* Physics

Heat & Thermodynamics

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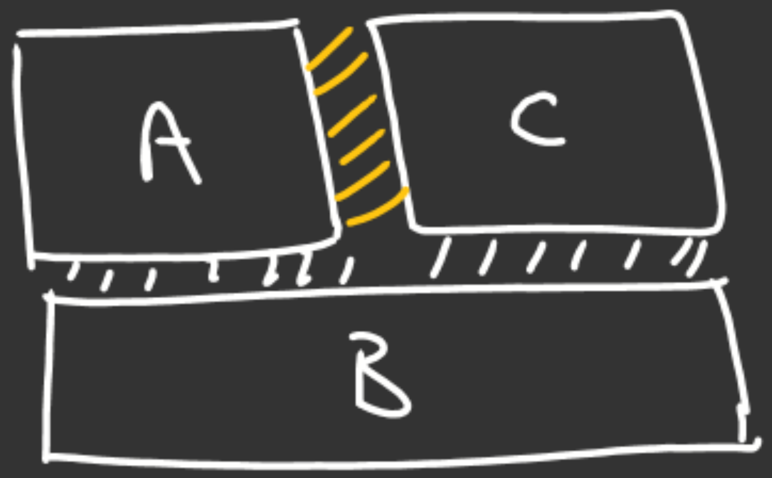
Heat Energy → Energy in Exchange (Diff in Temp)

By Default [Hotter to colder]

Temperature ⇒ Degree of Hotness koldness

Thermal Equilibrium ⇒ No net Heat Transfer ⇒ Same Temp.

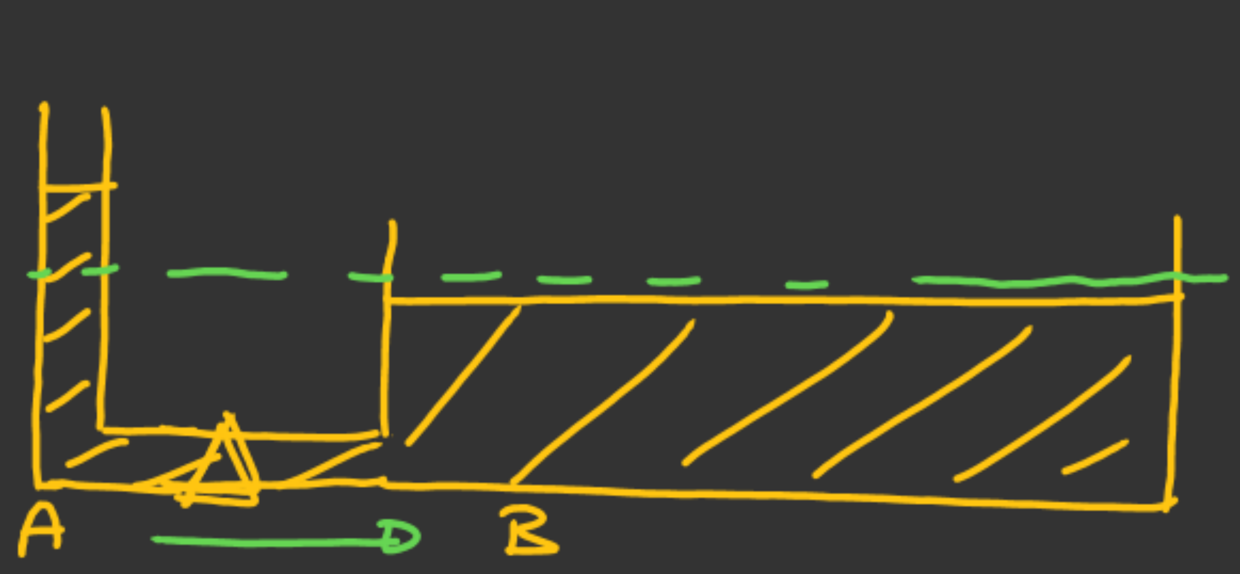
Zeroth law of thermodynamics

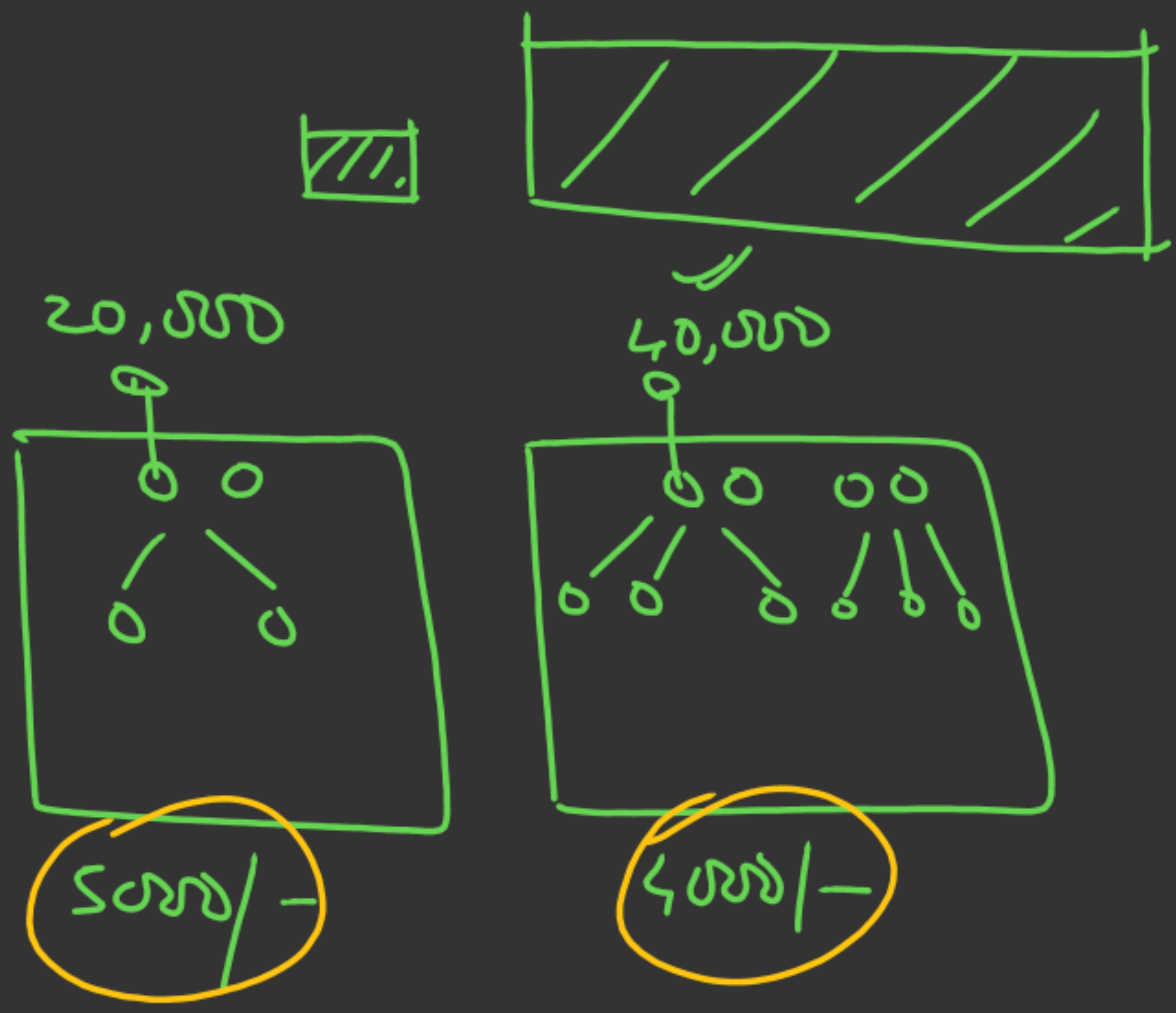


① $(\text{Internal Energy})_A > (\text{Internal Energy})_B$

② $T_A > T_B$

Above statements may or may not be true simultaneously





① H.T. takes place from Higher Temp to lower Temp

② Higher Temp ⇒ Higher Energy per molecule

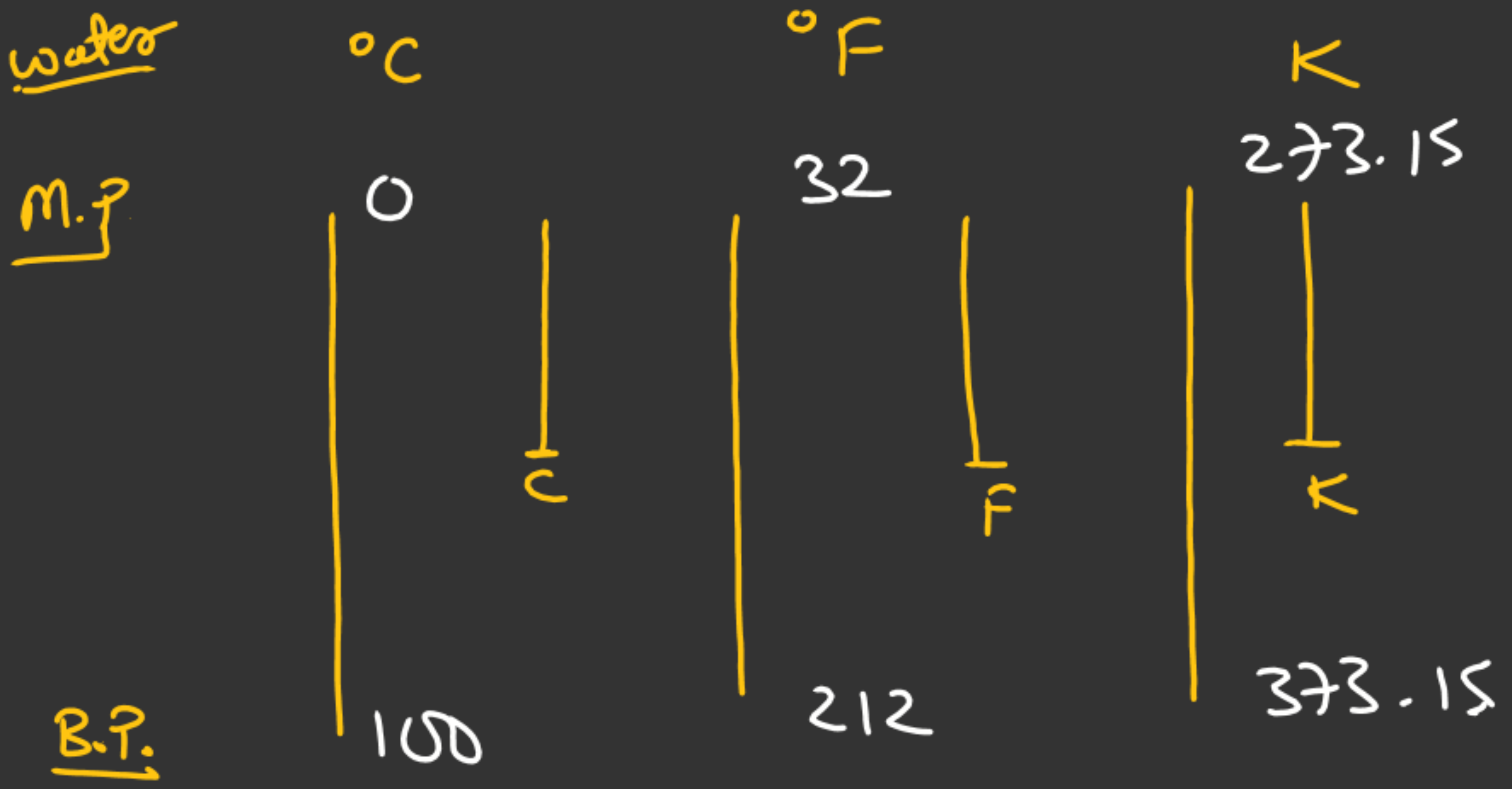
Statement H. T. is taking place from A to B

Conclude → ① $T_A > T_B$

② $(\text{Energy})_A$ may be more | less | Equal to $(\text{Energy})_B$

③ $\begin{pmatrix}\text{Energy} \\ \text{per molecule}\end{pmatrix}_A > \begin{pmatrix}\text{Energy per} \\ \text{molecule}\end{pmatrix}_B$

Temperature Scale



$$\frac{C-0}{100-0} = \frac{F-32}{212-32} = \frac{K-273}{373-273}$$

$$\boxed{\frac{C}{5} = \frac{F-32}{9} = \frac{K-273}{5}}$$

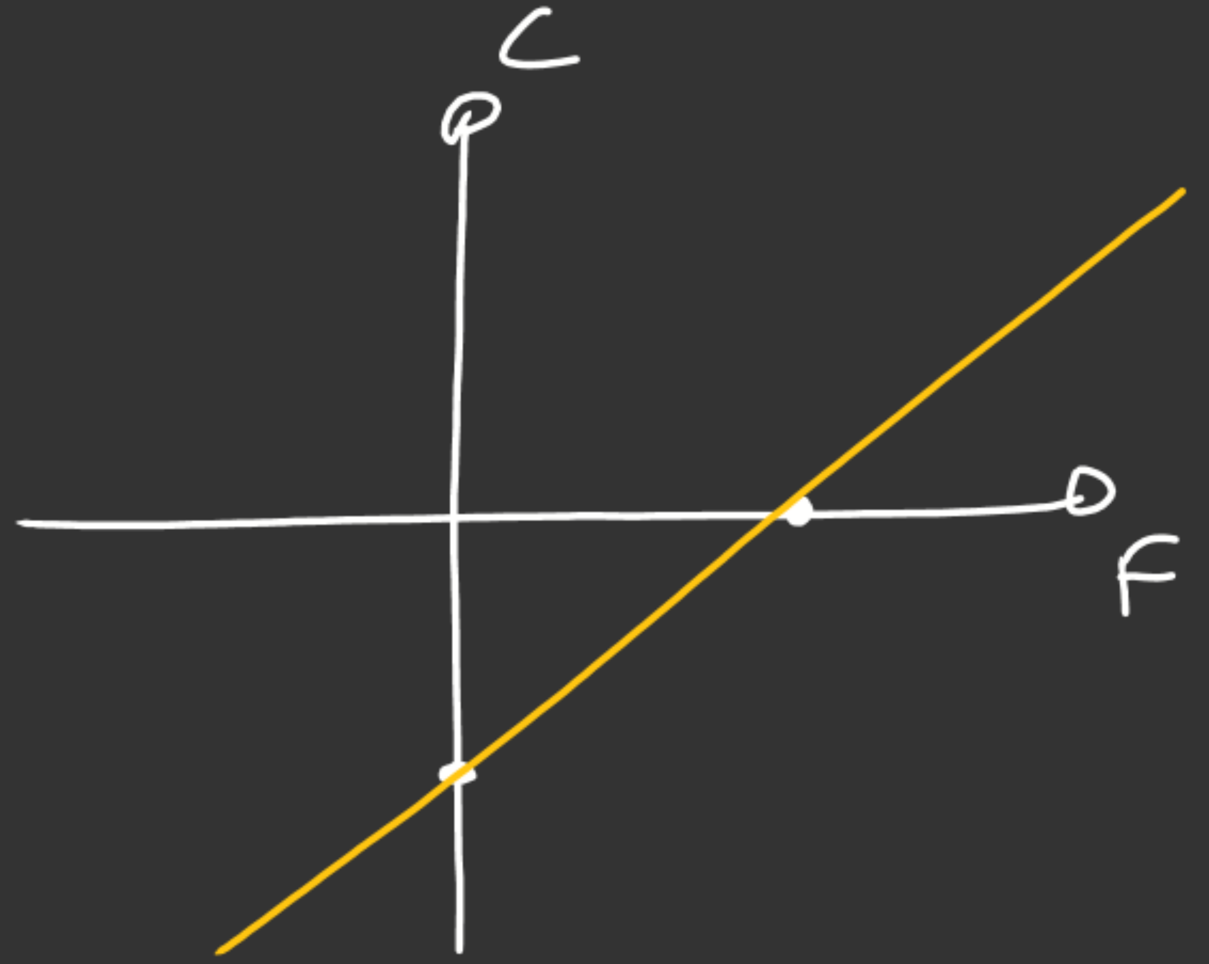
① Temp. at which C & F

$$\frac{x}{5} = \frac{x-32}{9}$$

$$9x = 5x - 160$$

$$4x = -160$$

$$\underline{x = -40^\circ C = -40^\circ F}$$



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

$$C = \frac{5}{9}F - \frac{160}{9}$$

$$\boxed{y = \left(\frac{5}{9}\right)X - \frac{160}{9}}$$

$F = 0 \qquad C = -\frac{160}{9}$

$F = 32 \qquad C = 0$

$$\boxed{\frac{\Delta C}{5} = \frac{\Delta F}{9}}$$

$$\left.\begin{aligned} \Delta\theta_1 &= 1^\circ C = 1.8^\circ F \\ \Delta\theta_2 &= 1^\circ F \end{aligned}\right\} \quad \underline{\Delta\theta_1 > \Delta\theta_2}$$

$$\Delta F = \frac{9}{5}\Delta C$$

$$\Delta F = \frac{9}{5}(1) = 1.8^\circ F$$

$$\frac{C-0}{100-0} = \frac{K-273}{373-273}$$

$$C = K - 273$$

$$\boxed{K = C + 273}$$

$$\theta_1 = 1^\circ C = 274\,K$$

$$\theta_2 = 2^\circ C = 275\,K$$

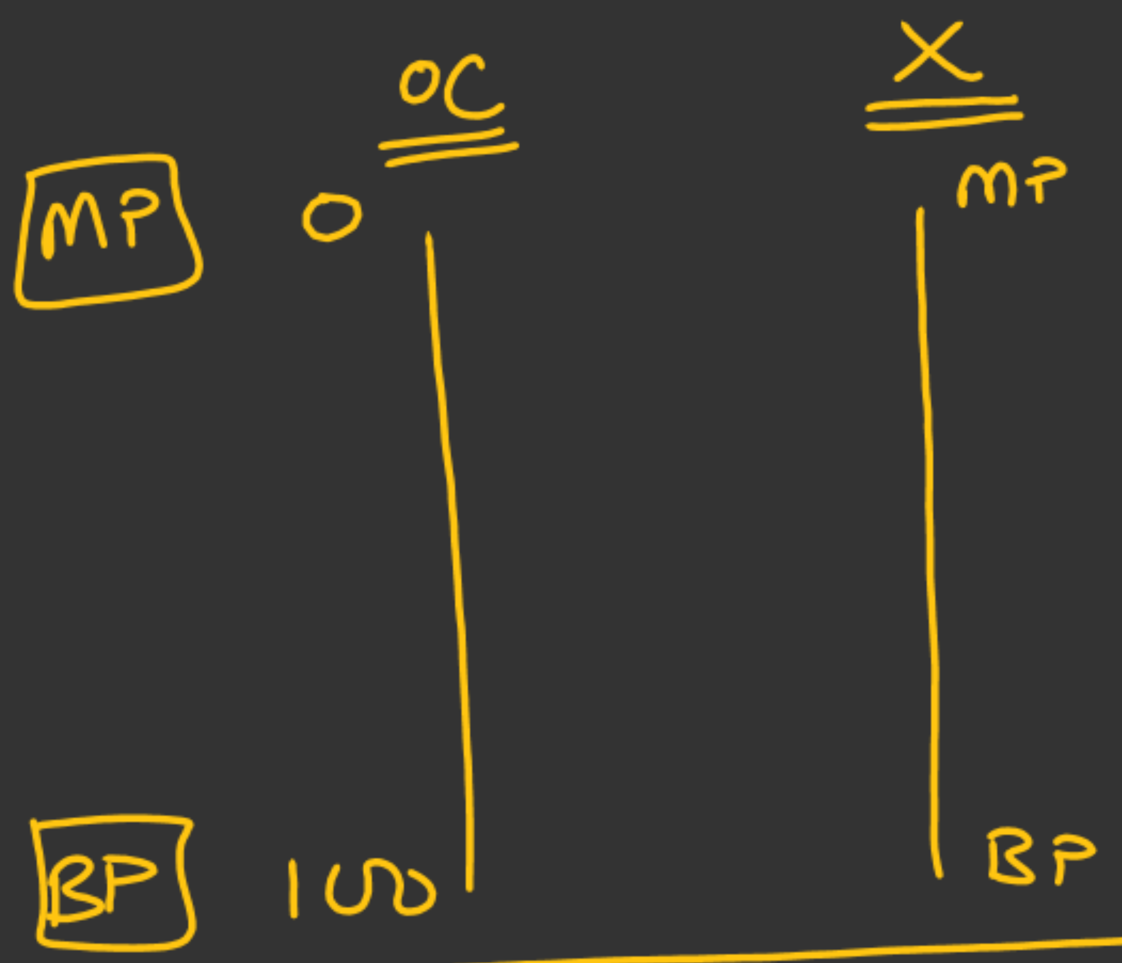
$$\Delta\theta = 1^\circ C = 1\,K$$

<u>Kelvin</u> $\Rightarrow$ Absolute Temperature

① Temp. of a body is $100^\circ C$ (373 K)

② Temp. of body increases by $100^\circ C$ (100 K)

New scale / Faulty Scale



$$\boxed{\frac{C-0}{100-0} = \frac{X - MP}{BP - MP}}$$

Q. 20 units
& 160 units

$$\frac{C-0}{100-0} = \frac{100-20}{160-20}$$

$$\frac{C}{100} = \frac{80}{140} = \frac{4}{7}$$

$$\boxed{C = \frac{400}{7} = 57.1^\circ C}$$

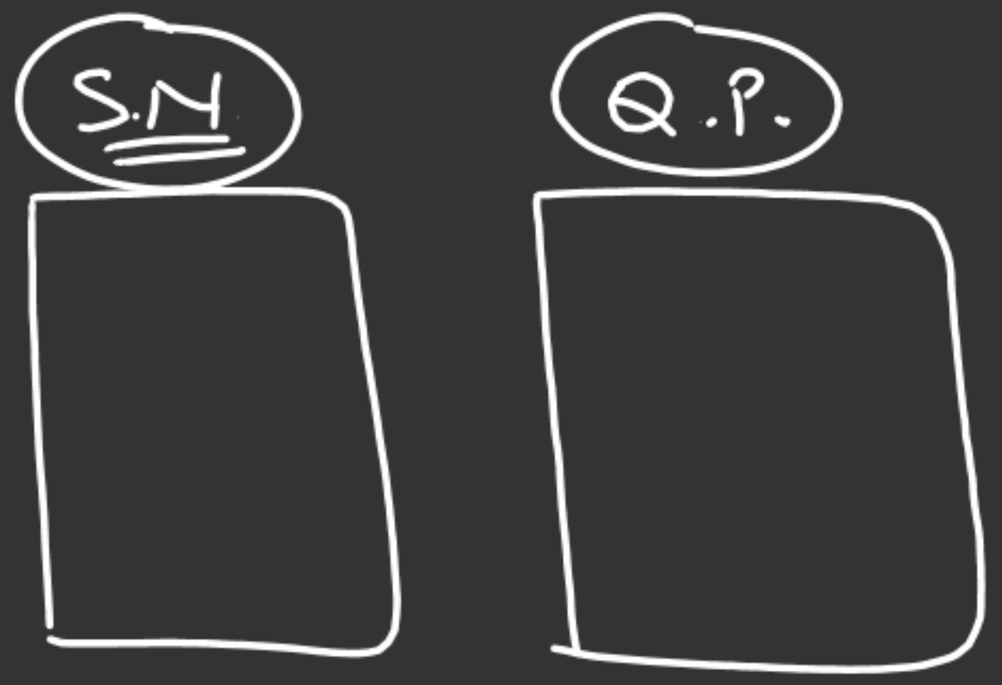
Q.

$$\frac{C-0}{100-0} = \frac{x-MP}{BP-MP}$$

$$\frac{C}{100} = \frac{40-(-20)}{120-(-20)}$$

$$\frac{C}{100} = \frac{60}{140} = \frac{3}{7}$$

$$\boxed{C = \frac{300}{7}\,{}^\circ C}$$



Effect of Pressure on M.P. & B.P. of water

M.P. B.P.

$P = 1\,atm$ $0^\circ C$ $100^\circ C$

$P \uparrow\uparrow$ [M.P. $\downarrow$ B.P. $\uparrow$]

$P \downarrow\downarrow$ [M.P. $\uparrow$ B.P. $\downarrow$]

- Triple point [S/L/G → Equilibrium]

$$\boxed{T_{tr} = 0.01^\circ C = 273.16\,K}$$

		Temp	Pressure
NTP	[Normal Temp Pressure]	$0^\circ C$	1 atm
STP	[Standard Temp Pressure]	$0.01^\circ C$	1 atm

$\boxed{NTP/STP} \Rightarrow$ Approx $\boxed{273K}$ $\boxed{1\ atm}$

1 mole of ideal gas at NTP/STP occupies 22.4 l

Thermometer

1. Hg ⇒ Thermal Expansion

2. Const. Volume gas Thermometer $PV = nRT$

3. Const. Pressure —— " —— $PV = nRT$

4. Pyrometer ⇒ Heat Radiations ⇒ To measure very High Temp.

5. Thermocouple ⇒

"industries"

Thermal Expansion

→ Examples

→ Railway Tracks

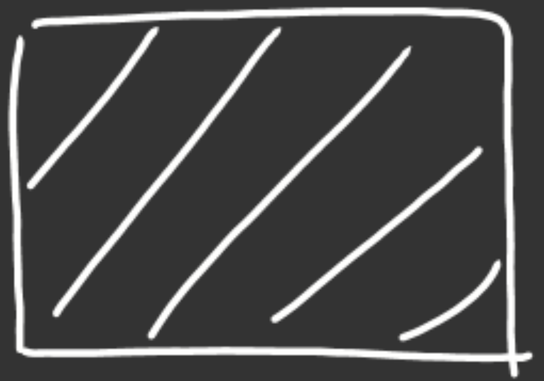
→ Bridges

→ Cartwheel → Rim

→ Themostat

↳ Bimetallic

a



b

$\boxed{OP}$

a ?

b ?

a

$\boxed{OP}$

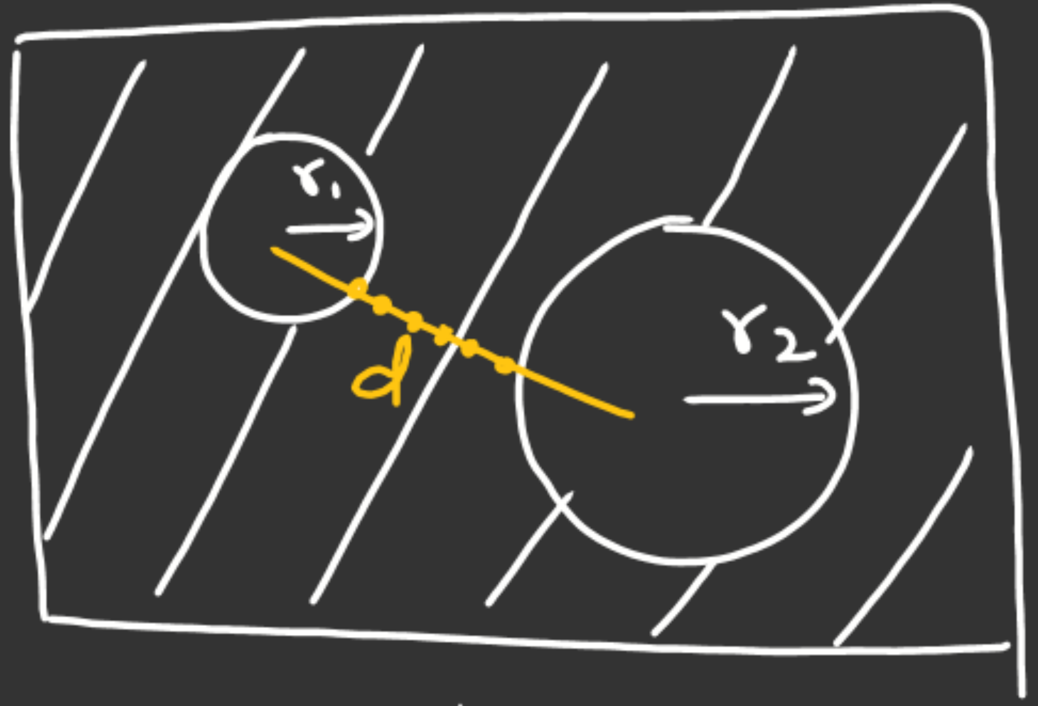
a ?

b ?

r ?

Photographic Zoom

a



b

$\boxed{OP}$

a ?

b ?

r_1 ?

r_2 ?

d ?

Linear Exp

$$\boxed{\alpha = \frac{\Delta l}{l_0 \Delta\theta}}$$

/°C

/K

Coeff. of linear thermal exp

(Relative)
Fractional Change

$$\frac{\Delta l}{l_0} = \alpha \Delta\theta$$

Change ✓✓

$$\boxed{\Delta l = l_0 \alpha \Delta\theta}$$

$l - l_0$

$$\boxed{l = l_0(1 + \alpha \Delta\theta)}$$

Surface Exp

$$\boxed{\beta = \frac{\Delta A}{A_0 \Delta\theta}}$$

/°C

/K

Coeff. of Area Exp

$$\frac{\Delta A}{A_0} = \beta \Delta\theta$$

$$\boxed{\Delta A = A_0 \beta \Delta\theta}$$

$$A = A_0(1 + \beta \Delta\theta)$$

Volume Exp

$$\boxed{\gamma = \frac{\Delta V}{V_0 \Delta\theta}}$$

/°C

/K

K^{-1}

Coeff. of volume exp.

$$\frac{\Delta V}{V_0} = \gamma \Delta\theta$$

$$\boxed{\Delta V = V_0 \gamma \Delta\theta}$$

$$V = V_0(1 + \gamma \Delta\theta)$$

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

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

Q. meter rod

$20^\circ C \longrightarrow 100^\circ C$

$\alpha = 10^{-5} /^\circ C$

① $\boxed{\Delta l = l_0 \, \alpha \, \Delta\theta}$

$\Delta l_0 = (1)(10^{-5})(80)$

$\Delta l_0 = 8 \times 10^{-4}$ m

$\Delta l_0 = 8 \times 10^{-1}$ mm

$= 0.8$ mm

② $\frac{\Delta l}{l_0} \times 100 = (\alpha \, \Delta\theta) \, 100$

$= 10^{-5} (80) \, 100$

$= \underline{0.08 \, \%}$

Q. $\boxed{\frac{\Delta l}{l_0} \times 100} = \boxed{\underline{(\alpha \, \Delta\theta)(100)}}$ $\boxed{1\%}$

Q. $\underline{\Delta D} = D_0 \, \alpha \, \Delta\theta$

$1 = 100 \, (10^{-4}) \, \Delta\theta$

$\boxed{100 = \Delta\theta}$

$100^\circ C$

$\frac{50 \quad 50}{100}$

101

$D = 2r$

$\boxed{\frac{\Delta D}{D} = \frac{\cancel{2} \, \Delta r}{\cancel{2} r}}$

$P = 2\pi r$

$\frac{\Delta P}{P} = \frac{\cancel{2\pi} \, \Delta r}{\cancel{2\pi} r}$

$\frac{\Delta D}{D} = \frac{\Delta r}{r} = \frac{\Delta P}{P} = \alpha \Delta\theta$

✲ Equivalent coeff. of linear thermal Exp

α_1 α_2

l_1 l_2

α_{eq}

$l_1 + l_2$

$$\Delta l = \Delta l_1 + \Delta l_2$$

$$(l_1 + l_2)\,\alpha_{eq}\,\Delta\theta = l_1\alpha_1\,\Delta\theta + l_2\alpha_2\,\Delta\theta$$

$$\boxed{\alpha_{eq} = \frac{l_1\alpha_1 + l_2\alpha_2}{l_1 + l_2}}$$

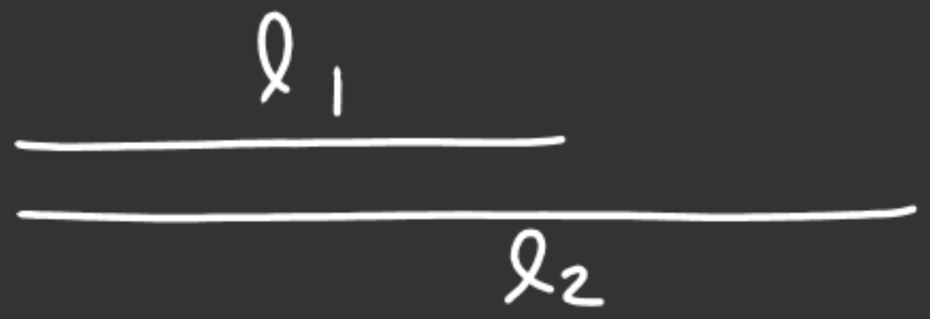
Q l $2l$

2α 3α

$\alpha_{eq} = ?$

$$\alpha_{eq} = \frac{l(2\alpha) + (2l)(3\alpha)}{l + 2l} = \frac{8\alpha}{3}$$

✲ Diff. of length remains const / independent of temp.



$\Delta l_1 = \Delta l_2$

$l_1 \alpha_1 \Delta\theta = l_2 \alpha_2 \Delta\theta$

$$\boxed{l_1 \alpha_1 = l_2 \alpha_2}$$

✲ V_{air} = const. with temp

$$\boxed{V_1 \gamma_1 = V_2 \gamma_2}$$

Pendulum Clock

$$\boxed{T = 2\pi\sqrt{\frac{l}{g}}}$$

$$\frac{\Delta T}{T} = \frac{1}{2}\left(\frac{\Delta l}{l}\right)$$

$$\frac{\Delta T}{T} = \frac{1}{2}(\alpha\,\Delta\theta)$$

$$\boxed{\Delta T = \frac{1}{2}(\alpha\,\Delta\theta)\,T}$$

$\theta \uparrow$ $\quad l \uparrow$ $\quad T \uparrow$ $\quad$ Slow $\quad$ lose time

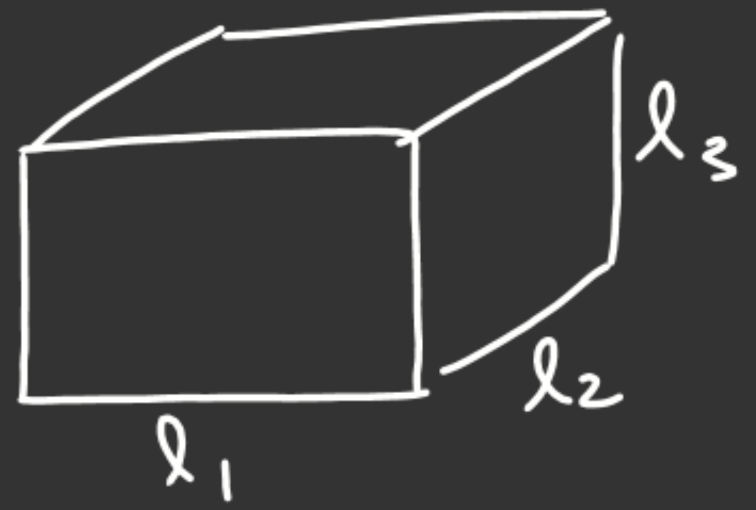
$\theta \downarrow$ $\quad l \downarrow$ $\quad T \downarrow$ $\quad$ fast $\quad$ gain time

$T = 86400$ sec in a day

Q. Correct $= 0$ $20^\circ C$ $\quad \alpha = 10^{-5}/^\circ C$

$$\Delta T = \frac{1}{2}(10^{-5})(20)(86400) = 8.64\ s$$

Anisotropic



$$V = l_1 l_2 l_3$$

$$\frac{\Delta V}{V} = \frac{\Delta l_1}{l_1} + \frac{\Delta l_2}{l_2} + \frac{\Delta l_3}{l_3}$$

$$\boxed{\gamma = \alpha_1 + \alpha_2 + \alpha_3}$$

$$\beta_{front} = \alpha_1 + \alpha_3 \qquad \beta_{Top} = \alpha_1 + \alpha_2$$

Isotropic

→ property → same in all dir.

$$\alpha_1 = \alpha_2 = \alpha_3 = \alpha$$

$$\boxed{\begin{aligned} \beta &= 2\alpha \\ \gamma &= 3\alpha \end{aligned}}$$

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

$$\boxed{6\alpha = 3\beta = 2\gamma}$$

Q.

$$\frac{\Delta V}{V} = 6\%$$

$$\gamma \Delta\theta = \frac{6}{100}$$

$$\gamma (20) = \frac{6}{100}$$

$$3\alpha = \gamma = 3\times10^{-3} /^\circ C$$

$$\boxed{\alpha = 10^{-3} /^\circ C}$$

Q.

$$\frac{\Delta l}{l} = \frac{2}{100} = (\alpha \Delta\theta)$$

$$\frac{\Delta V}{V} = \gamma \Delta\theta$$

$$= 3\,\alpha \Delta\theta$$

$$= 3(2\%)$$

$$= \underline{\underline{6\%}}$$

Q. % change in $A = 3\% = \beta \Delta\theta = 2\alpha \Delta\theta$

% change in $V = \gamma \Delta\theta = 3(\alpha \Delta\theta)$

$= 3\left(\frac{3}{2}\%\right)$

$= \frac{9}{2}\% = \underline{4.5\%}$

Q.

Same material
Same radius
$\Delta\theta = $ Same

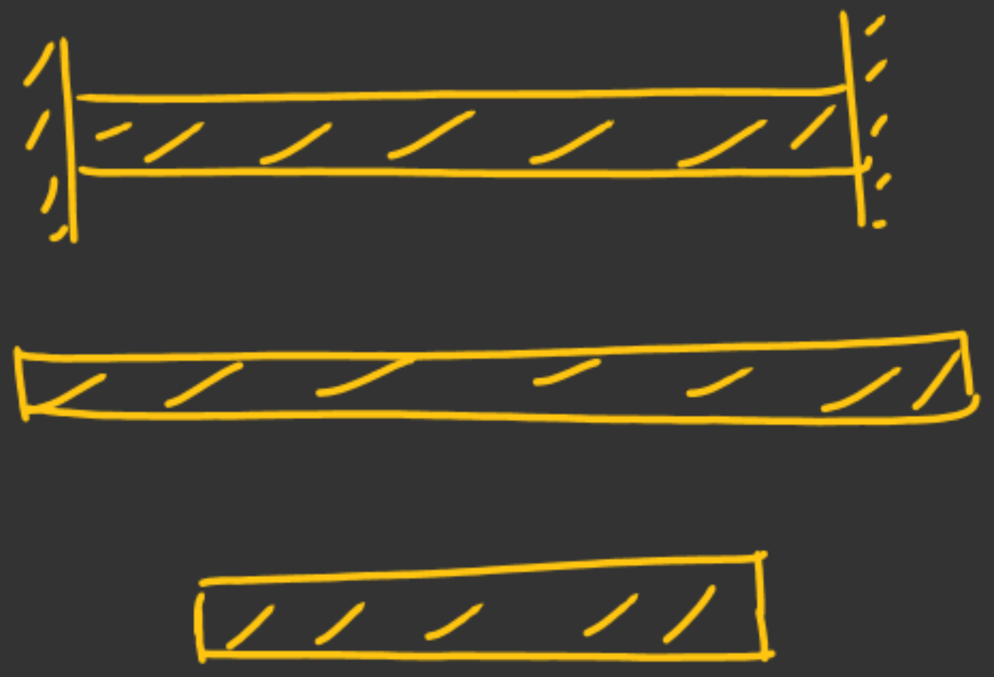
$\Rightarrow \frac{\Delta R}{R} = $ Same

Thermal Stress

① Rod is "free to Expand"

[No stress / No strain]

② Rigidly fixed at Ends



$\theta \uparrow$ compressive

$\theta \downarrow$ Tensile

longitudinal

$$\text{Stress} = Y\,(\text{Strain})$$

$$\frac{F}{A} = Y\left(\frac{\Delta l}{l}\right)$$

① Thermal Stress $= Y \alpha \Delta\theta$

② Tension $(F) = Y A \alpha \Delta\theta$

Q.

$l = 20\,cm$

$\alpha = 10^{-5} /°c$

$Y = 200\,GPa$

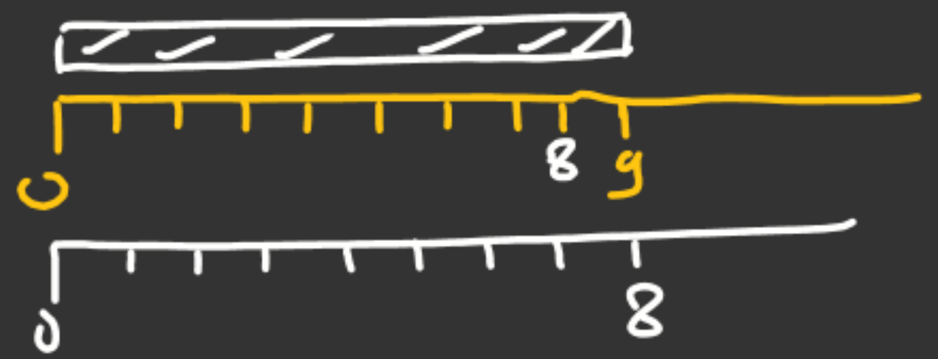
giga pascal

$T.S = Y \alpha \Delta\theta$

$= (200 \times 10^9)(10^{-5})(10)$

$= 2 \times 10^7\ Pa$

Reading of Scale



$\theta \uparrow$ $\quad R \downarrow$

$\theta \downarrow$ $\quad R \uparrow$

$$9 = 8(1 + \alpha \Delta \theta)$$

$$\boxed{R_{old} = R_{new}(1 + \alpha \Delta \theta)}$$

Q.

1) 40cm [20°C]

2) more than 40cm

3) less than 40cm ✓

Apparent Expansion

$\theta \uparrow$

①  $\gamma_l = \gamma_s$

②  $\boxed{\gamma_l > \gamma_s}$ generally

③  $\gamma_l < \gamma_s$

$$\Delta V_{app} = \Delta V_l - \Delta V_s$$

$$\Delta V_{app} = V_0 \gamma_l \Delta\theta - V_0 \gamma_s \Delta\theta$$

$$\boxed{\Delta V_{app} = V_0 (\gamma_l - \gamma_s) \Delta\theta = V_0 \gamma_{app} \Delta\theta}$$

Coeff. of Apparent Expansion

$$\gamma_{app} = \gamma_l - \gamma_s$$

Bimetallic Strip

$(\alpha_1 > \alpha_2)$

$\theta \uparrow$

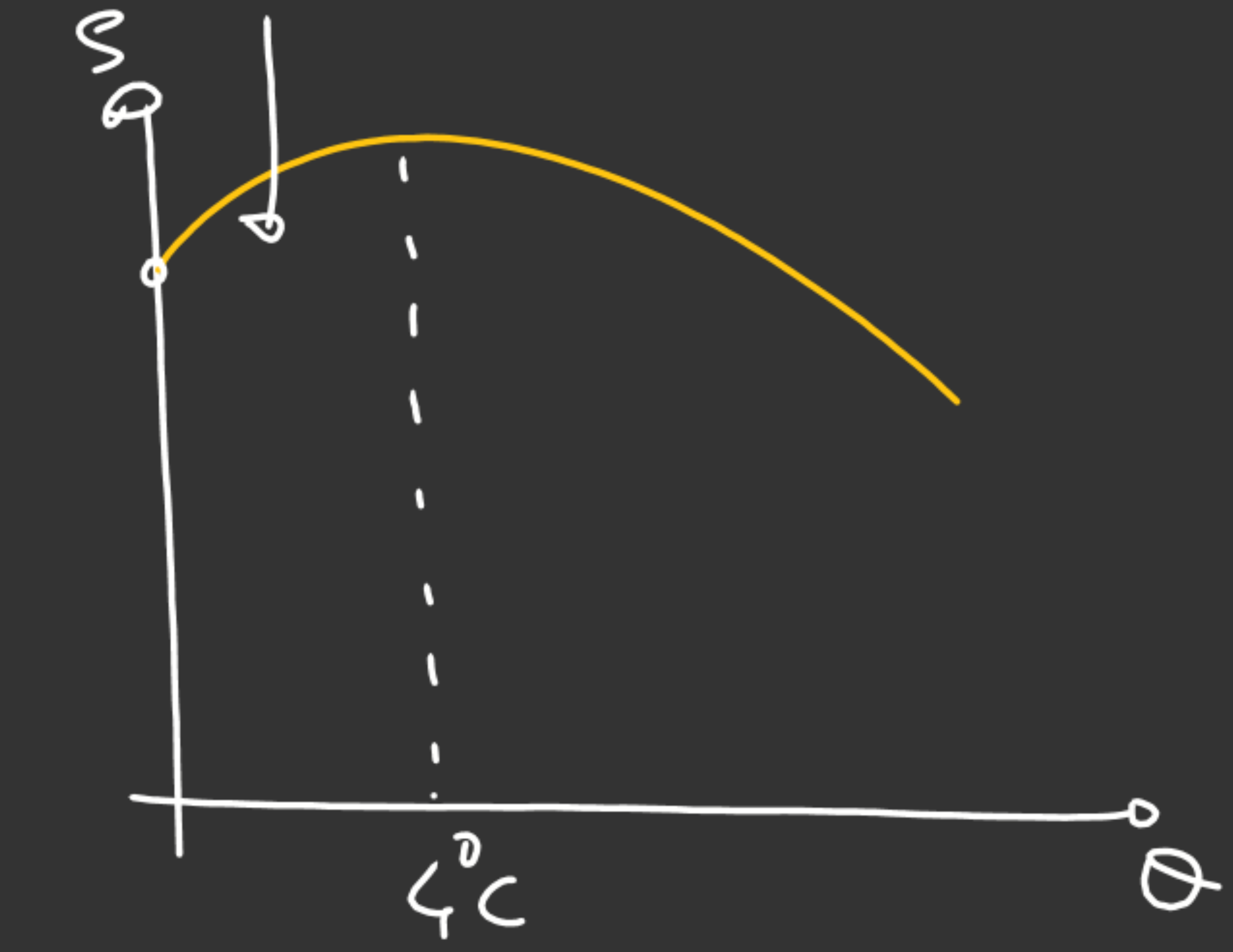
$\theta \downarrow$

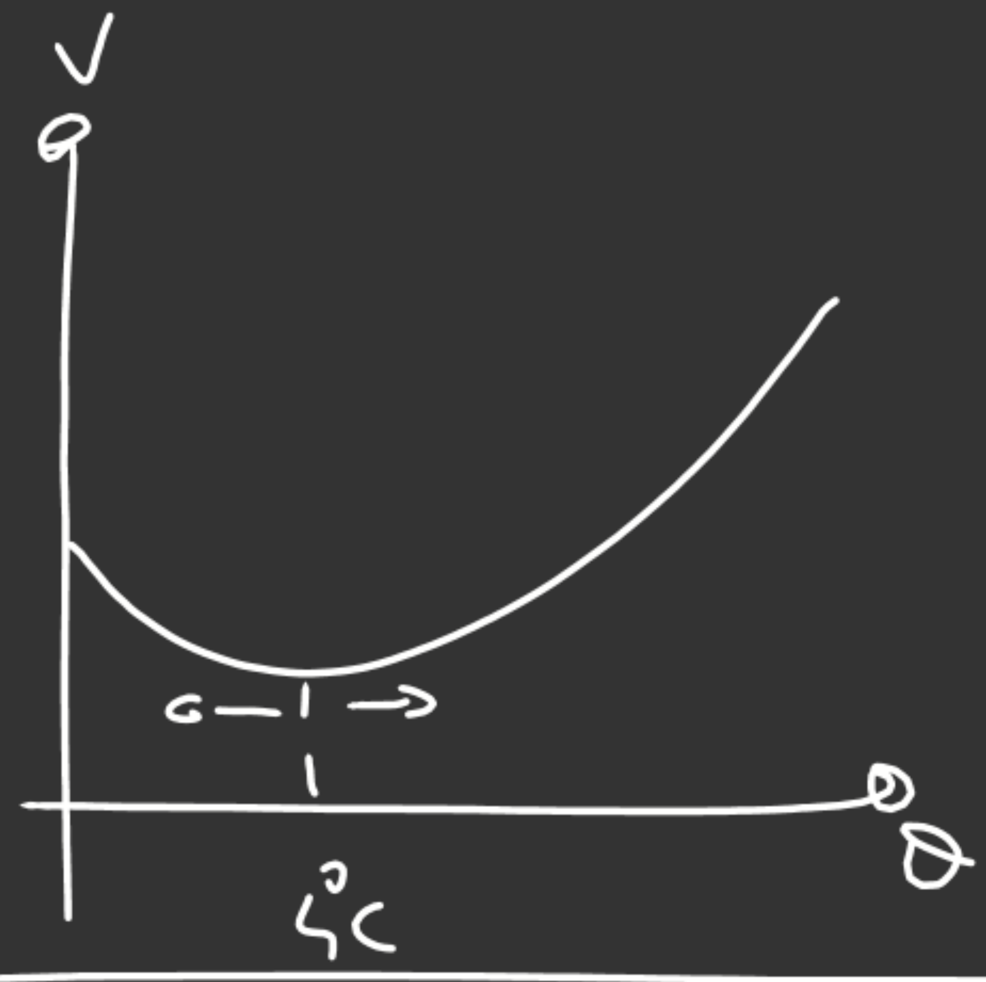
Q.

$\theta \uparrow$

$\boxed{\alpha_1 < \alpha_2}$

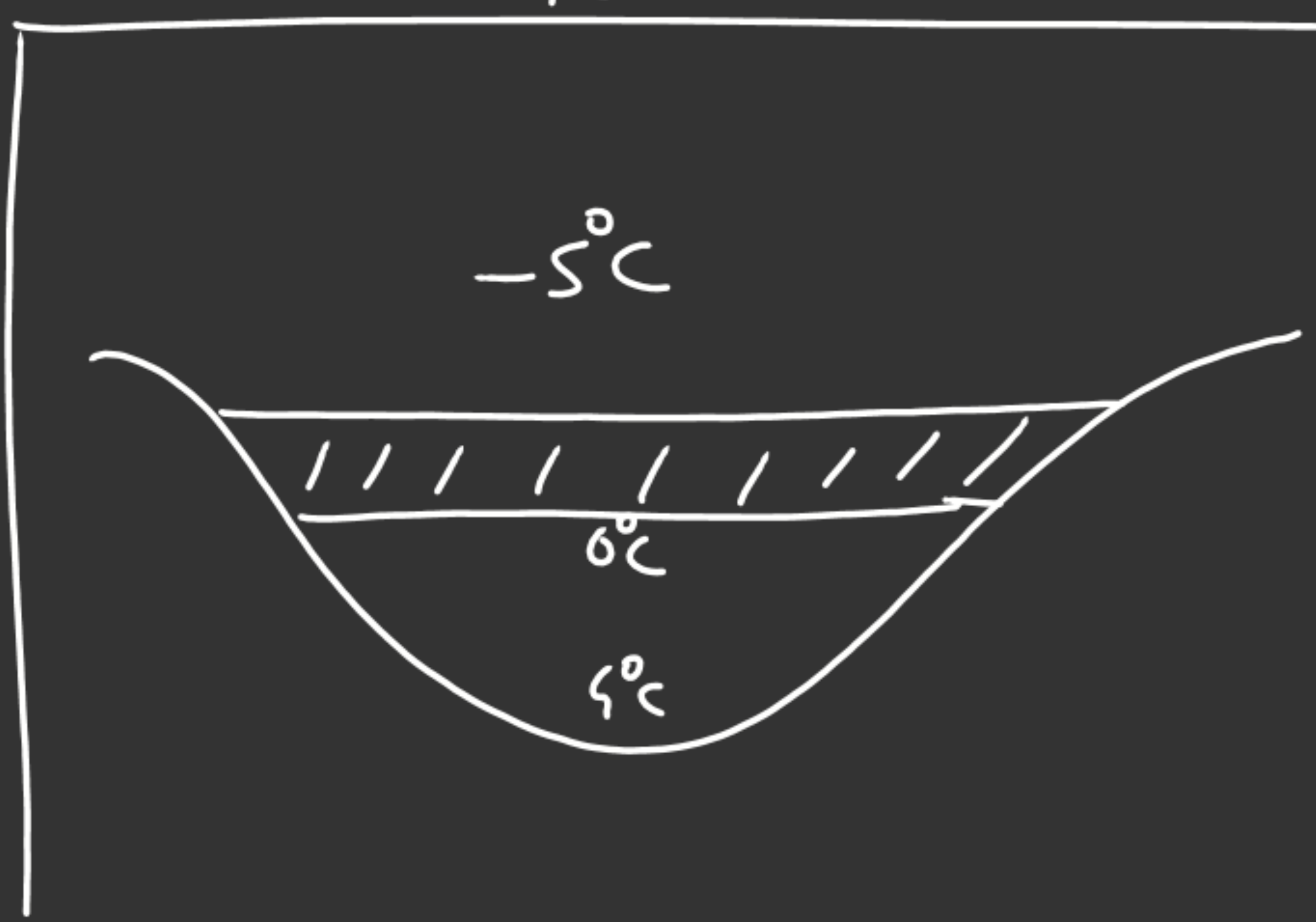
Anomalous Behavior Water





$\Rightarrow \rho_{max}$ at $4^\circ C$

$\Rightarrow \boxed{4^\circ C}$ → θ↑ spill
→ θ↓ spill



[θ of lake at Bottom] = 4°C

(2) $s = \dfrac{\Delta Q}{m\,\Delta\theta}$

$s_w = 4200 \dfrac{J}{kg - K} = 4200 \dfrac{J}{kg - 2.8\,X} = \dfrac{4200}{2.8}\left(\dfrac{J}{kg - X}\right)$

°C	X
$0 \longrightarrow 100$	$25 \longrightarrow 305$

$\dfrac{100}{}$ $\dfrac{280}{}$

$\Delta\theta = 1K = 1°C$ $\underline{2.8}$

$\Delta T = \frac{1}{2}\alpha\,\Delta\theta\,T$

$12 = \frac{1}{2}\alpha\,(40 - \theta_0)\,T$

$4 = \frac{1}{2}\alpha\,(\theta_0 - 20)\,T$

$\dfrac{12}{4} = \dfrac{40-\theta_0}{\theta_0 - 20}$

Homework

Page - 6 1, 2, 3, 4, 6, 7, 8

Page - 24 1, 2, 3, 4, 5, 6.

Page - 29 1 to 10.

Page - 33 12.

$$B = -\frac{\Delta P}{\left(\frac{\Delta V}{V}\right)}$$

$$K = \frac{P}{\gamma \Delta\theta} = \frac{P}{3\alpha \Delta\theta}$$

$$\frac{\Delta V_A}{\Delta V_B} = \frac{V_A \cancel{\gamma \Delta\theta}}{V_B \cancel{\gamma \Delta\theta}} = \frac{\pi (2r)^2 l}{\pi r^2 (2l)} = \frac{2}{1}$$

(4) $\frac{\Delta \rho}{\rho} = \gamma \Delta\theta$

A $\quad \underline{\underline{\gamma_1}} = \gamma_l - \gamma_A = \underline{\underline{\gamma_l - 3\alpha}}$

B $\quad \underline{\underline{\gamma_2}} = \gamma_l - \gamma_B = \underline{\underline{\gamma_l - 3\alpha_B}}$

$\Bigg\}$ 5

$$\boxed{v_{rms} = \sqrt{\frac{3RT}{M}}}$$

$$\Delta g = g_0 \gamma \Delta \theta$$

$$= 13.6\,(0.18 \times \cancel{10^{-3}})(2\cancel{00})$$

$$= 1.36 \times 0.18 \times 2$$

0.36

273

473

$$\begin{array}{r} 13.6 \\ .45 \\ \hline 13.15 \end{array}$$

Calorimetry

① Heat Capacity $C = \dfrac{\Delta Q}{\Delta \theta}$ $\quad \dfrac{J}{K} \quad \dfrac{Cal}{^\circ C}$

② Specific Heat Capacity $s = \dfrac{\Delta Q}{m \Delta \theta}$ $\quad \dfrac{J}{kg\text{-}K} \quad \dfrac{Cal}{g\text{-}^\circ C}$

$$\boxed{\Delta Q = m s \Delta \theta = C \Delta \theta}$$

$$\boxed{C = ms}$$

$s_w = 1\ Cal/g\text{-}^\circ C = 4200\ J/kg\text{-}K$

$s_{ice} = s_{steam} = 0.5\ Cal/g\text{-}^\circ C$

① $1\ cal = 4.2\ J$

② $1\ \dfrac{Cal}{^\circ C} = 4.2\ \dfrac{J}{K}$

③ $1\ Cal/g\text{-}^\circ C = 4200\ J/kg\text{-}K$

$$1\ \frac{Cal}{g\text{-}^\circ C} = \frac{4.2\ J}{10^{-3}\ kg\text{-}K}$$

Q. $4 \text{ Cal} = (4 \times 4.2) \text{ J}$

Q $100 \text{ J} = \frac{100}{4.2} \text{ Cal}$

Q. m r

m $2r$

$V = \left(\frac{4}{3}\pi\right) r^3$

① $\frac{s_1}{s_2} = \frac{1}{1}$

② $\frac{C_1}{C_2} = \frac{m_1 s_1}{m_2 s_2} = \left(\frac{V_1}{V_2}\right)\frac{1}{1} = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{1}{2}\right)^3 = \frac{1}{8}$

Q.

$\Delta Q = m s \Delta\theta$

① $\Delta Q = 20 (1)(15) = 300 \text{ cal}$
$= 300 \times 4.2 = \underline{1260 \text{ J}}$

② $\Delta Q = \frac{20}{1000} \boxed{(4200)} (15) = 1260 \text{ J}$

$\cancel{1000} \text{ J} = \frac{\cancel{200}}{\cancel{1000}} s (\cancel{50})$

$\boxed{s = 100 \text{ J/kg-K}}$

Principle of Caloriemetry

$$\begin{pmatrix}\text{Heat given} \\ \text{by 1 part} \\ \text{of system}\end{pmatrix} = \begin{pmatrix}\text{Heat taken} \\ \text{by remaining} \\ \text{part of System}\end{pmatrix}$$

Q. $\begin{pmatrix}10g \text{ water} \\ \text{at } 10^\circ C\end{pmatrix} + \begin{pmatrix}30g \text{ water} \\ \text{at } 20^\circ C\end{pmatrix}$

$\theta_f = ?$

$$10(s)(\theta - 10) = 30(s)(20 - \theta)$$

$$\theta - 10 = 3(20 - \theta)$$

$$\theta - 10 = 60 - 30$$

$$4\theta = 70$$

$$\theta = 17.5^\circ C$$

Q. $\begin{pmatrix}20g \text{ water} \\ \text{at } 80^\circ C\end{pmatrix} + \begin{pmatrix}80g \text{ water} \\ \text{at } 40^\circ C\end{pmatrix}$

$$\cancel{20}(\cancel{s})(80 - \theta) = \overset{4}{\cancel{80}}\,\cancel{s}(\theta - 40)$$

$$80 - \theta = 4\theta - 160$$

$$240 = 5\theta$$

$$\boxed{\theta = 48^\circ C}$$

$$(20)(1)(20 - 10) = 30(s)(50 - 20)$$

$$s = \frac{200}{900} = \frac{2}{9}\ cal/g\text{-}K$$

Q. $\begin{pmatrix} 20g \text{ Water} \\ \text{at } 20^\circ C \end{pmatrix} + \begin{pmatrix} 25 g \text{ water} \\ \text{at } 30^\circ C \end{pmatrix} + \begin{pmatrix} 5 g \text{ water} \\ \text{at } 40^\circ C \end{pmatrix}$

θ_f

$$20(1)(\theta - 20) + 25(1)(\theta - 30) = 5(1)(40 - \theta)$$

$$4(\theta - 20) + 5(\theta - 30) = 40 - \theta$$

$$4\theta - 80 + 5\theta - 150 = 40 - \theta$$

$$10\theta = 270$$

$$\boxed{\theta = 27^\circ C}$$

Water Equivalent

m_s

m_w

$$\Delta Q = m_s S_s \Delta\theta = m_w S_w \Delta\theta$$

$$\boxed{m_w = \frac{m_s S_s}{S_w}}$$

Q.

$20^\circ C \rightarrow 50^\circ C$

$$\Delta Q = m s \Delta\theta$$

$$= (450 + 50)(1)(30)$$

$$= \underline{15000 \text{ cal}}$$

Q.

10g  630°C

$$(500+100)(1)(30-25) = 10\,(s)(630-30)$$

$$6\cancel{00} \times (5) = 10\,(s)(6\cancel{00})$$

$$\boxed{s = \frac{1}{2}\ \text{cal/g-K}}$$

Latent Heat

Melting / Vaporisation

$$s = \frac{\Delta Q}{m \Delta \theta}$$

$$\boxed{s \rightarrow \infty}$$

$$\boxed{L = \frac{\Delta Q}{m}}$$

① $L_f = 80$ Cal/g [Latent Heat of fusion of Ice]

② $L_v = 540$ Cal/g [Latent Heat of vaporisation of water]

$$\boxed{\begin{array}{c} \Delta Q = m s \Delta \theta \\ \hline \Delta Q = m L \end{array}}$$

Q. 15g of Ice

$$\Delta Q = mL$$

$$= 15(80)$$

$$= \underline{1200 \text{ Cal}}$$

Q. Heater ⇒ 100 W

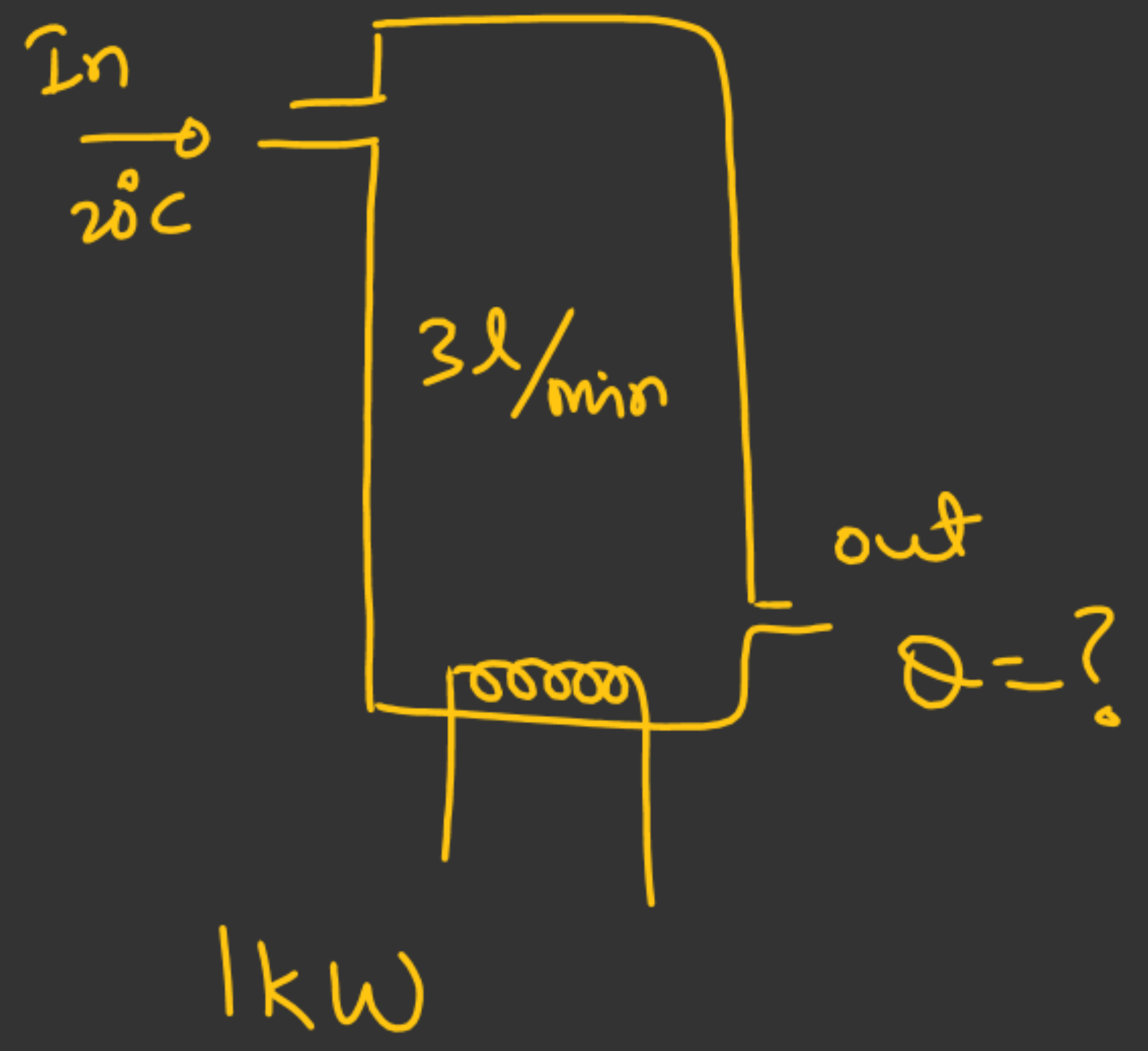
time req. to melt 100g of Ice

$$Pt = \text{Energy}$$

$$(100)t = (100)(80) \times 4.2$$

$$t = 336 \text{ s}$$

Q.



$$P\,t = m\,s\,\Delta\theta$$

$$(1000)(60) = (3000)(1)(\theta - 20)(4.2)$$

$$\theta - 20 = \frac{\overset{2}{\cancel{60}} \times 100\cancel{0}}{\cancel{300} \times \underset{21}{\cancel{42}}}$$

$$\theta - 20 = \frac{100}{21} = 4.9$$

$$\underline{\theta = 24.9°C}$$

Q. (10g Ice at $-20^\circ C$) $\xrightarrow{\Delta Q = ?}$ (Steam at $100^\circ C$)

$\Delta Q_1 = ms\Delta\theta$

$= 10(0.5)(20)$

$= 100$ cal

[Ice at $0^\circ C$]

$\Delta Q_2 = mL_f$

$= 10 \times 80$

$= 800$ cal

(water at $0^\circ C$)

$\Delta Q_3 = ms\Delta\theta = 10(1)100$

$= 1000$ cal

(water at $100^\circ C$)

$\Delta Q_4 = mL$

$= 10(540)$

$= 5400$ cal

$\Delta Q = 100 + 800 + 1000 + 5400$

$= 7300$ cal

Q.

→ collides & comes to rest

→ Entire energy → Heat

$s = 0.4\ \text{cal/g-K}$

Find $\Delta\theta = ?$

$$mgh = m s \Delta\theta$$

① $$\left[(m)(10)(20) = \left(\underset{(\text{gram})}{1000\,m}\right)(0.4)\,\Delta\theta\,(4.2)\right]$$

② $$gh = s\Delta\theta$$

$$(1\cancel{0})(\cancel{20}) = (0.\overset{0.2}{\cancel{4}} \times 42\cancel{00})\,\Delta\theta$$

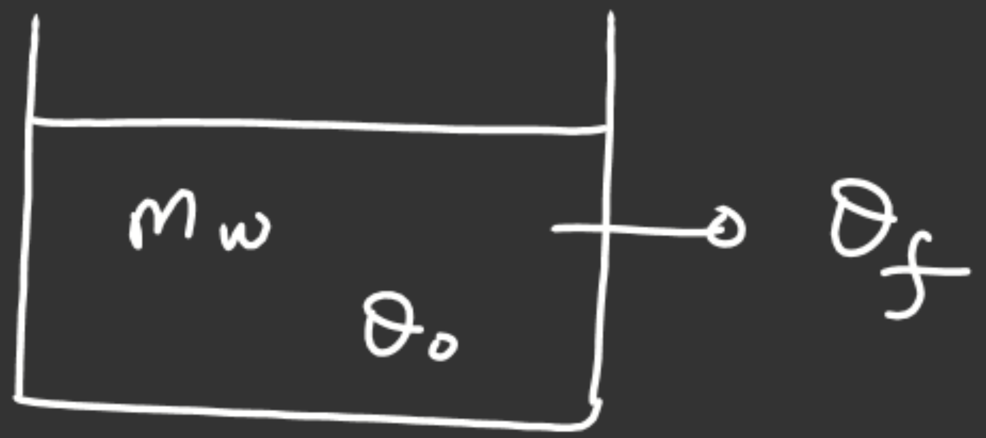
$$\Delta\theta = \frac{1}{8.4} = \frac{10}{84}\ {}^\circ C$$

10g water $20^\circ C \rightarrow 50^\circ C$

$$\Delta Q = \boxed{(10)}(1)(50-20)(4.2)$$

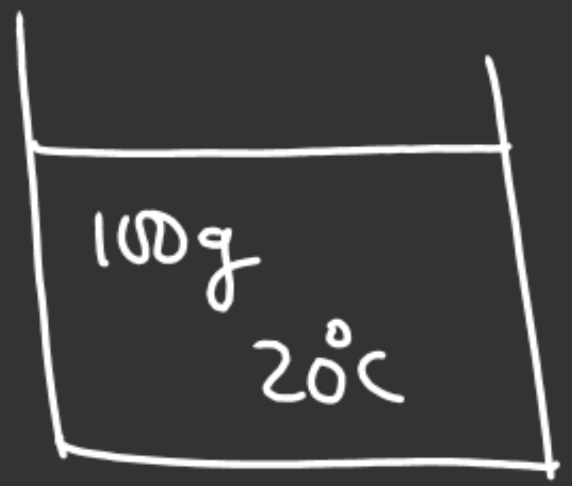
$$= \frac{10}{1000}(4200)(50-20)\ J$$

Case $\xrightarrow{\text{Steam @ } 100^\circ C}$



$$m_w s_w(\theta_f - \theta_0) = m_s L_v + m_s s_w(100 - \theta_f)$$

Q. $\xrightarrow{\text{steam @ } 100^\circ C}$



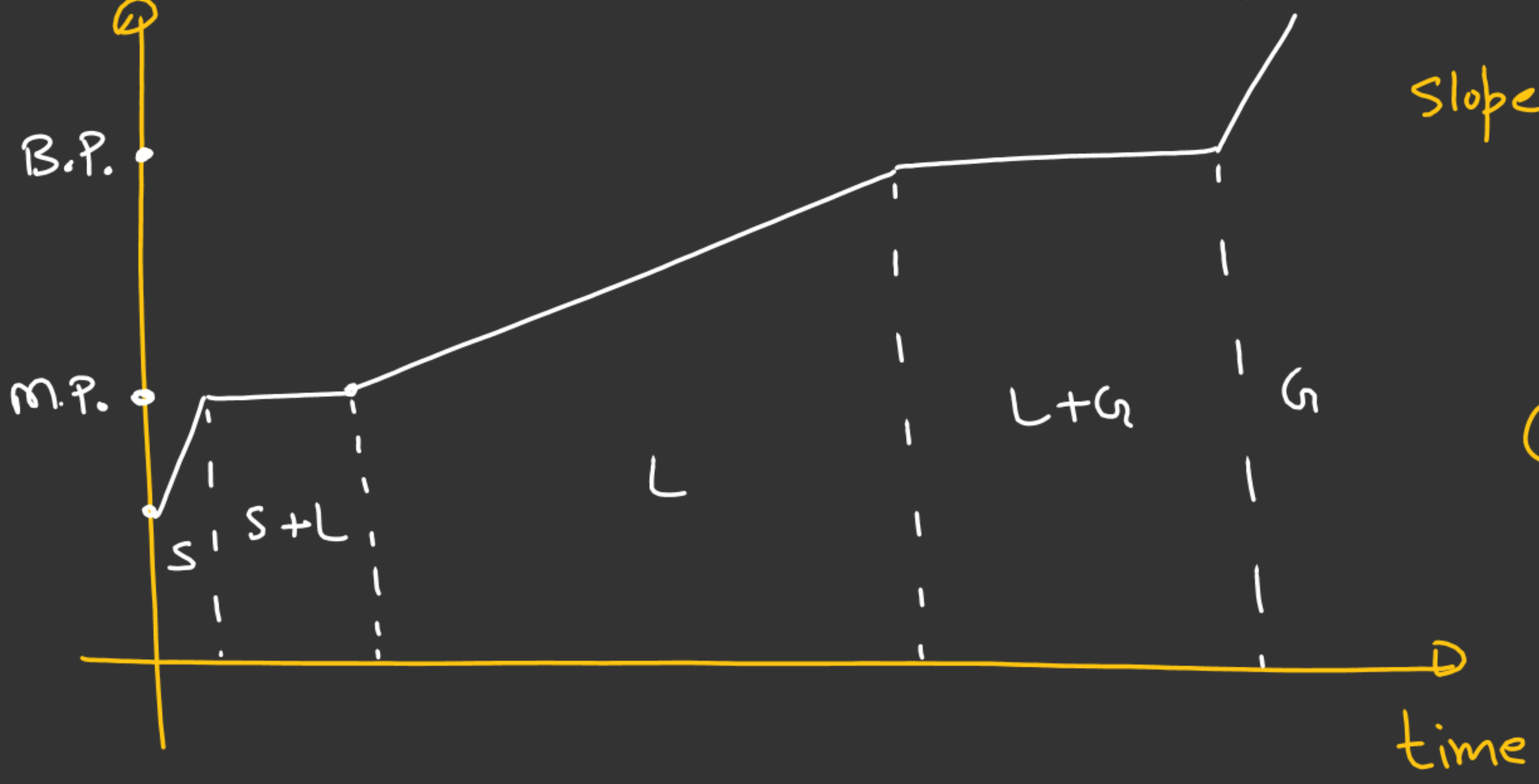
if $\theta_f = 80^\circ C$ then find mass of steam condensed

$$100 \times (1)(80-20) = m(540) + m(1)(100-80)$$

$$\cancel{100}^{25} \times \cancel{60}^{3} = \cancel{560}^{7} \times m$$

$$\boxed{m = \frac{75}{7}\, g}$$

Assume = 0 (Constant Power Source)



① $P\Delta t = m s \Delta\theta$

$$\text{Slope} = \frac{\Delta\theta}{\Delta t} = \frac{P}{ms}$$

$$\boxed{\text{slope} \propto \frac{1}{s}}$$

② $P\,\Delta t = \Delta m\, L$

$\tan\alpha = \frac{P}{B}$

Mixing (Ice + water)

① $D > S$

→ partial melting

→ Final temp = $0°C$

→ $m_{melt} L_f = S$

② $D = S$

→ Ice melts completely

→ Final temp = $0°C$

→ $(m_1 + m_2)$ water at $0°C$

③ $D < S$

→ Ice melts completely

→ Final temp = θ

① $$\boxed{\theta = \frac{S - D}{m_1 + m_2}}$$

② $m_1 L_f + m_1 s(\theta - 0) = m_2(s)(\theta_i - \theta)$

Q. $\begin{pmatrix} 5g \text{ Ice} \\ \text{at } 0^\circ C \end{pmatrix} + \begin{pmatrix} 10g \text{ water} \\ \text{at } 10^\circ C \end{pmatrix}$

$D = mL$

$D = 5 \times 80$

$\underline{D = 400 \text{ Cal}}$

$S = m s \Delta\theta$

$S = (10)(1)(10-0)$

$\underline{S = 100 \text{ Cal}}$

(water $0^\circ C$) (water $0^\circ C$)

$m_{melt}(80) = S = 100$

$m_{melt} = \frac{100}{80} = \underline{\underline{1.25g}}$

Q. $\begin{pmatrix} 10g \text{ Ice} \\ \text{at } 0^\circ C \end{pmatrix} + \begin{pmatrix} 20g \text{ water} \\ \text{at } 40^\circ C \end{pmatrix}$

$D = 10 \times 80$

$= 800$

$S = 20(1)(40-0)$

$= 800$

$(10+20)g$ water $0^\circ C$

Q $\left(\begin{array}{c}10g\ \text{Ice} \\ \text{at } 0^\circ C\end{array}\right) + \left(\begin{array}{c}40g\ \text{water} \\ 40^\circ C\end{array}\right)$

$D = 10 \times 80$
$= 800\ \text{cal}$

$S = 40\,(1)\,(40)$
$= 1600\ \text{cal}$

① $800 + 10\,(1)\,(\theta - 0) = 40\,(1)\,(40 - \theta)$

$$800 + 10\theta = 1600 - 40\theta$$

$$\boxed{\theta = \frac{1600 - 800}{10 + 40}} = 16^\circ C$$

Case

Ice $0^\circ C$ $\boxed{m}$

Steam $100^\circ C$ $\boxed{1m}$

then

$\frac{m}{3}$

$100^\circ C$

Q. $\left(1g \text{ Ice at } 0^\circ C\right) + \left(1g \text{ steam at } 100^\circ C\right)$

$D_1 = 1 \times 80$

$S = 1 \times 540$

water $0^\circ C$

water $100^\circ C$

$D_2 = 1 \times 1 \times 100$

water at $100^\circ C$

$\left(1g + \frac{1}{3}g\right)$

$\left[\frac{4}{3}g \text{ water} + \frac{2}{3}g \text{ steam}\right] 100^\circ C$

Heat Transfer

→ Conduction

→ mainly in solids

→ metals are good conductors

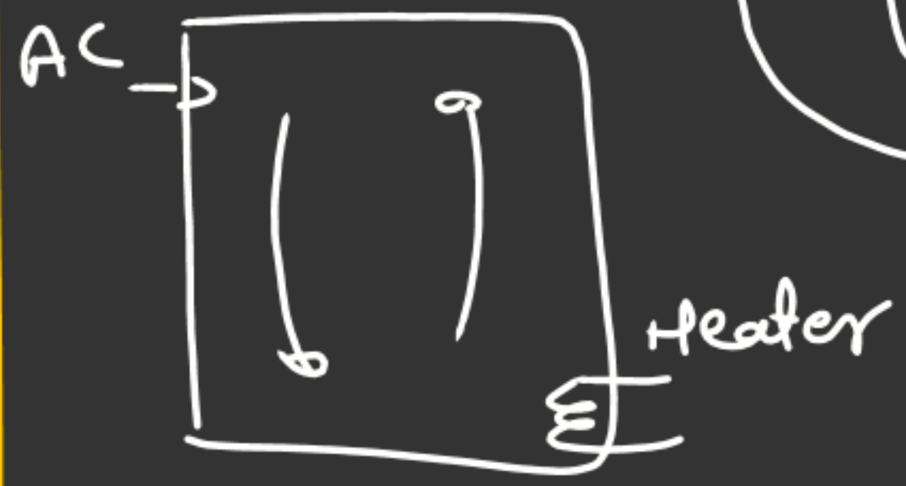
[free e^-]

Land Breeze (Night)

Convection

→ via mass transport

→ Natural



→ Forced

$\boxed{\rightarrow \text{Fan}}$

→ Difference in Density

→ Vertical

Sea Breeze (Day)

Radiation

→ Doesnot Req any med.

→ fastest mode

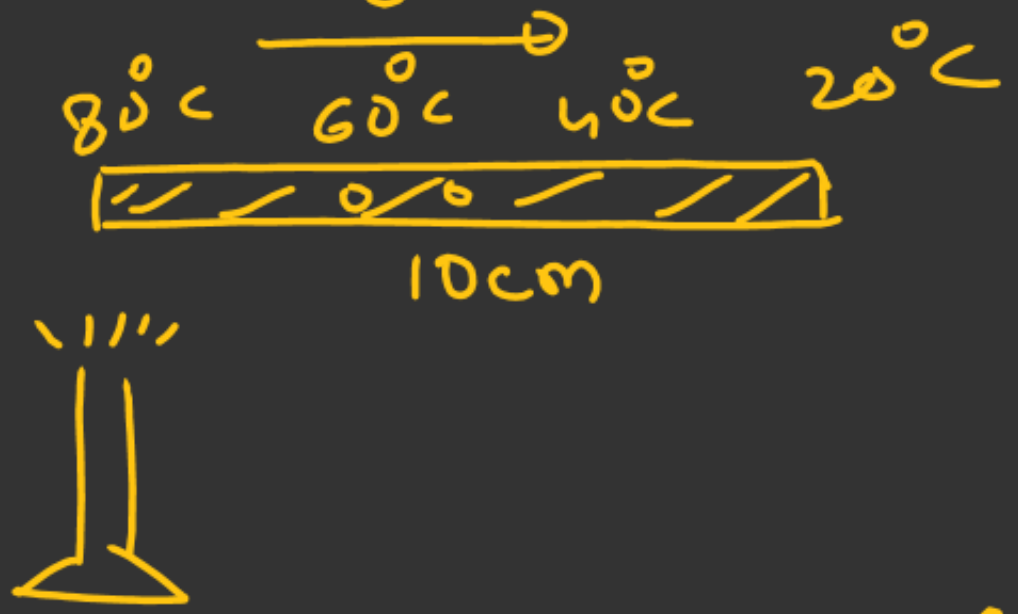
→ $c = 3 \times 10^8$ m/s

→ EMW

→ generally (InfraRed)

Conduction

→ Steady state



Rate of Heat Transfer

$$\boxed{\frac{\Delta Q}{\Delta t} = \frac{KA}{l}\Delta\theta}$$

$$\frac{\Delta Q}{\Delta t} = -KA\left(\frac{d\theta}{dx}\right)$$

K = Thermal conductivity

$$K \Rightarrow \frac{W}{m-K}$$

$$[K] = \frac{ML^2T^{-2}}{TLK} = [MLT^{-3}K^{-1}]$$

$$[F] = [MLT^{-2}]$$

$$[E] = [ML^2T^{-2}]$$

Temp. Gradient $= \frac{\Delta\theta}{l}$

Q.

$l = 20\,cm$

$A = 4\,cm^2$

$K = 400\ \frac{W}{m-K}$

$\frac{\Delta Q}{\Delta t} = ?$

$$\frac{\Delta Q}{\Delta t} = \frac{KA}{l}\Delta\theta$$

$$= \frac{400 \times (4\times10^{-4})}{20\times10^{-2}}(40)$$

$$= 32\ J/s$$

$$\text{Temp Grad.} = \frac{40}{0.2} = 200\ °C/m$$

$$R = \frac{l}{KA} = \frac{0.2}{400\times4\times10^{-4}} = 1.25\ K/W$$

Electrical

$$\boxed{I = \frac{1}{R} V}$$

I = Electric current

V = Voltage = Potential Diff

R = Electrical Resistance

$$R = \frac{\rho l}{A} = \frac{l}{\sigma A}$$

σ = Electrical conductivity

Thermal

$$\left(\frac{\Delta Q}{\Delta t}\right) = \left(\frac{KA}{l}\right) \Delta\theta$$

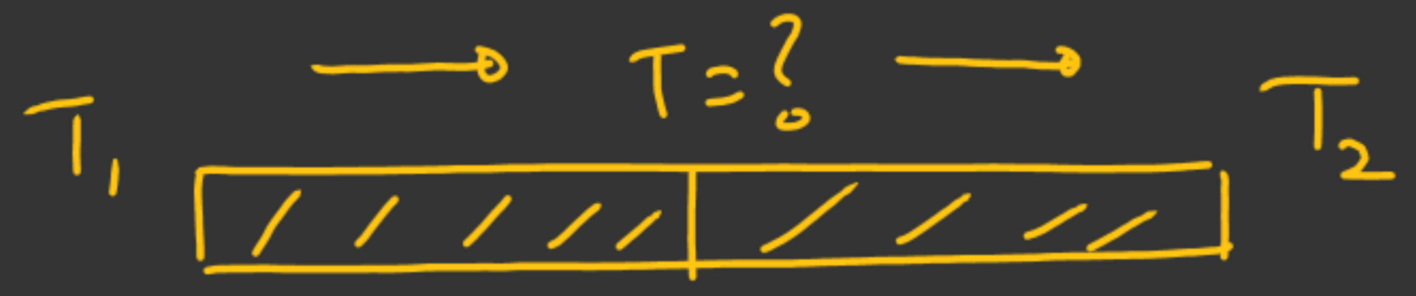
$\frac{\Delta Q}{\Delta t}$ = Thermal current

$\Delta\theta$ = Temp. diff.

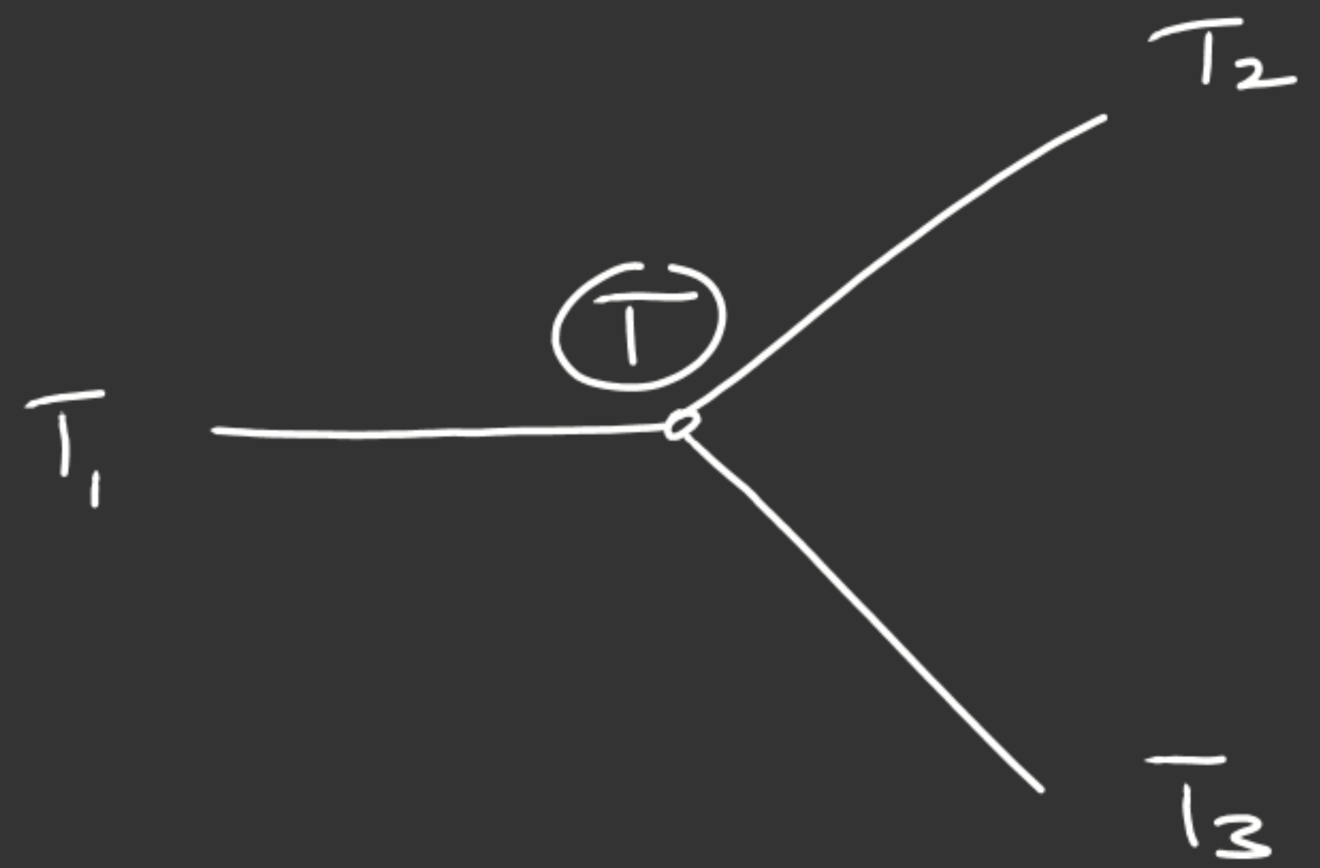
$$\boxed{R = \frac{l}{KA}}$$ = Thermal Resistance

K = Thermal conductivity

Junction Temperature

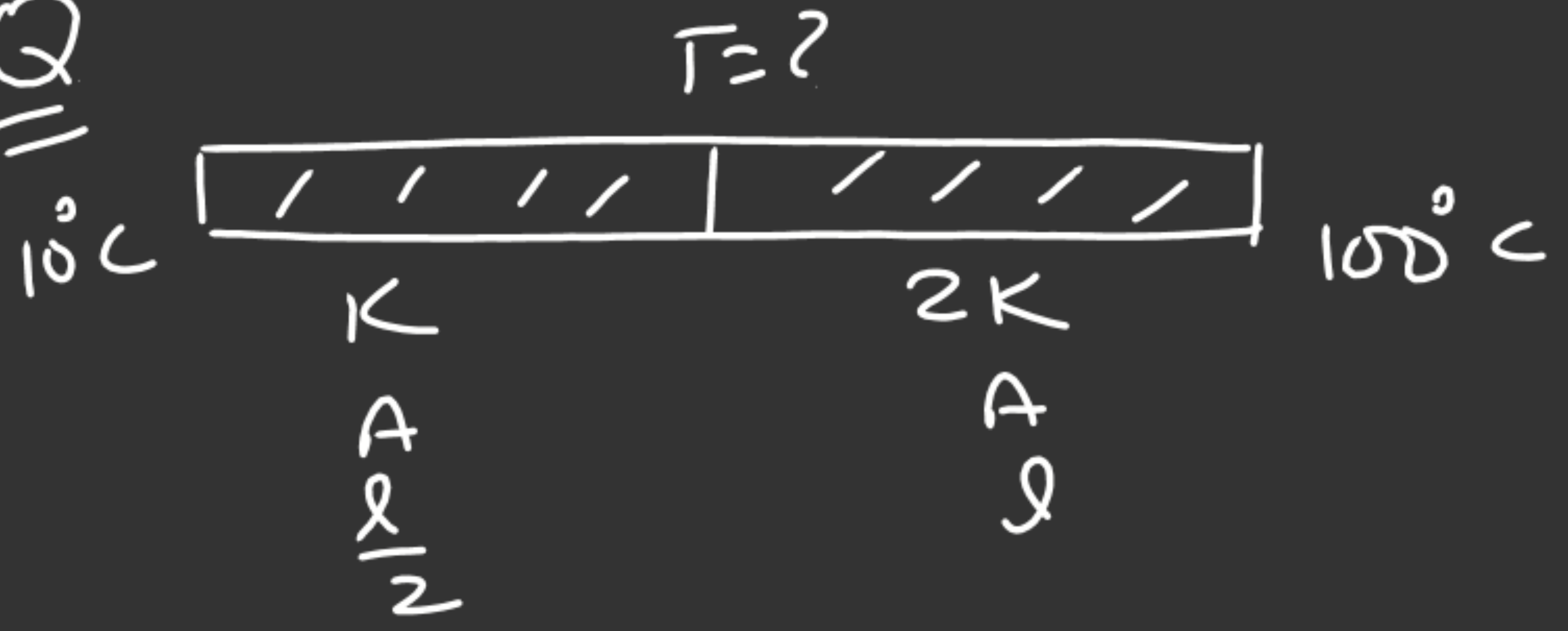


$$\frac{K_1 A_1}{l_1}(T_1 - T) = \frac{K_2 A_2}{l_2}(T - T_2)$$



$$\frac{K_1 A_1}{l_1}(T - T_1) + \frac{K_2 A_2}{l_2}(T - T_2) + \frac{K_3 A_3}{l_3}(T - T_3) = 0$$

Q

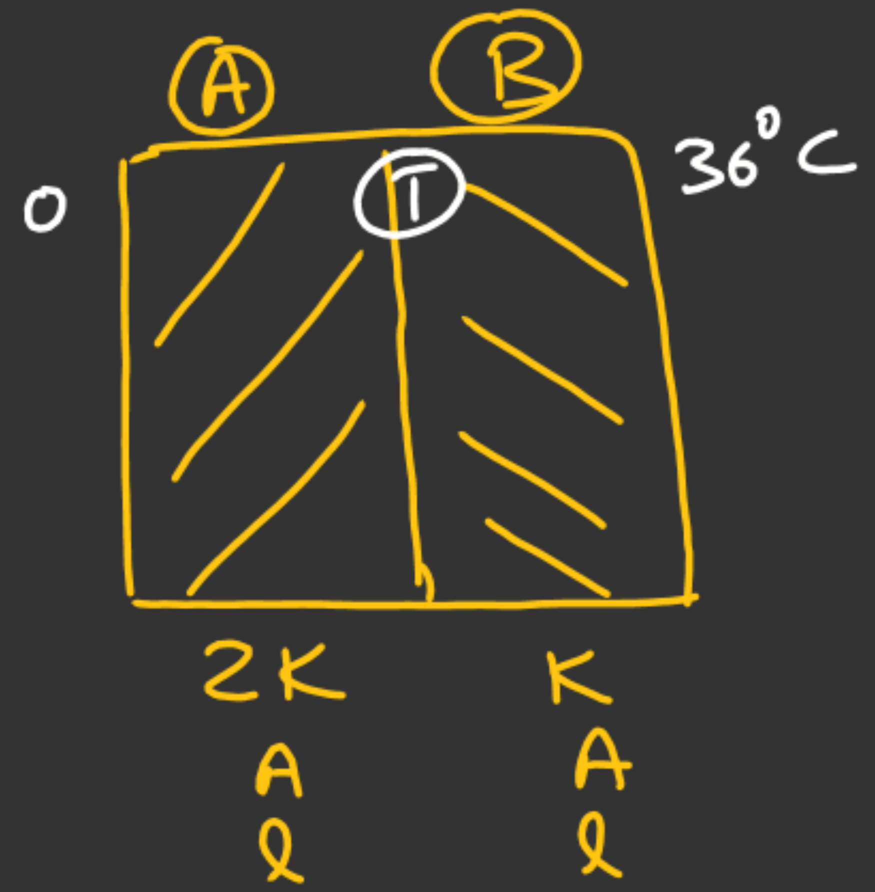


$$\frac{KA}{l/2}(T-10) = \frac{2KA}{l}(100-T)$$

$$T-10 = 100-T$$

$$2T = 110$$

$$\boxed{T = 55^\circ C}$$



$$\frac{2KA}{l}(T-0) = \frac{KA}{l}(36-T)$$

$$2T = 36-T$$

$$T = \frac{36}{3} = 12^\circ C$$

$$\boxed{\Delta\theta = T-0 = 12^\circ C}$$

Q

$$4\ \text{Cal/min} = \frac{KA}{2l}\,\Delta\theta$$

$$\frac{\Delta Q}{\Delta t} = \frac{K(2A)}{l}\,\Delta\theta$$

$$\frac{\left(\frac{\Delta Q}{\Delta t}\right)}{4} = \frac{2}{1/2} = 4$$

$$\boxed{\frac{\Delta Q}{\Delta t} = 16\ \text{Cal/min}}$$

Equivalent Thermal conductivity

① Series (Same $\frac{\Delta Q}{\Delta t}$)
[Assume A]

$$R_{eq} = R_1 + R_2$$

$$\frac{l_1 + l_2}{K_{eq} A} = \frac{l_1}{K_1 A} + \frac{l_2}{K_2 A}$$

$$\boxed{K_{eq} = \frac{l_1 + l_2}{\frac{l_1}{K_1} + \frac{l_2}{K_2}}}$$

Compound Slab
Parallel slab / Walls

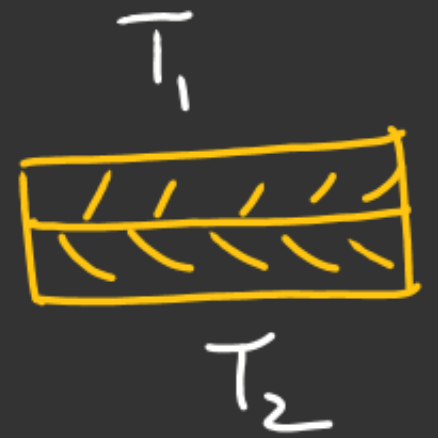
② Parallel (Same Temp. diff.)
[Assume l]

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{K_{eq}(A_1 + A_2)}{l} = \frac{K_1 A_1}{l} + \frac{K_2 A_2}{l}$$

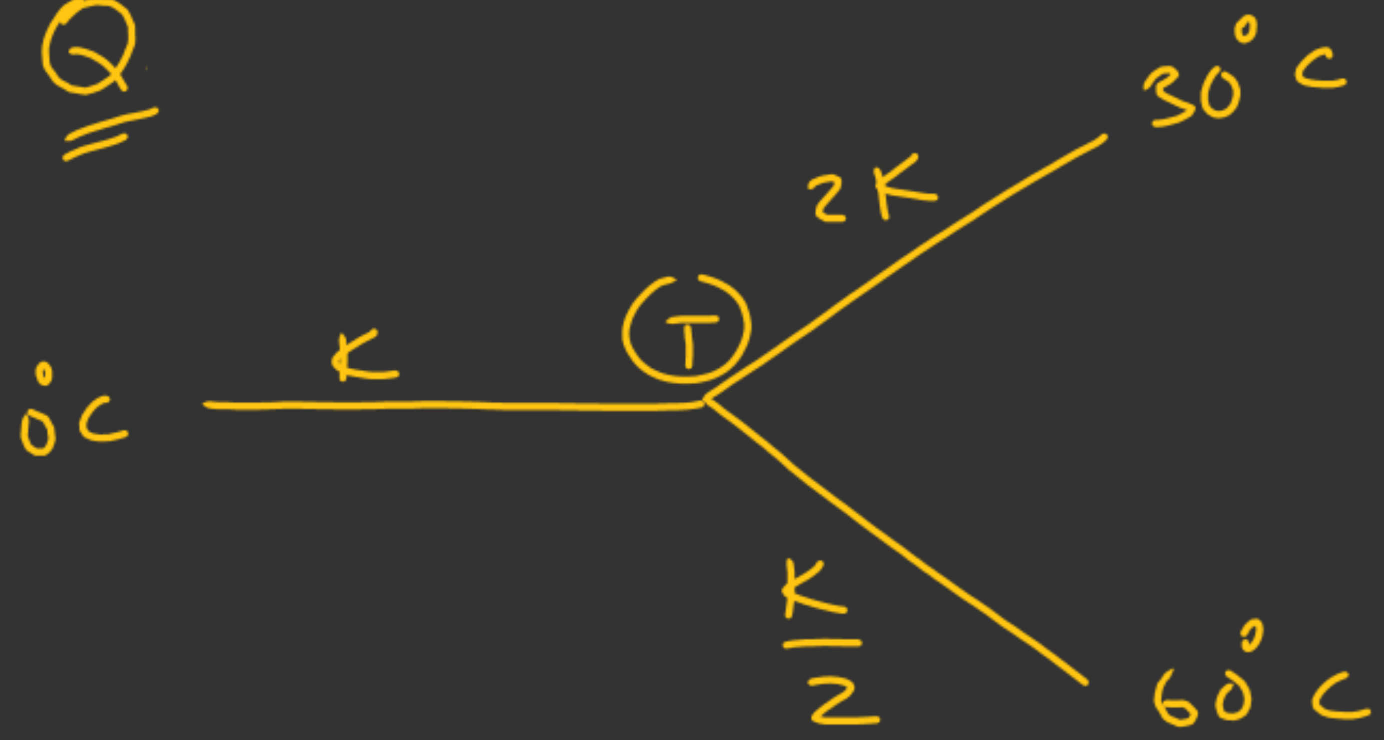
$$\boxed{K_{eq} = \frac{K_1 A_1 + K_2 A_2}{A_1 + A_2}}$$

Parallel



Series

Q



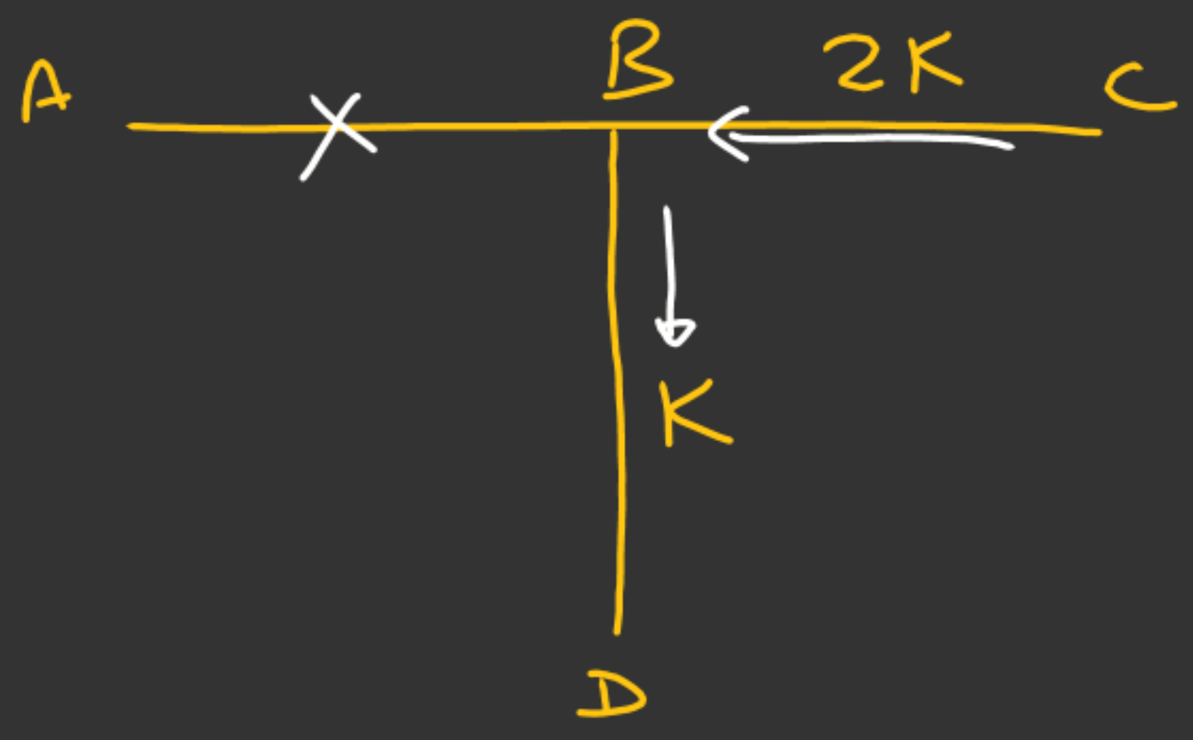
$$\frac{KA}{l}(T-0) + \frac{2KA}{l}(T-30) + \frac{KA}{2l}(T-60) = 0$$

$$T + 2(T-30) + \frac{1}{2}(T-60) = 0$$

$$\frac{7T}{2} - 90 = 0$$

$$\boxed{T = \frac{180}{7}^\circ C}$$

Q.



given

$T_D = 20^\circ C$

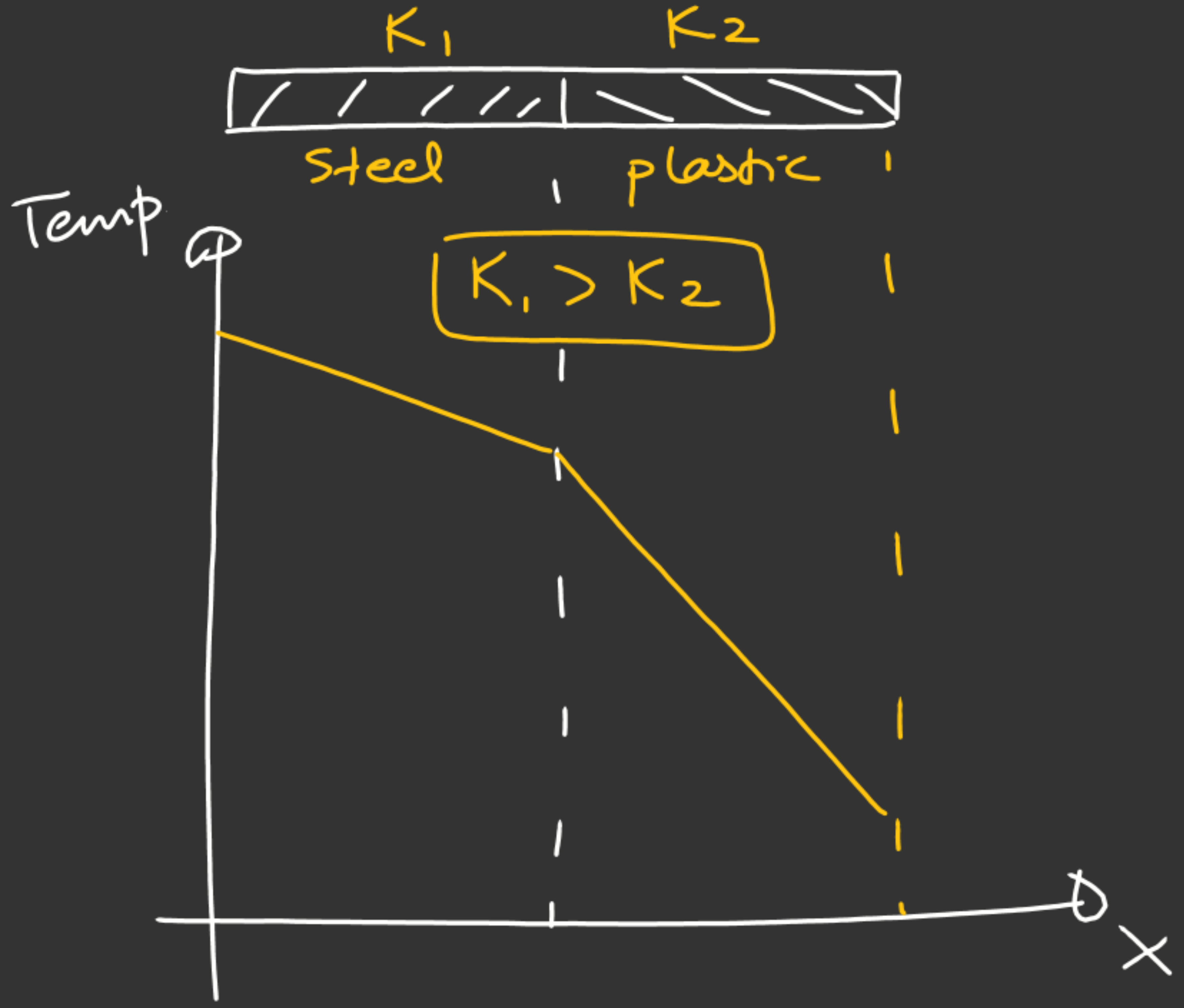
$T_c = 80^\circ C$

If there is no Heat Transfer from A to B then Find $T_B = ?$

$$\frac{2KA}{l}(80 - T_B) = \frac{KA}{l}(T_B - 20)$$

$$160 - 2T_B = T_B - 20$$

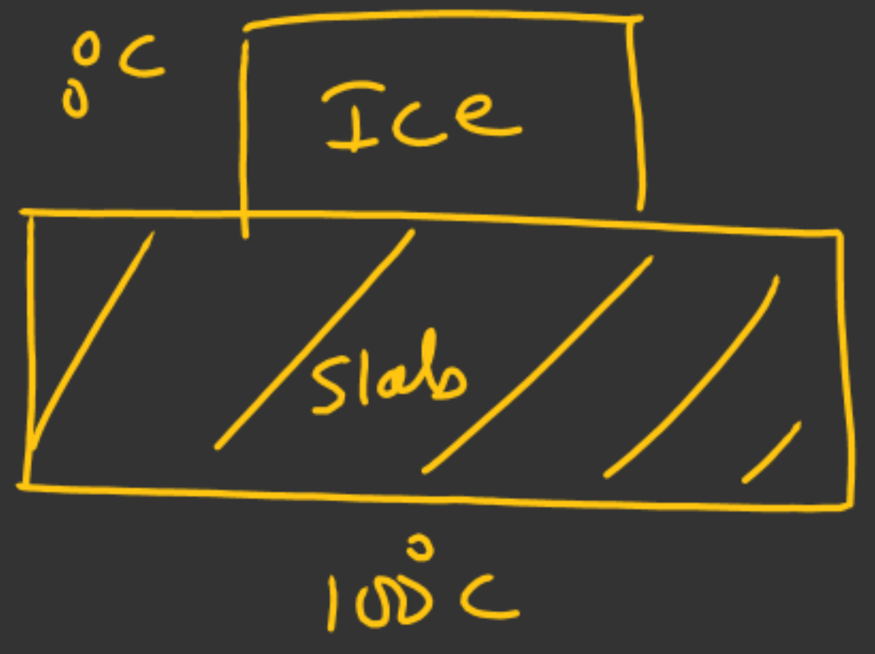
$$T_B = \frac{180}{3} = 60^\circ C$$



$$\boxed{\frac{\Delta Q}{\Delta t}} = -K\boxed{A}\left(\frac{dT}{dx}\right)$$

Utensil

	sp. Heat Cap	Thermal Conductivity
1)	Low	Low
2)	High	High
3)	$\boxed{\text{Low}}$	$\boxed{\text{High}}$
4)	High	Low



$A = 40\ cm^2$

$t = 5\ cm$

$K = 400\ \frac{W}{m\text{-}K}$

[Amount of Ice melts in 1 min?]

$$\frac{\Delta Q}{\Delta t} = \frac{KA}{\ell}\Delta\theta$$

$$\frac{mL}{60} = \frac{400 \times 40 \times 10^{-4}(100)}{5 \times 10^{-2}}$$

$$\frac{(4.2)\,m\,(\cancel{80})}{60} = \frac{400 \times \cancel{40}^{8}}{\cancel{5}}$$

$$m = \frac{40 \times 60}{4.2}$$

$$\boxed{m = 580\,g}$$

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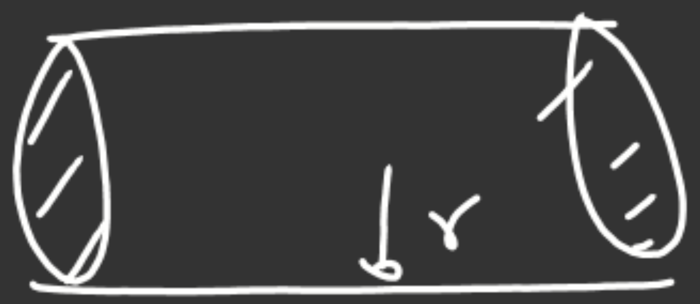
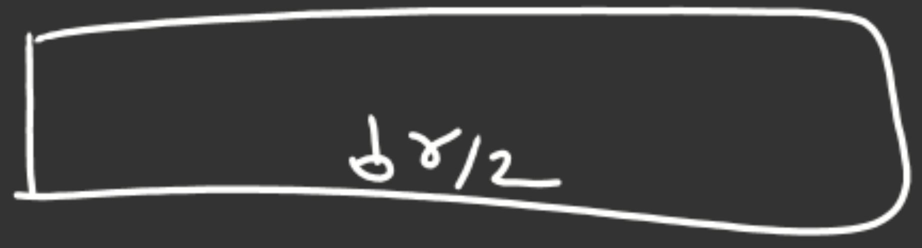


$$\frac{Q}{t} = \frac{K\pi r^2}{l}\Delta\theta$$

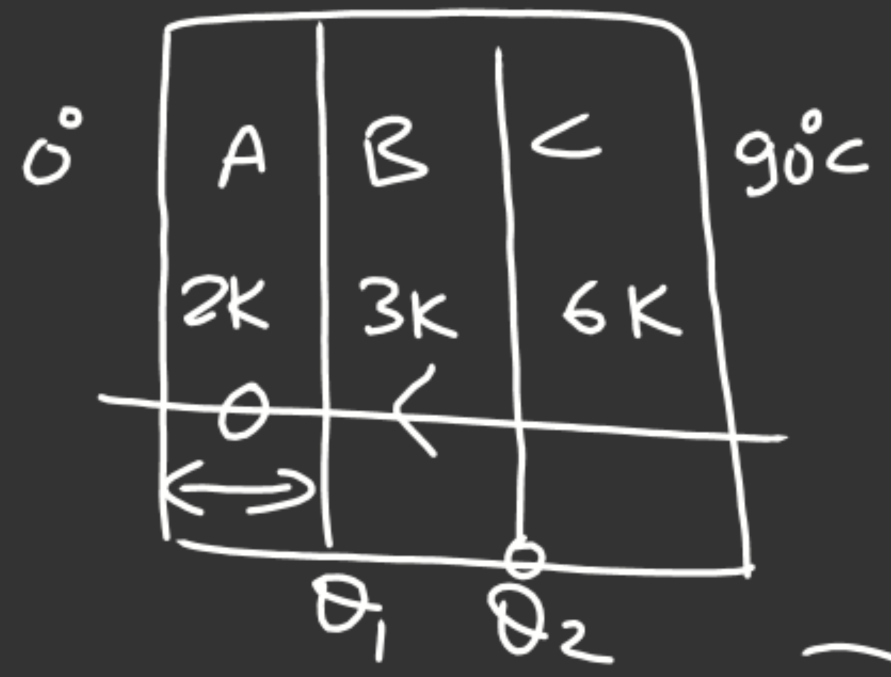


$$\frac{Q'}{t} = \frac{K\pi(r/2)^2}{4l}\Delta\theta = \frac{Q}{t}\left(\frac{1}{16}\right)$$

$$V = \pi r^2 l = \pi\left(\frac{r}{2}\right)^2 l'$$

$$\boxed{Q' = \frac{Q}{16}}$$

$$\frac{3l}{K_{eq}A} = \frac{l}{2KA} + \frac{l}{3KA} + \frac{l}{6KA}$$



$$\frac{6KA}{l}(90-\theta_2) = \frac{3KA}{l}(\theta_2-\theta_1) = \frac{2KA}{l}(\theta_1-0)$$

$\frac{l}{2KA}$ $\frac{l}{3KA}$ $\frac{l}{6KA}$

$1/2$ $1/3$ $1/6$

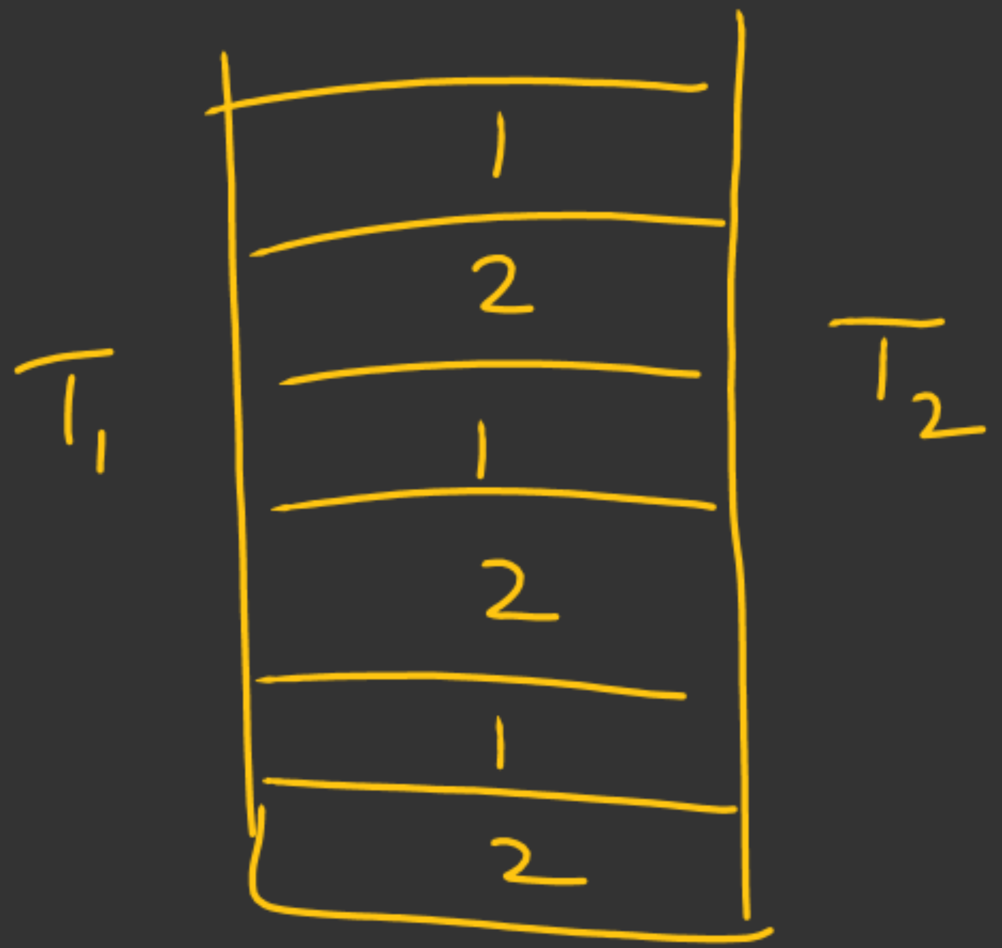
$\boxed{3R}$ $2R$ R

$\boxed{45}$ $\boxed{30}$ 15

$$\boxed{\frac{90-0}{3+2+1} = 15}$$

$$\left(\frac{K_{eq}A}{3l}(90-0) = \left[\frac{2KA}{l}(\theta-0)\right]\right)$$

$$\boxed{\frac{\Delta Q}{\Delta t}} = \frac{\Delta Q}{R}$$



$$\frac{K_{eq}(6A)}{d} = \left(\frac{K_1 A}{d} + \frac{K_2 A}{d}\right)3$$

$$\frac{385\,A}{l}(100-\theta) = \frac{50\,A}{l}(\theta-0)$$

Absorptive Power

$$a = \frac{\text{Energy Absorbed}}{\text{Energy Incident}}$$

$$0 \le a \le 1$$

$a = 0$ Perfect Reflector

$a = 1$ IBB

Emissive Power (E)

$$E = \frac{\text{Energy Radiated}}{\text{Area time}} \quad (W/m^2)$$

$$Q_i = Q_{Ref} + Q_{Ab} + Q_{trans}$$

Ideal Black Body (IBB)

Ferry's BB

→ Absorbs all

⇒ Lamp Black (98%)

⇒ Pin hole / Crack

Wein's BB

→ The Sun

Emissivity (e)

$$e = \frac{E(B)}{E(BB)}$$

$$0 \le e \le 1$$

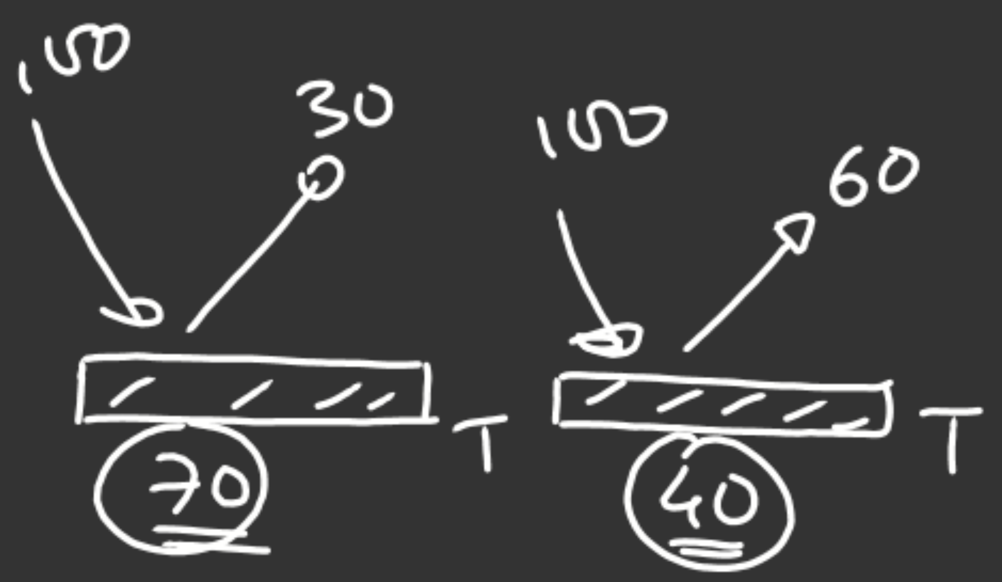
$e = 1$ IBB

Kirchoff's Law

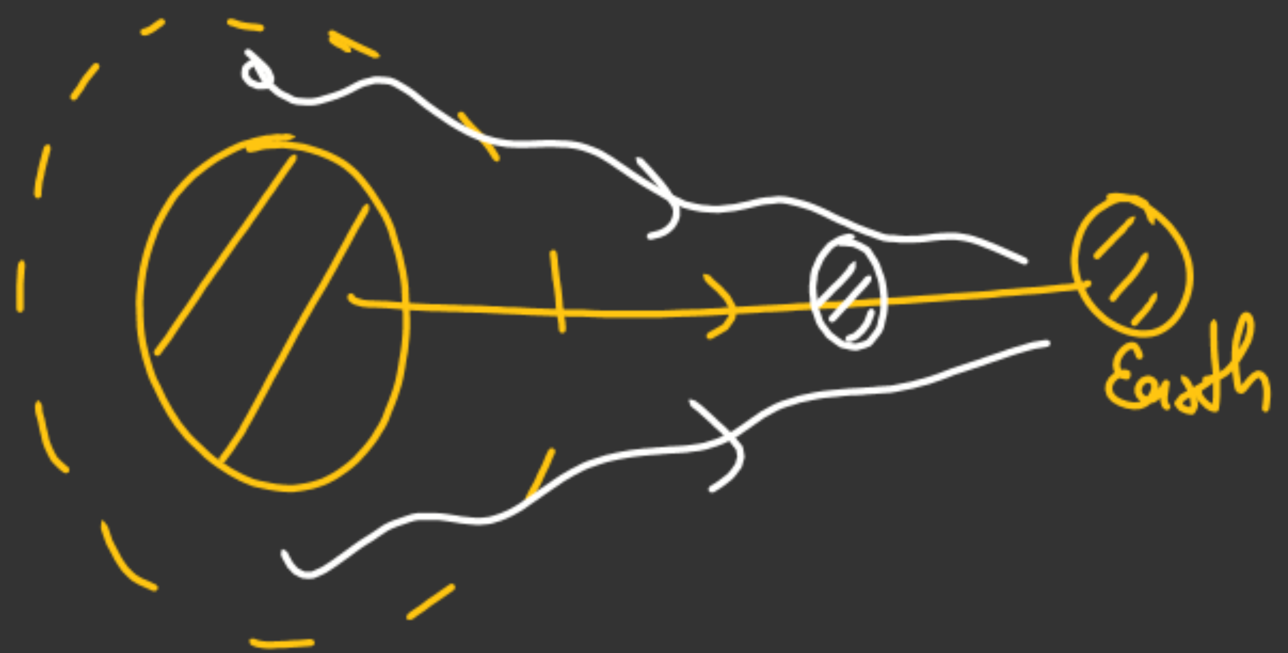
$$\frac{E_1}{a_1} = \frac{E_2}{a_2} = \frac{E_{BB}}{1}$$

① $a_1 = \dfrac{E_1}{E_{BB}} = e_1$

② Good ab $\Rightarrow$ Good em



Fraunhofer Lines



Normal Day $\rightarrow$ missing

Solar Eclipse Day $\rightarrow$ Found

Stefan's law

$\sigma = 5.67 \times 10^{-8} \frac{W}{m^2 - K^4}$

① Power Radiated $P = \sigma e A T^4$

T_0 = Atmospheric Temp

② Emissive Power $E = \sigma e T^4$

③ Rate of Heat loss $= \sigma e A (T^4 - T_0^4)$

$$-ms\frac{\Delta T}{\Delta t} = \sigma e A (T^4 - T_0^4)$$

④ Rate of cooling (Rate of fall of Temp.) $\left(-\frac{\Delta T}{\Delta t}\right) = \frac{\sigma e A}{ms}(T^4 - T_0^4)$

Cases

① $T \to 2T_0$

$P \to 16 P_0$

② Small % change

$$\frac{\Delta P}{P} = 4\frac{\Delta T}{T}$$

$T \uparrow$ by 2%

$P \uparrow$ by 8%

③ $T \uparrow$ by 10%

$P \uparrow$ by 46%

$$T = T_0\left(1+\frac{10}{100}\right) = 1.1\,T_0$$

$$P = (1.1)^4 P_0 = (1.46)\,P_0$$

$$2^4 = 2^2\, 2^2$$

$$3^4 = 3^2\, 3^2$$

$$(1.1)^4 = (1.1)^2 (1.1)^2 = (1.21)^2 = 1.46$$

④ $T \uparrow$ by 20%

$P \uparrow$ by 100%

⑤ $T \to 1.2T$

$P \to 2P$

Q at $27^\circ C$ 16 W

at $327^\circ C$ $P = ?$

$P = \sigma e A T^4$

$$\frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^4$$

$$\frac{P_2}{16} = \left(\frac{600}{300}\right)^4 = 2^4 = 16$$

$$\boxed{P_2 = 256 W}$$

Q. $27^\circ C$ 16 W

Rise in temp $P = 32 W$

$\because$ $P \rightarrow 2P_0$

$\therefore$ $T \rightarrow 1.2 T_0$

$T = 1.2(300) = 360 K$

$-300 K$

$\Delta\theta = 60 K = 60^\circ C$

Q. $127^\circ C$ 10 W

$227^\circ C$ Rate of Loss

$$\text{Rate of H.L} = \sigma e A\left(T^4 - T_0^4\right)$$

$$\frac{R_2}{10} = \frac{R_2}{R_1} = \frac{500^4 - 300^4}{400^4 - 300^4}$$

$$\frac{R_2}{10} = \frac{5^4 - 3^4}{4^4 - 3^4} = \frac{625 - 81}{256 - 81} = \frac{\cancel{544}^{\,22}}{\cancel{175}_{\,7}} \simeq 3$$

$$\boxed{R_2 = 30\,W}$$

Q. $P = \sigma e A T^4$

$$P = \sigma e\left(4\pi R^2\right) T^4$$

2^2 $\left(\frac{1}{2}\right)^4 = \frac{1}{4}$

$$P \rightarrow \frac{P_0}{4}$$

Same material

—"— Temp

① $\dfrac{(\text{Rate of Heat Loss})_2}{(\text{—— " ——})_1} = \dfrac{A_2}{A_1} = \left(\dfrac{2R}{R}\right)^2 = \dfrac{4}{1}$

② $\dfrac{(\text{Rate of Cooling})_2}{(\text{—— " ——})_1} = \dfrac{R_1}{R_2} = \dfrac{1}{2}$

$(\text{Rate of cooling}) \propto \dfrac{A}{m} \propto \dfrac{R^2}{R^3} \propto \dfrac{1}{R}$

Same Material

—"— Temp.

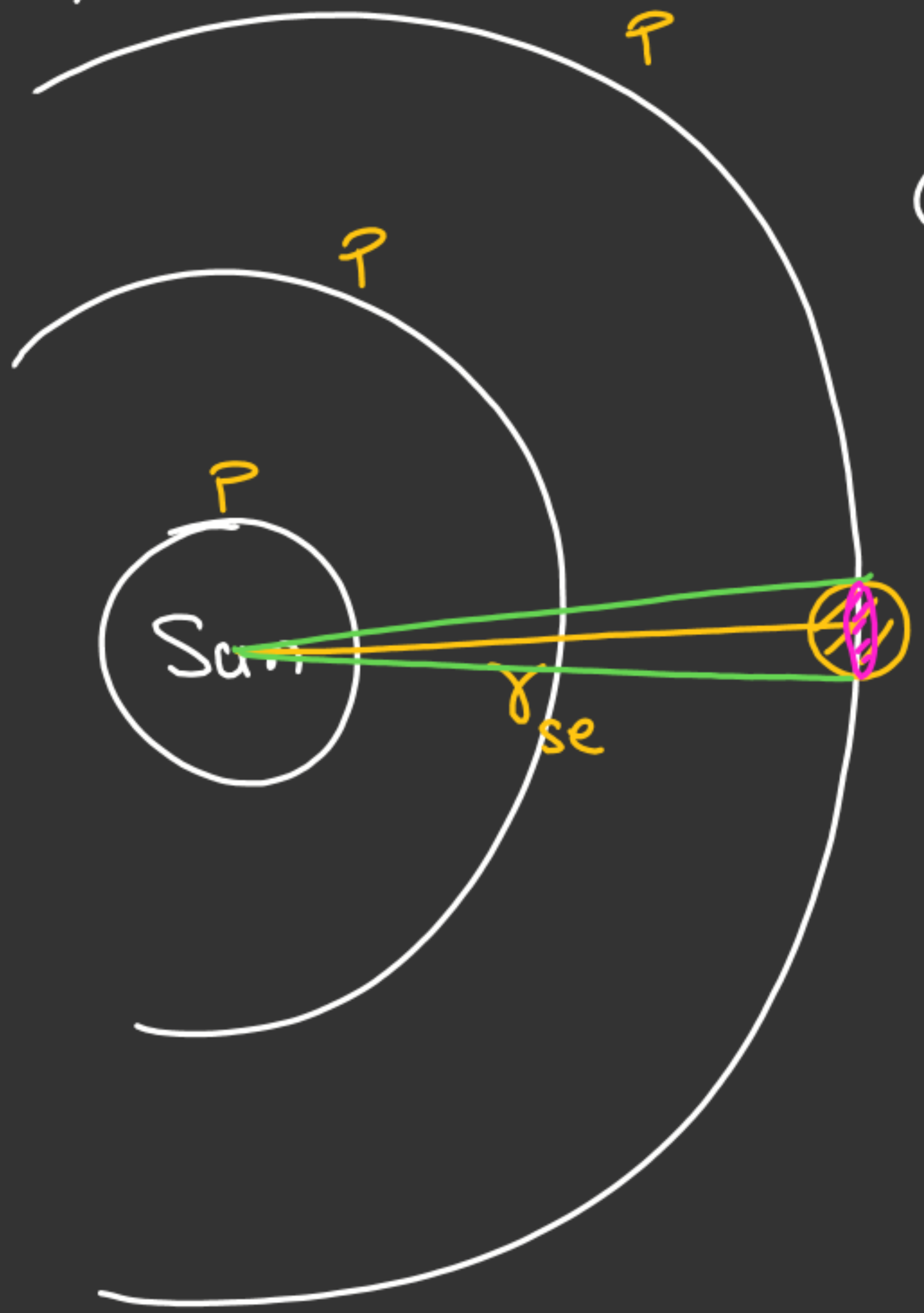
—"— Radius

① $\dfrac{(\text{Rate of Heat Loss})_2}{(\text{—— " ——})_1} = \dfrac{1}{1}$

② $\dfrac{(\text{Rate of cooling})_2}{(\text{—— " ——})_1} = \dfrac{m_1}{m_2}$

$\text{Rate of cooling} \propto \dfrac{1}{m}$

Solar Constant



$$\boxed{r_{se} = 1\,AU}$$

① Power Radiated by Sun $= \sigma 4\pi R_s^2 T^4$

② Solar Constant $= \dfrac{\sigma 4\pi R_s^2 T^4}{4\pi r_{se}^2}$

$$\boxed{S = \frac{\sigma R_s^2 T^4}{r_{se}^2}}$$

$$\frac{S_{mars}}{S_{earth}} = \left(\frac{r_{se}}{r_{sm}}\right)^2$$

③ Energy Recieved on Earth per sec.

$$= \left(\frac{\sigma R_s^2 T^4}{r_{se}^2}\right) \pi R_e^2$$

Newton's law of Cooling

→ Special case of stefan's law

→ Only for small temp. diff bet^n system & surr.

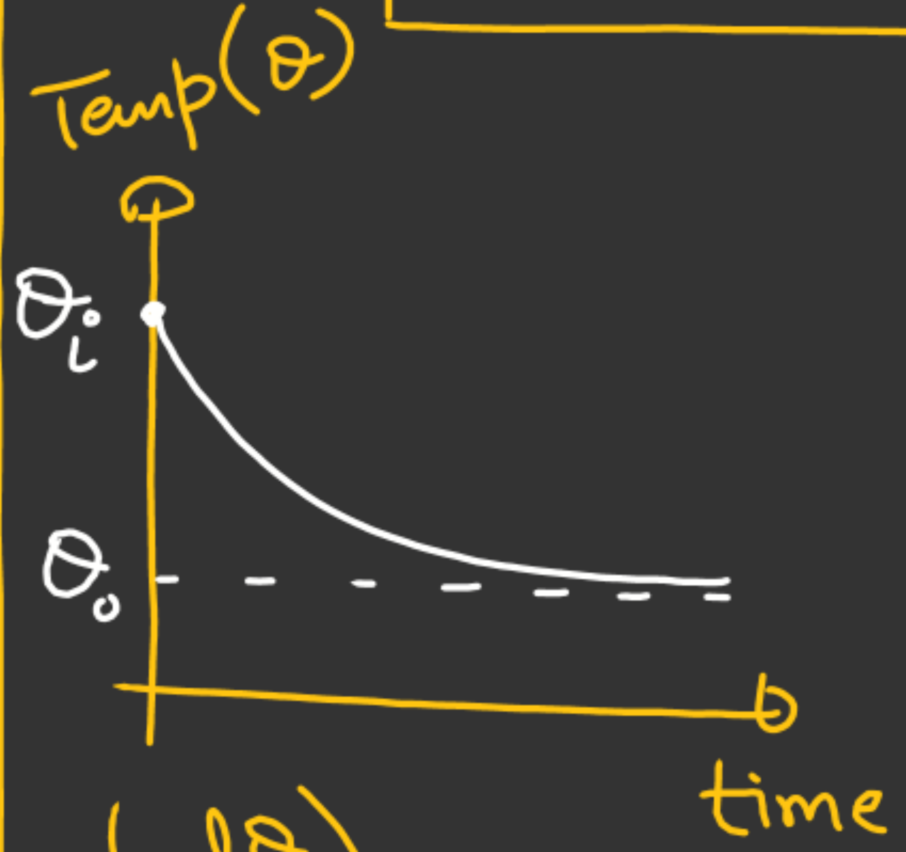
$$\boxed{-\frac{d\theta}{dt} = \frac{\sigma e A}{ms}\left(\theta^4 - \theta_0^4\right)}$$ stefan

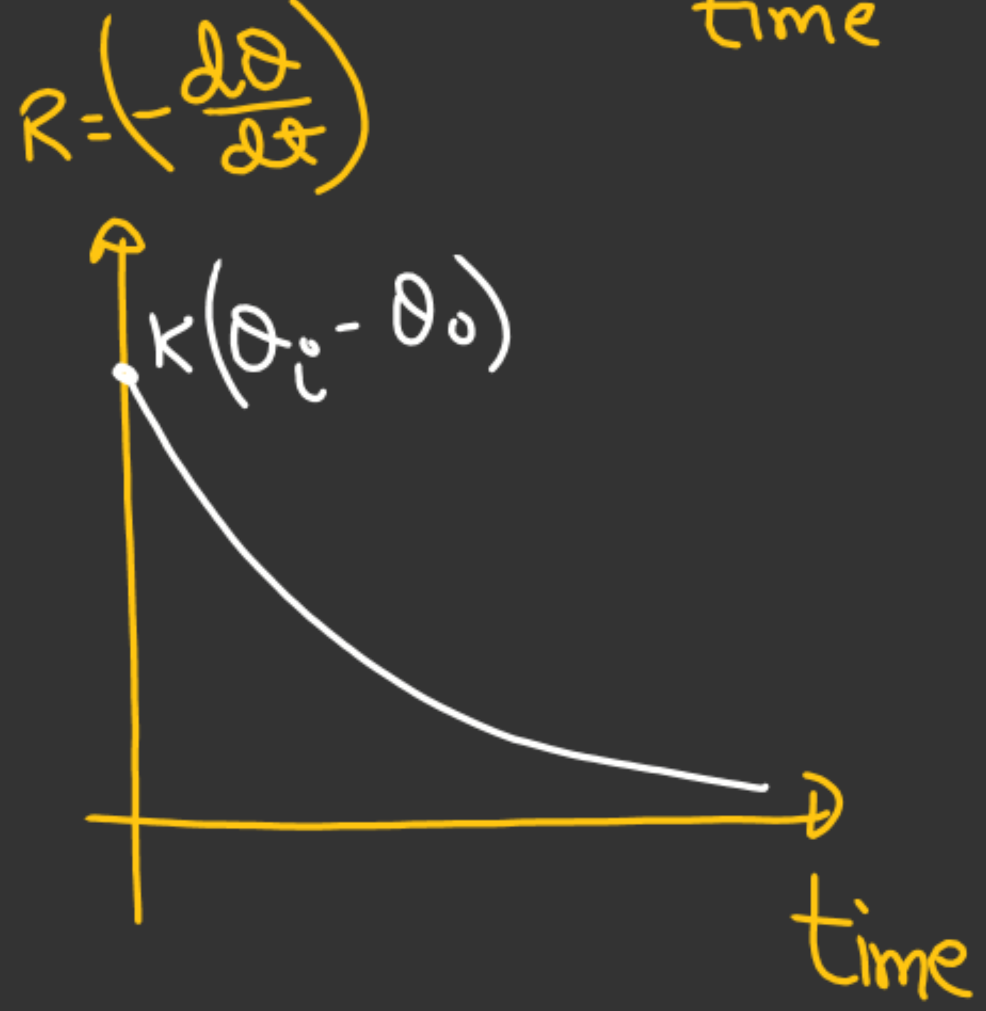
$\Delta\theta = (\theta - \theta_0)$ is very small

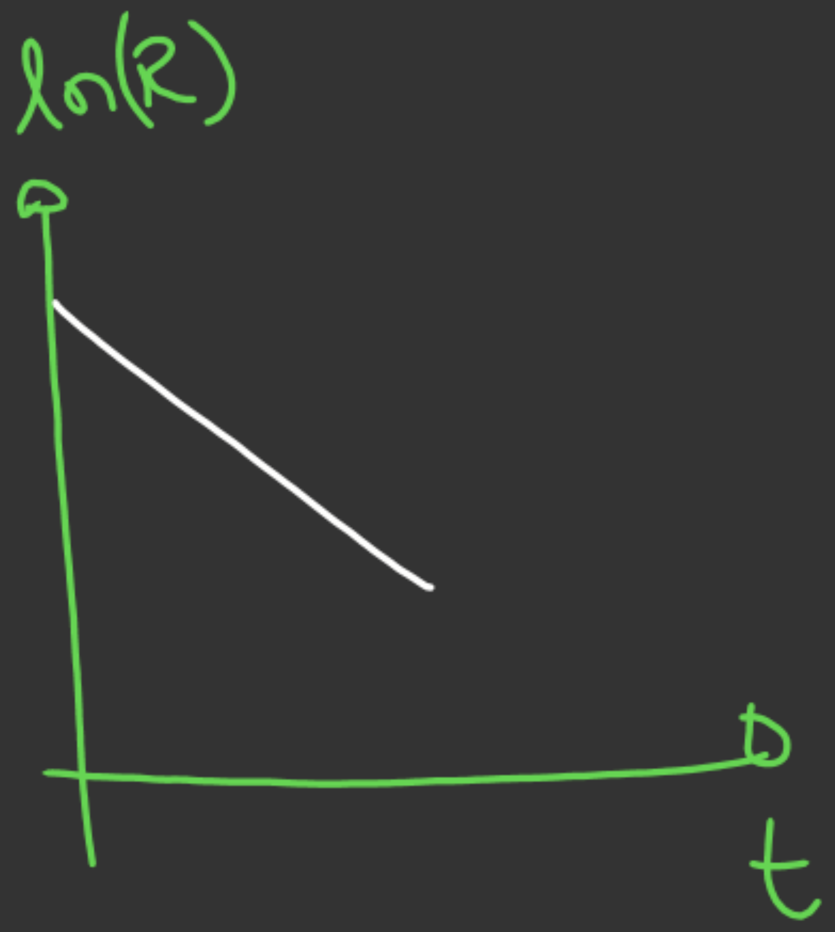
$$R = \boxed{\left(-\frac{d\theta}{dt}\right) = K(\theta - \theta_0)}$$ Newton

Rate of Cooling

$$\boxed{R \propto (\theta - \theta_0)}$$







$$\frac{\theta_1 - \theta_2}{t} = K\left[\frac{\theta_1+\theta_2}{2} - \theta_0\right]$$

Q.

$$\frac{70-60}{5} = K\left[\frac{70+60}{2} - 25\right]$$

$$\frac{60-50}{t} = K\left[\frac{60+50}{2} - 25\right]$$

$$\frac{\cancel{10}}{5} = \cancel{K}(4\cancel{0})$$

$$\frac{\cancel{10}}{t} = \cancel{K}(3\cancel{0})$$

$$\frac{t}{5} = \frac{4}{3}$$

$$\boxed{t = \frac{20}{3} \text{ min}}$$

Q.

$$\frac{60-50}{10} = K\left[\frac{60+50}{2} - 25\right]$$

$$\frac{50-\theta}{10} = K\left[\frac{50+\theta}{2} - 25\right]$$

$$\frac{\cancel{10}}{\cancel{10}} = K(30)$$

$$\frac{50-\theta}{10} = K\left(\frac{\theta}{2}\right)$$

$$\frac{50-\theta}{1\cancel{0}} = \frac{1}{3\cancel{0}}\left(\frac{\theta}{2}\right)$$

$$300 - 6\theta = \theta$$

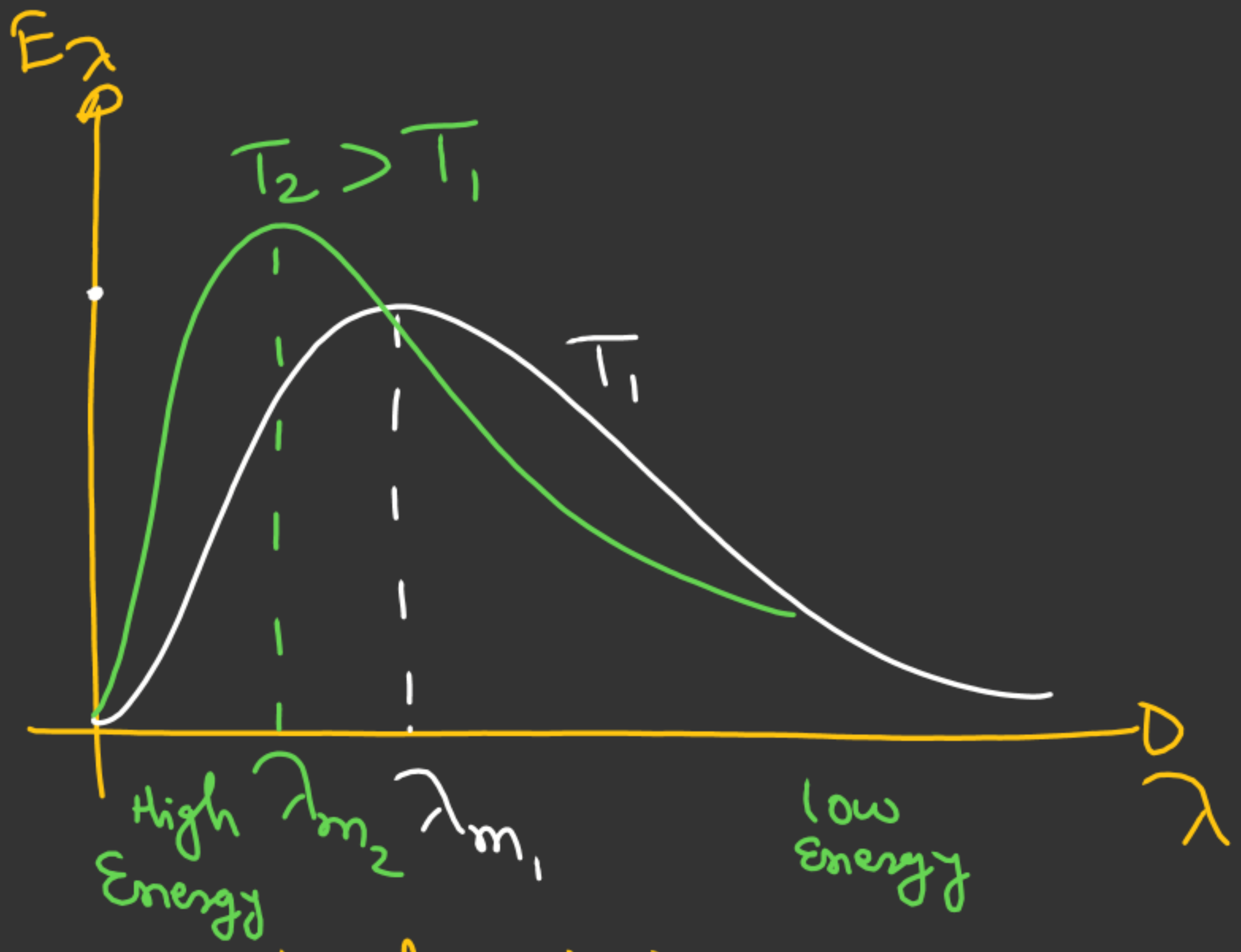
$$\theta = \frac{300^\circ}{7} = \underline{\underline{43^\circ C}}$$

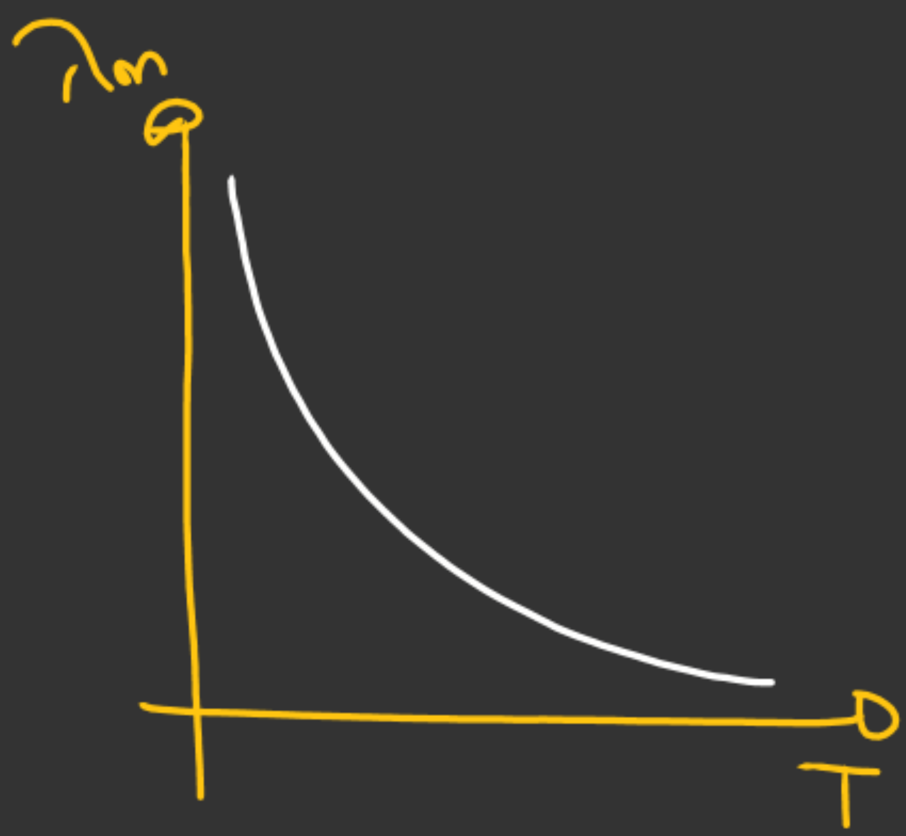
Wein's Displacement Law

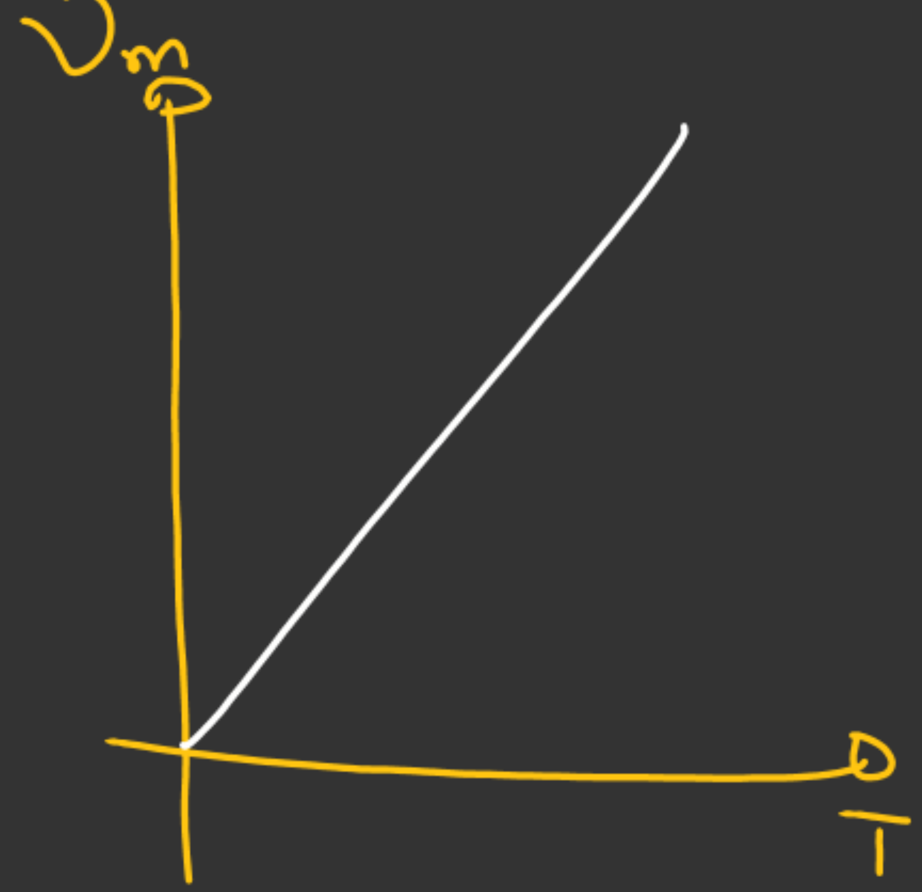
$$\boxed{\lambda_m T = b}$$

Wein's Const. $b = 2.89 \times 10^{-3}$ m-K

$\lambda_m \propto \frac{1}{T}$ $\qquad$ $\nu_m \propto T$







E_λ = Spectral emissive power

$\lambda_m =$

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

(1) $\lambda_{m_1} T_1 = \lambda_{m_2} T_2$

(2) Area of curve $= E = \sigma A T^4$

(3) $$\frac{(\text{Area of curve})_2}{(\text{—— " ——})_1} = \frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4 = \left(\frac{\lambda_{m_1}}{\lambda_{m_2}}\right)^4$$

Iron Rod

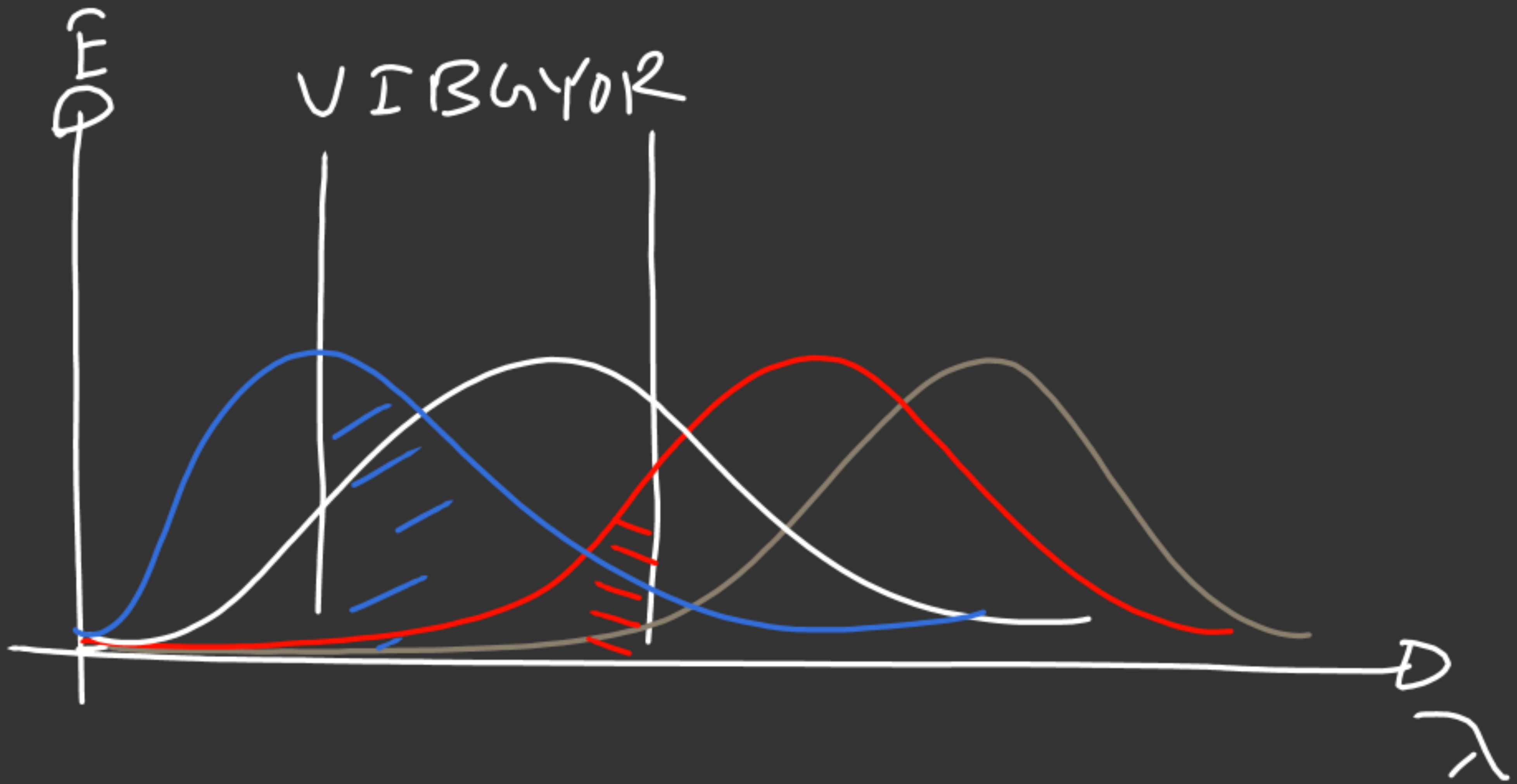
R.T. Reflection

Red Hot 1100°c

Yellow

White Hot

Blue Hot



$T_{Blue} > T_{white} > T_{Red}$

Q. $\lambda_{m_1} T_1 = \lambda_{m_2} T_2$

$(9000)(300) = (6000)\, T_2$

$T_2 = 450\,K$

$\underline{-273}$

$\underline{\underline{177^\circ C}}$

Q. $\dfrac{E_2}{E_1} = \left(\dfrac{T_2}{T_1}\right)^4 = \left(\dfrac{\lambda_1}{\lambda_2}\right)^4$

$\dfrac{E_2}{32} = \left(\dfrac{\lambda_0}{2\lambda_0}\right)^4 = \dfrac{1}{16}$

$E_2 = \dfrac{32}{16} = \underline{\underline{2W}}$