Handwritten Notes

on

Thermal Properties

LearningMantrasOfficial LearningMantras

T_{tr} = Triple point of water

Date ___/___/___
Page ___

- **Calibration of thermometer**

	Celcius	Farenheit
T_i =	0°C	32° F
T_s =	100°C	212°F
	100° div	180 div

→ **Relation b/w two scales x and Y**

x_1 → ice point in x scale	x	$\frac{y-y_1}{y_2-y_1} = \frac{x-x_1}{x_2-x_1}$
x_2 → steam point		
y_1 → ice point	y	↓
y_2 → steam point		straight line equation

Q. C and F x.

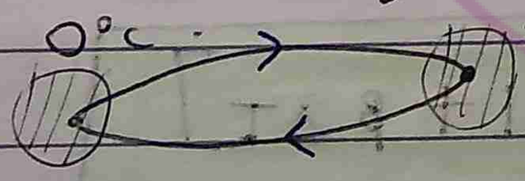
$x°F = -x°C$

$\frac{C}{5} = \frac{F-32}{9}$

$\frac{-x}{5} = \frac{x-32}{9} \Rightarrow -9x = 5x - 160 \Rightarrow x = \frac{160}{14} = \frac{80}{7} = 11.43°$

$\Rightarrow$ 11.43° F = − 11.43° C : (Temperature at which C° and F° have same numerical value but opposite sign)

- **Thermocouple:**



$V = a + bT + cT^2$
(voltage)

- **Constant Volume gas thermometer:** $P \propto T$.

$\frac{P_1}{T_1} = \frac{P_2}{T_2} \Rightarrow T_2 = \frac{P_2 \times T_1}{P_1}$

T_{tr} = 273.16 K → absolute scale. 273.15 ice pt
373.15 steam point
100 divisions

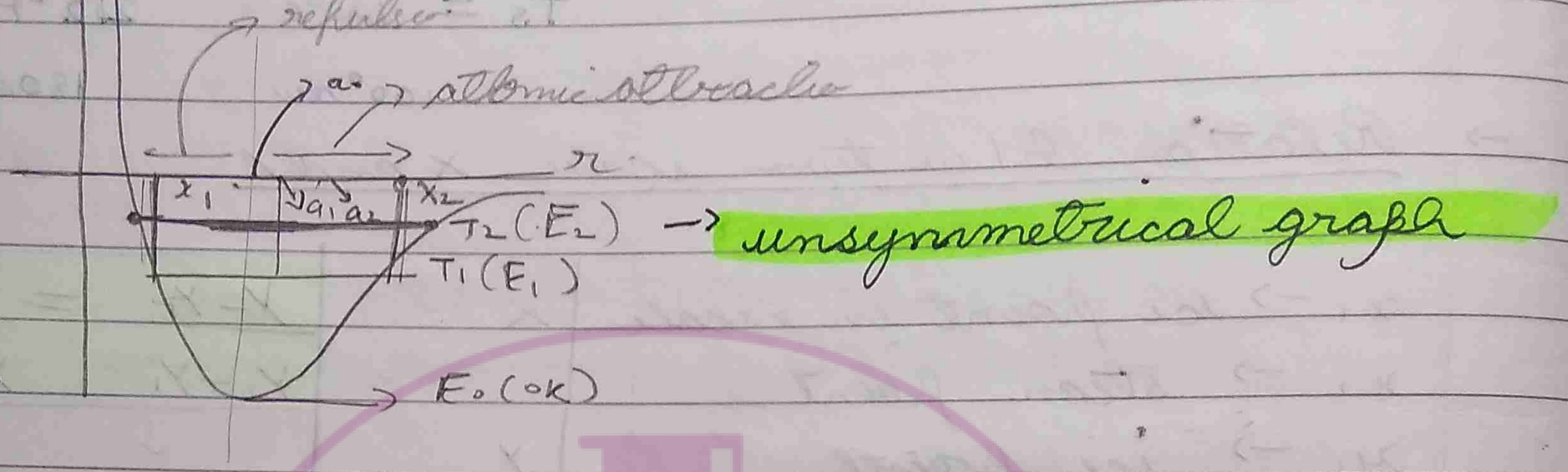
$T_2 = \frac{P_2}{P_1} \times 273.16$ K.

LEARNING MANTRAS
myCOMPANION
For More PDFs Visit: LearningMantras.com

Expansion due to temperature : gas > liquid > solid

Date __/__/__
Page

- **Thermal Expansion**: expansion due to temperature rise



→ unsymmetrical graph

- **Coefficient of linear expansion**: (α)

$$\alpha = \frac{1}{L_0} \frac{dL}{dT}$$

dL → change in length
L_0 → original length
dT → change in temperature

$$\Rightarrow \int_{L_0}^{L} dL = \int_{T_1}^{T_2} \alpha L_0 \, dT \quad \Big| \quad = L - L_0 = \alpha L_0 (T_2 - T_1)$$

$$\Rightarrow \boxed{L = L_0(1 + \alpha \Delta T)}$$

- $\beta = \frac{1}{A_0} \frac{dA}{dT} \Rightarrow \boxed{A = A_0[1 + \beta \Delta T]}$

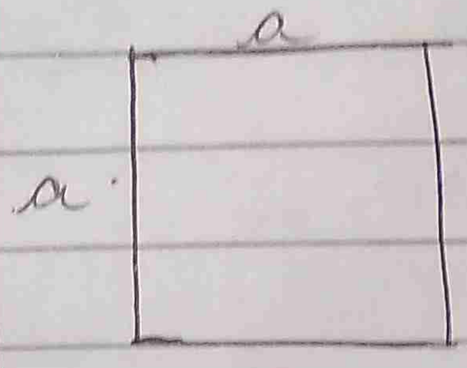
↙ coefficient of Areal expansion

- $\gamma = \frac{1}{V_0} \frac{dV}{dT} \Rightarrow \boxed{V = V_0(1 + \gamma \Delta T)}$

↙ coefficient of Volume expansion

LEARNING MANTRAS
MyCOMPANION
For More PDFs Visit: LearningMantras.com

- Fractional change in time $\Rightarrow \frac{1}{2}\alpha\Delta\theta$
- Change in time $\Rightarrow \frac{1}{2}\alpha\Delta\theta T$



$A_0 = a^2$

$a' = a(1+\alpha\Delta T)$

$A = a'^2$

$\Rightarrow a^2(1+\alpha\Delta T)^2$ if $\alpha\Delta T << 1$

$\Rightarrow a^2(1+2\alpha\Delta T)$.

$$A = A_0(1+2\alpha\Delta T).$$

$\Rightarrow \beta = 2\alpha \quad \gamma = 3\alpha$

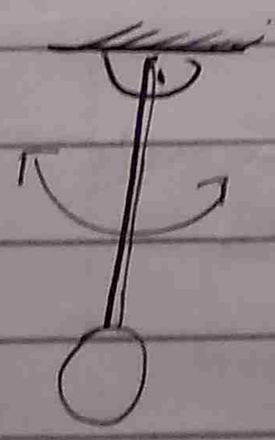
$\rightarrow \frac{\alpha}{1} = \frac{\beta}{2} = \frac{\gamma}{3}$

- **Anisotropic solids**

$$\beta = \alpha_1 + \alpha_2$$
$$\gamma = \alpha_1 + \alpha_2 + \alpha_3$$

- **Application of thermal expansion:**

1. **Time period of pendulum:**



$$T_0 = 2\pi\sqrt{\frac{l_0}{g}}$$

$$T = 2\pi\sqrt{\frac{l_0(1+\alpha\Delta\theta)}{g}} \Rightarrow T_0\left(1+\frac{1}{2}\alpha\Delta\theta\right)$$

$(\because \alpha\Delta\theta << 1)$.

- **fractional change** $= \frac{T-T_0}{T_0}$

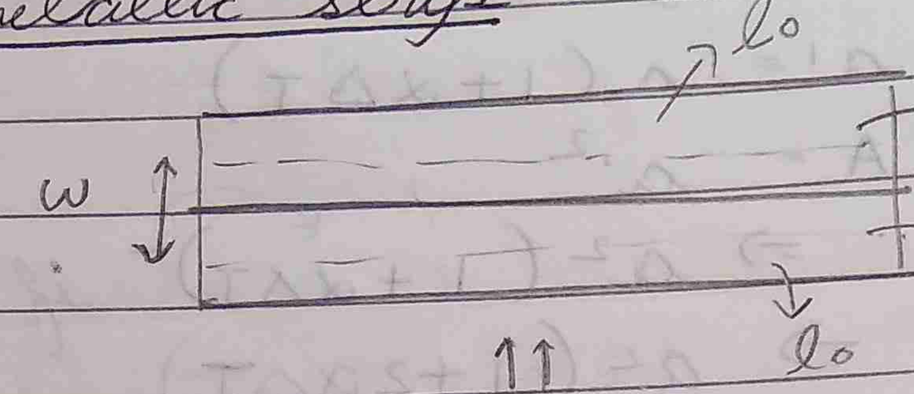
$\Rightarrow \frac{1}{2}\alpha\Delta\theta$

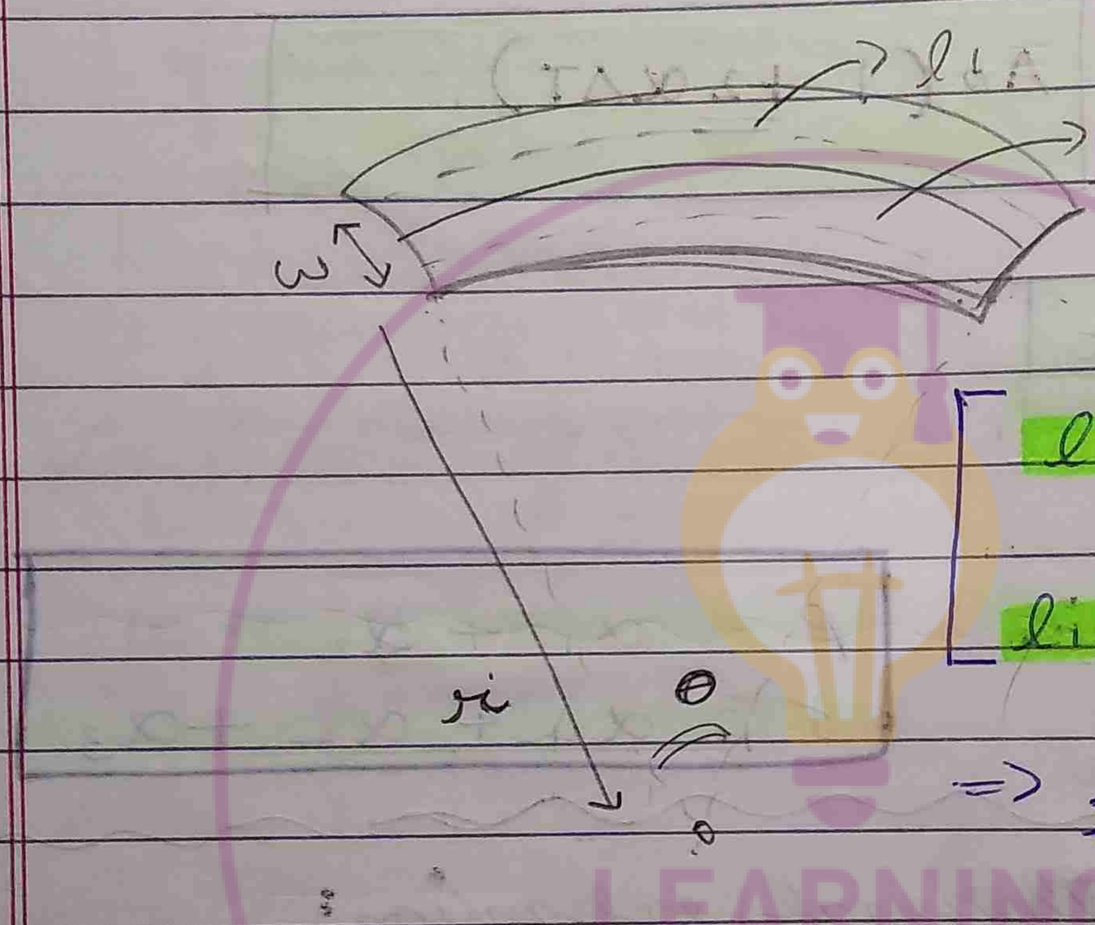
LEARNING MANTRAS
myCOMPANION
For More PDFs Visit: LearningMantras.com

$\theta \propto \frac{1}{s}$ ← unit vise parallel to yard.

$T\theta \propto \frac{1}{s}$ ← unit ⚠ yard.

2 **Bimetallic strip.**





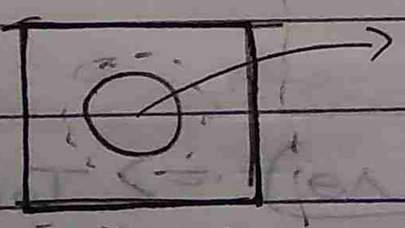
$l_2 = r\theta = l_0(1 + \alpha_2 \Delta T)$

$l_1 = (r + w)\theta = l_0(1 + \alpha_1 \Delta T)$

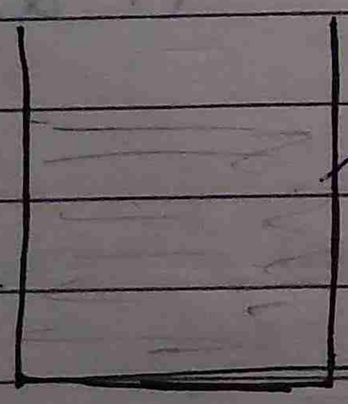
$\Rightarrow$ $r\theta$ ---- find.

3 **Expansion of whole / cavity**

Both cavity and plate expands

*  → dia of hole

$d = d_0(1 + \underset{\text{Plate}}{\alpha} \Delta T)$

*  → $V = V_0(1 + \gamma_{vessel} \Delta T)$ ----

$\gamma_{liq} > \gamma_{vessel}$ → level rises

$\gamma_{liq} < \gamma_{vessel}$ → level falls.

- Apparent expansion of liquid $\gamma_{a.liq} = \gamma_{r.liq} - \gamma_{vessel}$

LEARNING MANTRAS
My COMPANION
For More PDFs Visit: LearningMantras.com

from 0°—4°C water $C_V > C_P$

from 4°—80°C water $C_P > C_V$

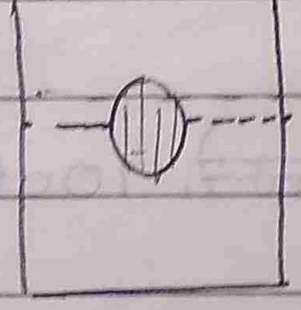
Date __/__/__

Page _____

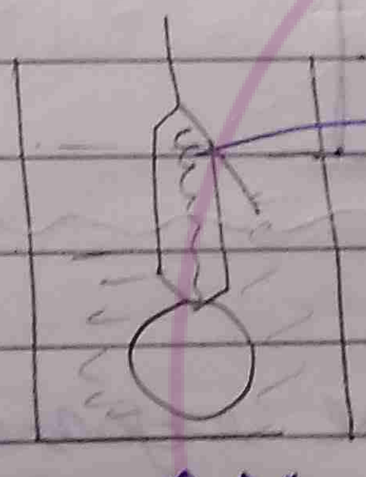
4. Change in density :

$$\rho = \frac{m}{V} = \frac{m}{V_0(1+\gamma\Delta T)} \Rightarrow \boxed{\rho = \frac{\rho_0}{1+\gamma\Delta T}}$$

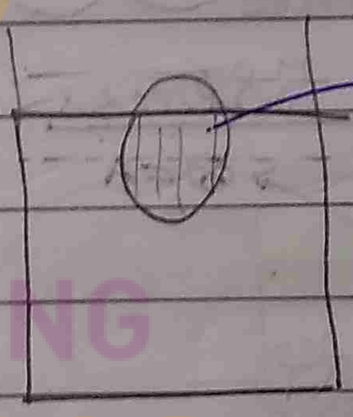
* Density decreases as temperature is increased.



$\boxed{\gamma_s < \gamma_e}$ ∴ submerged volume will increase

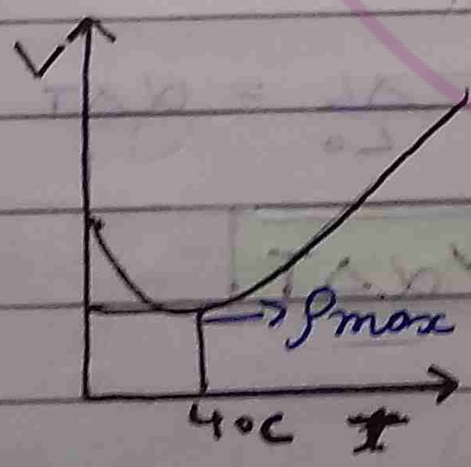


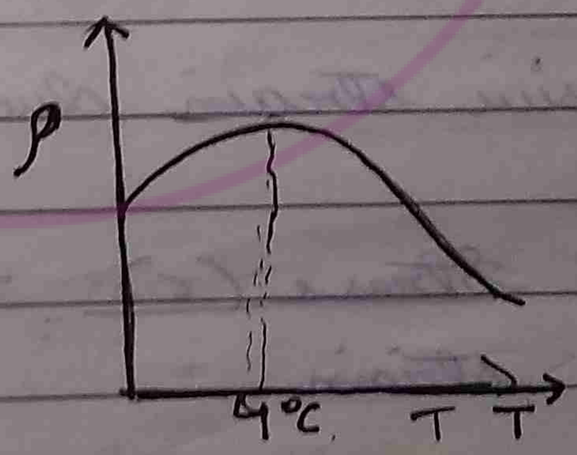
→ weight increases.



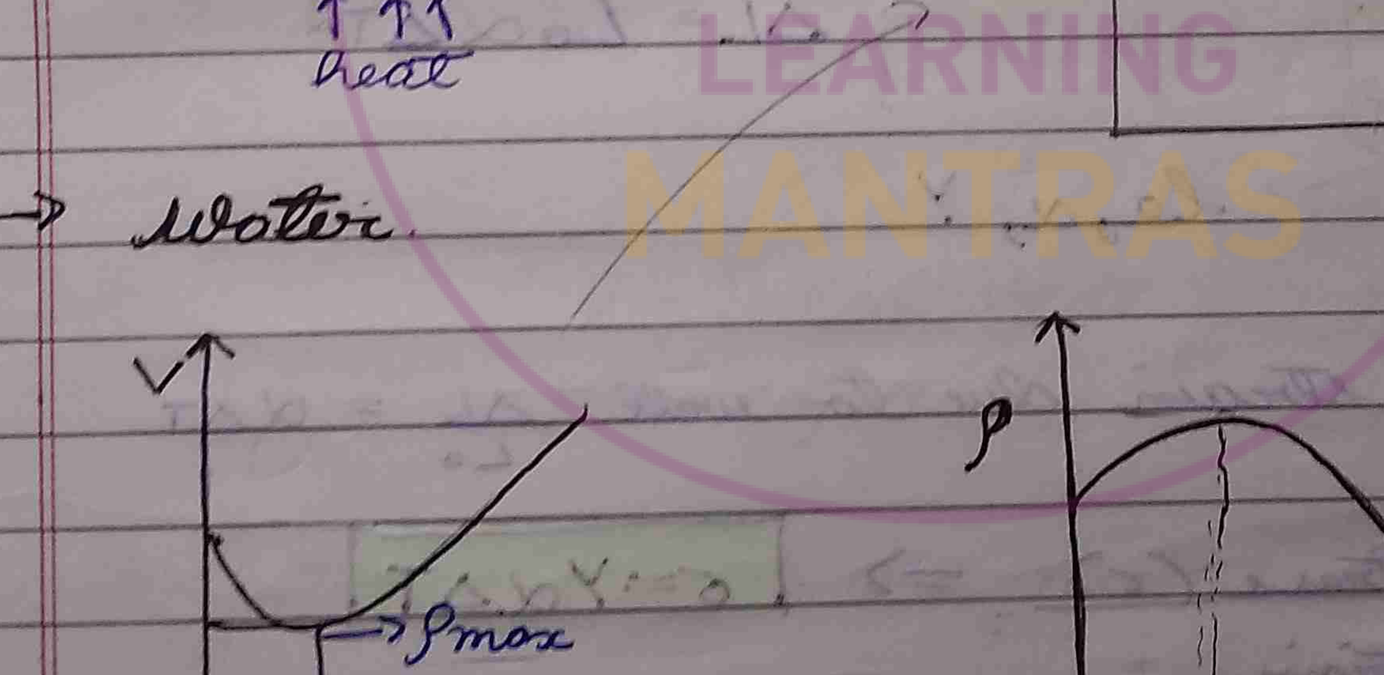
In water submerged volume will decrease from 0°-4°C and increases 4-80°C

→ Water.





Ex.



* $h_1 = 52.8$ cm

Find $\gamma_{liq} = ?$

$$\rho = \frac{\rho_0}{(1+\gamma\Delta T)}$$

LEARNING MANTRAS
MyCOMPANION
For More PDFs Visit: LearningMantras.com

$$P_{atm} + \frac{\rho_0 g h_1}{1+95\gamma} - \frac{\rho_0 g h_0}{1+5\gamma} + \frac{\rho_0 g h_0}{1+95\gamma} - \frac{\rho_0 g h_2}{1+5\gamma} = P_{atm}$$

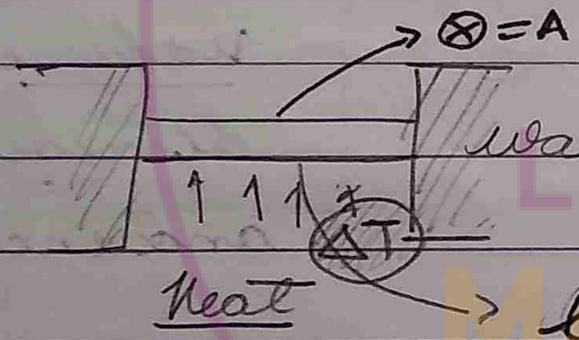
$$\Rightarrow \frac{h_1 + h_0}{1+95\gamma} = \frac{h_2 + h_0}{1+5\gamma}$$

$$\Rightarrow (52.8 + 49)(1+5\gamma) = (100 + 950\gamma)\,100(1+95\gamma)$$

$$\Rightarrow 101.8 + 509\gamma = 100 + 9500\gamma$$

$$\Rightarrow 1.8 = 8991\gamma \Rightarrow \boxed{\gamma = \frac{1.8}{8991}}$$

Thermal Stress :

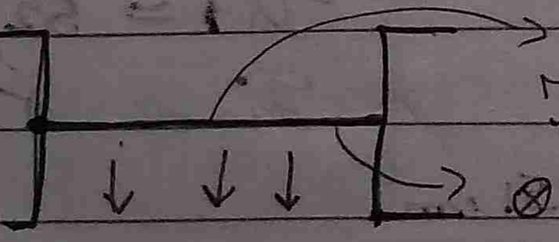


- Thermal expansion
$\Delta L = L_0 \alpha \Delta T$

- Compressive strain due to wall $= \frac{\Delta L}{L_0} = \alpha \Delta T$

$$\Rightarrow Y = \frac{\text{Stress } (\sigma)}{\text{Strain}} \Rightarrow \boxed{\sigma = Y\alpha\Delta T}$$

$\Rightarrow$ Compressive force (exerted by wall) $= F = \sigma \times A = \boxed{(Y\alpha\Delta T)A}$



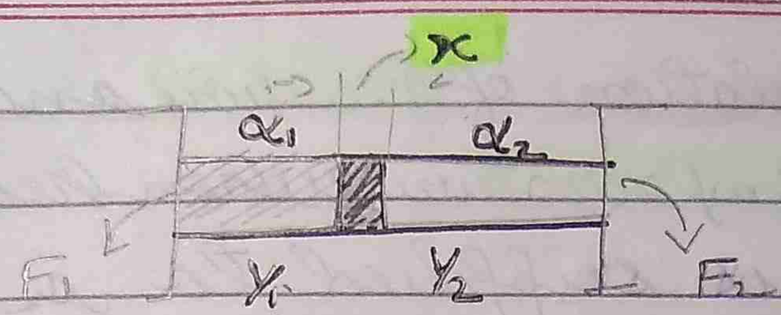
$\boxed{\sigma = Y\alpha\Delta T}$

$\Rightarrow \boxed{\text{Tension developed} = (Y\alpha\Delta T)A}$

LEARNING MANTRAS
myCOMPANION
For More PDFs Visit: LearningMantras.com

m.s ⇒ total heat capacity.
or thermal capacity.

H = heat required to increase temperature of whole body.



$x = (\Delta L_{\text{thermal expansion}} - \Delta L_{\text{compression}})$

$x = (\Delta L_{2\,\text{compression}} - \Delta L_{2\,\text{expansion}})$

$F_1 = F_2$

∴ Stress ⇒ same (If A = same)

Heat

1 Sensible heat : change temperature of a body

2 Latent heat : phase of a body.

→ Sensible heat: $Q = m\,s\,\Delta T$ (ΔT → Temperature change)

m → mass

s → specific heat: heat required to raise temp of unit mass by 1°c

H = Total heat capacity

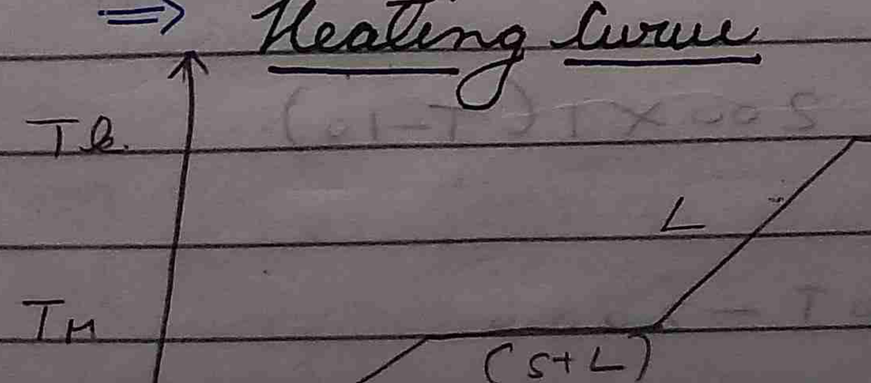
→ Latent Heat ⇒ $Q = m\,L$ or $M \cdot L$

$S_w = 1\ cal/g/°C$, $1\ cal = 4.18\ J$

$L_{ice} = 80\ cal/g$ $\quad$ $L_v = 540\ cal/g$

Specific heat of ice and steam is 0.5

⇒ Heating curve



∴ of horizontal line

Length ∝ L (latent heat)

Slope ∝ 1/Heat capacity

* Lesser will be the heat capacity faster will be the rise in temperature greater will be the slope.

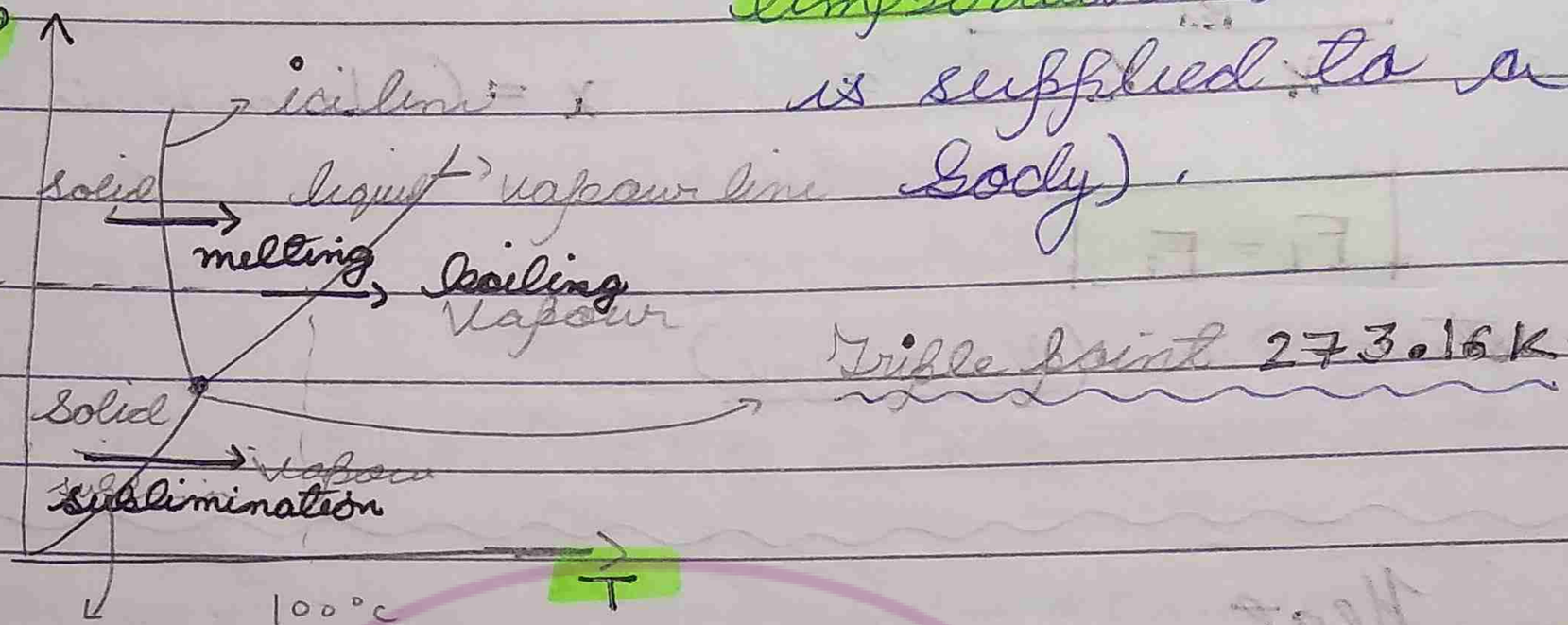
MYCOMPANION

For More PDFs Visit: LearningMantras.com

- slope $\propto \frac{1}{\text{heat capacity}}$ because of heat capacity is less, it will take smaller time to reach a temp., If heat capacity is high it will take longer time to reach a temp.

Date / /
Page

Phase diagram (Relation of Pressure and temperature when heat is supplied to a body).

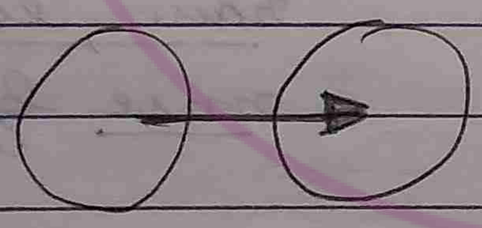


Calorimetry → Heat calculation

$Q = mS\Delta T =$ (sensible heat)

$Q = mL$ (latent heat).

Conservation of energy (Based on)



Heat lost = Heat gained

Ex 200g water at 10°C + 100g water at 80°C
⇒ final temperature of mixture = ?

T = final temperature

⇒ $100 \times 1 \times (80 - T) = 200 \times 1 (T - 10)$.

⇒ $8000 - 100T \Rightarrow 200T - 2000$

⇒ $T = \frac{10000}{300} \Rightarrow 33.3\ ^\circ C$

For More PDFs Visit: LearningMantras.com

★ Whenever there is possibility of phase change check if total phase change occurs or not.

Date __/__/__
Page _____

Ex: → 10g steam passed (100°C) (L = 540 cal/g)

Q_c => 5400 cal.

Final temperature ?

→ 2000g water at 60°C.

100°

↓

Q_{max} = 2000 × 1 (100 - 60)

it can gain => 80000 cal

cannot provide enough heat for water to reach 100°C

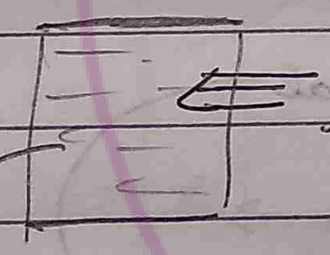
Final temperature is 'T' say.

2000 × 1 (T - 60) = 10 × 540 + 10 × 1 × (100 - T)

=> 200T - 12000 = 5400 + 1000 - 10T

=> T = 62°C

Ex.



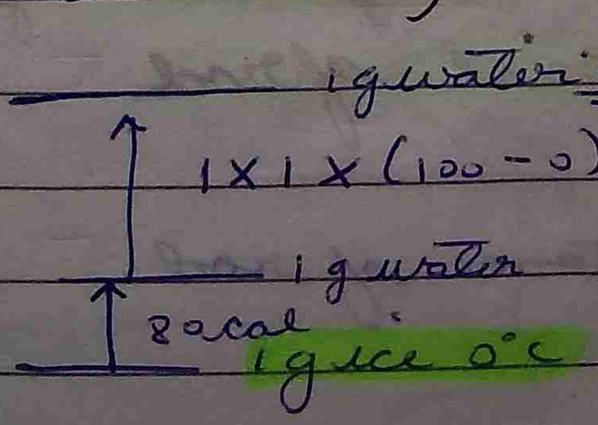
→ 10 × 540 => Q = 5400 cal.
max loose

$Q_{max\ gain}$ = 20 × 1 × (100 - 60) → 800 cal.

★ x g of steam condenses

→ x × 540 = 800 => x = 40/27 g

Ex 1g ice at 0°C + 1g steam at 100°C:
Final composition and temperature?



1g steam 100°C
↓ 1 × 540 = 540 cal.
1g water at 100°C.

myCOMPANION
For More PDFs Visit: LearningMantras.com

$x \times 540 = 180$

$\Rightarrow x = \frac{180}{540} = \frac{1}{3} g$

Only $\frac{180}{540} = \frac{1}{3}$ g of steam condenses.

$\Rightarrow$ total water = $\frac{1}{3} + 1 \Rightarrow \frac{4}{3} g$

$\Rightarrow$ steam left = $\frac{2}{3} g$ $\rightarrow$ at 100°C

q = Heat transfer rate

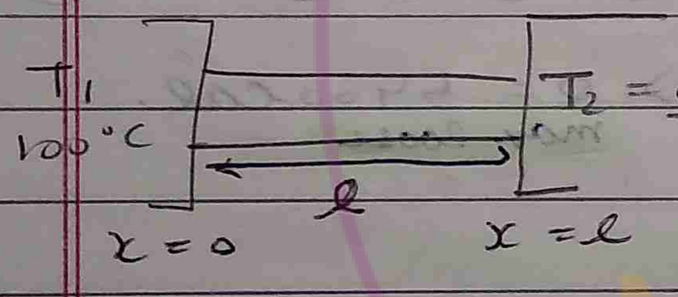
Date / /

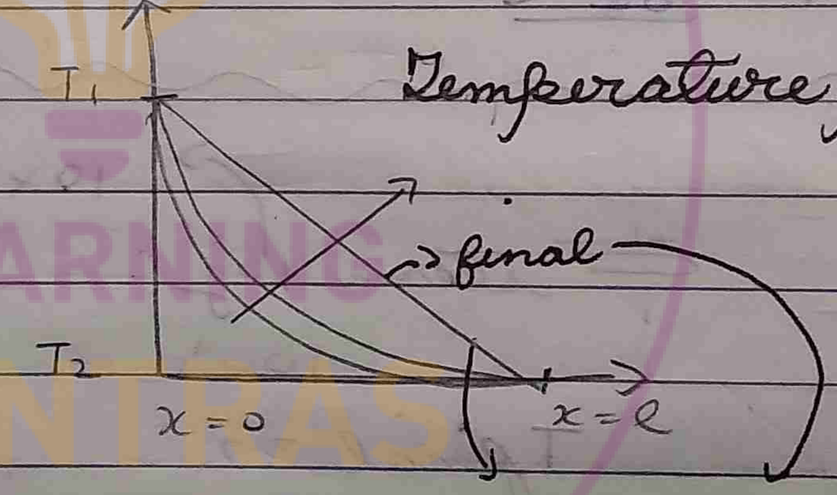
Page

Modes of Heat Transfer:

- Conduction → No bulk movement, Med required
- Convection → Medium particles move.
- Radiation → In the form of EM wave, Medium not required

Conduction





Temperature profile

Steady state conduction:

J/s = watt

Heat transfer rate $\leftarrow q \propto \frac{(T_1 - T_2)}{\ell}$

$q \propto A$

Final temperature profile -

$$\frac{T_1 - T_2}{\ell}$$ temp gradient

$$q = KA \frac{T_1 - T_2}{\ell}$$

K → conductivity const. of material of rod

$$q = \frac{(T_1 - T_2)}{(\ell / KA)}$$

Current I → driving force (voltage)

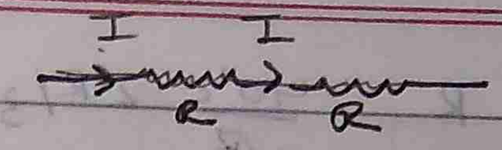
→ Thermal resistance of rod.

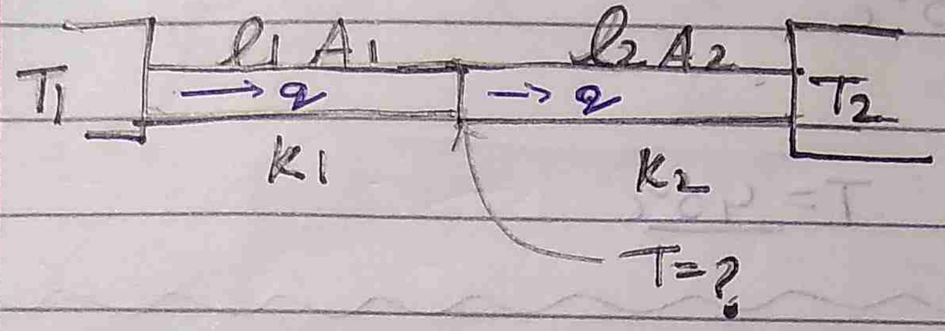
LEARNING MANTRAS
mycompanion
For More PDFs Visit: LearningMantras.com

series $R_{eq} = R_1 + R_2 = \frac{l_1}{K_1 A_1} + \frac{l_2}{K_2 A_2}$: Hence $q = \frac{T_1 - T_2}{R_{eq}}$

Date ___/___/___
Page _____

Series combination





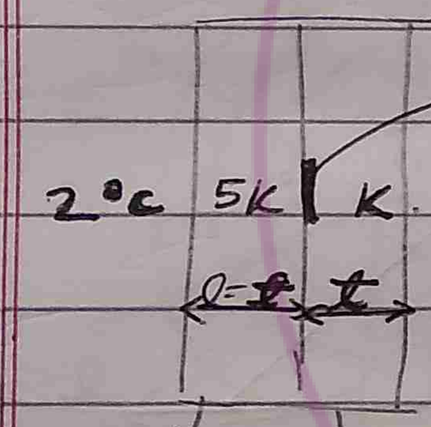
$$q = \frac{T_1 - T}{l_1/K_1A_1} = \frac{T - T_2}{l_2/K_2A_2} = \frac{T_1 - T_2}{\frac{l_1}{K_1A_1} + \frac{l_2}{K_2A_2}}$$ ← find

Temperature fall in 1 rod : $\frac{T_1 - T}{T - T_2} = \frac{l_1/K_1A_1}{l_2/K_2A_2} = \frac{l_1 K_2 A_2}{l_2 K_1 A_1}$ ← in 2nd rod

$$T = \frac{\frac{K_1}{l_1}T_1 + \frac{K_2}{l_2}T_2}{\frac{K_1}{l_1} + \frac{K_2}{l_2}}$$

If $l_1 = l_2$ $A_1 = A_2$ $\Rightarrow$ $\frac{(\Delta T)_1}{(\Delta T_2)_2} = \frac{K_2}{K_1}$

Q Composite wall.

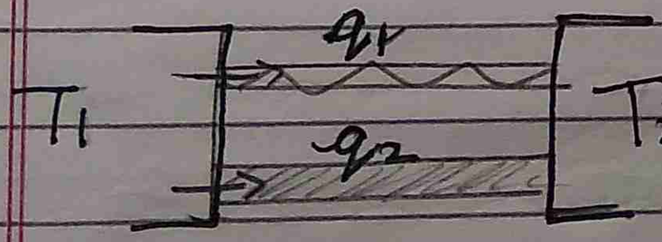


$\frac{T-2}{26-T} = \frac{K}{5K} \Rightarrow 5T - 10 = 26 - T$

$\Rightarrow 6T = 36 \Rightarrow T = 6°C$

$R_{eq} = R_1 + R_2 \Rightarrow q = \frac{T_1 - T_2}{R_{eq}}$

Parallel combination



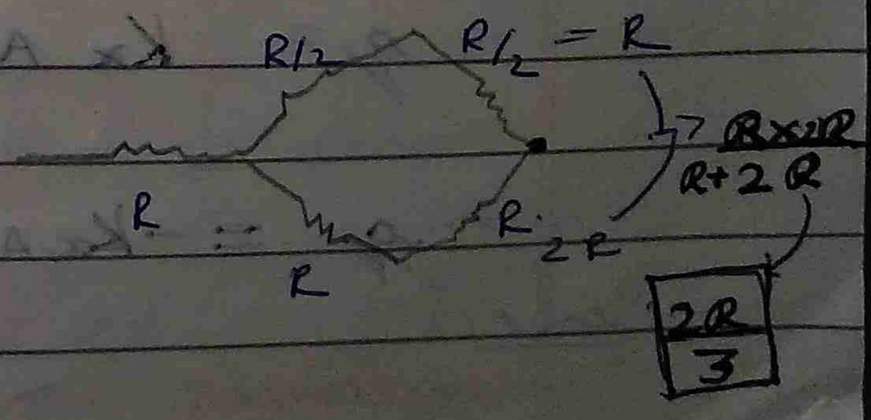
$q = q_1 + q_2 \Rightarrow \frac{T_1 - T_2}{R_1} + \frac{T_1 - T_2}{R_2}$

$R_1 = l_1/K_1A_1$ $R_2 = l_2/K_2A_2$

Ex →

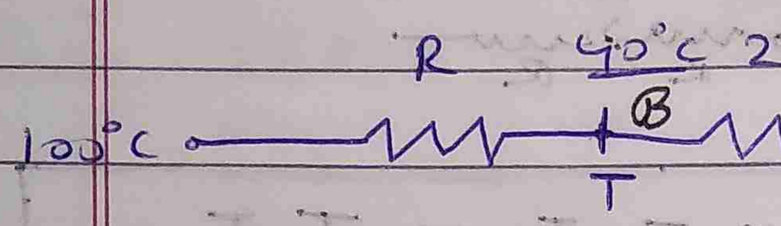
(Q): Temp. of C, D and B = ?

no heat flow if rod is connected in between.



LEARNING MANTRAS
myCOMPANION
For More PDFs Visit: LearningMantras.com

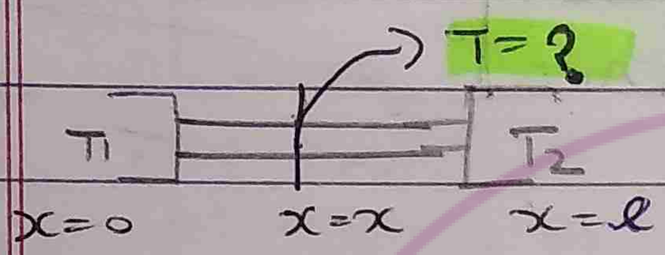
• Temperature gradient $\left(\frac{dT}{dx}\right)$ = Rate of falling temperature with distance



$$\frac{100-T}{R} = \frac{3T-0}{2R}$$

$$\Rightarrow 3T = 200 - 2T \Rightarrow T = 40°C$$

Temperature profile:



$$\frac{T_1 - T}{\frac{x}{KA}} = \frac{T - T_2}{\frac{\ell - x}{KA}}$$

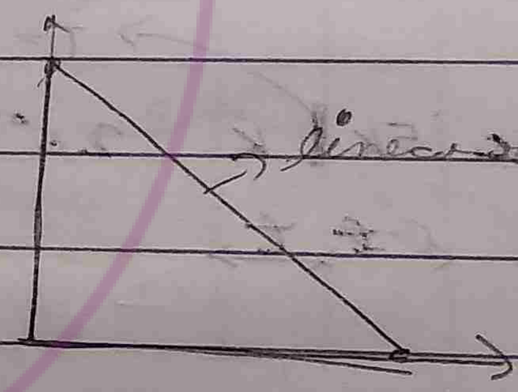
$$\Rightarrow (T_1 - T)(\ell - x) = (T - T_2).x$$

$$\Rightarrow T_1\ell - T_1x - T\ell + Tx \Rightarrow Tx - T_2x$$

$$\Rightarrow T_0\ell = T_1\ell - T_1x + T_2x$$

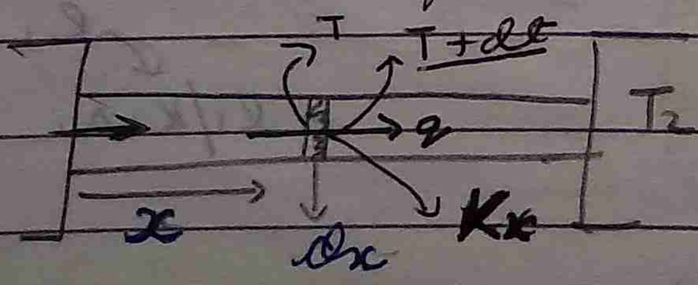
$$\boxed{T = T_1 - \frac{T_1 - T_2}{\ell}x}$$

fall in temperature from $x = 0$ to $x = x$



Non-uniform rod:

(a) K is a function of x.



$$q = K_x A \frac{(T - (T + dT))}{dx}$$

$$\Rightarrow q = -K_x A \frac{dT}{dx}$$

const

LEARNING MANTRAS
MyCOMPANION
For More PDFs Visit: LearningMantras.com

Date ____/____/____

Page _____

$$\int_{x=0}^{x=l} \frac{dx}{Kx} = -\frac{A}{q}\int_{T_1}^{T_2} dT \Rightarrow \log\left[\frac{(a+bx)}{b}\right]_0^l = +\frac{A}{q}(T_1-T_2)$$

↙

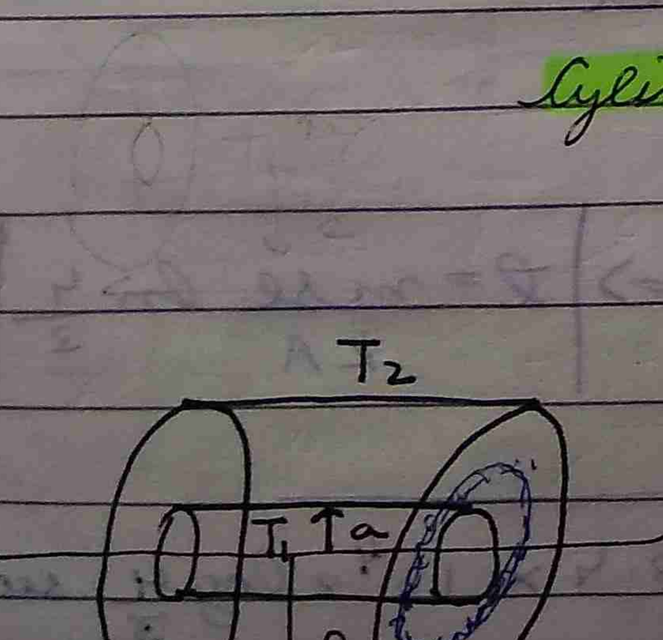
e.g $\frac{(a+bx)}{a}$

$$\Rightarrow \ln\frac{a+bl}{a} = \frac{Ab}{q}(T_1-T_2)$$

$$\Rightarrow \boxed{q = \frac{Ab(T_1-T_2)}{\ln\left(\frac{a+bl}{a}\right)}}$$

Spherical shell constant

$$q = K \cdot 4\pi r^2 \left(-\frac{dT}{dr}\right)$$



$$\Rightarrow \int_a^b \frac{dr}{r^2} = -\frac{4\pi K}{q}\int_{T_1}^{T_2} dT$$

$$\left[\frac{-1}{r}\right]_a^b = \frac{4\pi K}{q}(T_1-T_2)$$

$$\Rightarrow \left(\frac{1}{a}-\frac{1}{b}\right) = \frac{4\pi K}{q}(T_1-T_2) \Rightarrow \boxed{q = \frac{4\pi Kab(T_1-T_2)}{b-a}}$$

Cylindrical shell →

$$\boxed{q = \frac{2\pi Kl(T_1-T_2)}{\ln b/a}}$$

$$q = K 2\pi r l \left(\frac{-dT}{dr}\right)$$

$$\int_a^b \frac{dr}{r} = \frac{2\pi Kl}{q}\int_{T_1}^{T_2} -dT$$

$$\ln\frac{b}{a} = \frac{2\pi Kl}{q}(T_1-T_2)$$

LEARNING MANTRAS

mycompanion

For More PDFs Visit: LearningMantras.com

Reservoir : temperature doesn't chang constant heat source.

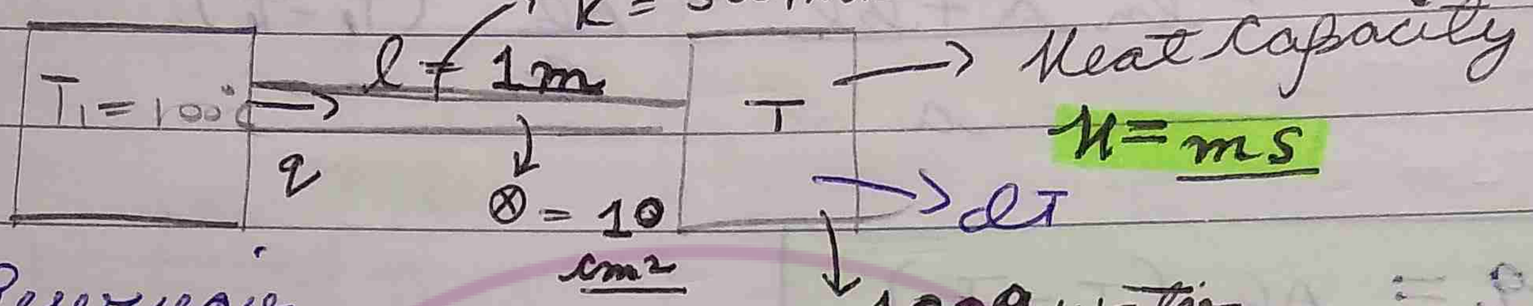
- during temperature calculation difference in celcius and kelvin is same.

Calculation of time :

$$t = \frac{\text{Total heat required}}{\text{Heat transfer rate}}$$

If heat in both reservoir is constant.

Q



Rate of heat flow ← $q = \frac{KA(100-T)}{l}$

heat requi ← $q\,dt = H\,dT = ms\,dT$

Heat transffered in dT time.

$$\frac{KA(100-T)\,dt}{l} = ms\,dT$$

$$\Rightarrow \int_0^t \frac{KA}{msl}\,dt = \int_{20°C}^{40°C} \frac{dT}{100-T}$$

$$\Rightarrow \left[\frac{\ln(100-T)}{-1}\right]_{20}^{40} = \frac{KA}{msl}\,dt$$

$$\Rightarrow \ln 80 - \ln 60 = \frac{KA}{msl}\,t \Rightarrow \boxed{t = \frac{msl}{KA}\ln\frac{4}{3}}$$

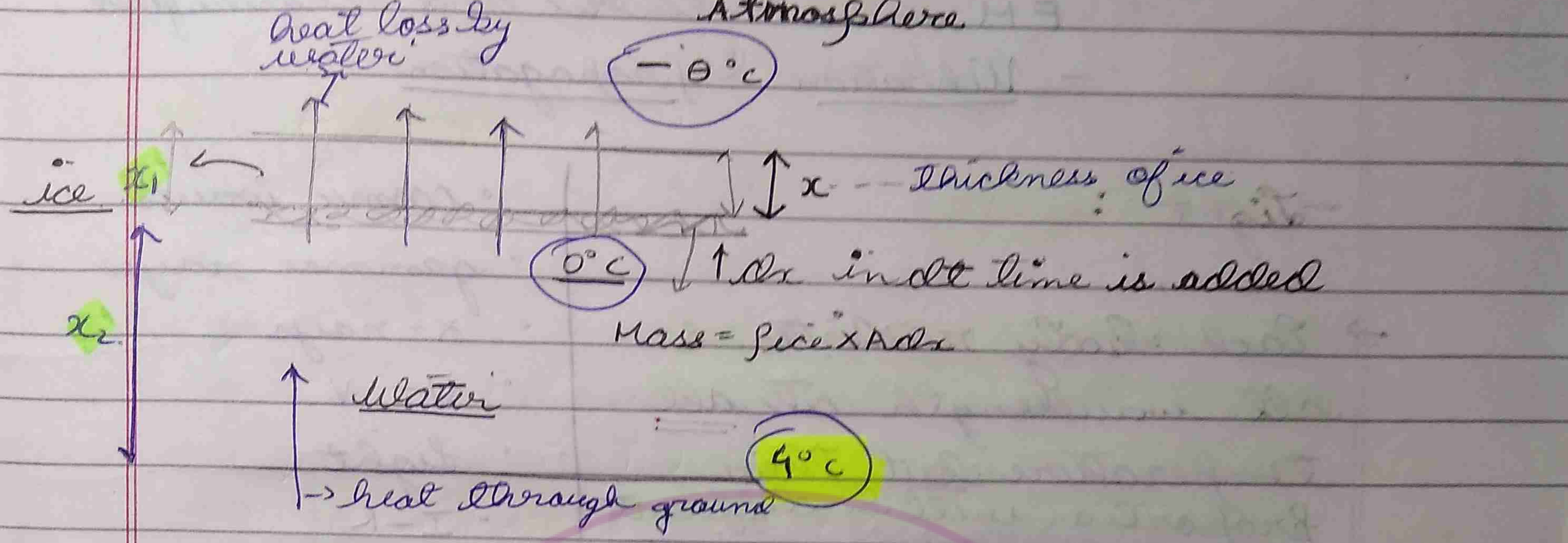
$$\Rightarrow \frac{100g \times 4.2 \times 1}{5 \times 10 \times 10^{-4}} \Rightarrow \boxed{t = 8.4 \times 10^4 \times \log\frac{4}{3}\ \text{seconds}}$$

LEARNING MANTRAS
mycompanion
For More PDFs Visit: LearningMantras.com

x = Thickness of ice

Date __/__/__
Page

Formation of ice on pond :



$$q = \frac{K_{ice} A (0-(-\theta))}{x} \Rightarrow q = \frac{K_{ice} A\theta}{x} \quad (i)$$

(L_{ice} = latent heat of fusion)

loss of heat in time dt ← $q\,dt = (\rho_{ice} \cdot A dx) \cdot L_{ice}$

[independent of surface area]

$$\Rightarrow \frac{K_{ice} A\theta}{x} dt = \rho_{ice} A dx L_{ice}$$

$$\int_0^t dt = \frac{\rho_{ice} L_{ice}}{K_{ice}\theta} \int_0^x x\,dx \Rightarrow \boxed{t = \frac{\rho_{ice} L_{ice} \cdot x^2}{2 K_{ice} \theta}}$$

$$\boxed{t \propto x^2} \qquad \boxed{\frac{t_1}{t_2} = \frac{x_1^2}{x_2^2}}$$

→ Final Thickness ⇒ : In equilibrium $q_{water} = q_{ice}$

$\Rightarrow \boxed{\frac{K_{ice} A\theta}{x_1} = \frac{K_w A 4}{x_2}}$

$\Rightarrow \boxed{\frac{x_1}{x_2} = \frac{K_{ice}\theta}{K_w 4}}$

q_{water} → Heat through water

q_{ice} → Heat through ice

equilibrium is achieved when ground looses heat

LEARNING MANTRAS
mycompanion
For More PDFs Visit: LearningMantras.com

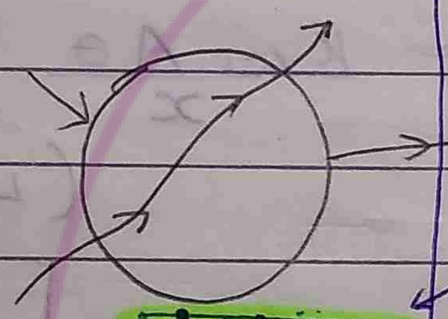
Date __/__/__
Page

Radiation :

EM waves ⇒ Electric and magnetic field
- Vibration & Propagation

- Light :

→ Each body radiates all wavelength at all temperature but their proportion will be different



- Emmision
- absorption
- reflection
- transmission

→ Radiation

- cosmic waves
- gamma rays
- X-rays
- U-V
- Light
- I-R.
- μ-waves
- Radio waves.

- Black body : A body which absorbs 100% of incident radiation.

- Grey body : Absorption < 100 %.

Absorptivity (a) = Radiant energy absorbed / Radiant energy incident

- for Black body $a = 1$
- for grey Body $a < 1$

- reflectivity (r) transmittivity (t)

$a + r + t = 1$ always.

★ Black body $a = 1 \Rightarrow r = t = 0$.

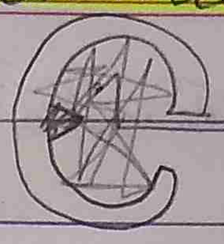
LEARNING MANTRAS
mycompanion
For More PDFs Visit: LearningMantras.com

cavity maintained at constant temperature is closest to a black body.

Date __/__/__
Page _____

ϵ (emissivity) does not depend on material depends only on surface.

- **Lamp black, cavity** :



cavities acts as black body.

- **Emission** :

q = rate of emission (J/s or watt)

$q \propto T^4$ (T = absolute temp) i.e in Kelvin

$q \propto A$ (Exposed surface area)

$$\Rightarrow \boxed{q = \sigma A T^4}$$ perfectly for a black body

σ = Stefan's const = 5.67×10^{-8} W/m^2K^4

G.B $\Rightarrow$ $\boxed{q = \epsilon \sigma A T^4}$ → Kelvin

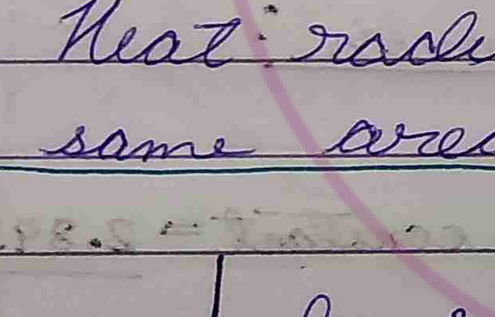
ϵ = emissivity.

☆ ϵ = Heat radiated by a body / Heat radiated by a black body of same area and temperature.

| $\epsilon = 1$ | for B.B | $\epsilon < 1$ | G.B |

| $\epsilon \rightarrow$ surface phenomenon | $\epsilon_{polished} < \epsilon_{rough\ surface}$ |

- **Kirchoff's law**: A body which absorbs more also emits more



Because T remains constant

Mathematically

$a = \epsilon$

$a = \epsilon = 1$ Black body.

$a_\lambda = \epsilon_\lambda$ → spectra absorption coefficient, Spectral emissivity

$\boxed{a_\lambda = \epsilon_\lambda}$

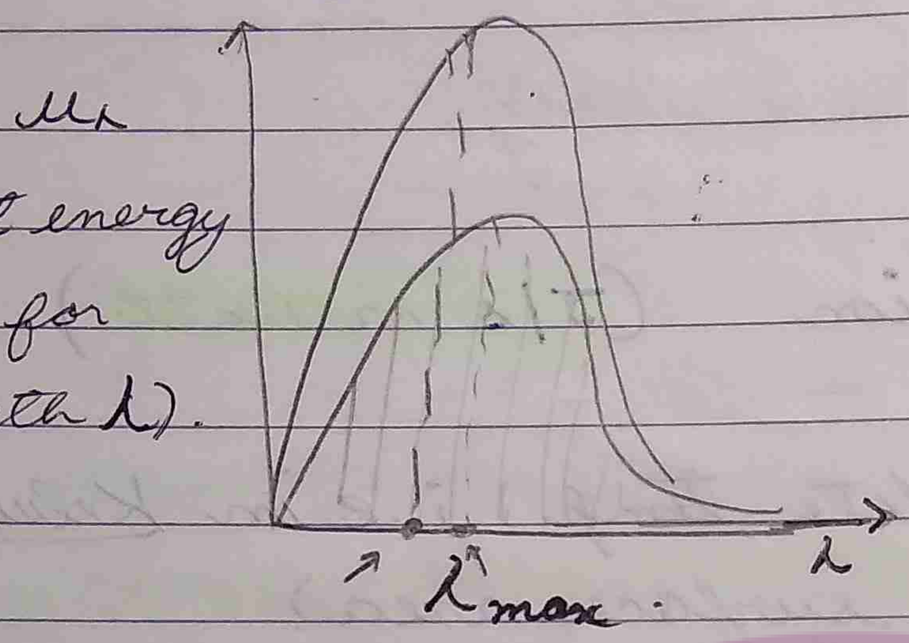
MyCOMPANION

For More PDFs Visit: LearningMantras.com

$$\frac{A_1}{A_2} = \frac{T^4}{T^4}$$

$\therefore q \propto T^4$ (from stefans law)

- Intensity distribution of wavelengths.



- Normal distribution curve.

- area under the curve represents total energy density.

① changing temperature:

(i) → position of λ shifts to left side.

$E = \frac{hc}{\lambda}$

$T \uparrow = \lambda \downarrow$

(ii) • Area under the curve increases with increase in temperature.

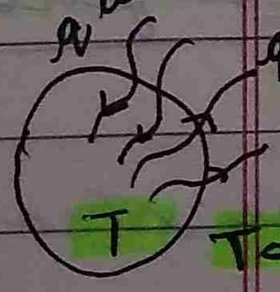
$A \propto T^4$ (T = absolute temperature)

$\therefore q \propto T^4$ → (from stefans law).

→ Weins Displacement formula:

$\lambda_{max} \times T = \text{const.}$ (b) ⇒ weins constant = 2.893×10^{-3} m.K

• Prevost exchange theory:



$q_{net} = q_{emitted} - q_{absorbed}$

case → (Net loss $T > T_0$ → temperature of surroundings)

(e.g) → body temperature

$q_{emitted} = e \sigma A T^4$

$q_{absorbed} = \underbrace{a \sigma A T_0^4}_{\text{radiant incident}}$ $(e = a)$ ⇒ By kirchoffs law

LEARNING MANTRAS
myCOMPANION
For More PDFs Visit: LearningMantras.com

If just emission rate is asked ⇒ $Q = \varepsilon \sigma A T^4$

Date __/__/__
Page _____

- Initially the rate of cooling is fast but the rate keeps on decreasing as temp. difference becomes less.

$$\boxed{q_{net} = \varepsilon \sigma A (T^4 - T_0^4)}$$

q_{net} / heat loss

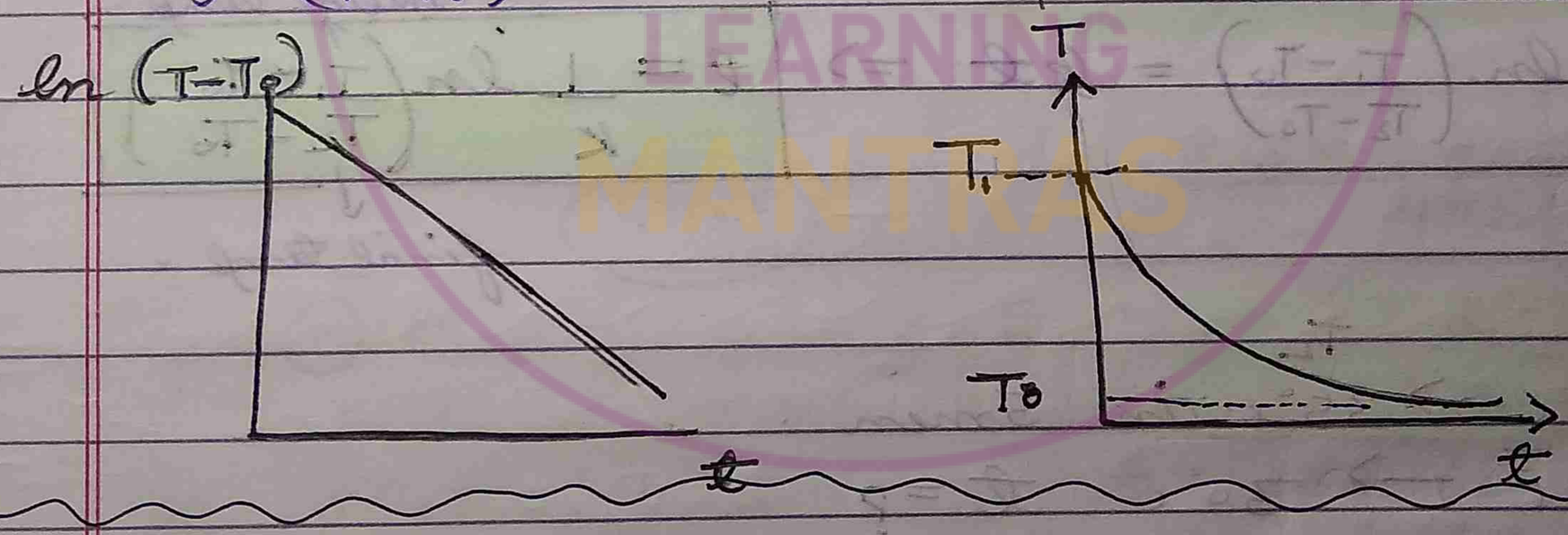
- **Newton's law of cooling :**

Rate of cooling $= -\frac{dT}{dt}$

$$\boxed{-\frac{dT}{dt} \propto (T - T_0)}$$ condition $(T - T_0)$ is small compared to T or T_0.

$$-\frac{dT}{dt} = K(T - T_0)$$

$$\Rightarrow \int -\frac{dT}{(T - T_0)} = \int K\, dt \Rightarrow \boxed{\ln(T - T_0) = -kt + c}$$



- **Proof of Newton's law**

Net loss $= \varepsilon A \sigma (T^4 - T_0^4)$

$T = T_0 + \Delta T$ $\quad \Delta T$ is very small.

$$\Rightarrow q = \varepsilon \sigma A \left((T_0 + \Delta T)^4 - T_0^4\right)$$

$$\Rightarrow \varepsilon \sigma A T_0^4 \left(\left(1 + \frac{\Delta T}{T_0}\right)^4 - 1\right) \quad \Delta T \ll T_0 \left(1 + \frac{\Delta T}{T_0}\right)$$

$$\approx 1 + \frac{4\Delta T}{T_0}$$

mycompanion

For More PDFs Visit: LearningMantras.com

→ rate of heat loss

$$q = 4e\sigma A T_0^3 \Delta T \Rightarrow q = 4e\sigma A T_0^3 (T - T_0)$$

- 'dT' loss in 'dt' time

$$q\,dt = -ms\,dT$$

$$\Rightarrow -\frac{dT}{dt} = \frac{q}{ms} = \frac{4e\sigma A T_0^3 (T - T_0)}{ms}$$

ms. ⇒ const

$$\Rightarrow \left| -\frac{dT}{dt} = K(T - T_0) \right| = \ln(T - T_0) = -kT + C$$

~~ln(T~~ $\ln(T - T_0) = -kt + C$

body temp $T_1 \rightarrow T_2$ in $0 \rightarrow t$ time.

$$\ln(T - T_0)\Big]_{T_1}^{T_2} = -kt\Big]_0^t$$

$$\Rightarrow \ln\left(\frac{T_1 - T_0}{T_2 - T_0}\right) = kt \Rightarrow \boxed{t = \frac{1}{K} \ln\left(\frac{T_1 - T_0}{T_2 - T_0}\right)}$$

(T_1: initial temp; T_2: final temp.)

Ex $T_1 \rightarrow T_2$

$40^\circ C \rightarrow 35^\circ C$ in 5 min.

$35^\circ C \rightarrow 30^\circ C$ $t = ?$

$T_0 = 20^\circ C$

$$5\,min = \frac{1}{K} \ln \frac{20}{15} \quad \ldots (i)$$

$$t = \frac{1}{K} \ln \frac{15}{10} \quad (ii)$$

$$\Rightarrow \frac{t}{5} = \frac{\ln 3/2}{\ln 4/3}$$

$$\boxed{t = \frac{5 \ln(1.5)}{\ln(1.33)}}$$

LEARNING MANTRAS
mycompanion
For More PDFs Visit: LearningMantras.com

Date ___/___/___
Page ___

- Method 2 → Rate of cooling ∝ avg. temperature difference

$$\frac{5^\circ C}{5\,min} = K\left(\frac{40+35}{2} - 20\right) \quad \text{(i)} \rightarrow 17.5$$

$$\frac{5^\circ C}{t} = K\left(\frac{35+30}{2} - 20\right) \quad \text{(ii)} \rightarrow 12.5$$

$$\frac{t}{5} = \frac{17.5}{12.5} \Rightarrow \frac{7}{5} \Rightarrow 7\,min$$

- Temperature of Sun

Solar constant **S**: Heat incident per unit area per unit time $S = 1400\ W/m^2$

$4\pi r^2$

T_S ○ → R_S ——— r ——— E

$$q = \sigma(4\pi R_S^2).T_S^4$$

$$\Rightarrow S = \frac{q}{4\pi r^2}$$

$$\Rightarrow S = \frac{4\pi R_S^2 T_S^4}{4\pi r^2}$$

$$\Rightarrow T_S^4 = S.\frac{r^2}{R_S^2}$$

1400 W/m² ↑

$$\Rightarrow T_S = \left[S\frac{r^2}{R_S^2}\right]^{1/4} \Rightarrow T_S = 5800K$$

6060 K

$$\Rightarrow \boxed{T_S = 6000K}$$

E_x = 5802 K ○ $\lambda_1 = 0.01$ — $T_2 = ?$ ○ $\lambda_2 = 0.81$ — $A_1 = A_2$

$\lambda_{max_1} - \lambda_{max_2} = 1\mu m$

$\lambda_{max_2} = ?$

Radiating ↑ Power at same rate

$$\phi \varepsilon_1 A_1 T_1^4 = \phi \varepsilon_2 A_2 T^4$$

$$\Rightarrow T_2^4 = \left[\frac{\varepsilon_1 T_1^4}{\varepsilon_2}\right] \Rightarrow T_2 = \frac{1}{3} \times 5802$$

$$\Rightarrow 1934K$$

LEARNING MANTRAS
myCOMPANION
For More PDFs Visit: LearningMantras.com

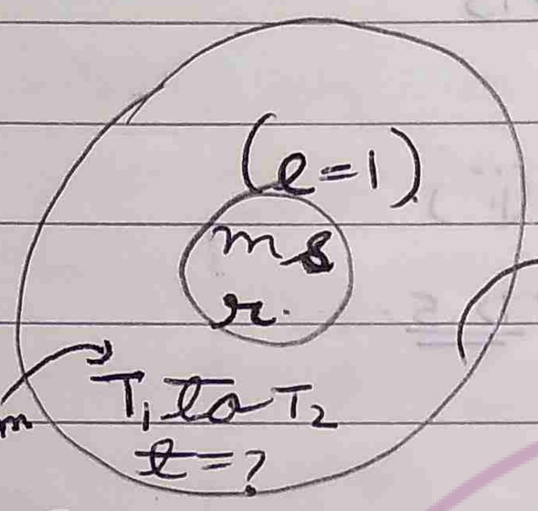
$\lambda_1 T_1 = \lambda_2 T_2$ (Wien's law)

$\Rightarrow \lambda_2 = 3\lambda_1$ $\Rightarrow \lambda_2 - \lambda_1 = 1\mu m$

$\Rightarrow \lambda_1 = 0.5\mu m$.

$\lambda_2 = 1.5\mu m$.

Ex



$q = \sigma A (T^4 - 0^4)$ ... (i)

$q\,dt = -ms\,dT$ ... (ii)

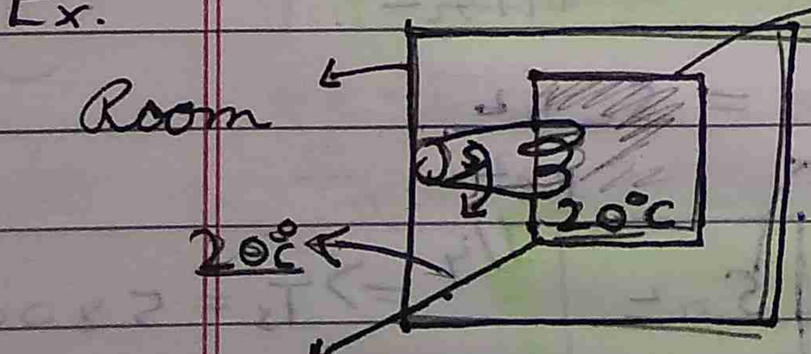
$\Rightarrow \sigma A T^4 dt = -ms\,dT$.

$$\int_{T_1}^{T_2} \frac{dT}{T^4} = -\int_0^t \frac{\sigma A}{ms}\,dt.$$

$$\Rightarrow \frac{\sigma A}{ms}\,t = +\left[\frac{1}{3T^3}\right]_{T_1}^{T_2}$$

$$\Rightarrow \boxed{t = \frac{ms}{3\sigma A}\left[\frac{1}{T_2^3} - \frac{1}{T_1^3}\right]}$$

Ex.



Heat capacity

$H = m.s = 80\ J/^\circ C$

$20^\circ C \longrightarrow 30^\circ$

At $30^\circ C$, Heater is switched off.

just after switching on $\frac{dT}{dt} = +2^\circ C/s$

just after switching of $\frac{dT}{dt} \Rightarrow -0.2^\circ C/s$.

1. Power of Heater.
2. Power radiated by body just after switching off.

LEARNING MANTRAS
myCOMPANION
For More PDFs Visit: LearningMantras.com

Date __/__/__
Page _____

3 Rate of radiation when temperature falls to 25°C.

4 Time taken to raise the temperature of block from 20°C to 30°C.

1 $P = 80\,J/°C \times 2°C/s = 160\,W$

2 $q = 80\,J/K \times 0.2\,°C/s \Rightarrow 16\,W$ ($30°C - 20° = 10°C$)

difference

3 $25°C$ - diff = $5°C$

$\Rightarrow$ Power radiated = $8\,W$

$|160\,W - 8\,W|$ $\boxed{Pw = 152\,W}$ average rate of power supply to the block

$80\,J/C° \times 10°C = 800\,J \Rightarrow t = \frac{800\,J}{152\,W} \Rightarrow 5.2$ seconds.

LEARNING MANTRAS

mycompanion

For More PDFs Visit: LearningMantras.com