = \_\_$

Container at Constant speed:

$v \rightarrow$ Const.

$T \rightarrow$ Const.

QUESTIONS BASED ON

VALUE OF EQUIVALENT γ FOR A MIXTURE

$U_{mix} = U_1 + U_2$ $\qquad U = \frac{f}{2} nRT$ & $f = \frac{2}{\gamma - 1}$

$\gamma_{eq} = \gamma_{mix} = \frac{C_P}{C_V} = \frac{n_1 C_{P_1} + n_2 C_{P_2} + \dots}{n_1 C_{V_1} + n_2 C_{V_2} + \dots}$

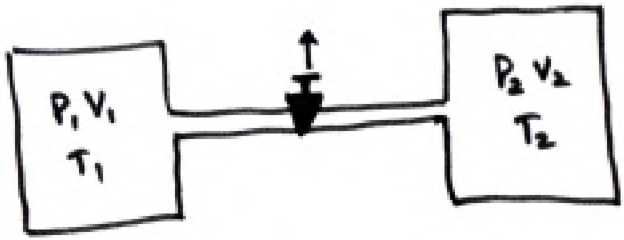
$\frac{nRT}{\gamma_{eq} - 1} = \frac{n_1 RT}{\gamma_1 - 1} + \frac{n_2 RT}{\gamma_2 - 1}$

$\frac{n_1 + n_2}{\gamma_{eq} - 1} = \frac{n_1}{\gamma_1 - 1} + \frac{n_2}{\gamma_2 - 1} + \dots$

$\gamma_{eq} = \text{—}$

QUESTIONS BASED ON

MIXTING OF TWO GASES BY CONNECTING CHAMBERS



$$n_1 + n_2 = n_T$$

$$\frac{P_1 V_1}{T_1} + \frac{P_2 V_2}{T_2} = \frac{P_f (V_1 + V_2)}{T_f}$$

for Cons of IE $\longrightarrow$ $$T_f = \frac{n_1 f_1 T_1 + n_2 f_2 T_2}{n_1 f_1 + n_2 f_2}$$

for similar atomicity of gases $$T_f = \frac{n_1 T_1 + n_2 T_2}{n_1 + n_2}$$

QUESTIONS BASED ON

C_p AND C_v PER UNIT MASS

for per mole of an ideal gas

$$C_p - C_v = R$$

for 1 gm of gas $\quad C_p' = \frac{C_p}{M}$

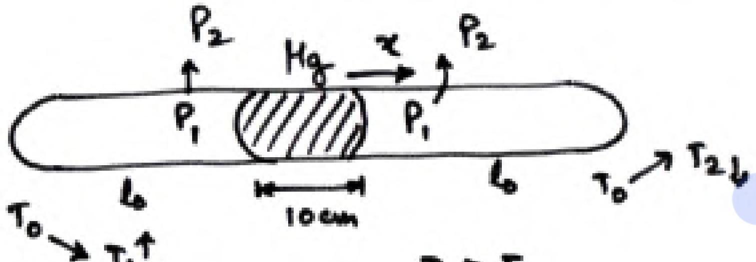
$M \rightarrow$ molar mass in gm

$$C_p' = \frac{C_p}{M} \; ; \; C_v' = \frac{C_v}{M}$$

$$C_p' - C_v' = \frac{R}{M}$$

Questions Based on

Hg Pallet in a Horizontal Tube



$T_1 > T_2$

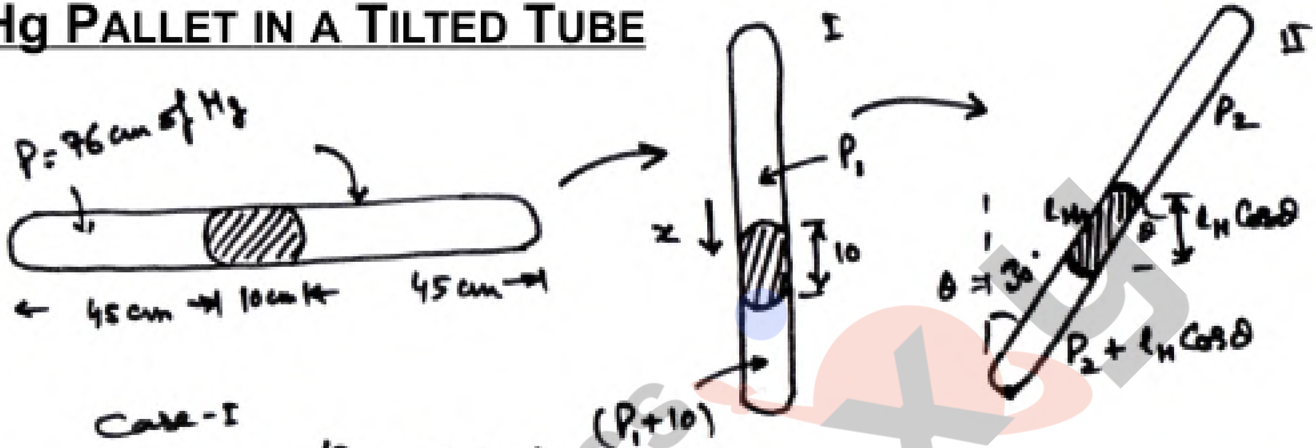
Q: displacement in pallet

$$\frac{P_1 l_0}{T_0} = \frac{P_2 (l_0 + x)}{T_1} = \frac{P_2 (l_0 - x)}{T_2}$$

$x =$ ______

Questions Based on

Hg Pallet in a Tilted Tube



Case-I

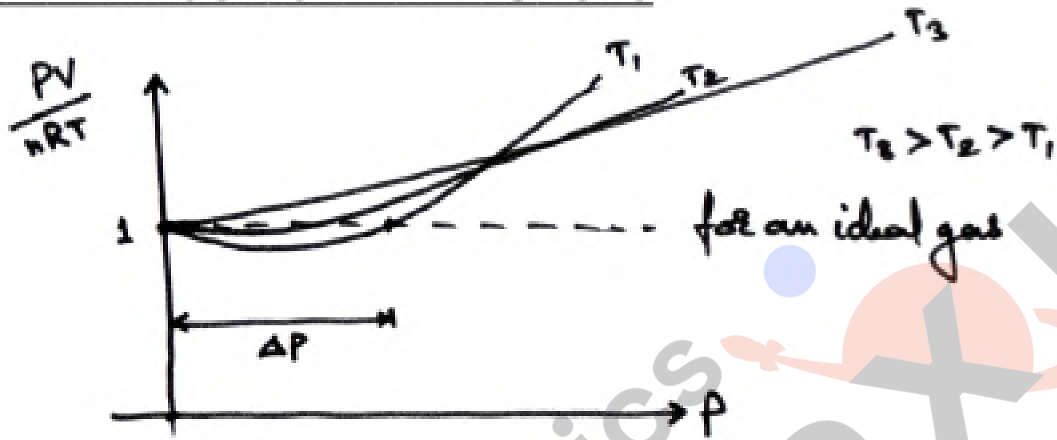
$$P_1(45+x) = (P_1+10)(45-x)$$

Case-II

$$P_2(45+x) = (P_2+10\cos 30°)(45-x)$$

QUESTIONS BASED ON

BEHAVIOUR OF REAL GASES

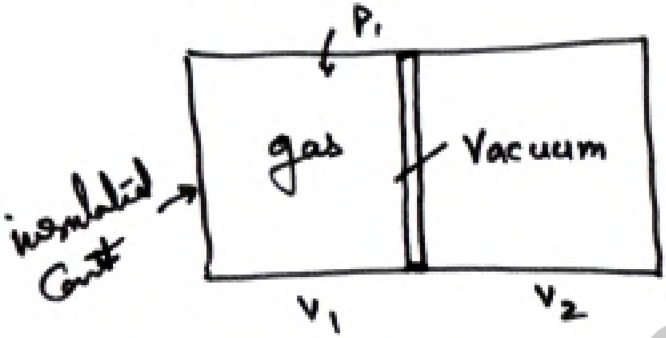


A real gas behaves like an ideal gas at v. low pressure & high temp

Questions Based on

Free Expansion of a Gas

in vacuum.



$P_1 V_1 = P_2 (V_1 + V_2)$

$P_2 =$ ——

There is no W/D against

exp in vacuum

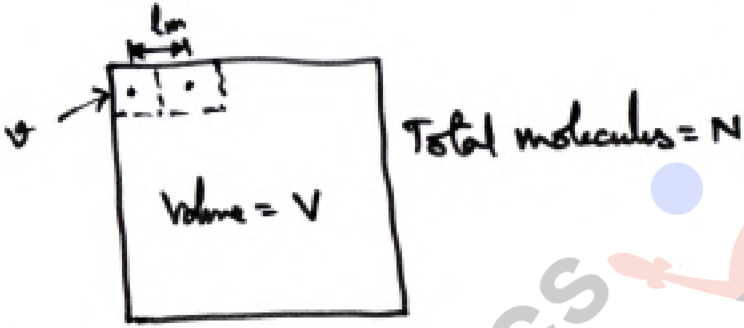
$\underline{W = 0}$ & $\Delta Q = 0$

$\underline{\Delta U = 0}$

$\Rightarrow T \rightarrow$ Const.

QUESTIONS BASED ON

MEAN DISTANCE BETWEEN GAS MOLECULES

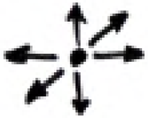


volume/molecule $v = \frac{V}{N}$

$$l_m = (v)^{1/3} = \left(\frac{V}{N}\right)^{1/3}$$

QUESTIONS BASED ON

SPECIFIC HEAT OF A SOLID BY KTG

for a Solid  3 dir of vib × 2 = 6 Dof

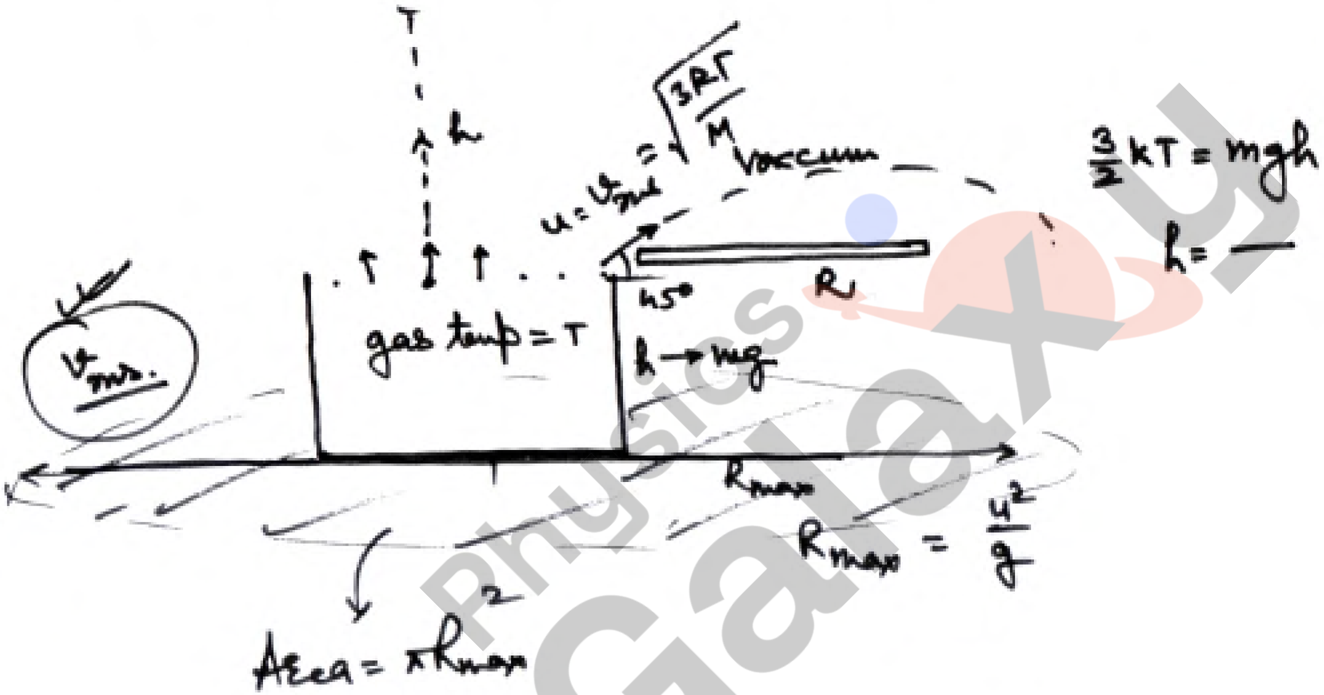
Energy of one molecule in a Solid $E = \frac{f}{2}kT = 3kT$

per mole sp. heat $C_V = \frac{f}{2}R = 3R$

per ~~mole~~ gm sp. heat $s = \frac{C_V}{M} = \frac{3R}{M}$ (approx)

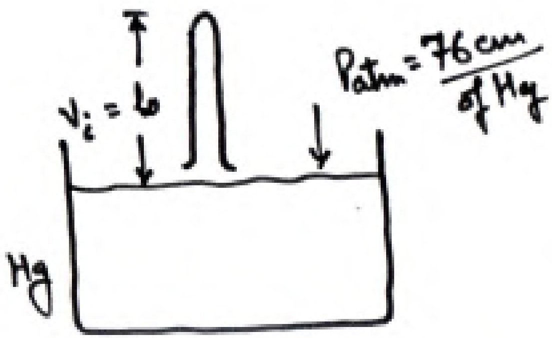
QUESTIONS BASED ON

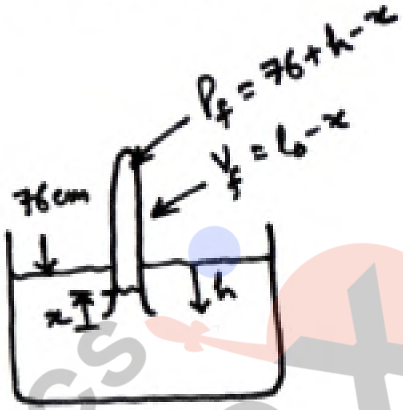
OPENING A CONTAINER IN VACUUM



QUESTIONS BASED ON

OPEN TEST TUBE IMMERSION IN Hg





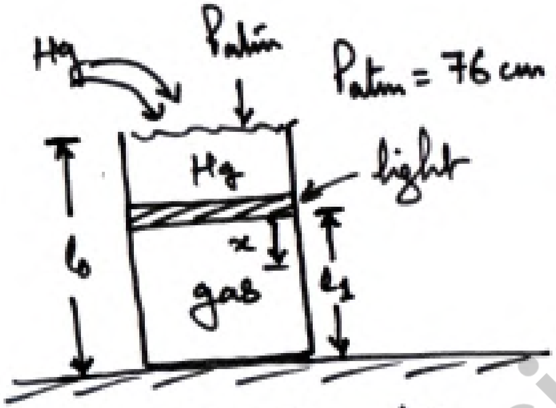
Considering T → Const

$$76 \times l_0 = (76 + h - x)(l_0 - x)$$

$x =$ ____ ✓

Questions Based on

Pouring Hg on a Piston-Cylinder System



$P_{atm} = 76$ cm of Hg

$P_i = 76$ cm of Hg

Considering T → Const

$$76 \times l_1 = (76 + l_0 - l_1 + x)(l_1 - x)$$

$x =$ ——

QUESTIONS BASED ON

INTERNAL ENERGY IN TERMS OF P & V OF GAS

IE of gas $U = \frac{f}{2}nRT = \frac{f}{2}PV$

QUESTIONS BASED ON

ESCAPING A GAS FROM A PLANET

$$v_{esc} = \sqrt{2gR} = \sqrt{\frac{2GM}{R}}$$

for max no of molecules to escape from planet

$$v_{mp} = \sqrt{\frac{2RT}{M_g}} = \sqrt{\frac{2GM_p}{R}}$$

$T =$ ____

Questions Based on

Mean Time Between Collisions

for ideal gas

mean sep between molecules $d_m = \left(\frac{V}{N}\right)^{1/3}$

mean time between collisions $t_m = \frac{d_m}{v_m} = \frac{(V/N)^{1/3}}{\sqrt{\frac{8RT}{M}}}$

$$t_m \propto \frac{V^{1/3}}{T^{1/2}} \propto \frac{T^{1/3}}{P^{1/3}T^{1/2}} \propto \frac{1}{P^{1/3}T^{1/6}}$$

$$\frac{t_{m_1}}{t_{m_2}} = \frac{P_2^{1/3}T_2^{1/6}}{P_1^{1/3}T_1^{1/6}}$$

QUESTIONS BASED ON

ENERGY CHANGES IN HEATING A LIQUID

$$\Delta Q = ms\Delta T \rightarrow \Delta U + \Delta W$$

volume exp → neglect $\Delta W = 0$

Considering volume exp

$\Delta V = \gamma V \Delta T$

$\Delta T \uparrow$

$$W = P_{atm}\Delta V$$

QUESTIONS BASED ON

SPECIFIC HEAT VARIATION WITH TEMPERATURE

for solids & liq if $s = f(T)$

heat supp $Q = \int_{T_1}^{T_2} msdT = $ ___

[for gases $C = f(T)$ ___

$Q = \int_{T_1}^{T_2} nCdT = \Delta U + \Delta W$

$\Delta U \rightarrow nC_V(T_2 - T_1)$

$\Delta W \rightarrow \int PdV$

$\Delta W = Q - \Delta U = $ ___

Questions Based on

P = αV^m Based Cases

$PV^{-m} = \text{Const}$ [Polytropic processes]

$PV^n = \text{Const}$ [$n = -m$]

Specific heat of gas in given process $C = C_v + \frac{R}{1-n} = C_v + \frac{R}{1+m}$

$n \rightarrow$ polytropic Constant

heat supp

$Q = nC\Delta T = nC(T_2 - T_1)$

$\Delta U = nC_v\Delta T = nC_v(T_2 - T_1)$

$W = Q - \Delta U$

$n = \gamma$ (adiabatic)

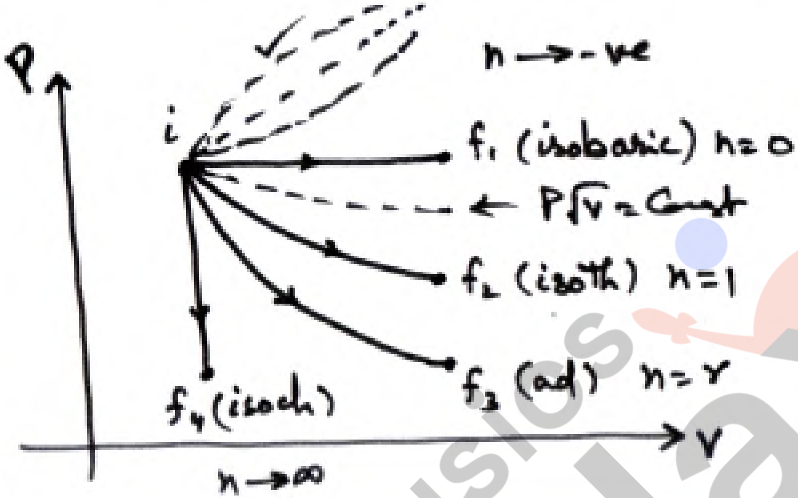
$n = 1$ (Isothermal)

$n = 0$ (Isobaric)

$n \rightarrow \infty$ (Isochoric)

Questions Based on

Indicator Diagram of Polytropic Processes



$PV^{1/2}$ = Const

$P\sqrt{V}$ = Const

$n = 1/2$

$P = a\sqrt{V}$

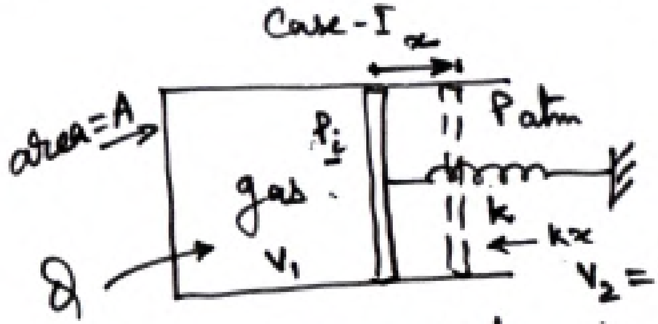
$PV^{-1/2}$ = Const

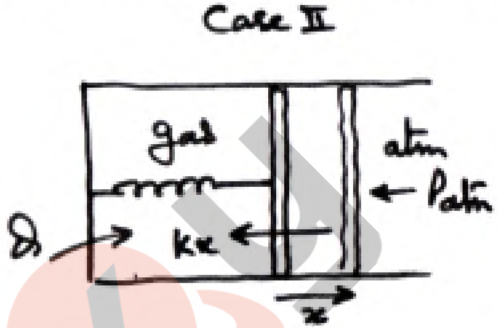
$n = -1/2$

Slope $\dfrac{dP}{dV} = \dfrac{a}{2\sqrt{V}}$ | as $V\uparrow \Rightarrow \dfrac{dP}{dV}\downarrow$

Questions Based on

Spring Based Piston Cylinder Cases Open to Atmosphere





Initially spring is relaxed

$\Rightarrow P_i = P_{atm}$

final pressure

$P_f = \left(P_{atm} + \frac{kx}{A}\right)$

W/D by gas $= P_{atm}(Ax) + \frac{1}{2}kx^2$

$\Delta U = nC_v(T_2 - T_1)$

$Q = \Delta U + W$

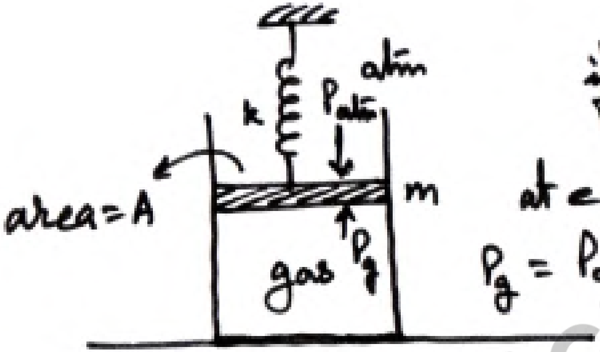
$V_i = V_1 \qquad V_f = V_1 + Ax$

$P_i = P_{atm} \qquad P_f = P_{atm} + \frac{kx}{A}$

by Gas law $\frac{P_{atm} V_1}{T_1} = \frac{\left(P_{atm} + \frac{kx}{A}\right)(V_1 + Ax)}{T_2}$ ✓

Questions Based on

Piston Cylinder System with Vertical Spring



if spring is relaxed

at eq^m

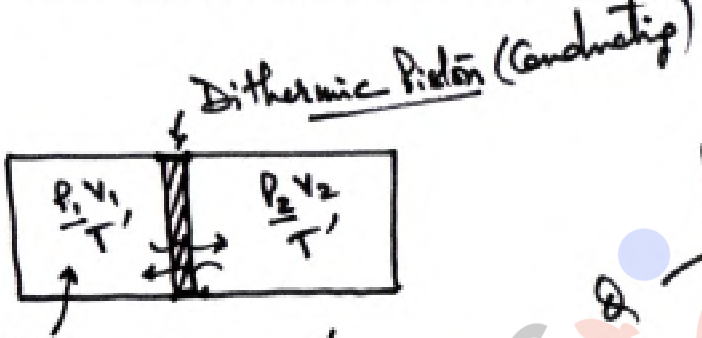
$$P_g = P_{atm} + \frac{mg}{A}$$

at spring compression x $\quad P_g = P_{atm} + \frac{kx}{A} + \frac{mg}{A}$

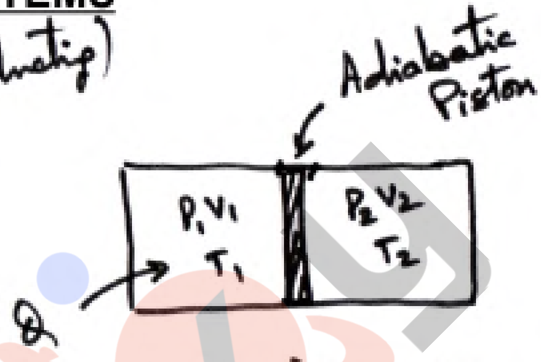
at spring elongation x $\quad P_g = P_{atm} - \frac{kx}{A} + \frac{mg}{A}$

Questions Based on

Closed Piston-Cylinder Systems



$T \longrightarrow T'$



if fixed piston $\Rightarrow \Delta W = 0$

$$Q = \left(\frac{P_1 V_1}{RT}\right) C_v (T' - T) + \left(\frac{P_2 V_2}{RT}\right) C_v (T' - T)$$

$$T' = \_\_\_\_$$

$$\frac{P_1^f V_1}{T'} = \frac{P_1 V_1}{T}$$

$$P_1^f = \_\_\_\_$$

$$\frac{P_{2f}}{T'} = \frac{P_2}{T}$$

$$P_{2f} = \_\_\_\_$$

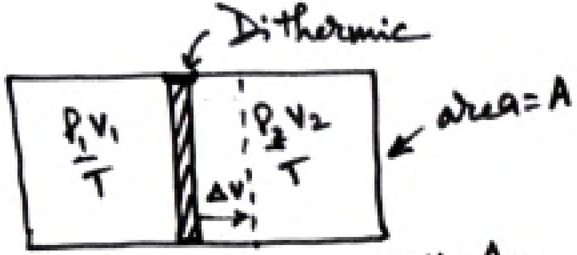
$$Q = \left(\frac{P_1 V_1}{RT_1}\right) C_v (T_{1f} - T_1)$$

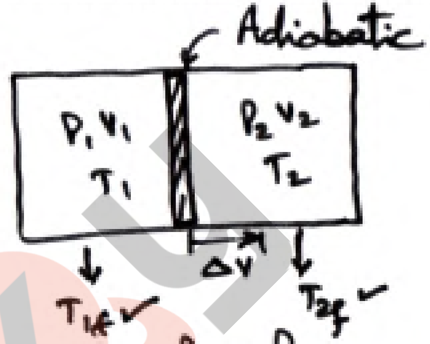
$$T_{1f}$$

$$\frac{P_{1f}}{T_{1f}} = \frac{P_1}{T_1} \Rightarrow P_{1f} = \_\_\_\_.$$

QUESTIONS BASED ON

CLOSED PISTON-CYLINDER SYSTEMS WITH MOVABLE PISTON





$\Delta V = Ax$

if piston is released

$T \rightarrow T_f$ ✓

$P_{1f} = P_{2f} = P_f$ ✓

$P_{1f} = P_{2f} = P_f$

$$\frac{P_1 V_1}{T} = \frac{P_f (V_1 + \Delta V)}{T_f}$$

$$\& \quad \frac{P_2 V_2}{T} = \frac{P_f (V_2 - \Delta V)}{T_f}$$ ✓

$$P_1 V_1^{\gamma} = P_f (V_1 + \Delta V)^{\gamma}$$

$$T_1 V_1^{\gamma - 1} = T_{1f} (V_1 + \Delta V)^{\gamma - 1}$$

$$\frac{P_1 V_1}{T_1} = \frac{P_f (V_1 + \Delta V)}{T_{1f}}$$

$$\& \quad \frac{P_2 V_2}{T_2} = \frac{P_f (V_2 - \Delta V)}{T_{2f}}$$

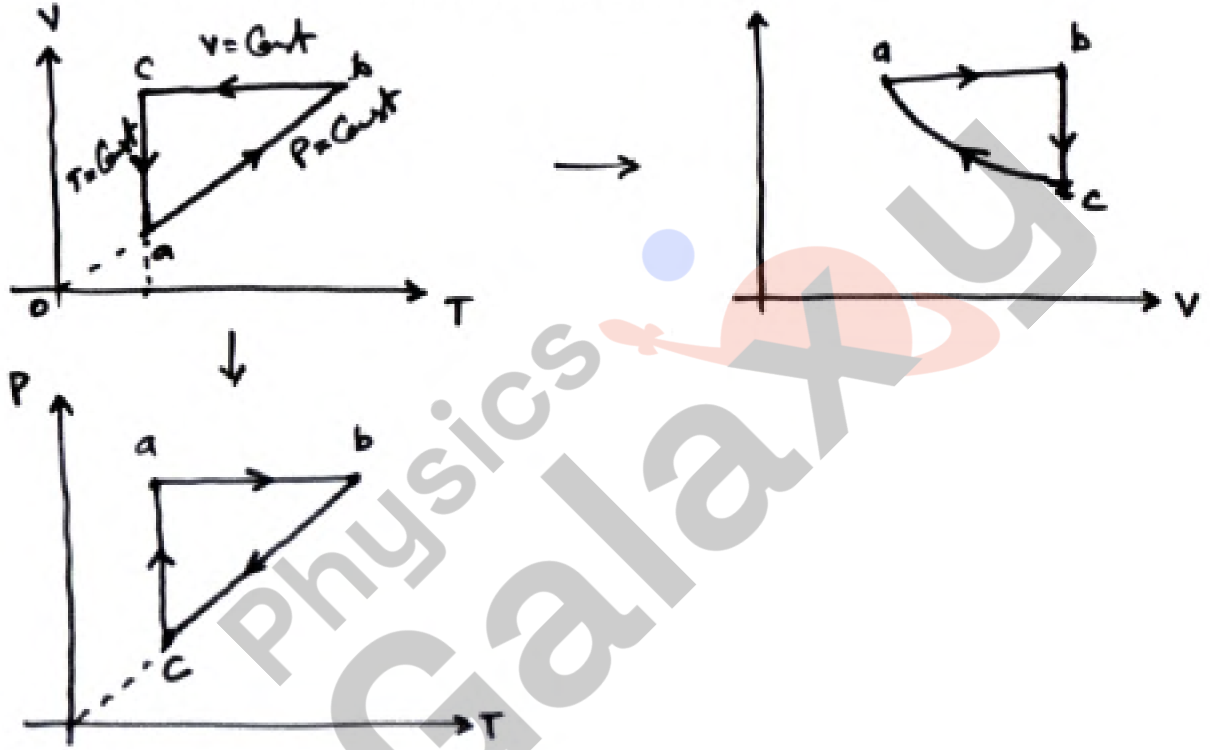
$$|W_{gas 1}| - |W_{on gas 2}| = (n_1 + n_2) C_v (T_f - T)$$ ✓

$$|W_{gas 1}| = -nC_v(T_{1f} - T)$$

$$|W_{on gas 2}| = nC_v(T_{2f} - T)$$

Questions Based on

Redrawing of Indicator Diagrams



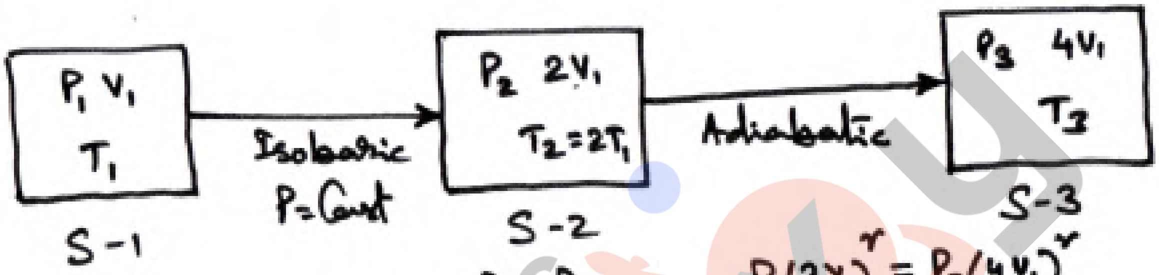
$\underline{P}V = nR\underline{T}$

↓

Const

QUESTIONS BASED ON

CASCADING OF THERMODYNAMICS PROCESSES



$P_2 = P_1$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} = \frac{2V_1}{T_2}$$

$\Rightarrow T_2 = 2T_1$

$W_1 = P\Delta V = \underline{P_1 V_1}$

$\Delta U_1 = nC_V T_1$

$Q_1 = W_1 + \Delta U_1$

$P_1(2V_1)^\gamma = P_3(4V_1)^\gamma$

$$\Rightarrow P_3 = \frac{P_1}{2^\gamma}$$

$(2T_1)(2V_1)^{\gamma-1} = T_3(4V_1)^{\gamma-1}$

$T_3 = $ —

$W = $ ✓

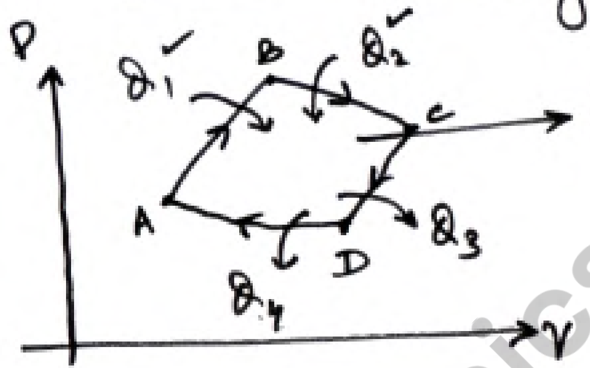
$\Delta U = $ ✓

$Q = $ ✓

QUESTIONS BASED ON

HEAT ENGINE BASED QUESTIONS

Cyclic Process clockwise



work done by gas in One complete Cycle

$$W = (Q_1 + Q_2) - (Q_3 + Q_4)$$

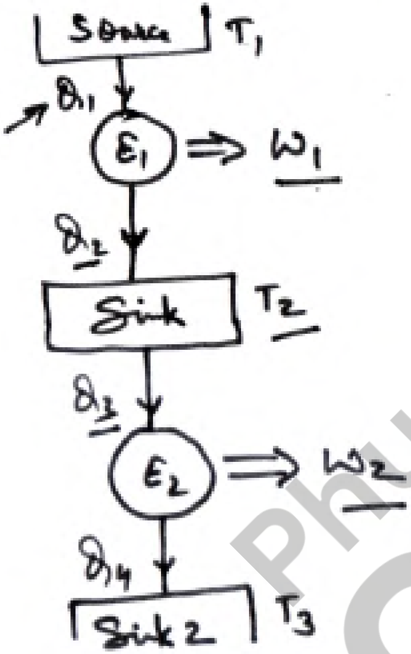
Cycle efficiency $\eta = \dfrac{W}{Q_1 + Q_2} = 1 - \dfrac{Q_3 + Q_4}{Q_1 + Q_2} = 1 - \dfrac{Q_{out}}{Q_{in}}$

Carnot Cycle → 2 isoth + 2 ad.

$$\eta = 1 - \frac{T_2}{T_1}$$

QUESTIONS BASED ON

CASCADING OF HEAT ENGINES



Efficiency of E_1 $\eta_1 = 1 - \frac{T_2}{T_1} \times 100\%$

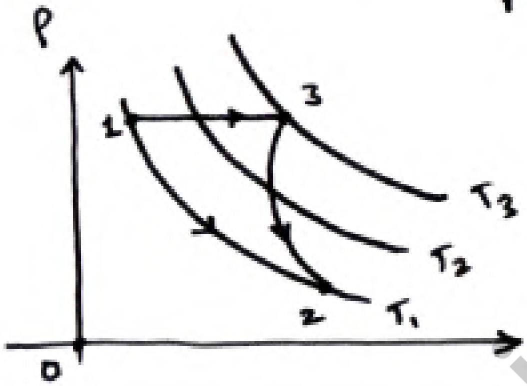
Efficiency of E_2 $\eta_2 = 1 - \frac{T_3}{T_2} \times 100\%$

Total efficiency $\eta_T = \frac{W_1 + W_2}{Q_1} = $ ——

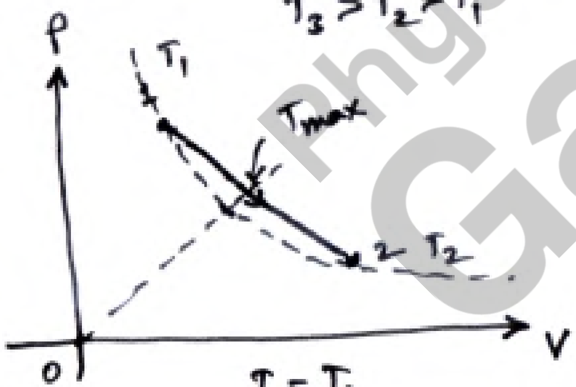
Questions Based on

Family of Isotherms

$P \propto \frac{1}{V} \rightarrow$ isothermal process



$T_3 > T_2 > T_1$



$T_1 = T_2$

Questions Based on

Density Variation of a Gas in a Process

$\downarrow$ $\rho = \frac{m}{V}$

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

$\rho' \longrightarrow 20\rho$

Compression

from $V \longrightarrow \frac{V}{20}$

for adiabatic process

$PV^{\gamma} = \text{Const}$

$\Rightarrow P\rho^{-\gamma} = \text{Const}$

or $P = k\rho^{\gamma}$

for isothermal process

$PV = \text{Const}$

$\Rightarrow P = k\rho$

Questions Based on

Sudden Processes → Reversible or NOT

↓

No time available for heat exchange ⇒ adiabatic

↓

As process is v. quick ⇒ at intermediate states its (gas) state cannot be considered in eqm

⇒ Not quasistatic

⇒ Not reversible.

QUESTIONS BASED ON

HEAT EXCHANGE WITH A GAS OF RIGID MOLECULES

⇓ no vib mode is present

$\Rightarrow f_v = 0$

if x vib modes are present

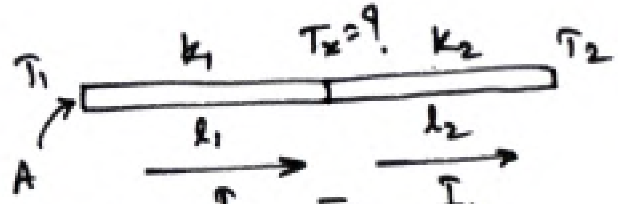
$\Rightarrow f_v = 2x$

Sp heat →

- $C_V = \frac{f}{2}R$
- $C_P = \frac{f+2}{2}R$
- C = const for polytropic process
- $C = f(P/V/T)$ for Non-polytropic process

Questions Based on

Thermal Resistance Based Questions on Conduction



$$I_1 = I_2$$

$$R_1 = \frac{1}{k_1} \cdot \frac{l_1}{A}$$

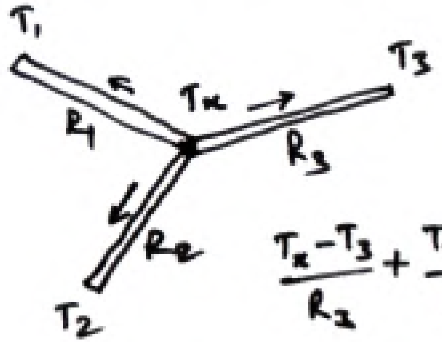
$$R_2 = \frac{1}{k_2} \cdot \frac{l_2}{A}$$

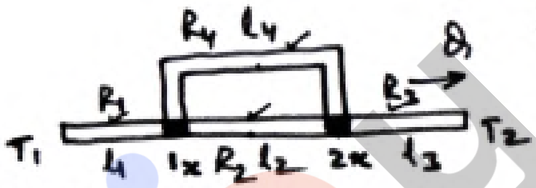
$$\frac{T_1 - T_x}{R_1} = \frac{T_x - T_2}{R_2}$$

$$T_x = \_\_\_$$

Questions Based on

Heat Current in Different Circuits



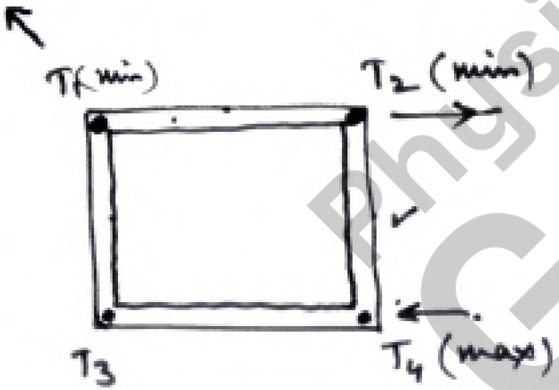


$$q = \frac{T_1 - T_2}{R_{eq}}$$

$$R_{eq} = R_1 + \frac{R_2 R_4}{R_2 + R_4} + R_3$$

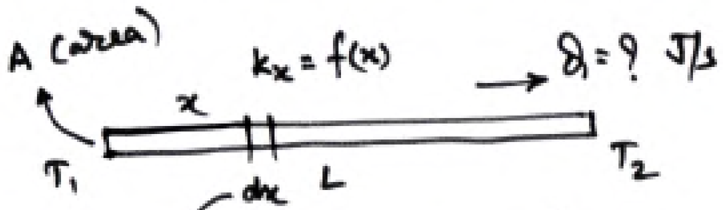
$$\frac{T_x - T_3}{R_3} + \frac{T_x - T_2}{R_2} + \frac{T_x - T_1}{R_1} = 0$$

$$T_x = \text{—}$$



QUESTIONS BASED ON

VARIATION IN THERMAL CONDUCTIVITY



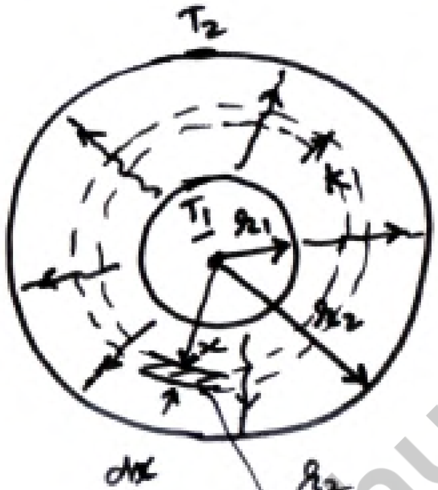
$$R_{th} = \int dR = \int \frac{1}{k} \cdot \frac{dx}{A} = \frac{1}{A} \int_0^L \frac{dx}{f(x)} = \_\_\_\_$$

$$Q = \frac{T_1 - T_2}{R_{th}}$$

Questions Based on

Heat Conduction in Spherical Shell

$T_1 > T_2$



$$\frac{dH}{dt} = Q_{th} = \frac{T_1 - T_2}{(r_2 - r_1)} \cdot 4\pi k r_1 r_2$$

$$R_{th} = \int dR = \int_{r_1}^{r_2} \frac{1}{k} \cdot \frac{dx}{4\pi x^2} = \frac{1}{4\pi k}\left[-\frac{1}{x}\right]_{r_1}^{r_2}$$

$(2\pi x l)$ if it is cylindrical shell

$$R_{th} = \frac{r_2 - r_1}{4\pi k r_1 r_2}$$

QUESTIONS BASED ON

RADIATION & ABSORPTION BY NON-BLACK BODIES

Surr temp = T_s

Total radiation power for BB

$$P_{th} = \sigma A T^4 - \sigma A T_s^4 = \sigma A(T^4 - T_s^4)$$

for Non-black bodies, we use

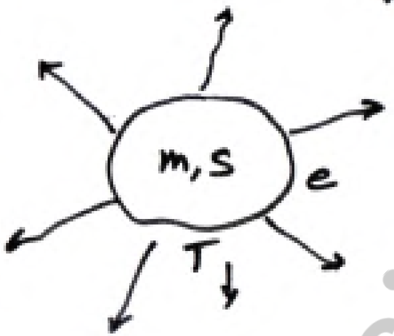
emissivity (e) & absorptivity (a)

$0 \le e \le 1$ $\quad$ $0 \le a \le 1$

$$P_{th} = e\sigma A T^4 - a\sigma A T_s^4$$

QUESTIONS BASED ON

COOLING OF A BODY BY RADIATION



vacuum 0K / T_s in space.

Radiation power $= \sigma T^4 \times e$ J/s-m^2

heat current $= \sigma A T^4 e$ watt

rate of cooling $\frac{dT}{dt}$ (°C/s) of body is related to heat current as-

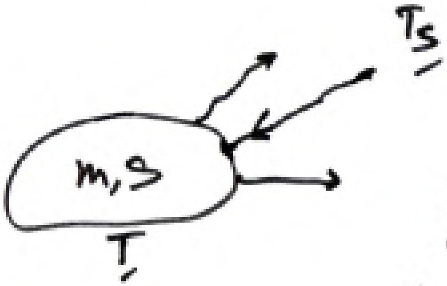
$\Delta Q = -ms\,\Delta T\downarrow$

$\frac{dQ}{dt} = -ms\frac{dT}{dt}$ → $eA\sigma T^4 = ms\frac{dT}{dt}$

$\frac{dT}{dt} = \frac{eA\sigma T^4}{ms}$ °C/s

QUESTIONS BASED ON

COLLING OF A BODY PLACED AT A SURROUNDING TEMPERATURE



for a black body

$$\frac{dH}{dt} = ms\frac{dT}{dt} = (\sigma T^4 - \sigma T_s^4)A$$

heat current

$$\left|\frac{dT}{dt}\right| = \frac{\sigma A}{ms}(T^4 - T_s^4)$$

for a gen^r body

$$ms\frac{dT}{dt} = \sigma e A T^4 - \sigma a A T_s^4$$

$$\frac{dT}{dt} = \frac{\sigma A}{ms}\left[eT^4 - aT_s^4\right]$$

Questions Based on

Colling of a Body When T ≈ T_S

↓

Newton's law of Cooling ✓

v. imp

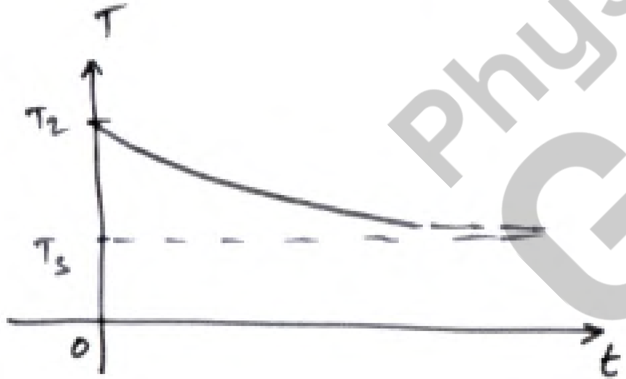
depends on T_s, A, e

$$\frac{dT}{dt} = -\frac{C}{ms}(T - T_s)$$

$$\int_{T_2}^{T_t} \frac{dT}{T - T_s} = -\frac{C}{ms}\int_0^t dt$$

$$\ln\left(\frac{T - T_s}{T_2 - T_s}\right) = -\frac{Ct}{ms}$$

$$T = T_s + (T_2 - T_s)e^{-Ct/ms}$$



QUESTIONS BASED ON AVERAGE FORM OF NLC

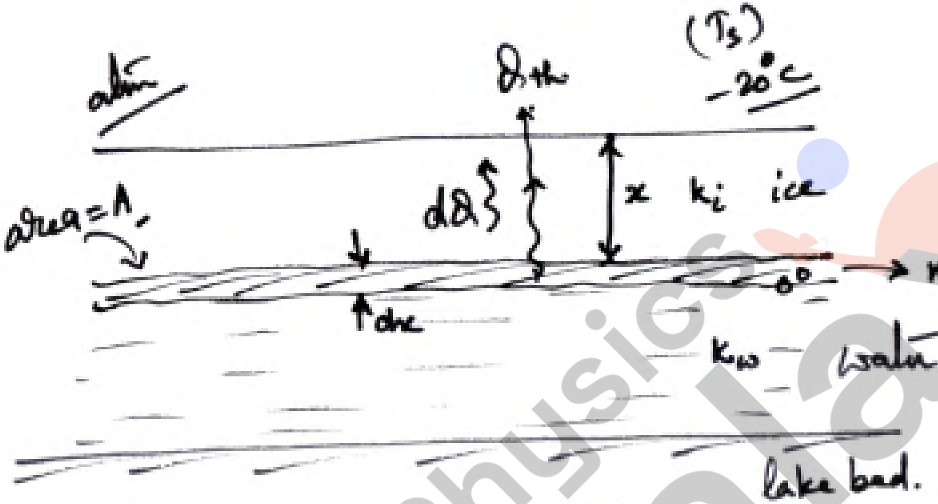
$$\frac{dT}{dt} = -\frac{C}{ms}(T - T_s)$$

if body cooling down from T_2 to T_1 in δt seconds

$$\frac{T_2 - T_1}{\delta t} = -\frac{C}{ms}\left(\frac{T_1 + T_2}{2} - T_s\right)$$

Questions Based on

Freezing of a Lake



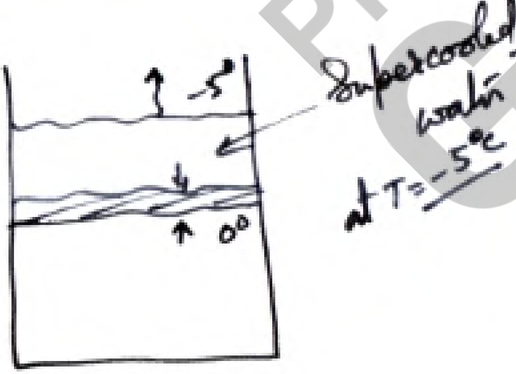
$$Q_{th} = \frac{k_i A (T_s)}{x} \quad J/s$$

$$\frac{dQ}{dt} = \left[\frac{k_i A T_s}{x}\right] = A\rho\, dx \cdot L_f$$

$$\text{mass} = A\, dx \cdot \rho$$

$$\int_0^t dt = \int_0^x \frac{A\rho L_f\, x\, dx}{k_i A T_s}$$

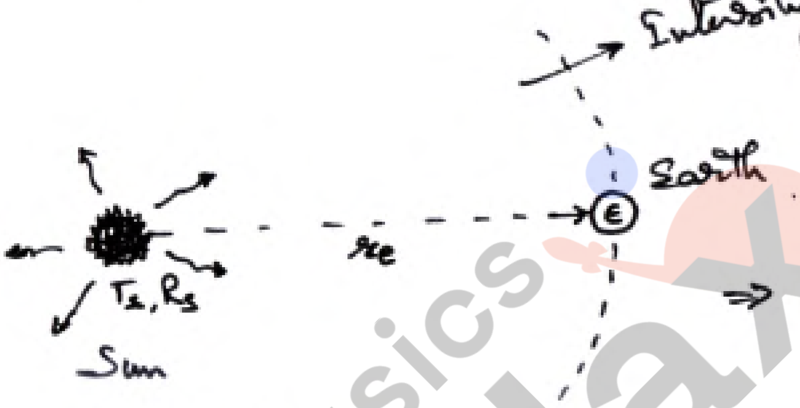
$$t = \frac{\rho L_f}{k_i T_s} \cdot x^2$$



$$t \propto x^2$$

Questions Based on

Solar Constant



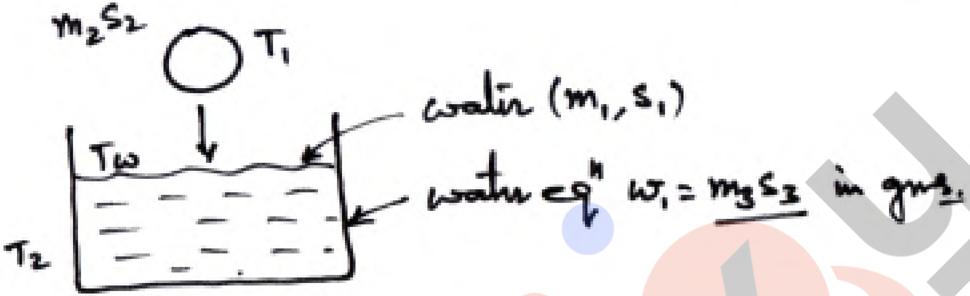
$$I = \frac{P_{th}}{4\pi r_E^2} \ W/m^2$$

$$\Rightarrow S = \frac{\sigma T_s^4 (R_s^2)}{r_E^2}$$

$$(P_{th}) \text{ Rad power} = \sigma T_s^4 \cdot (4\pi R_s^2)$$

QUESTIONS BASED ON

PLACING A HOT METAL SHPERE IN A LIQUID BOTH



$$\text{Mixture} = \text{Everything at } 0^\circ C + \left\{ [m_2 s_2 T_1 + m_1 s_1 T_w + m_3 s_3 T_4] - Q \right\}$$

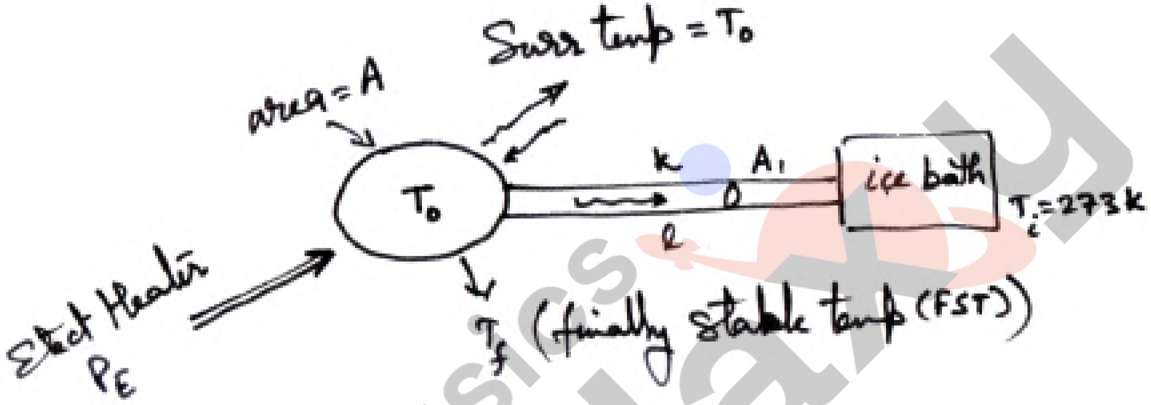
$$= \text{Everything at } 100^\circ C + (\;\;)$$

amount of vapour produced $= \dfrac{(\;\;)}{L_v}$

Heat reqd to raise the temp of mixture from 0 to 100 is

$$Q = [m_2 s_2 (100) + m_1 s_1 (100) + m_3 s_3 (100)]$$

Questions Based on
Equilibrium For Radiation & Heating Together



by Conservation of energy

if cond is present

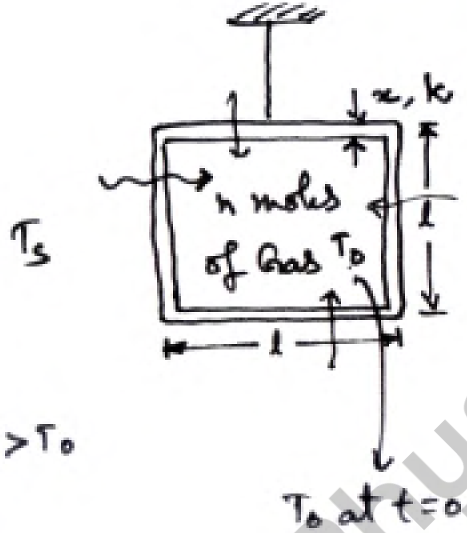
$$P_E + \sigma A a T_0^4 = \sigma A e T_f^4 \left(+ \frac{k A_1 (T_f - 273)}{l} \right)$$

$$T_f = \text{\_\_\_\_\_ Ans}$$

Questions Based on

Heating of a Gas by Conduction

Q: find gas temp as a f^n of time t



$T_s > T_0$

$$\frac{dH}{dt} = \frac{k(6l^2)(T_s - T)}{x}$$

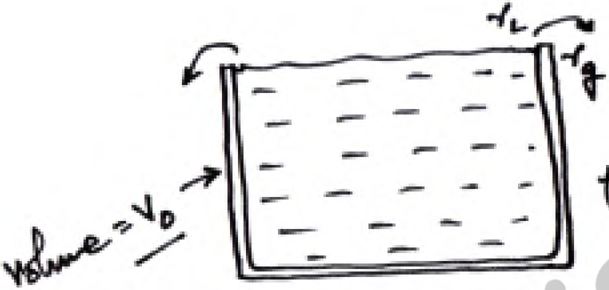
$$\int_{T_0}^{T_f} \frac{nC_v\,dT}{T_s - T} = \int_0^t \frac{6kl^2}{x}\,dt$$

$\Rightarrow$ — — — T_f = ——— ✓

QUESTIONS BASED ON

APPARENT EXPANSION OF A LIQUID

As $\gamma_L > \gamma_g \Rightarrow$ liq will expand more



temp↑ by ΔT

* overflow volume $\Delta V_{of} = V_0(\gamma_L - \gamma_g)\Delta T$

$A_T = A_i(1 + 2\alpha_g \Delta T)$

$\gamma_{ap} \rightarrow$ Coeff of app exp of liq w.r.to glass.

temp↑ by ΔT

$$h = \frac{\Delta V_{of}}{A_{tube}}$$

QUESTIONS BASED ON

PENDULUM CLOCK VS DIGITAL CLOCK

↓ temp invariant

time lost/gained per sec compared to DC

In Summers → clock slows down

In Winters → clock speeds up

$$\frac{\delta t}{t} = \frac{1}{2}\alpha\Delta T$$

↓ rise/fall of temp from graduation temp of Pendulum clock. (T_{PC})

QUESTIONS BASED ON

THERMOMETRY RELATION

$$\left[\frac{\text{Temp at X Scale} - LFP}{UFP - LFP}\right] = \text{Constant}$$

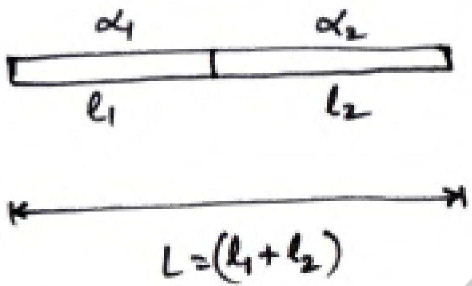
°C → 0 to 100°

°F → 32 to 212°

K → 273 to 373K

Questions Based on

Equivalent Coefficient of Expansion



temp ↑ by ΔT

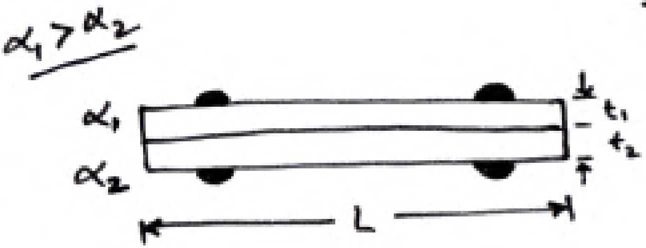
$$L_f = L(1 + \alpha_{eq} \Delta T)$$

$$L_f = l_1(1 + \alpha_1 \Delta T) + l_2(1 + \alpha_2 \Delta T)$$

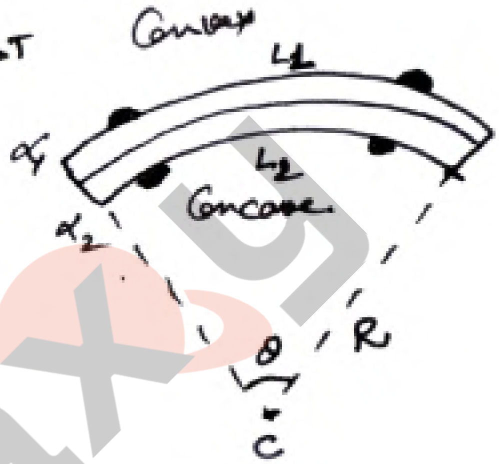
$$\alpha_{eq} = - - - -$$

QUESTIONS BASED ON

EXPANSION OF RIVETED RODS



temp ↑ by ΔT



$$\theta = \frac{L_2}{R} = \frac{L_1}{R + t_{1f} + t_{2f}}$$