Topics to be covered

1) Thermometry
2) Calorimetry
3) Thermal Expansion
4) Heat Transfer

Thermometry

Measurement of Temperature.

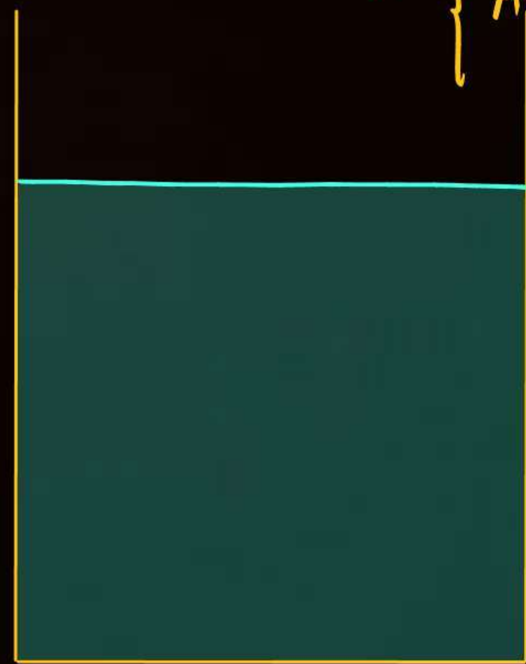
fundamental physical Qty

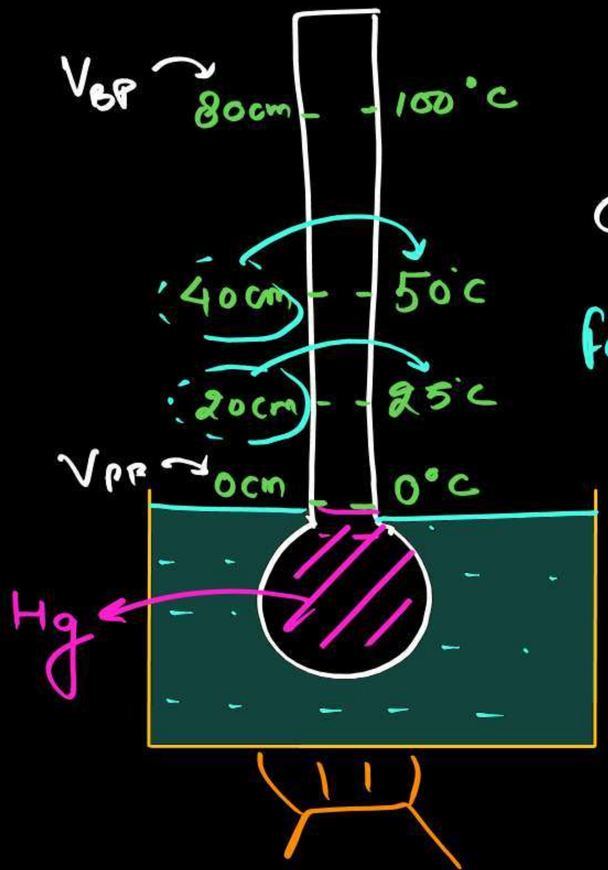
Degree of Hotness

{Avg. K.E of molecules}

Phy. Qty. that vary with temp.

- Volume
- Pressure of gas at Const vol. $\left\{ \begin{array}{l} PV = nRT \\ \Rightarrow P \propto T \end{array} \right\}$
- Density
- Electrical Resistance
- Thermal Radiation





$V_{f.p.} \longleftrightarrow V \qquad V_{B.P}$

f.P $\qquad$ B.P.

Celcius: $0°c \longleftrightarrow C \qquad 100°c$ (100)

fahrenheit: $32°f \longleftrightarrow f \qquad 212°f$ (180)

chota

kelvin: $273k \longleftrightarrow k \qquad 373k$

bada

100

$T_{FP} \longleftrightarrow T \qquad T_{BP}$

fP = freezing pt. of water

BP = Boiling pt. of water.

** Brahmastra

$$\frac{V - V_{fP}}{V_{BP} - V_{fP}} = \frac{c - 0}{100 - 0} = \frac{f - 32}{212 - 32} = \frac{k - 273}{373 - 273} = \frac{T - T_{fP}}{T_{BP} - T_{fP}}$$

$$\frac{C}{100} = \frac{F-32}{180}$$

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

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

$$\Delta C = \frac{5}{9} \times 45 = \boxed{25^\circ C}$$

1) Convert $41^\circ F$ into $^\circ C$

$$C = \frac{5}{9}(41-32)$$

$$= \frac{5}{9} \times 9 = 5^\circ C.$$

ΔT

2) Temp. of body rises by $45^\circ F$.

What is the temp. change in $^\circ C$?

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

$$C + \Delta C = \frac{5}{9}(F+45-32)$$

$$=$$

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

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

$$\boxed{\Delta C = \Delta K}$$

QUESTION

(1) Convert 50°C into Fahrenheit.

(2) At what temp, Fahrenheit scale & Celsius scale will give same reading.

(3) A body is heated such that its temp. rises from 20° C to 50° C. Find the temp. change of body in Fahrenheits.

1) $\frac{C-0}{100-0} = \frac{F-32}{212-32}$

$\frac{\cancel{50}}{\cancel{100}_{\cancel{2}}} = \frac{F-32}{1\cancel{80}_{90}} \Rightarrow F = 90+32$

$F = 122°F$

2) $\frac{C-0}{100-0} = \frac{C-32}{212-32}$

$\Rightarrow \frac{C}{100} = \frac{C-32}{180}$

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

$\left(\frac{9}{5}-1\right)C = -32$

$C = -40°F$

3) $\Delta C = 30°C$

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

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

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

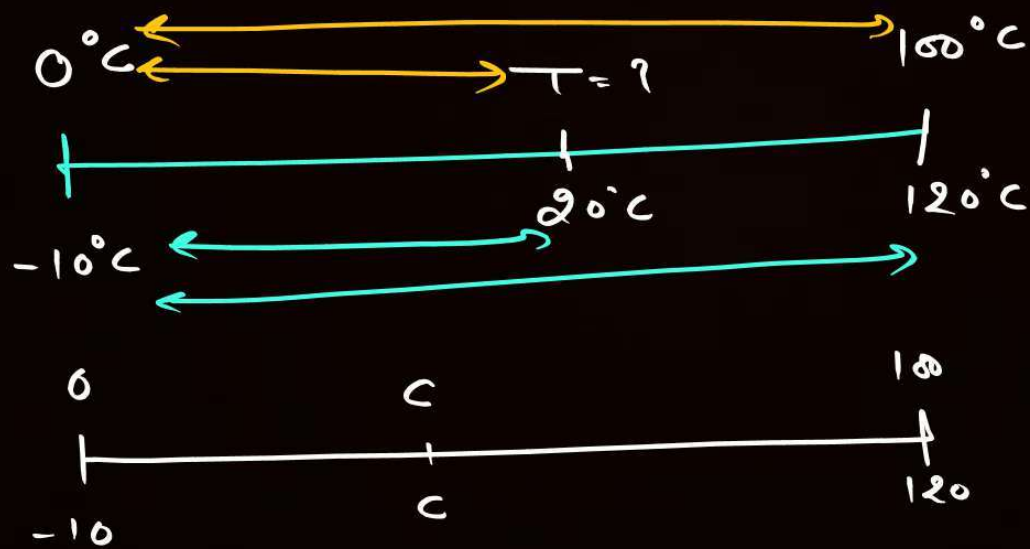
$\cancel{30}^{6} = \frac{\cancel{5}}{9}\Delta F \Rightarrow \Delta F = 54°F$

Ans.

QUESTION

Custom scale.

A faulty thermometer reads –10°C at freezing pt. of water & 120° C at boiling point of water when the thermometer roads 20°C what is the actual temp. of body? At what temp. will the thermometer give correct reading? $\rightarrow C = \frac{100}{3}°C$



$$\frac{T-0}{100-0} = \frac{20-(-10)}{120-(-10)}$$

$$T = \frac{100}{130} \times 30$$

$$T = \frac{300}{13}°C \text{ Ans.}$$

$$\frac{C}{100} = \frac{C-(-10)}{130} \Rightarrow C = \frac{10}{13}(C+10)$$

$$\frac{13C}{10} = C+10$$

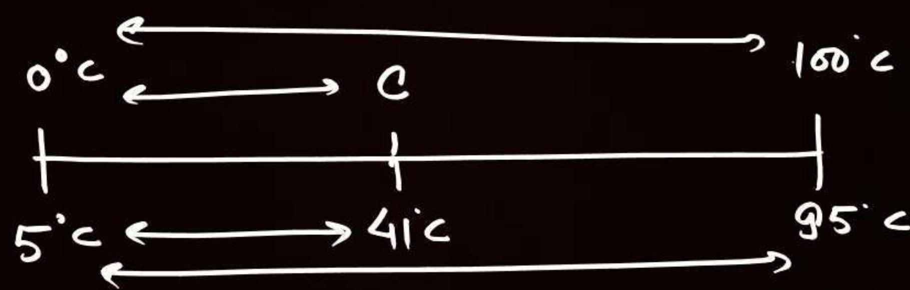
$$\frac{3C}{10} = 10$$

QUESTION (JEE Mains – Jan. 30, 2023 (II))

A faulty thermometer reads 5°C in melting ice and 95°C in steam. The correct temperature on absolute scale will be ______ K when the faulty thermometer reads 41°C.

kelvin

$$\frac{41-5}{95-5} = \frac{C-0}{100-0}$$

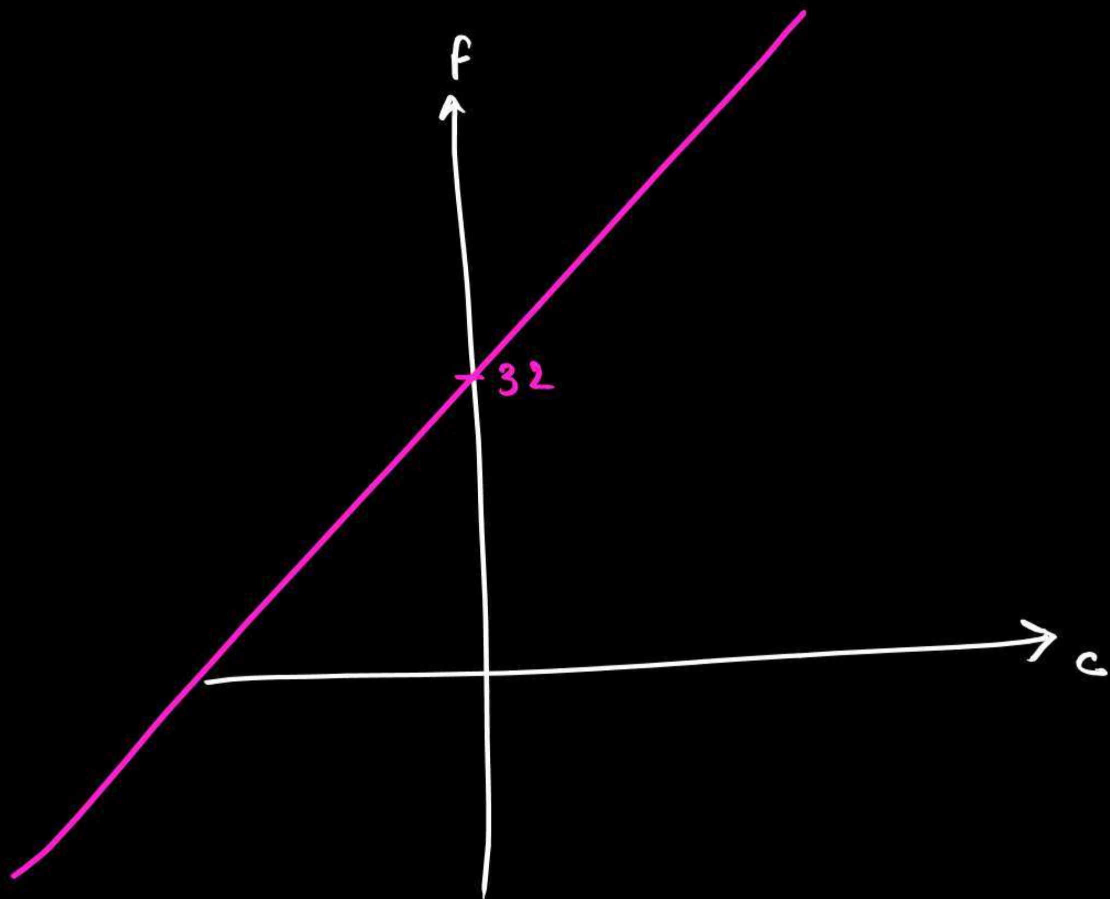


$$C = \frac{\cancel{36}\,4}{\cancel{90}\,9} \times 10\cancel{0}$$

$$C = 40°C$$

$$K = 273 + 40$$

$$K = 313\ K$$ Ans



$$C = \frac{5}{9}(f - 32)$$

$$f = \frac{9}{5}C + 32$$

$$\begin{array}{ccc} f & & C \\ \downarrow & & \downarrow \\ y & & x \end{array}$$

$$y = \frac{9}{5}x + 32$$

QUESTION (JEE Mains – Jan. 25, 2023 (II)

The graph between two temperature scales P and Q is shown in the figure. Between upper fixed point and lower fixed point there are 150 equal divisions of scale P and 100 divisions on scale Q. The relationship for conversion between the two scales is given by:

(A) $\frac{t_Q}{150} = \frac{t_P - 180}{100}$

(B) $\frac{t_Q}{100} = \frac{t_P - 30}{150}$

(C) $\frac{t_Q}{180} = \frac{t_Q - 40}{100}$

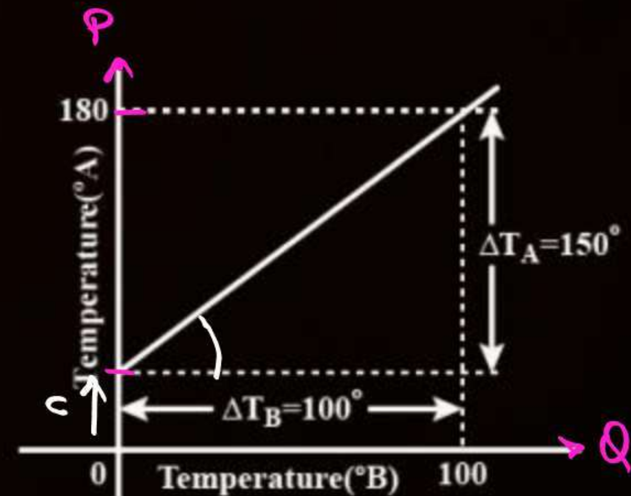
(D) $\frac{t_P}{100} = \frac{t_Q - 180}{150}$

$y = mx + c$

$P = \frac{150}{100} \times Q + 30$

$P - 30 = \frac{150}{100} Q$

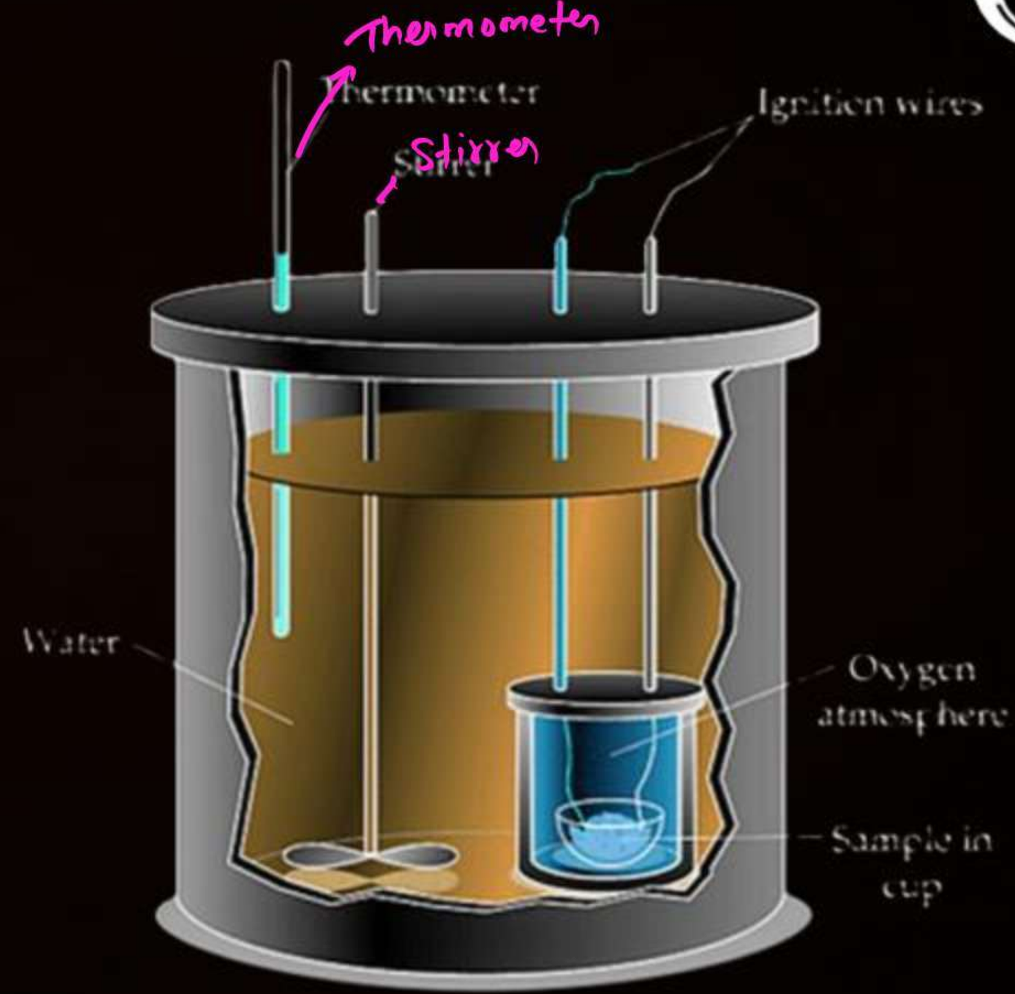
$\frac{Q}{100} = \frac{P - 30}{150}$



Calorimetry

↓

Study of heat exchanged b/w different materials due to temp. difference



Specific Heat Capacity

mass	ΔT	Q
$1\,g$	$1^\circ C$	S cal.
$m\,g$	$1^\circ C$	ms
$m\,g$	$\Delta T^\circ C$	$ms\Delta T$

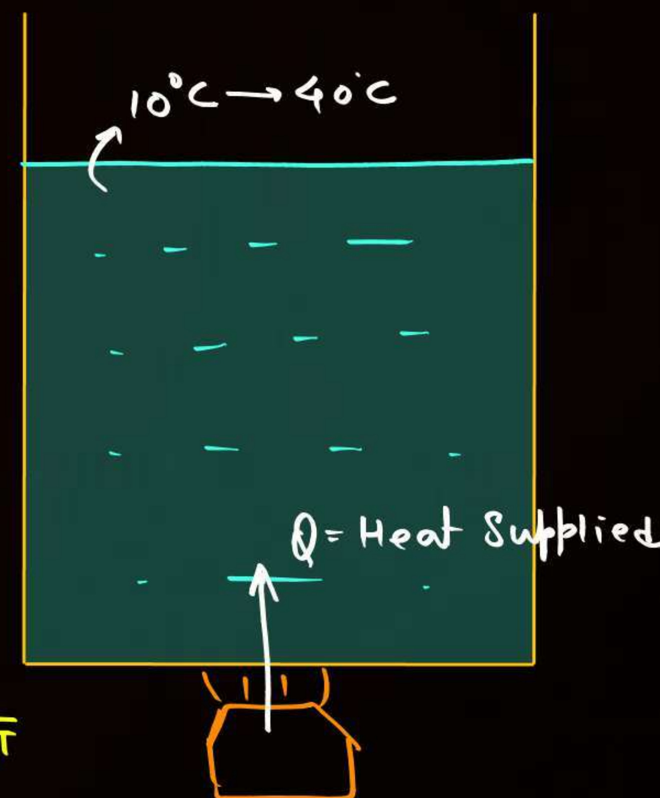
$S \rightarrow$ Sp. Heat Capacity

$$Q = ms\Delta T$$

$$S = \frac{Q_{\times 2}}{2 \times m\Delta T}$$

$\cancel{S \propto \frac{1}{m}}$

$\cancel{S \propto \frac{1}{\Delta T}}$



$1\,cal = 4.2\,J$

- Sp. Heat capacity is the property of material only, it does not depend on mass & temp. change of body.

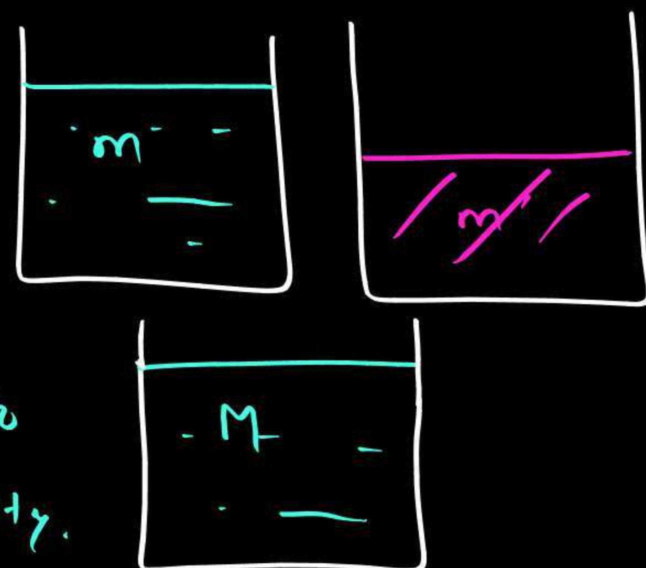
very High

- $S_{water} = 1\ cal/g°c$ — 4200 J/kg.k

$S_{Ice} = \frac{1}{2}\ cal/g°c$

$S_{steam} = \frac{1}{2}\ cal/g°c$

- Sp. Heat cap. is the heat req. to raise temp. of unit mass by unity.



High Sp. Heat cap. $\rightarrow$ गरम करने में ज्यादा Heat लगेगी $\longrightarrow$ गरम करना मुश्किल $\longrightarrow$ Better Coolant

Heat Capacity

⇒ Heat required to raise temp. of any mass by unity.

$$Q = \underbrace{ms}\Delta T$$

$$Q = C\Delta T$$

$$C = ms$$

Unit : J/K or Cal/°C

$$C \propto m$$

$1g \longrightarrow 1°C \longrightarrow s$

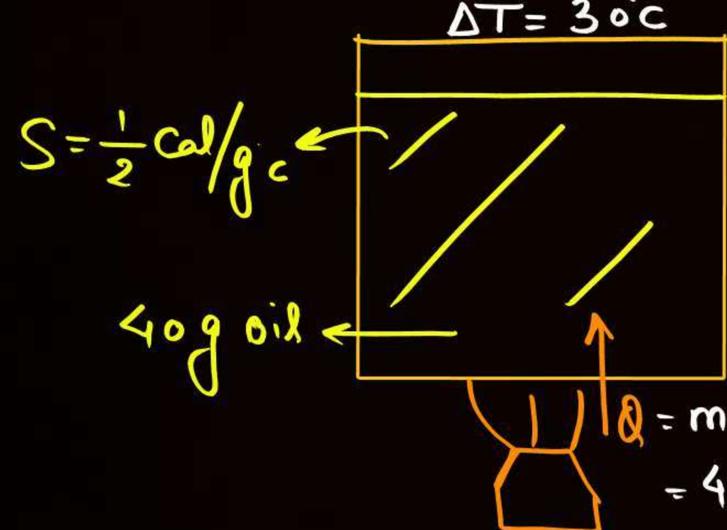
$mg \longrightarrow 1°C \longrightarrow ms = C$

$mg \longrightarrow \Delta T \longrightarrow ms\Delta T$

Water Equivalent

Amount of water which is thermally equivalent to given material.

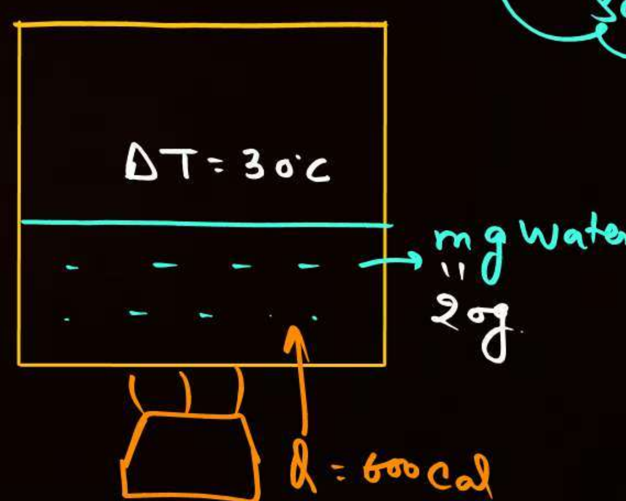
Same Heat देने पर
Same temp. change.



$Q = ms\Delta T$

$= 40 \times \frac{1}{2} \times 30$

$Q = 600\ \text{cal}$



$Q = ms\Delta T$

$600 = m \times 1 \times 30$

$m = 20\ \text{g}$

$$Q = ms\Delta T$$

$$m_w \cdot s_w \cancel{\Delta T} = ms\cancel{\Delta T}$$

Water equivalent $\longrightarrow$ $\boxed{m_w = ms}$

SI unit : kg

CGS unit : g

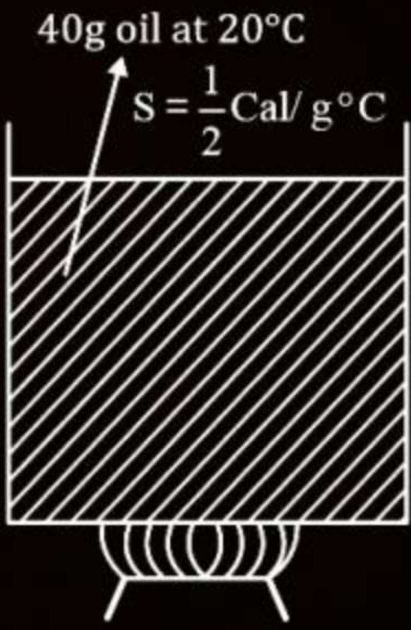
QUESTION

Find heat req to raise temp. of oil to 50°.

$$Q = ms\Delta T$$

$$= 40 \times \frac{1}{2} \times 30$$

$$\boxed{Q = 600\ \text{cal}}$$



QUESTION

1000g

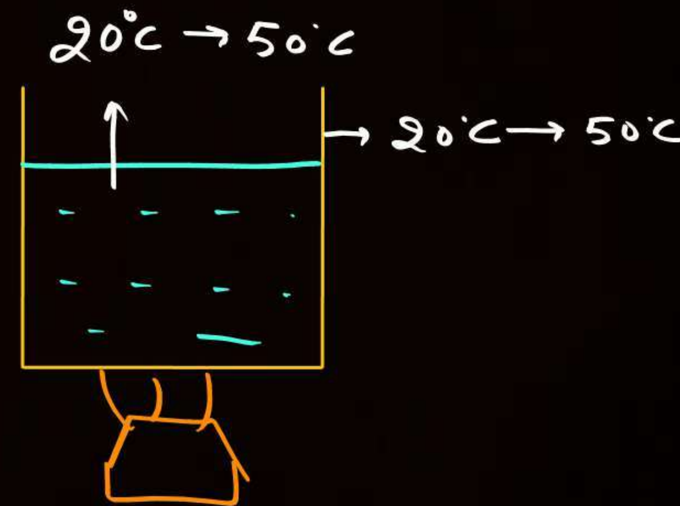
A container of mass 1 kg contains 40 g oil at 20° C. If the sp. Heat cap. of oil is 1/2 cal/g° c. Find the heat req to raise temp. of oil to 50°C ($S_{container}$ = 0.1 cal/g° C)

$$Q = m_1 s_1 \Delta T + m_2 s_2 \Delta T$$

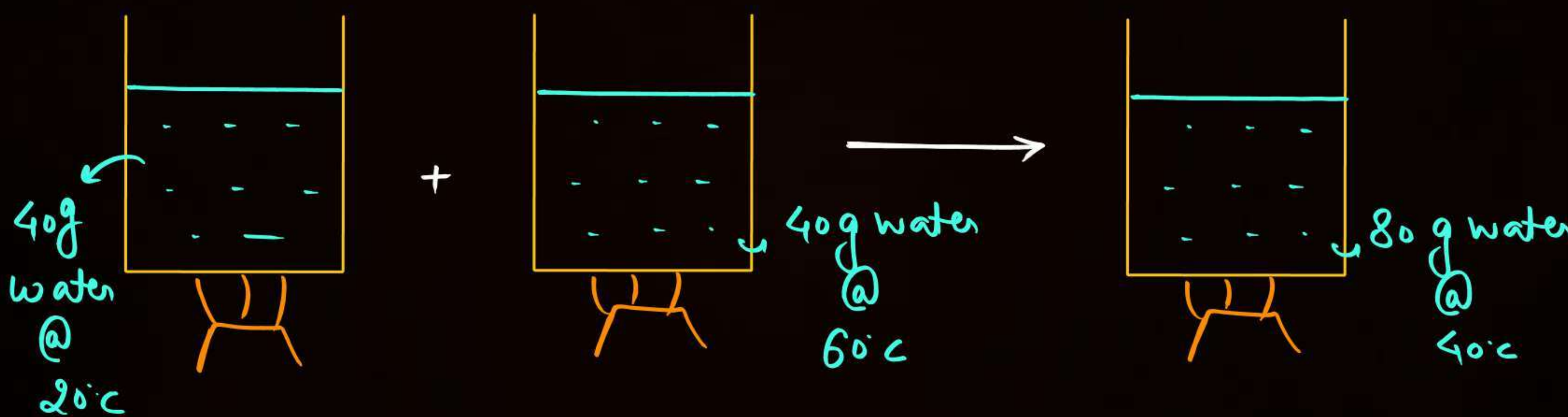
$$= 40 \times \frac{1}{2} \times 30 + 1000 \times 0.1 \times 3\cancel{0}$$

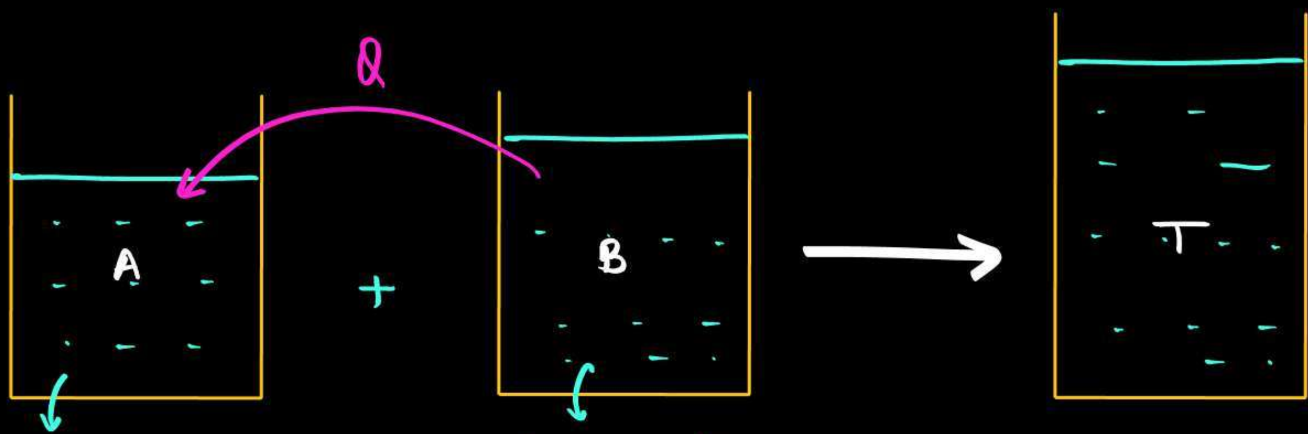
$$= 600 + 3000$$

$$= 3600 \text{ cal}$$



Mixture of Liquids at Different Temperatures





40g water @ 20°C

60g water @ 60°C

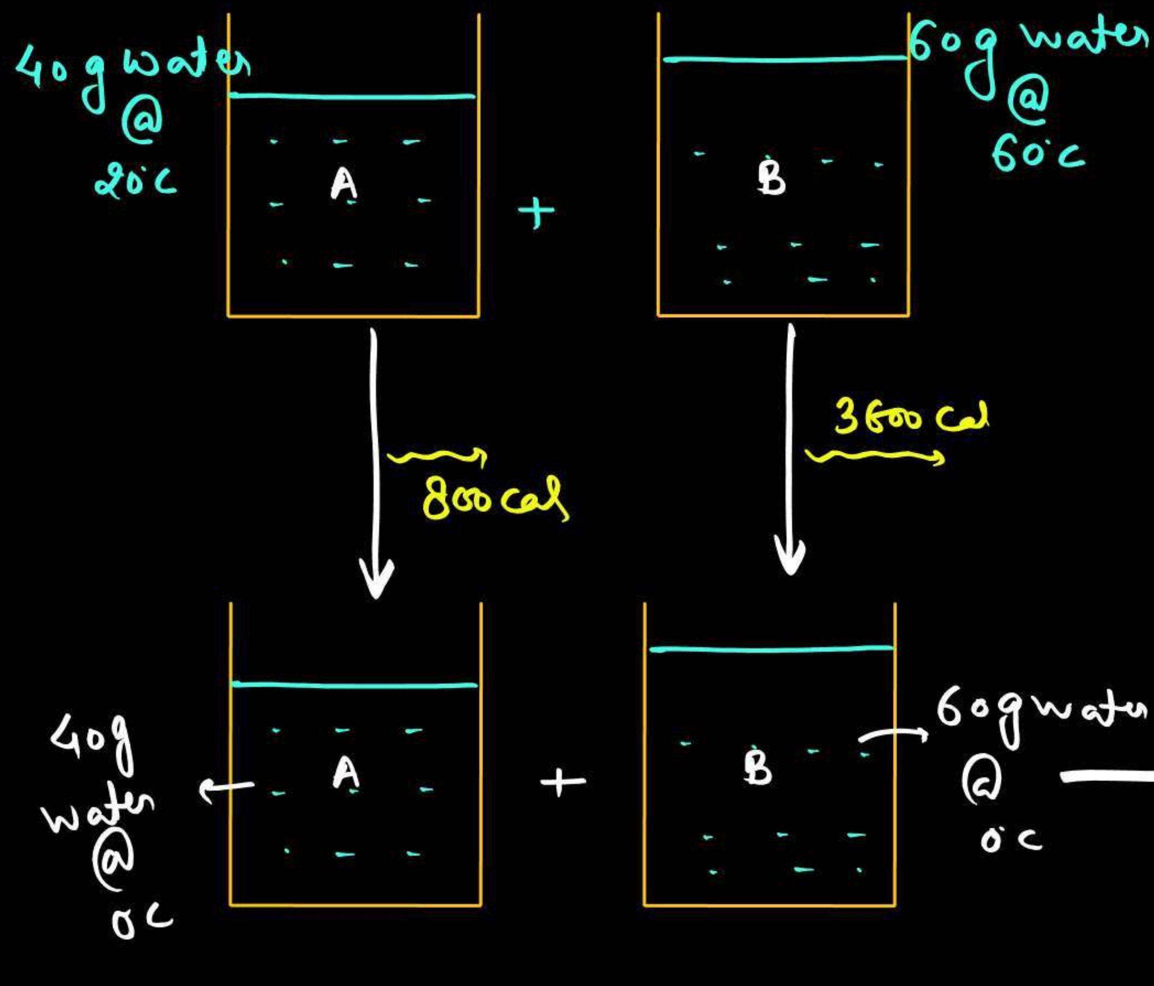
Aam Zindagi

Heat lost by B = Heat gained by A

$$60 \times 1 \times (60 - T) = 40 \times 1 \times (T - 20) \Rightarrow 3600 - 60T = 40T - 800$$

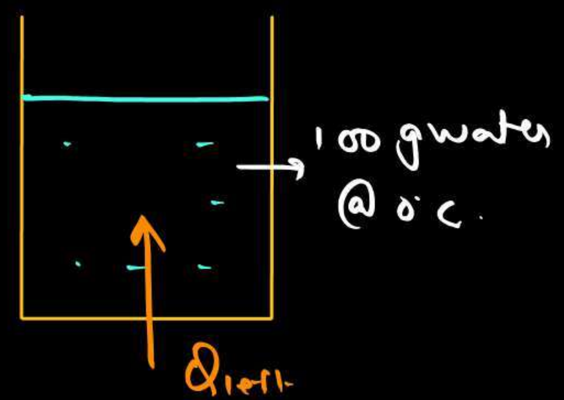
$$100T = 4400$$

$$T = 44^\circ C$$



$$Q_{left} = 40\times1\times20 + 60\times1\times60$$
$$= 800 + 3600$$
$$= 4400\text{ cal}$$

$$4400 = 100\times1\times(T-0)$$
$$T = 44^\circ C$$



Brahmastra - 2

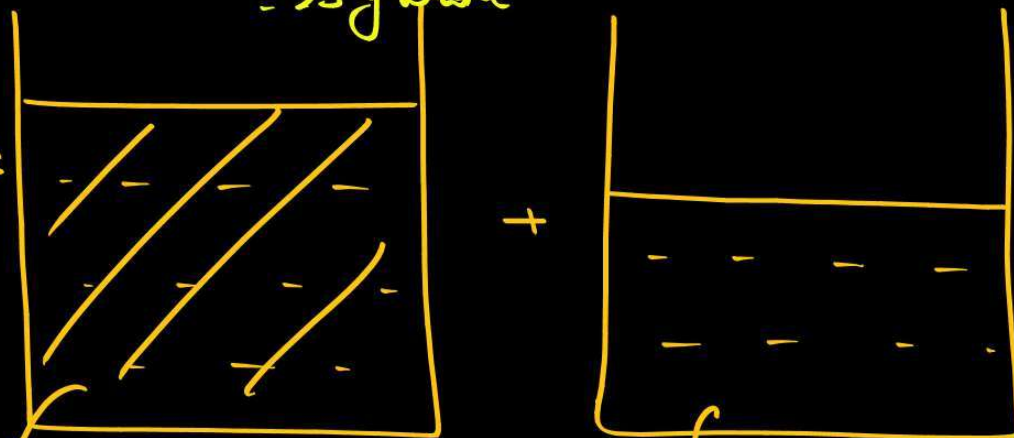
- $\boxed{\text{Convert Everything into } 0^\circ C \text{ water equivalent.}}$
- Find Q_{left}.
- Give back Q_{left} to entire water equivalent.

$$Q_{left} = m_{total} \times 1 \times (T - 0)$$

$m_w = mS = 100 \times \frac{1}{4}$

$= 25$ g water

$S_{oil} = \frac{1}{4}$ cal/g°C



100 g oil at 80°C

↓

$100 \times \frac{1}{4} = 25$ g water @ 80

↓

25 g water @ 0°C.

50 g water @ 10°C

↓

50 g water @ 0°C

$Q_{left} = 25 \times 80 + 50 \times 10$

$= 2000 + 500$

$= 2500$ cal.

$M_{total} = 25 + 50$

$= 75$ g water.

$Q_{left} = M_{total} \cdot S \cdot \Delta T$

$2500 = 75 \times 1 \times T$

$T = \frac{\cancel{2500}\ 100}{\cancel{75}\ 3} = \frac{100}{3}$ °C

QUESTION

Find final temperature if 130 grams water at 10°C is added to 60 grams liquid at 80°C kept in the shown container.

$$Q_{left} = 130\times1\times10 + 20\times1\times80 + 50\times1\times80$$

$$= 1300 + 1600 + 4000$$

$$= 6900 \text{ cal.}$$

$$m_{total} = 130 + 20 + 50 = 200 \text{ g}$$

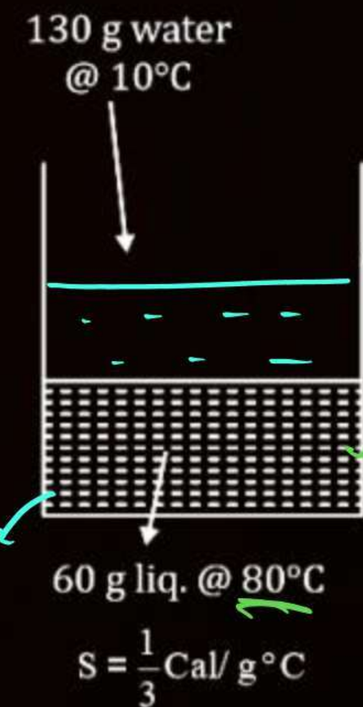
$$Q_{left} = m_{total} \cdot S \cdot \Delta T$$

$$6\cancel{900} = 2\cancel{00}\times1\times(T-0)$$

$$T = \frac{69}{2} = 34.5°C \text{ Ans.}$$

$m_W = 60\times\frac{1}{3}$

$= 20 \text{ g}$



Actual mass of container

50 g water.

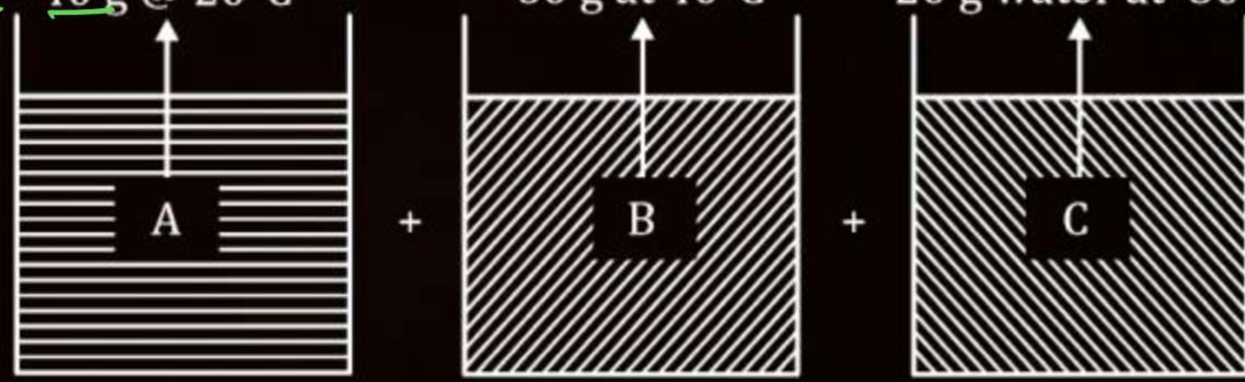
water equivalent

QUESTION

Find final temp. of mixture.

10g water@20°c   20g water@40°c

40 g @ 20°C   60 g at 40°C   20 g water at 80°C



$S_A = \frac{1}{4} Cal/g°C$ $S_B = \frac{1}{3} Cal/g°C$

$$\frac{10\times 20+20\times 40+20\times 80}{10+20+20}$$

$$\frac{200+800+1600}{50}$$

$$\frac{26\cancel{00}}{5\cancel{0}} = 52°C$$

Ans

$$T_f = \frac{m_1 S_1 T_1 + m_2 S_2 T_2 + \ldots}{m_1 S_1 + m_2 S_2 + \ldots}$$

मत याद करना

Equivalent Heat Capacity of Mixtures

$$S_{eq} = \frac{m_1 S_1 + m_2 S_2 + \ldots}{m_1 + m_2 + \ldots}$$

Latent Heat

Latent Heat of fusion

Solid $\longrightarrow$ Liquid

mass

1 g $\longrightarrow L_f$

m g $\longrightarrow m L_f$

$Q = m L_f$

L_f for water $= 80$ cal/g.

Latent Heat of Vaporization.

Liquid $\longrightarrow$ Gas

1 g $\longrightarrow L_v$

m g $\longrightarrow Q = m L_v$

L_v for water $= 540$ cal/g.

QUESTION

Find heat req to raise temp. of 20 g ice at –10°C to 140°C.

$$\text{20 g ice @ } -10^\circ C \longrightarrow \text{20 g ice @ } 0^\circ C \longrightarrow \text{20 g water @ } 0^\circ C \longrightarrow \text{20 g water @ } 100^\circ C \longrightarrow \text{20 g steam @ } 100^\circ C \longrightarrow \text{20 g steam @ } 140^\circ C$$

$Q_1 = ms\Delta T = 20 \times \frac{1}{2} \times 10 = 100\,cal$

$Q_2 = mL_f = 20 \times 80 = 1600\,cal$

$Q_3 = ms\Delta T = 20 \times 1 \times 100 = 2000\,cal$

$Q_4 = mL_v = 20 \times 540 = 10{,}800\,cal$

$Q_5 = ms\Delta T = 20 \times \frac{1}{2} \times 40 = 400\,cal$

$$Q_{total} = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 = 14{,}900\,cal$$

Temp. of water does not change until entire ice is melted.

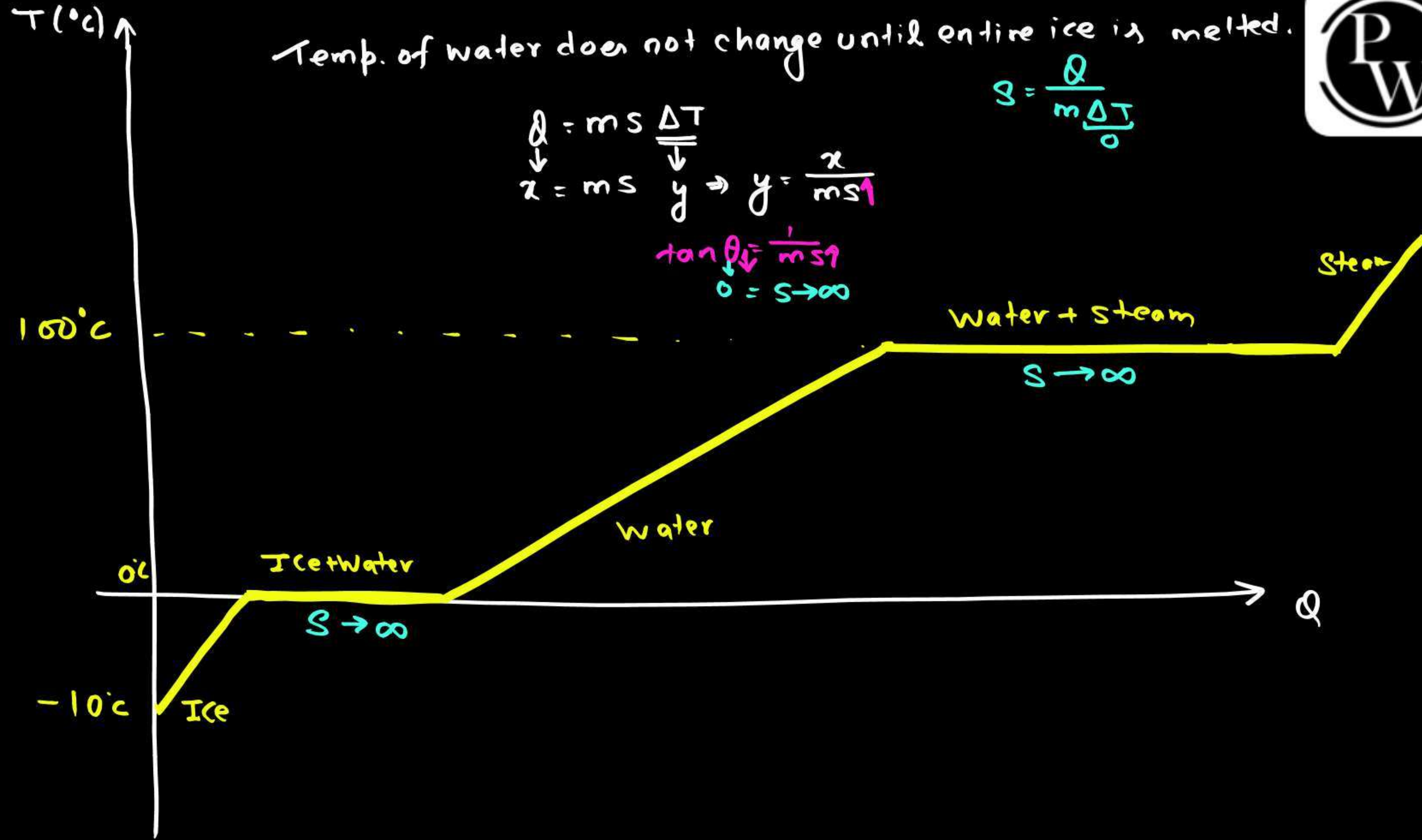
$$s = \frac{Q}{m\underbrace{\Delta T}_{0}}$$

$$\underset{\downarrow}{Q} = ms\,\underset{\downarrow}{\Delta T}$$

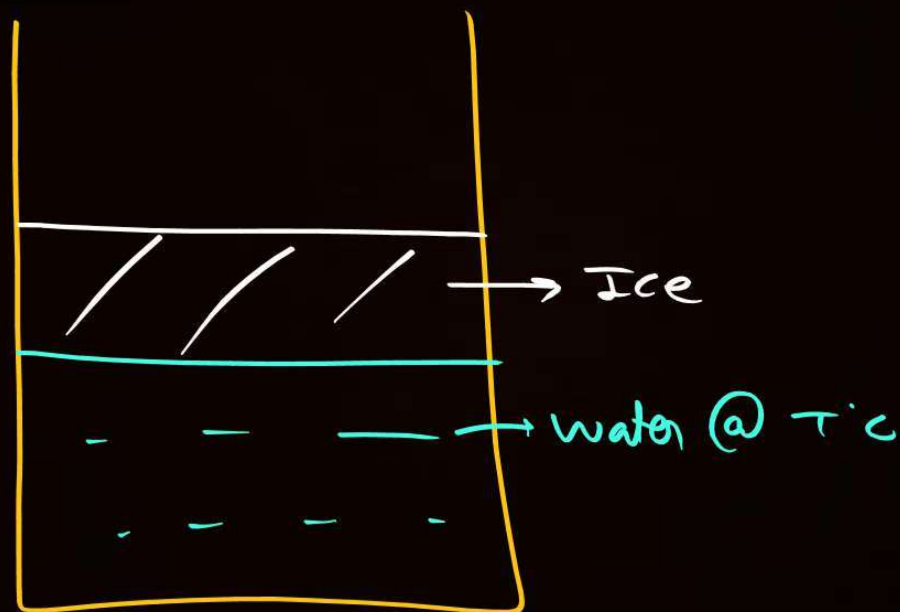
$$x = ms\,y \Rightarrow y = \frac{x}{ms\uparrow}$$

$$\tan\theta\downarrow = \frac{1}{ms\uparrow}$$

$$\theta = 0 \quad s \to \infty$$



Ice Water Mixture



no. of friends = 20

Cost of one ticket = 80/-

Total money required = $20 \times 80 = 1600/-$

Papa ने रुपये दिये = 1,600/-

कितने दोस्त picture देखेंगे = 20

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no. of friends = 20

Cost of one ticket = 80/-

Total money required = $20 \times 80 = 1600/-$

Papa ने रुपये दिये = 800/-

कितने रुपये कम पड़े = $1600 - 800 = 800/-$

कितने दोस्त picture नहीं देख पायेंगे = $\frac{800}{80} = 10$

कितने दोस्त picture देखेंगे = $\frac{800}{80} = 10$

or $20 - 10 = 10$

no. of friends = 20

Cost of one ticket = 80/-

Total money required = $20 \times 80 = 1600/-$

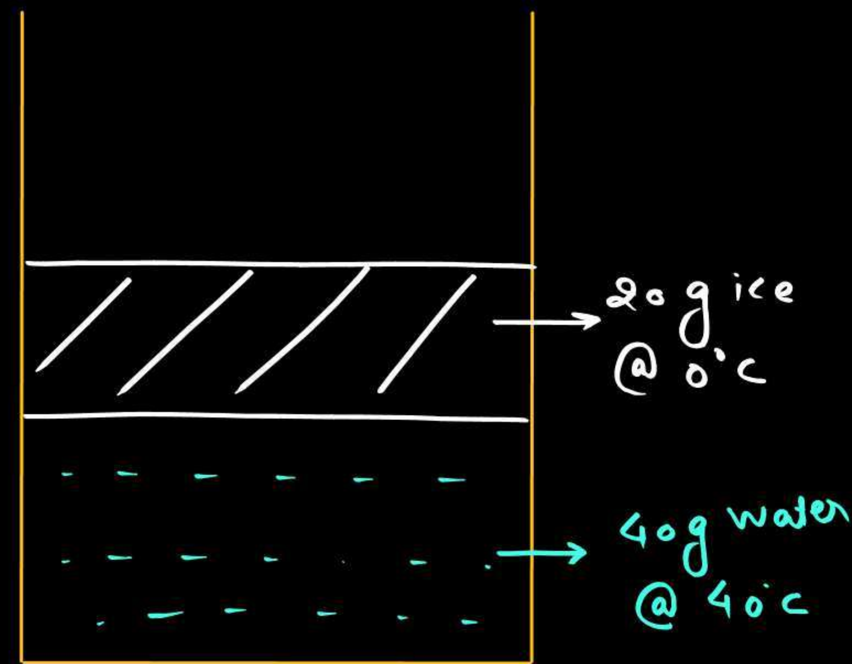
Papa ने रुपये दिये = 2000/-

कितने रुपये extra मिले = 2000/- − 1600 = 400/-

कितने दोस्त picture देखेंगे = 20

party के लिये extra रुपये = 400/-

⇒ Convert everything into 0°c water equivalent.



$$Q_{left} = 40\times1\times40 - 20\times80$$

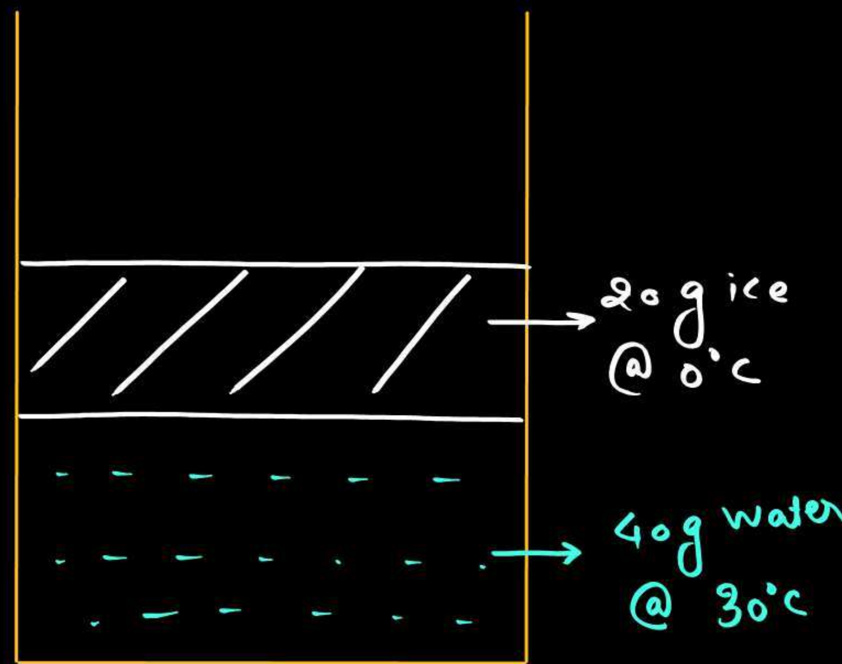
$$= 1600 - 1600$$

$$Q_{left} = 0 \text{ cal}$$

Entire ice has just melted.

$$T_{final} = 0\,°c.$$

⇒ Convert everything into 0°c water equivalent.



$$Q_{left} = 40 \times 1 \times 30 - 20 \times 80$$

$$= 1200 - 1600$$

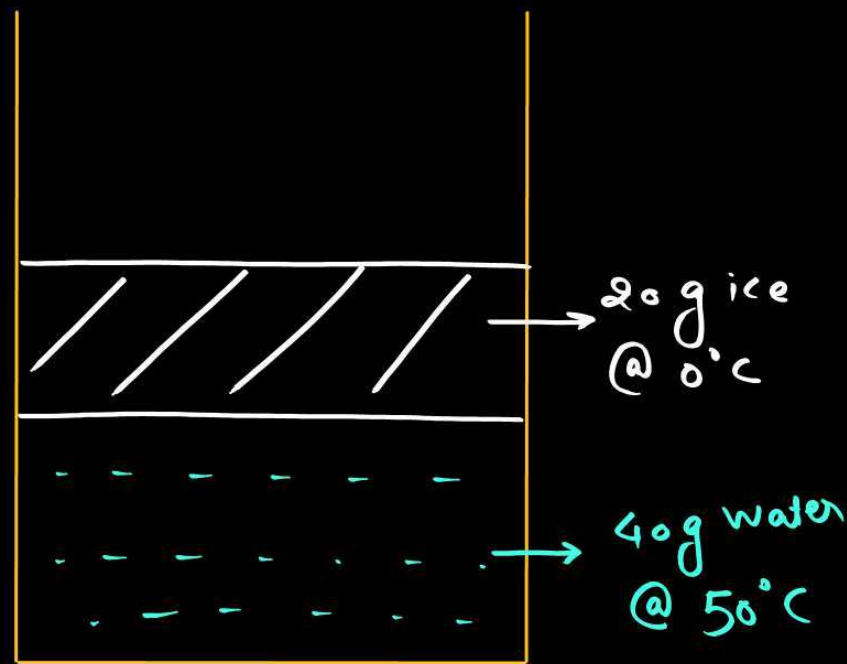
$$Q_{left} = -400\ cal$$ 400 रुपये कम पड़ गये

$$\text{Amt. of ice left} = \frac{400}{80} = 5g$$

$$\text{Amt. of water} = 15 + 40 = 55g$$

$$T_{final} = 0°c$$

⇒ Convert everything into 0°C water equivalent.



$Q_{left} = 40 \times 1 \times 50 - 20 \times 80$

$= 2000 - 1600$

$Q_{left} = 400$ cal.

Entire ice has melted.

$m_{ice} = 0$

$m_{water} = 40 + 20 = 60g$

$Q_{left} = m_{total} \cdot s \Delta T$

$400 = 60 \times 1 \times (T - 0)$

$T = \frac{400}{60} = \frac{20}{3}$ °C

QUESTION

Find final temperature and composition.

$$Q_{left} = 30\times60 - 20\times\frac{1}{2}\times20 - 20\times80$$

$$= 1800 - 200 - 1600$$

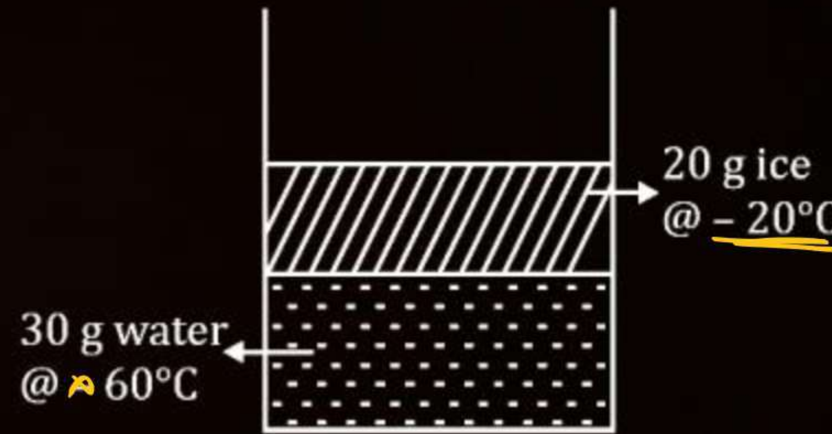
$$= 0$$

Entire ice just melts.

$m_{ice} = 0$

$m_{water} = 50g$

$T_{final} = 0^\circ C$



QUESTION

Find final temperature & composition.

$$Q_{left} = 40\times 50 - 20\times\frac{1}{2}\times 10 - 20\times 80$$

$$= 2000 - 100 - 1600$$

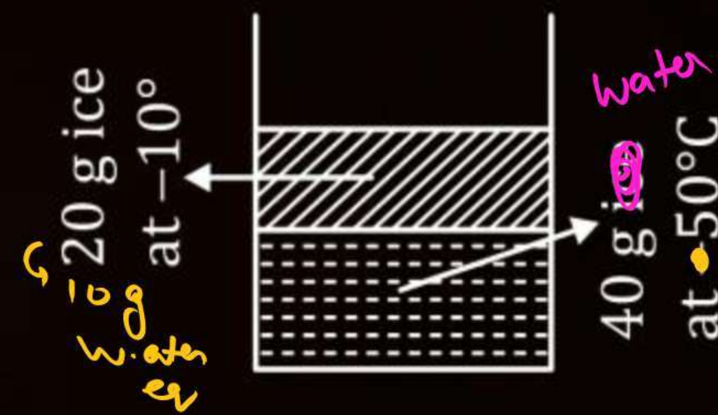
$$= 300\ \text{cal}$$

Entire ice melts.

$$Q_{left} = m_{total}\cdot s\cdot \Delta T$$

$$300 = 60\times 1\times T$$

$$\boxed{T = 5^\circ C}\ \text{Ans.}$$



Ice Steam Mixture

Use same Brahmastra

QUESTION

$L_v = 540\ \text{cal/g}$

Find min. amount of steam required to completely melt the entire ice.

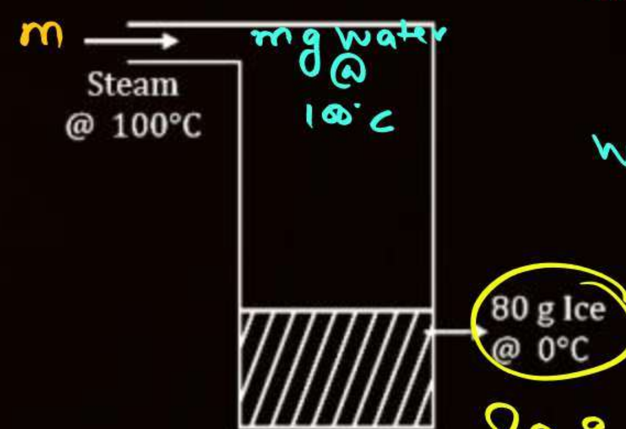
Steam @ 100°C
↓
Water @ 100°C
↓
Water @ 0°C

$$Q_{left} = m \times 540 - 80 \times 80$$

→ Common mistake

$$0 = m \times 540 - 6400$$

$$m = \frac{6400}{540} = \frac{640}{54}\ g$$



80 g ice @ 0°C.

$$Q_{left} = m \times 540 + m \times 1 \times 100 - 80 \times 80$$

$$0 = m \times 640 - 6400 \quad m = 10\ g$$

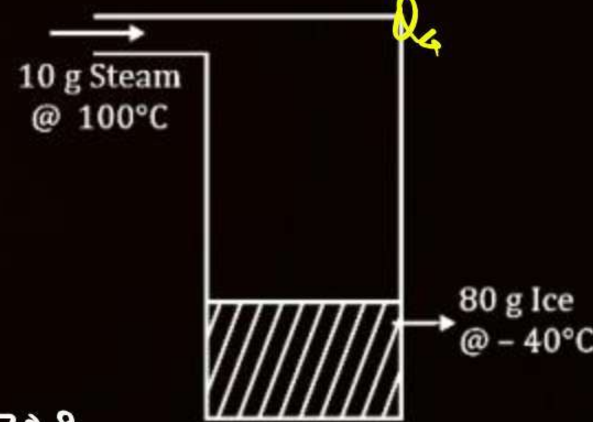
1 g steam @ $100^\circ c$ can completely melt 8 g ice @ $0^\circ c$.

QUESTION

Find final temp. & composition.

$$\text{Steam @ } 100^\circ C \xrightarrow[Q_1]{} \text{Water @ } 100^\circ C \xrightarrow[Q_2]{} \text{Water @ } 0^\circ C$$

$$\text{Water @ } 0^\circ C \xleftarrow[Q_4]{} \text{Ice @ } 0^\circ C \xleftarrow[Q_3]{} \text{Ice @ } -40^\circ$$



$$Q_{left} = \overbrace{10\times 540}^{Q_1} + \overbrace{10\times1\times100}^{Q_2} - \overbrace{80\times\frac{1}{2}\times 40}^{Q_3} - \overbrace{80\times 80}^{Q_4}$$

$$= \cancel{10\times 640} - 1600 - \cancel{6400}$$

$Q_{left} = -1600$ cal | $T_{final} = 0^\circ C$

$$m_{ice} = \frac{160\cancel{0}}{8\cancel{0}}$$

$m_{ice} = 20g$

$m_{water} = 90 - 20 = 70g$

QUESTION (JEE Mains – Sep. 03, 2020 (II))

A calorimter of water equivalent 20 g contains 180 g of water at 25°C, 'm' grams of steam at 100°C is mixed in it till the temperature of the mixture is 31°C. The value of 'm' is close to (Latent heat of water = 540 cal g^{-1}, specific heat of water = 1 cal.g^{-1} °C^{-1})

(A) 2

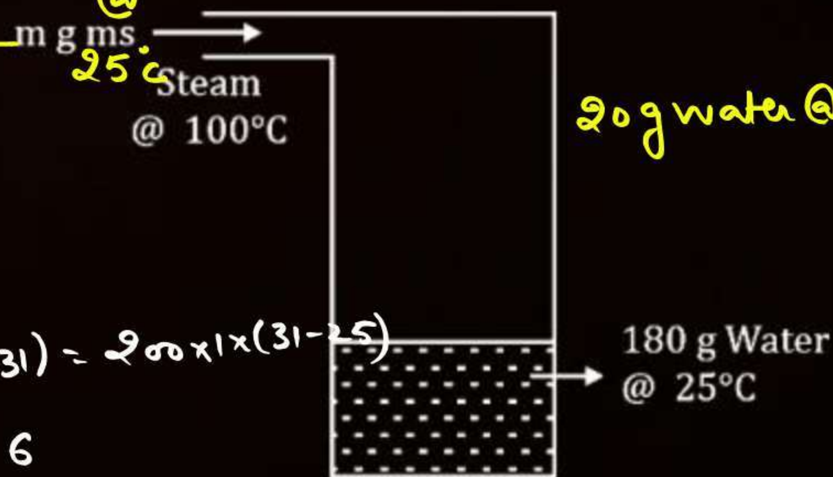
(B) 4

(C) 3.2

(D) 2.6

m g Steam @ 100°C $\longrightarrow$ Water @ 31°C

(180+20) g water @ 25°C



20 g water @ 25°C.

$$Q_{loss} = Q_{gain}$$

$$m \times 540 + m \times 1 \times (100 - 31) = 200 \times 1 \times (31 - 25)$$

$$m \times (540 + 69) = 200 \times 6$$

$$m = \frac{1200}{609}$$

QUESTION (JEE Mains – Sep. 04, 2020 (I))

$\frac{1700}{\cancel{20}}$ $= 85\,\text{cal}$ $\frac{3.4\times10^5\times}{4.2\times1000}$ cal $= \frac{340}{42}$ $=$

The specific heat of water = 4200 J kg^{-1} K^{-1} and the latent heat of ice = 3.4×10^5 J kg^{-1}. 100 grams of ice at 0°C is placed in 200 g of water at 25°C. The amount of ice that will melt as the temperature of water reaches 0°C is close to (in grams):

(A) 61.7

(B) 63.8

(C) 69.3

(D) 64.6

$$Q_{left} = 200\times25 - 100\times85$$

$$= 5000 - 8500$$

$$Q_{left} = -3500$$

$$m_{ice} = \frac{\cancel{3500}}{\cancel{85}} = \frac{700}{17} =$$

mass of ice melted –

$$100 - \frac{700}{17}$$

$$\frac{1700-700}{17}$$

$$= \frac{1000}{17}$$

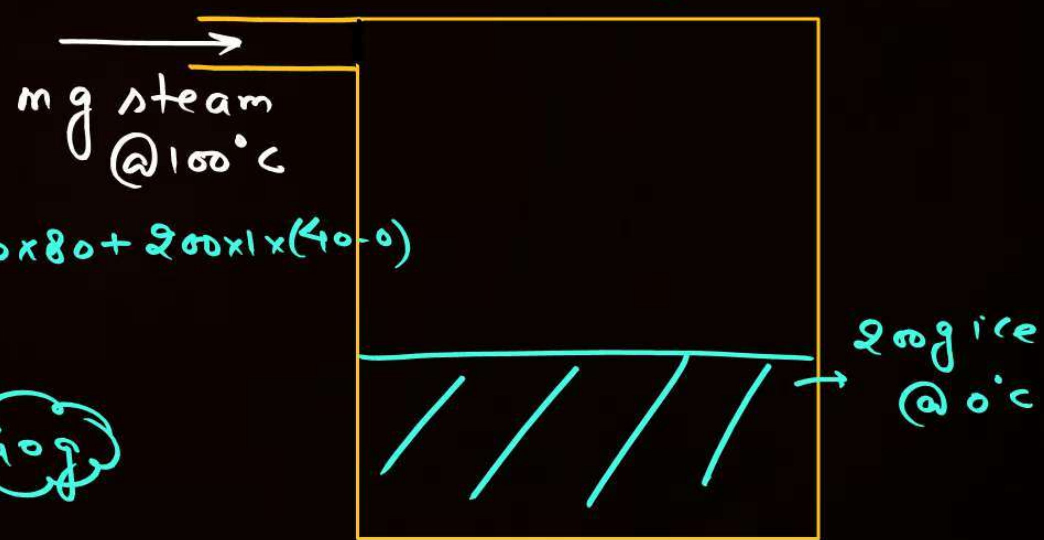
$$= 5$$

QUESTION (JEE Mains – NA 7 Jan. 2020 II)

T_{final}

M grams of steam at 100°C is mixed with 200 g of ice at its melting point in a thermally insulated container. If it produces liquid water at 40°C [heat of vaporization of water is 540 cal/g and heat of fusion of ice is 80 cal/g], the value of M is 40g.

Heat lost by steam = Heat gained by ice



$$m \times 540 + m \times 1 \times (100 - 40) = 200 \times 80 + 200 \times 1 \times (40 - 0)$$

$$600\,m = 16000 + 8000$$

$$= \frac{24\cancel{000}}{6\cancel{00}} = 40\,g$$

QUESTION (JEE Mains – 12 April 2019 I)

When M_1 gram of ice at $-10°C$ (Specific heat $= 0.5$ cal g^{-1} $°C^{-1}$) is added to M_2 gram of water at $50°C$, finally no ice is left and the water is at $0°C$. The value of latent heat of ice, in cal g^{-1} is:

(A) $\frac{50M_2}{M_1} - 5$

(B) $\frac{5M_1}{M_2} - 50$

(C) $\frac{50M_2}{M_1}$

(D) $\frac{5M_2}{M_1} - 5$

Heat absorbed by ice = Heat lost by water.

$$M_1 \times \frac{1}{2} \times (10-0) + M_1 L = M_2 \times 1 \times 50$$

$$5M_1 + LM_1 = 50M_2$$

$$(5+L)M_1 = 50M_2$$

$$L = \frac{50M_2}{M_1} - 5$$

QUESTION (JEE Mains – 2017)

A copper ball of mass 100 gm is at a temperature T. It is dropped in a copper calorimeter of mass 100 gm, filled with 170 gm of water at room temperature. Subsequently, the temperature of the system is found to be 75°C. T is given by

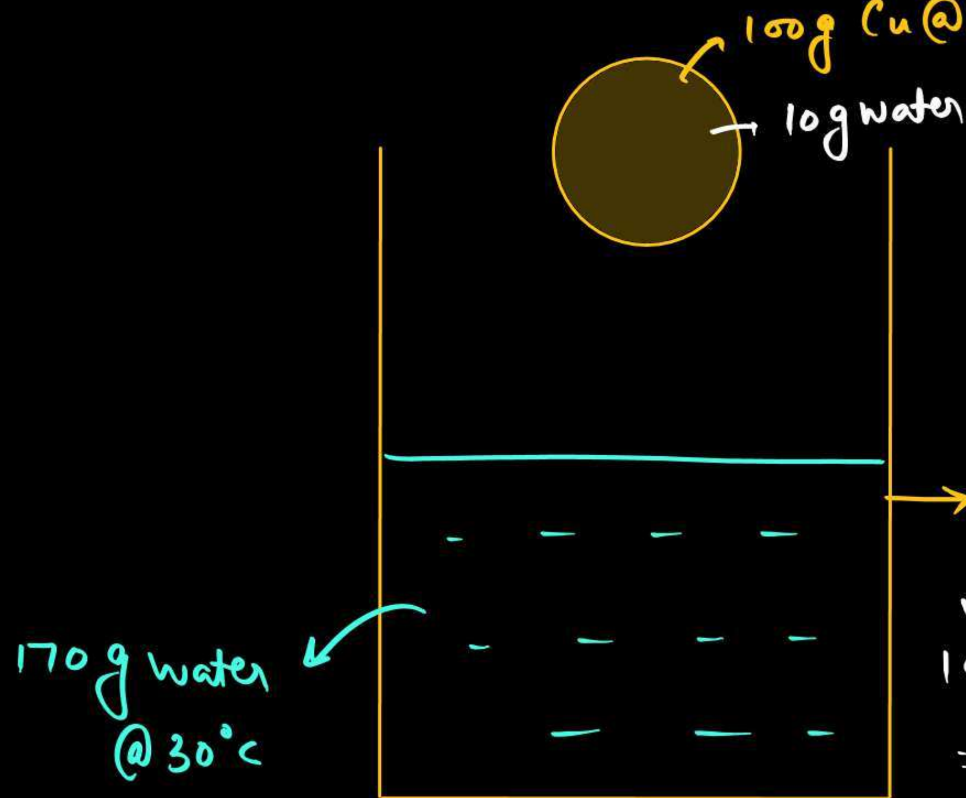
(Given : room temperature = 30° C, specific heat of copper = 0.1 cal/gm°C

(A) 1250°C

(B) 825°C

(C) 800°C

(D) 885°C



Heat lost by Cu ball = Heat gained by water & Calorimeter.

$$\cancel{1}0\times1\times(T-75) = 18\cancel{0}\times1\times(75-30)$$

$$T-75 = 18\times45$$

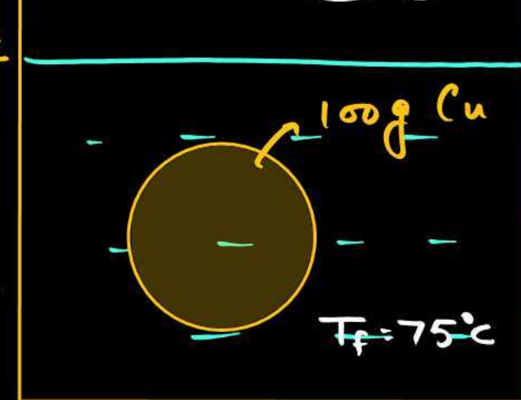
$$T = 18\times45+75$$
$$= 810+75 = \boxed{885^\circ C}$$

100g @ 30°C

Cu

100×0.1 g water equivalent

= 10g water @ 30



QUESTION (JEE Mains – Online April 8, 2017)

200g Al

In an experiment a sphere of aluminium of mass 0.20 kg is heated upto 150°C. Immediately, it is put into water of volume 150 cc at 27°C kept in a calorimeter of water equivalent to 0.025 kg. Final temperature of the system is 40°C. The specific heat of aluminium is: (take 4.2 Joule=1 calorie)

150g water

25g

(A) 378 J/kg – °C

(B) 315 J/kg – °C

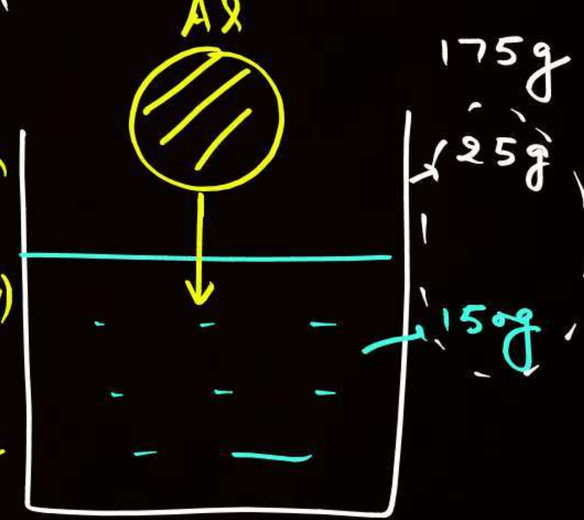
(C) 476 J/kg – °C

(D) 434 J/kg – °C

Heat lost by Al = Heat gained by water

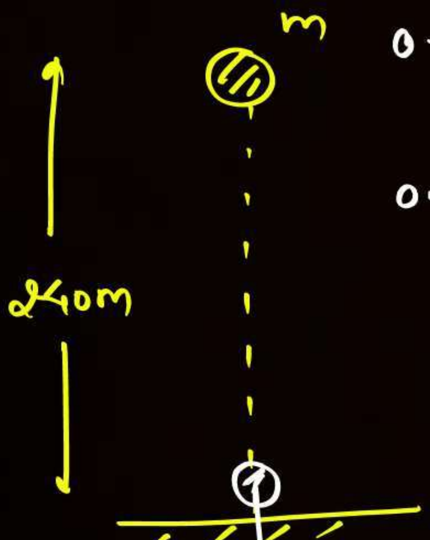
$$200 \times S \times (150-40) = 175 \times 1 \times (40-27)$$

$$S = \frac{\cancel{175}^{7} \times 13}{\cancel{200}_{8} \times 110} = \frac{13 \times 7}{110 \times 8} \text{ Cal/g°C}$$



QUESTION

A ball of mass m falls from height 240 m. If after hitting the ground, entire K.E. of balls gets converted into thermal energy which heats up the ball. Find the change in temp. of ball (S = 0.2 cal/g° C)



$KE = mgH$

$0.2 \frac{cal}{g°C}$

$0.2 \times \frac{4.2\,J}{10^{-3}\,kg\,K}$

$0.84 \times 10^{3}\ J/kg\cdot K$

840

$$\underbrace{\cancel{m}gH}_{J} = \underbrace{\cancel{m}s\Delta T}_{cal}$$

$$\Delta T = \frac{gH}{s}$$

Common mistake.

$$\Delta T = \frac{10 \times 240}{0.2}$$

$$\Delta T = 12{,}000\ °C$$

$$\Delta T = \frac{gH}{s}$$

$$= \frac{10 \times 240}{840}$$

$$= \frac{60}{21} = \frac{20}{7}\ °C$$

Ans

Share your JEE Reg. details

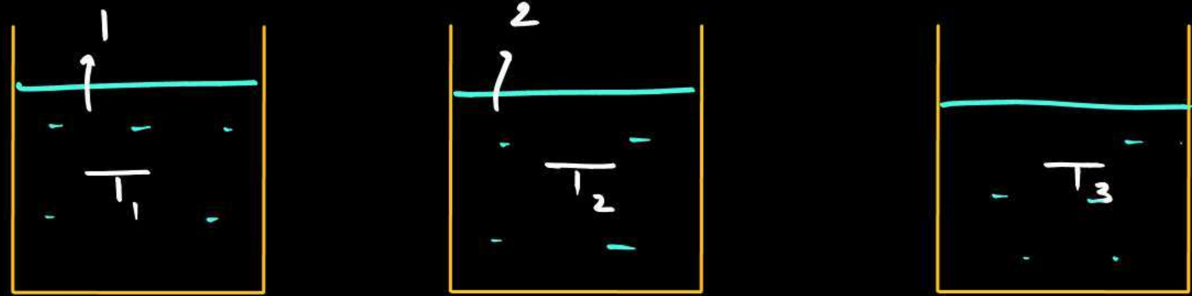
https://bit.ly/JEE_24Fa

QUESTION (JEE Mains – Jan. 08, 2020 (II))

Three containers C_1, C_2 and C_3 have water at different temperatures. The table below shows the final temperature T when different amounts of water (given in liters) are taken from each container and mixed (assume no loss of heat during the process)

The value of θ (in °C to the nearest integer) is ______.

C_1	C_2	C_3	T
$1l$	$2l$	–	60°C
–	$1l$	$2l$	30°C
$2l$	–	$1l$	60°C
$1l$	$1l$	$1l$	θ



C_1 $\quad$ C_2 $\quad$ C_3

$$T = \frac{1\times1\times T_1 + 2\times1\times T_2}{3}$$

$$3\times60 = T_1 + 2T_2 \quad - (1)$$

$$30 = \frac{1\times T_2 + 2T_3}{3}$$

$$T_2 + 2T_3 = 90 \quad - (2)$$

$$\frac{2T_1 + T_3}{3} = 60$$

$$2T_1 + T_3 = 180 \quad - (3)$$

$$T_1 + 2T_2 = 180 \quad - (1)$$

$$T_2 + 2T_3 = 90 \quad - (2)$$

$$2T_1 + T_3 = 180 \quad - (3)$$

$$3T_1 + 3T_2 + 3T_3 = 450$$

$$\theta = \frac{T_1 + T_2 + T_3}{3} = \frac{150}{3}$$

$$\theta = 50$$

$$\frac{T_1 + T_2 + T_3}{3} = \theta$$

QUESTION (JEE Mains – Jan. 11, 2019 (II)

H.W

A metal ball of mass 0.1 kg is heated upto 500°C and dropped into a vessel of heat capacity 800 JK^{-1} and containing 0.5 kg water. The initial temperature of water and vessel is 30°C. What is the approximate percentage increment in the temperature of the water? [Specific heat Capacitates of water and metal are, respectively 4200 $J\,kg^{-1}\,K^{-1}$ and 400 $J\,kg^{-1}\,K^{-1}$]

(A) 15 %

(B) 30 %

(C) 25 %

(D) 20 %

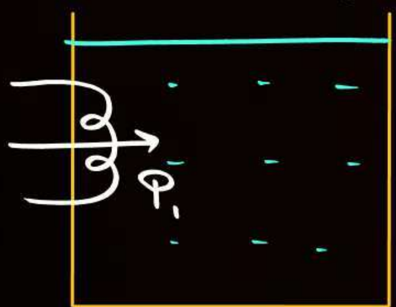
QUESTION (JEE Mains – June. 29, 2022 (I))

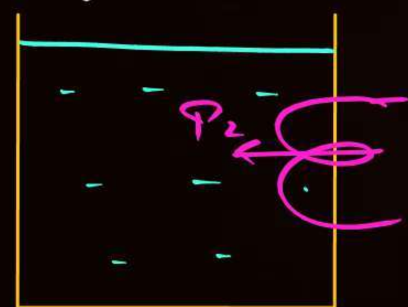
Two coils require 20 minutes and 60 minutes respectively to produce same amount of heat energy when connected separately to the same source. If they are connected in parallel arrangement to the same source; the time required to produce same amount of heat by the combination of coils, will be ______ min.

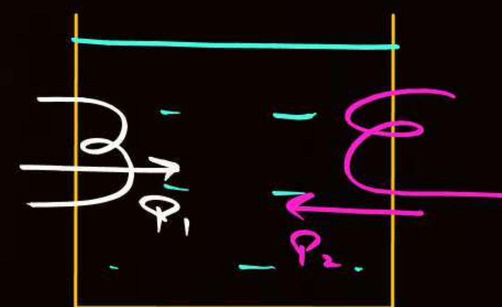
Q = Heat req.

$$\frac{1}{T} = \frac{1}{T_1} + \frac{1}{T_2} = \frac{1}{30} + \frac{1}{60}$$

$$\boxed{T = 20\,\text{min}}$$







$$T_1 = \frac{Q}{P_1}$$

$$P_1 = \frac{Q}{T_1}$$

$$T_2 = \frac{Q}{P_2}$$

$$P_2 = \frac{Q}{T_2}$$

$$T = \frac{Q}{P_1 + P_2} \Rightarrow T = \frac{\cancel{Q}}{\frac{\cancel{Q}}{T_1} + \frac{\cancel{Q}}{T_2}}$$

QUESTION (JEE Mains – JEE Adv, 2019)

T = temp.
t = time

A current carrying wire heats a metal rod. The wire provides a constant power (P) to the rod. The metal rod is enclosed in an insulated container. It is observed that the temperature (T) in the metal rod changes with time (t) as:

$$T(t) = T_0(1 + \beta t^{1/4})$$

$T = T_0 + T_0 \beta t^{1/4}$

$T_0 \beta t^{1/4} = T - T_0$

Where β is a constant with appropriate dimension while T_0 is a constant with dimension of temperature. The heat capacity of the metal is

$dQ = C\,dT$

$P.dt = C\,dT$

$C = \frac{P}{(dT/dt)}$

$t^{1/4} = \frac{T - T_0}{\beta T_0}$

$t^{3/4} = \left[\frac{T - T_0}{\beta T_0}\right]^3$

(A) $\frac{4P(T(t)-T_0)^3}{\beta^4 T_0^4}$

(B) $\frac{4P(T(t)-T_0)}{\beta^4 T_0^2}$

(C) $\frac{4P(T(t)-T_0)^4}{\beta^4 T_0^5}$

(D) $\frac{4P(T(t)-T_0)^2}{\beta^4 T_0^3}$

P

$$\frac{4P}{T_0^4\beta^4}$$

Heat supplied by wire in t sec.

$$Q = P \times t$$

$$T = T_0\left(1+\beta T^{1/4}\right)$$

$$\frac{dT}{dt} = T_0 \times \beta \times \frac{1}{4} t^{-3/4}$$

$$C = \frac{P}{\left(\frac{dT}{dt}\right)} = \frac{P}{\frac{T_0\beta}{4} t^{-3/4}}$$

$$= \frac{4P\left(t^{3/4}\right)}{T_0\beta}$$

$$= \frac{4P}{T_0\beta}\left[\frac{T-T_0}{\beta T_0}\right]^3$$

QUESTION (JEE Mains – Jan. 31, 2023 (II)

A water heater of power 2000 W is used to heat water. The specific heat capacity of water is 4200 J kg^{-1} K^{-1}. The efficiency of heater is 70%. Time required to heat 2 kg of water from 10°C to 60°C is ______ S.

(Assume that the specific heat capacity of water remains constant over the temperature range of the water).

Power delivered = 70% of rated power

$= 0.7 \times 2000$

$= 1400 \frac{J}{s}$

$Q = ms\Delta T$

$P \times t = ms\Delta T$

$1400 \times t = 2 \times 4200 \times 50$

$t = \frac{84 \times 50}{14}$

$t = 300 s$ Ans.

QUESTION (JEE Mains – June. 25, 2022 (II))

A copper block of mass $\underbrace{5.0 \text{ kg}}$ $\rightarrow 5000\,g$ is heated to a temperature of 500°C and is placed on a large ice block. What is the maximum amount of ice that can melt? [Specific heat of copper: 0.39 J g^{-1} °C^{-1} and latent heat of fusion of water: 335 J g^{-1} °C^{-1}

(A) 1.5 kg

(B) 5.8 kg

(C) 2.9 kg

(D) 3.8 kg

$T_f = 0°C$

Heat supplied by Cu = Heat absorbed by ice.

$$5000 \times 0.39 \times (500 - 0) = m \times 335$$

$$5000 \times 39 \times 5 = m \times 335$$

$$m = \frac{5000 \times 5 \times 39}{335} \text{ gram.}$$

$$= \frac{5\cancel{00} \times 195}{335 \times 1\cancel{000}_2} \text{ kg} = \frac{19\cancel{50}}{67\cancel{0}} \text{ kg}$$

QUESTION (JEE Mains – Aug. 26, 2021 (II))

H.W

S_1 S_2 S_3

The temperature of equal masses of three different liquids x, y and z are 10°C, 20°C and 30°C respectively. The temperature of mixture when x is mixed with y is 16°C and that when y is mixed with z is 26°C. The temperature of mixture when x and z are mixed will be:

(A) 28.32° C

(B) 23.84° C

(C) 25.62° C

(D) 20.28° C

QUESTION (JEE Mains – Aug. 27, 2021 (II))

H.W

The height of victoria falls is 63 m. What is the difference in temperature of water at the top and at the bottom of fall?

[Given 1 cal = 4.2 J and specific heat of water = 1 cal g^{-1} °C^{-1}]

$\cancel{m}gH = \cancel{m}s\Delta T$

(A) 0.147 °C

(B) 14.76 °C

(C) 1.476 °C

(D) 0.014 °C

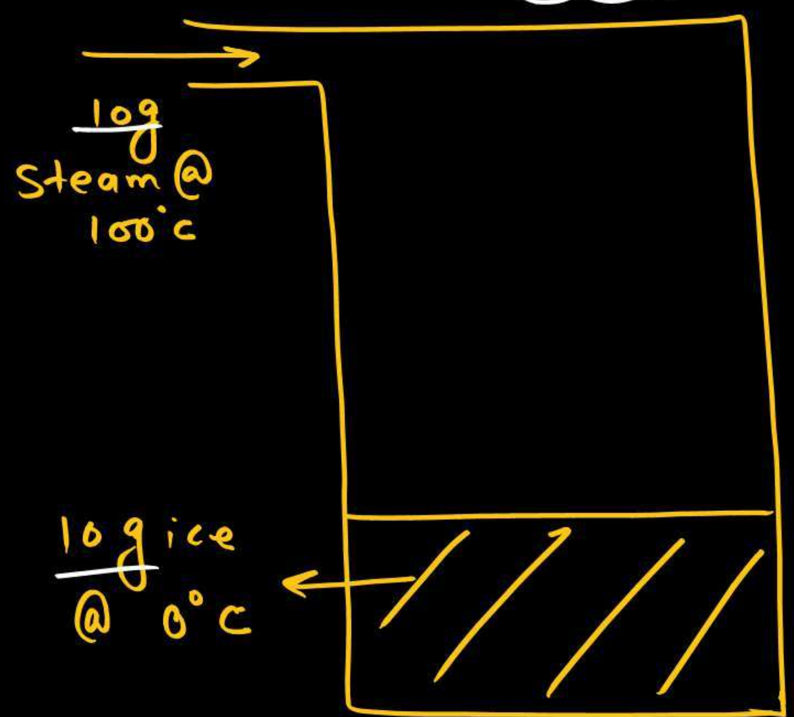
QUESTION (JEE Mains – July. 25, 2022 (II)

H.W

A block of ice of mass 120 g at temperature 0°C is put in 300 g of water at 25°C. The xg of ice melts as the temperature of the water reaches 0°C. The value of x is ______. [Use specific heat capacity of water = 4200 J kg^{-1} K^{-1}, Latent heat of ice = 3.5×10^5 Jkg^{-1}]

Q. Find final temp. & Comp.

$T_f = 100^\circ C$



$$Q_{left} = 10 \times 540 + 10 \times 1 \times 100 - 10 \times 80$$

$$= 10 \times 640 - 800$$

$$= 6400 - 800$$

$$Q_{left} = 5600\,cal$$

$$Q_{left} = m s \Delta T$$

$$5600 = 20 \times 1 \times (T - 0)$$

$$T = \frac{560}{2} = 28\cancel{0}^\circ C > 100^\circ C$$

$0^\circ \to 100^\circ C$

$$Q = m s \Delta T$$

$$= 20 \times 1 \times 100$$

$$= 2000\,cal.$$

$$Q_{left} = 5600 - 2000 = 3600\,cal.$$

$$m_{steam} = \frac{Q_{left}}{540} = \frac{3600}{540}\,g.$$

QUESTION (JEE Mains – Sep. 05, 2020 (I)

A bullet of mass 5g, traveling with a speed of 210 m/s, strikes a fixed wooden target. One half of its kinetic energy is converted into heat in the bullet while the other half is converted into heat in the wood. The rise of temperature of the bullet if the specific heat of its material is $\underbrace{0.030\ \text{cal}/}$$(g - °C)(1\ \text{cal} = 4.2 \times 10^7\ \text{ergs})$ close to:

$S = 0.030 \times \frac{4.2\ J}{g\,°C}$

$m = 5g$

$210\ m/s$

(A) 83.3° C

(B) 38.4° C

(C) 87.5° C

(D) 119.2° C

$$k.E = \frac{1}{2} m v^2$$

$$m s \Delta T = \frac{1}{2} k.E$$

$$\cancel{m} s \Delta T = \frac{1}{4} \cancel{m} v^2$$

$$\Delta T = \frac{v^2}{4s}$$

QUESTION (JEE Mains – JEE Adv, 2019)

A liquid at 30°C is poured very slowly into a Calorimeter that is at temperature of 110°C. The boiling temperature of the liquid is 80°C. It is found that the first 5 gm of the liquid completely evaporates. After pouring another 80 gm of the liquid the equilibrium temperature is found to be 50°C. The ratio of the Latent heat of the liquid to its specific heat will be ________ °C. [Neglect the heat exchange with surrounding]

Heat absorbed by liq. = Heat released by Calorimeter.

$$Q = 5\times s\times(80-30) + 5\times L = C\times(110-80)$$

$$\Rightarrow 250s + 5L = 30C$$

$$\Rightarrow 50s + L = 6C \quad - (1)$$

5g $30^\circ \rightarrow 80^\circ C \longrightarrow$ vapor

80g $30^\circ \rightarrow 50^\circ C$

Heat abs. by liq. = Heat supplied by Cal

$$80\times s\times(50-30) = C\times(80-50)$$

$$80\times s\times 2\cancel{0} = 3\cancel{0}\,C$$

$$160s = 3C$$

$$\therefore C = \frac{160s}{3} \quad - (2)$$

$$50s + L = \overset{2}{\cancel{6}}\times\frac{160s}{\cancel{3}}$$

$$50s + L = 320s$$

$$270s = L$$

$$\boxed{\frac{L}{s} = 270}$$ Ans

$\rightarrow 110^\circ C$

$\downarrow$

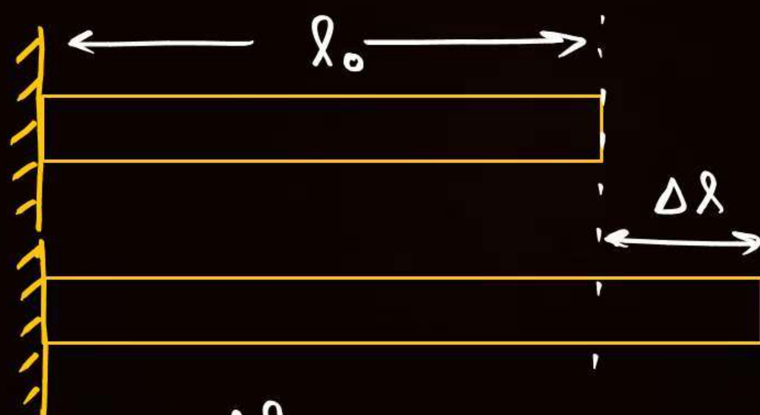
$80^\circ C$

$\downarrow$

$50^\circ C$

Thermal Expansion

① Linear Thermal Expansion →



fractional change in length of rod → $\frac{\Delta l}{l_0} = \alpha \Delta T$

$\Delta l \propto \Delta T$

$\propto l_0$

$\Delta l = l_0 \alpha \Delta T$

Prop. of material

Prop. const.

(Thermal coeff. of linear Expansion)

unit of $\alpha = /°C$

$[\alpha] = [T^{-1}]$

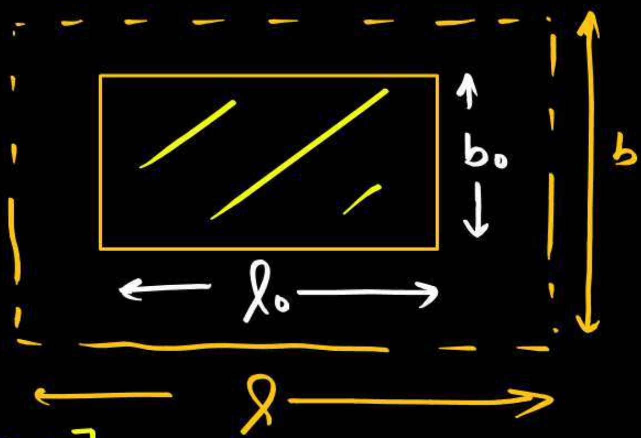
$l = l_0 + \Delta l$

$= l_0 + \alpha l_0 \Delta T$

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

Usually, α is very small.

(2) Areal thermal Expansion $\longrightarrow$



$\sigma = \sigma_0[1 - \beta\Delta T]$
$\downarrow$
Areal density.

$$\Delta A = \beta A_0 \Delta T$$

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

$$A_0 = l_0 b_0$$

$$A = l b$$

$$A = l_0(1+\alpha\Delta T)\, b_0(1+\alpha\Delta T)$$

$$A = l_0 b_0 (1+\alpha\Delta T)^2$$

$$A = A_0(1+\underbrace{\alpha\Delta T}_{\text{very small}})^2$$

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

$$\boxed{A = A_0(1+\beta\Delta T)}$$

β $\downarrow$ Th. coeff. of areal expansion. ($\beta = 2\alpha$)

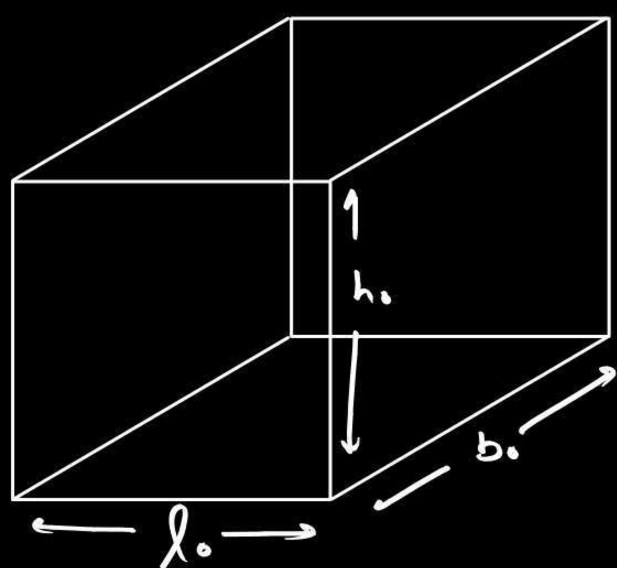
③ Volumetric Thermal Expansion →

$$\rho_0 = \frac{M}{V_0}$$

$$\boxed{V = V_0(1+\gamma\Delta T)}$$

γ ↓ Th. coeff. of vol. expansion.

$$\gamma = 3\alpha$$



$$\Delta V = V_0 \gamma \Delta T$$

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

$$\rho = \frac{M}{V} \Rightarrow \rho = \frac{M}{V_0(1+\gamma\Delta T)} = \frac{M}{V_0}(1+\gamma\Delta T)^{-1}$$

$$\boxed{\rho = \rho_0(1-\gamma\Delta T)}$$

Effect on Shape

Thermal Expansion is similar to zooming an image. It does not change the shape of object.

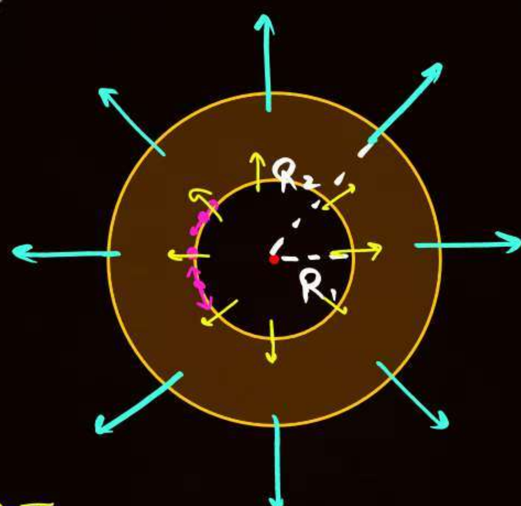
QUESTION

Find the effect of heating on-

(1) $R_1 \uparrow$

(2) $R_2 \uparrow$

(3) $R_2 - R_1 \uparrow$

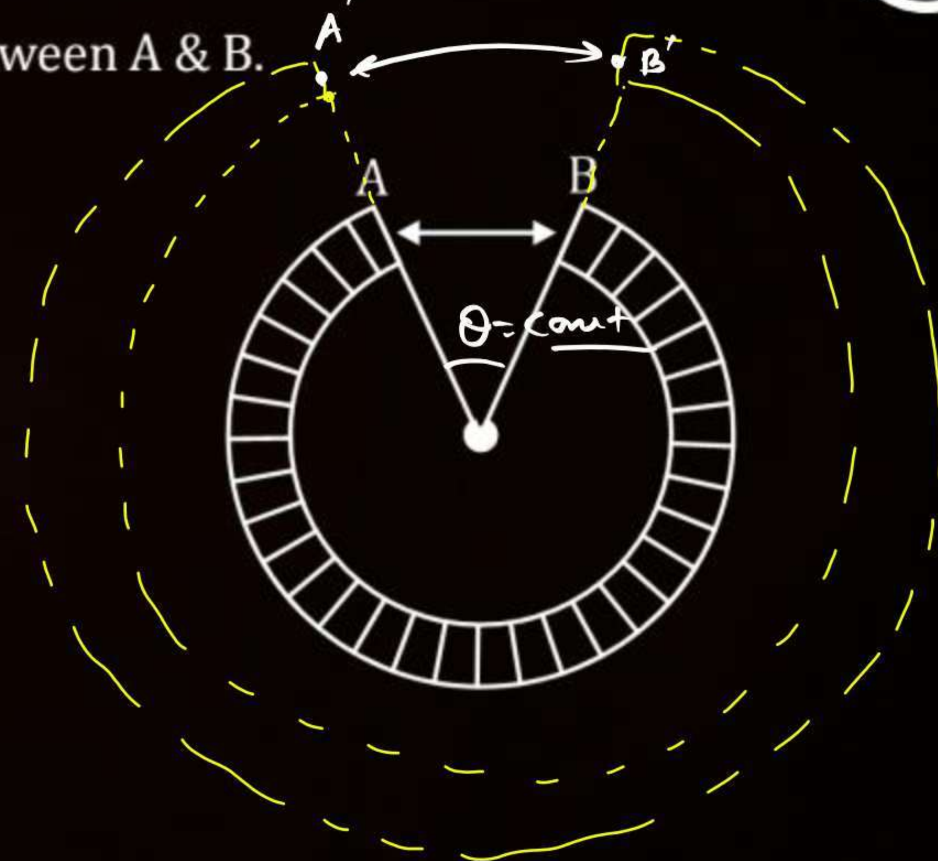


$\uparrow l = \uparrow l_0 (1 + \alpha \Delta T)$

$\uparrow \Delta l = \uparrow l_0 \alpha \Delta T$

QUESTION

What will be the effect of heating on dist. between A & B.



QUESTION

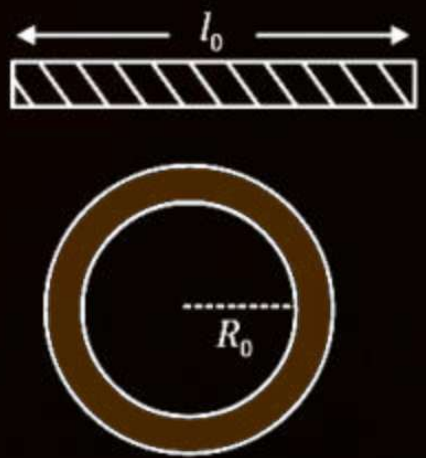
A rod of length ℓ_0 & th. coeff. Of linear expansion $\propto$ is bent to form a ring. If the ring is now heated, Find the change in radius of ring & area of ring (change in temp = ΔT).

$$l = l_0(1+\alpha\Delta T)$$

$$\cancel{2\pi} R = \cancel{2\pi} R_0(1+\alpha\Delta T)$$

$$R = R_0(1+\alpha\Delta T)$$

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



QUESTION

An iron rim of radius ~~0.2~~ 0.8 m is to be fitted on a wooden wheel of radius 1m. Find the temp. change in iron to perfectly fit the wooden wheal ($\propto_{\text{iron}} = 0.002/°C$)

$$R = R_0(1+\alpha\Delta T)$$

$$1 = 0.8(1+0.002\times\Delta T)$$

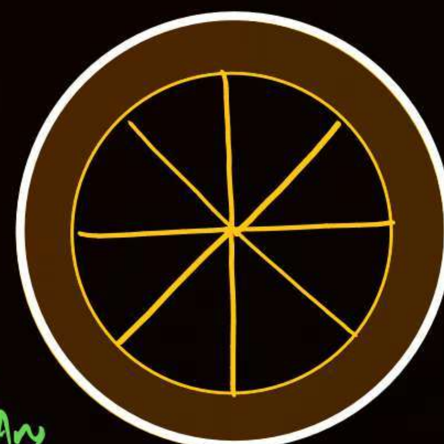
$$\frac{1}{0.8} = 1+0.002\,\Delta T$$

$$\frac{1}{4} = 0.002\,\Delta T$$

$$\Delta T = \frac{1}{4\times 0.002} = \frac{1000}{8} = \frac{500}{4}$$

$$\Delta T = 125°C$$

Ans



QUESTION (JEE Mains – Jan 24, 2023 (I))

$\Delta T = 177 - 27 = 150^\circ C$

A hole is drilled in a metal sheet. At 27°C, the diameter of hole is 5 cm. When the sheet is heated to 177°C, the change in the diameter of hole is $d \times 10^{-3}$ cm. The value of d will be ______ if coefficient of linear expansion of the metal is $1.6 \times 10^{-5}/^\circ C$.

$$d = d_0(1 + \alpha \Delta T)$$

$$\Delta d = d_0 \alpha \Delta T$$

$$= 5 \times 1.6 \times 10^{-5} \times 150$$

$$= 8 \times 150 \times 10^{-5} \text{ cm}$$

$$= 120 \times 10^{-4} \text{ cm}$$

$$\Delta d = \underbrace{12}_{\Delta d} \times 10^{-3} \text{ cm}$$

QUESTION (JEE Mains – Sep. 02, 2020 (II))

$V = l^3 \Rightarrow \frac{\Delta V}{V} = 3 \times \frac{\Delta l}{l}$

When the temperature of metal wire is increase from 0°C to 10°C, its length increase by 0.02%. The percentage change in its mass density will be closed to:

(A) 0.008

(B) 0.8

(C) 0.06

(D) 2.3

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

$\frac{\Delta \rho}{\rho} = -\frac{\Delta V}{V}$

$= -0.06\%$

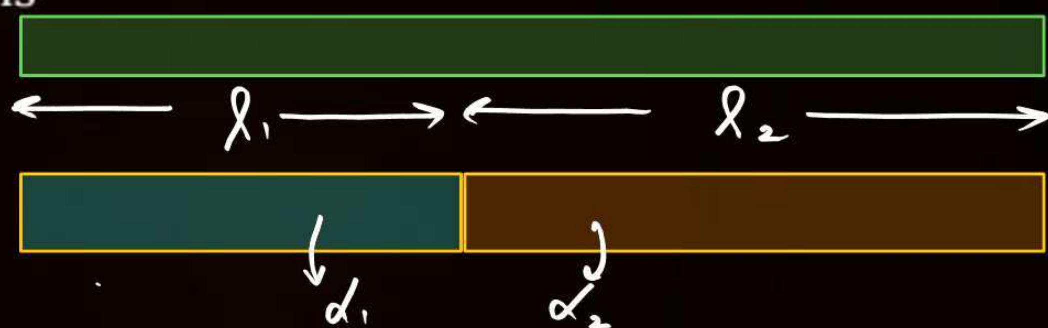
$\frac{\Delta l}{l} = 0.02\%$

$\frac{\Delta V}{V} = 3 \times 0.02\%$

$= 0.06\%$

QUESTION (JEE Mains – Sep. 05, 2020 (II))

Two different wires having lengths L_1 and L_2 and respective temperature coefficient of linear expansion α_1 and α_2, are joined end-to-end. Then the effective temperature coefficient of linear expansion is



(A) $\sqrt[2]{\alpha_1\alpha_2}$

(B) $\frac{4\alpha_1\alpha_2}{\alpha_1+\alpha_2}\frac{L_2L_1}{(L_2+L_1)^2}$

(C) $\frac{\alpha_1+\alpha_2}{2}$

(D) $\frac{\alpha_1L_1+\alpha_2L_2}{L_1+L_2}$ ✓

$$\Delta l_{total} = \Delta l_1 + \Delta l_2$$

$$(l_1+l_2)\alpha_{eq}\cancel{\Delta T} = l_1\alpha_1\cancel{\Delta T} + l_2\alpha_2\cancel{\Delta T}$$

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

Non-Isotropic Thermal Expansion

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

अलग - अलग direcn. में α अलग - अलग है।

QUESTION (JEE Mains – Jan. 07, 2020 (I)

A non-isotropic solid metal cube has coefficients of linear expansion as: 5×10^{-5} /°C along the x-axis and 5×10^{-6}/°C along the y and the z-axis. If the coefficient of volume expansion of the solid is $C \times 10^{-6}$/°C then the value of C is

$$\alpha_x = 5\times10^{-5}/^\circ C = 50\times10^{-6}/^\circ C$$

$$\alpha_y = \alpha_z = 5\times10^{-6}/^\circ C$$

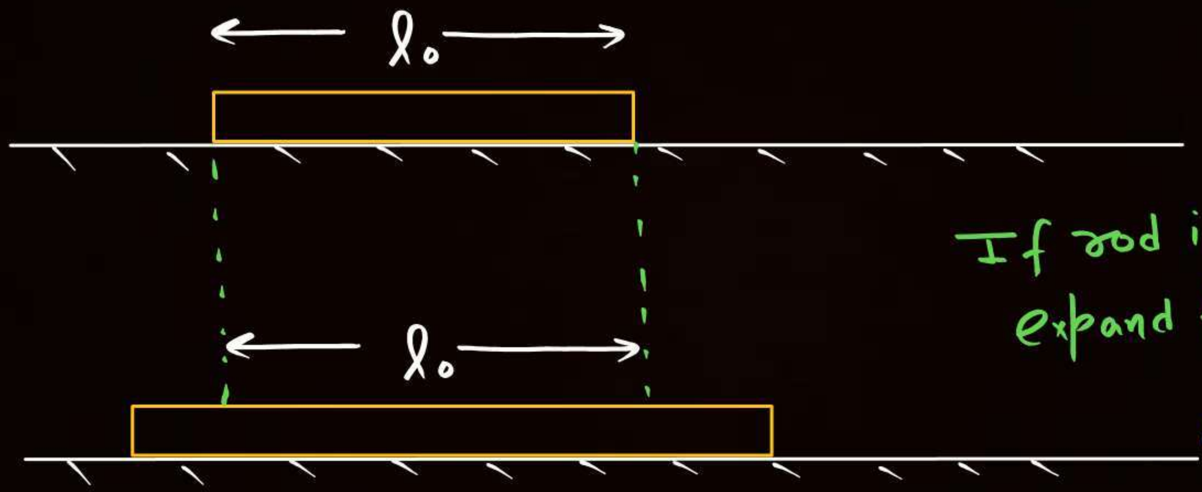
$$\gamma = \alpha_x + \alpha_y + \alpha_z$$

$$= 50\times10^{-6} + 2\times5\times10^{-6}$$

$$= \underbrace{60}_{C}\times10^{-6}/^\circ C$$

Thermal Stress and Strain

Stress = Y × Strain

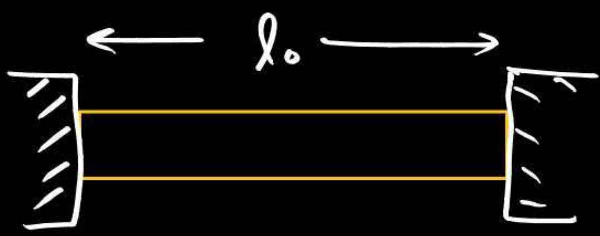


If rod is allowed to expand freely →

Thermal stress = 0

Thermal strain = 0

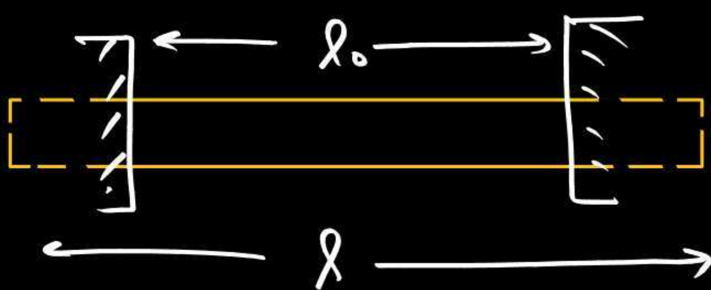
$$\frac{\Delta l}{l_0} = \alpha \Delta T$$



Thermal Strain, $\varepsilon = \frac{\Delta l}{l} \simeq \frac{\Delta l}{l_0}$

Th. stress = $Y \times$ Th. strain

$$\sigma = Y\left[\frac{\Delta l}{l_0}\right]$$



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

→ Rod will be in compression.

QUESTION (JEE Mains – 1 Sep, 2021 (S-II)

A steel rod with $y = 2.0 \times 10^{11}$ Nm and $\alpha = 10^{-5}\ {}^\circ C^{-1}$ of length 4 m and area of cross-section 10 cm^2 is heated from 0°C to 400°C without being allowed to extend. The tension produced in the rod is $x \times 10^5$ N where the value of x is ______.

$$\boxed{\sigma_{th.} = Y \alpha \Delta T}$$

$$\frac{F}{A} = Y\alpha\Delta T$$

$$F = Y\alpha\Delta T . A$$

$$= 2 \times 10^{11} \times 10^{-5} \times 400 \times 10 \times 10^{-4}$$

$$= \underset{x}{8} \times 10^5 \text{ N}$$

QUESTION (JEE Mains – 22 July, 2021 (S-II))

The area of cross-section of a railway track is 0.01 m^2. The temperature variation is 10°C. Coefficient of linear expansion of material of track is 10^{-5}/°C. The energy stored per meter in the track is J/m. (Young's modulus of material of track is 10^{11} m^{-2})

$$\boxed{\text{Energy density} = \frac{1}{2} \times \text{Stress} \times \text{Strain}}$$

$$\frac{U}{\text{Vol.}} = \frac{1}{2} \times \sigma \times \varepsilon$$

$$\frac{U}{l \times A} = \frac{1}{2} \times \sigma \times \varepsilon$$

$$\frac{U}{l} = \frac{1}{2} \times \sigma \times \varepsilon \times A$$

$$\frac{U}{l} = \frac{1}{2}(Y \alpha \Delta T) \times (\alpha \Delta T) \times A$$

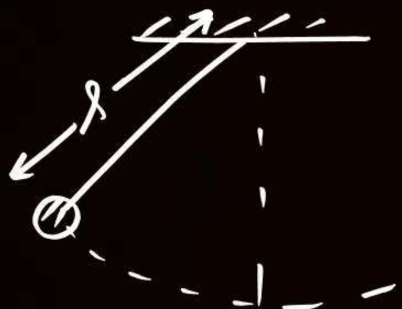
$$= \frac{1}{2} Y \alpha^2 A (\Delta T)^2$$

$$= \frac{1}{2} \times 10^{11} \times (10^{-5})^2 \times 0.01 \times 10^2$$

$$= \frac{10}{2} = 5\ \text{J/m}$$

Ans.

Time Period of Simple Pendulum



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

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

$$\boxed{\underbrace{\frac{\Delta T}{T}}_{\text{fractional change in time period of simple pendulum.}} = \frac{1}{2}\alpha \underbrace{\Delta\theta}_{\text{Temp. change}}}$$

$y = x^n$

$\frac{\Delta y}{y} = n\frac{\Delta x}{x}$

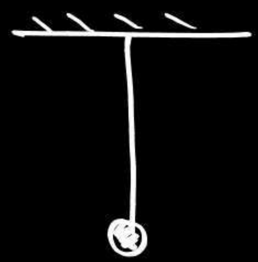
for small change

$\frac{\Delta T}{T}$ → 1s में कितना change आया

$T \rightarrow 1s$

$\frac{\Delta T}{T}$ → 1 din में कितना change आया.

$T \rightarrow 1$ day



Temp.

$T_0 \longrightarrow$ correct time — 1 tick → 1 sec

$T > T_0 \longrightarrow$ Clock will become slow & lose time. — 1 tick → > 1 sec

$T < T_0 \longrightarrow$ Clock will become fast & will gain time

QUESTION

A clock working on simple pendulum principle is calibrated to run correctly at 10°C. If the clock is operated at 40°C, how much time it will lose/gain in a day? ($\propto = 0.001/°C$)

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

$$\frac{\Delta T}{T}$$

$$= \frac{1}{2} \times 0.001 \times (40-10)$$

$$\frac{\Delta T}{T} = 0.001 \times 15$$

$$\frac{\Delta T}{T} = 15 \times 10^{-3}$$

$$\Delta T = 15 \times 10^{-3} \times T$$

$$= 15 \times 10^{-3} \times 86400 \frac{\text{sec}}{\text{day}}$$

QUESTION

A clock gains 20 sec/day at 5°C & ~~loses~~ loses 10 sec/day at 35°C. Find temp at which clock will measure time correctly.

Method-1 :—

$$\frac{\Delta T}{T_0} = \frac{1}{2}\alpha\,\Delta\theta$$

$$\frac{\Delta T}{T_0} = \frac{1}{2}\alpha(\theta - \theta_0)$$

$$\frac{-20 = \cancel{\frac{1}{2}}\alpha[5-\theta_0] \quad -\text{(1)}}{+10 = \cancel{\frac{1}{2}}\alpha[35-\theta_0] \quad -\text{(2)}}$$

$$\Rightarrow -2 = \frac{5-\theta_0}{35-\theta_0}$$

$$\Rightarrow -70 + 2\theta_0 = 5 - \theta_0$$

$$3\theta_0 = 75$$

$$\theta_0 = 25^\circ C$$ Ans

Method-2:

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

$\Delta\theta$		$\Delta T/T$
$30^\circ c$	$\longrightarrow$	30
$20\ c$	$\longleftarrow$	20

QUESTION

A disc of mass M & radius R_0 is rotating abt. fixed axis passing through center with angle vel ω_0. IF due to change in temp ΔT. The disc expands, find the new angular vel. (Th. Coeff. of linear exp. = $\propto$)

$$I_1 \omega_1 = I_2 \omega_2$$

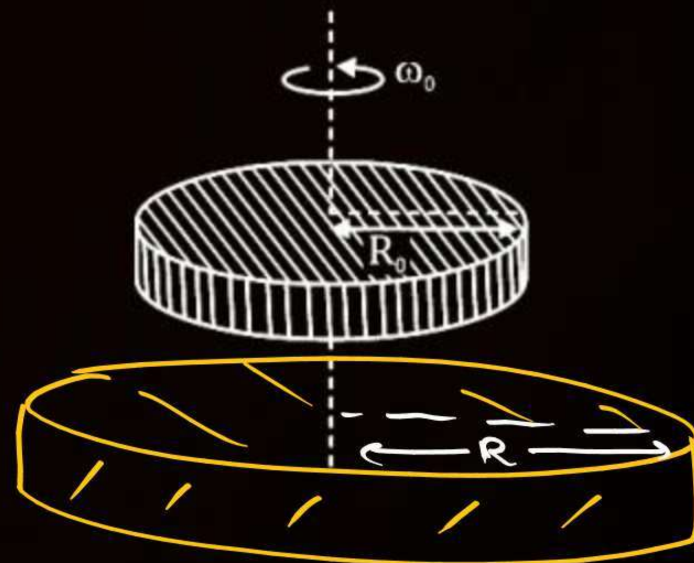
$$\cancel{\tfrac{1}{2}}\cancel{M}\cancel{R_0^2}\,\omega_0 = \cancel{\tfrac{1}{2}}\cancel{M}\left[\cancel{R_0}(1+\alpha\Delta T)\right]^2 \omega$$

$$\omega_0 = (1+\alpha\Delta T)^2 \omega$$

$$\omega = \frac{\omega_0}{(1+\alpha\Delta T)^2}$$

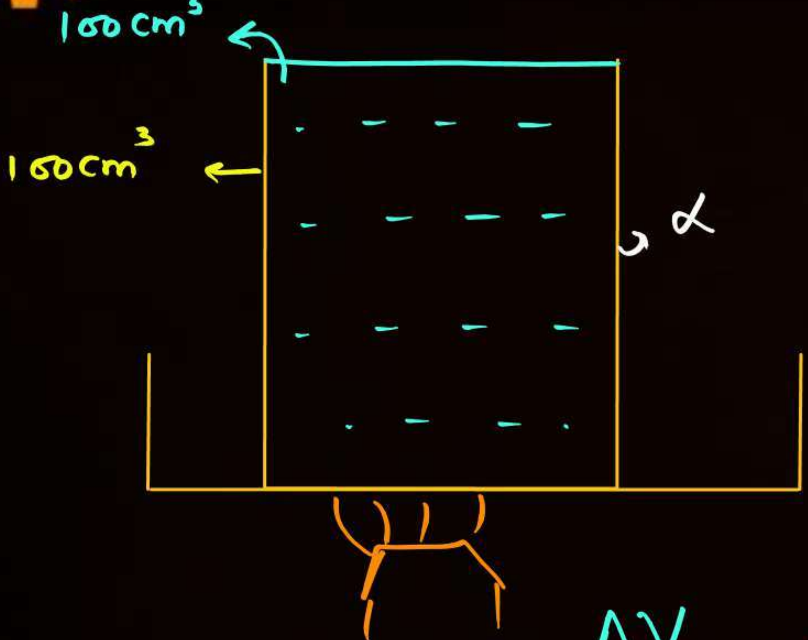
$$\omega = \omega_0(1+\alpha\Delta T)^{-2}$$

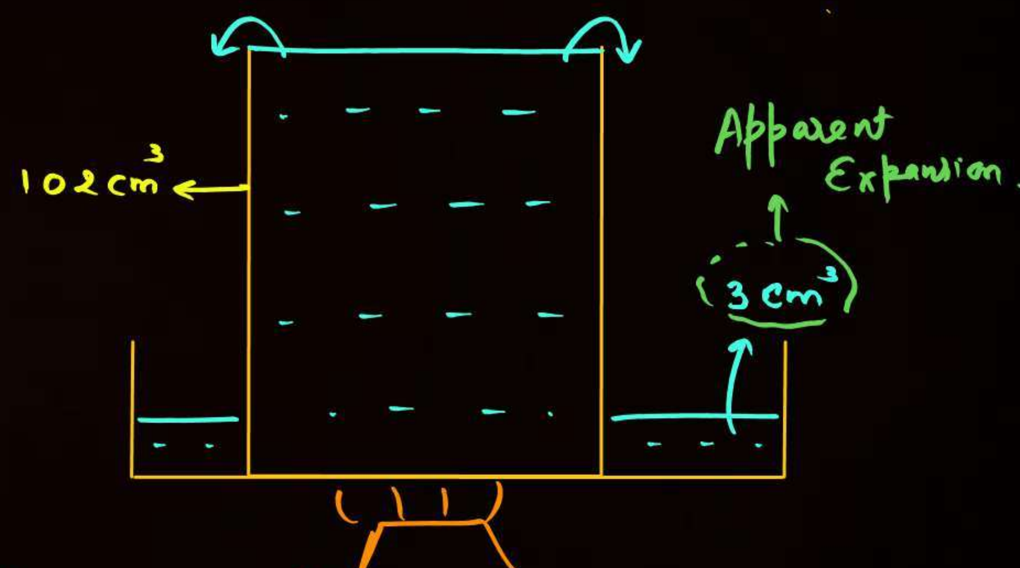
$$\omega = \omega_0(1-2\alpha\Delta T)$$ Ans.



Apparent Expansion of Liquid

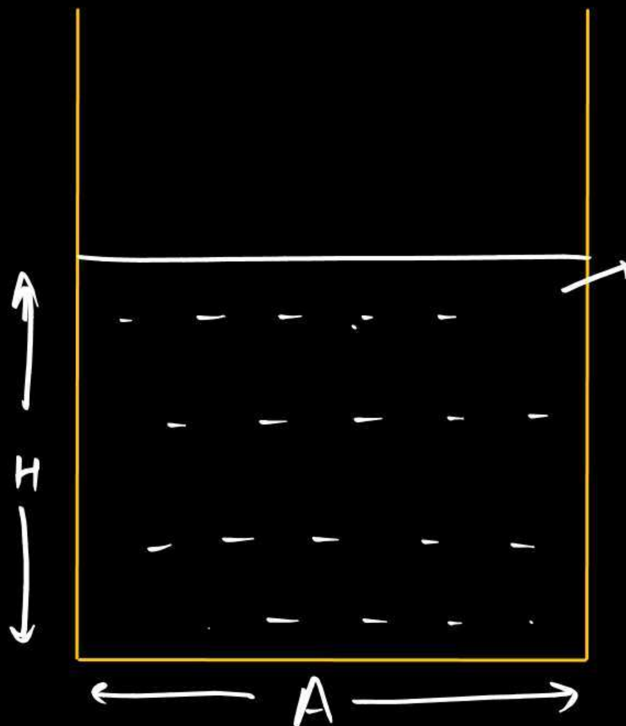
$$\gamma_{liq.} = 3\alpha_{cont.} + \gamma_{app.}$$





$$\Delta V_{actual} = \Delta V_{container} + \Delta V_{apparent}$$

$$\cancel{V_0}\,\gamma\,\cancel{\Delta T} = \cancel{V_0}(3\alpha)\cancel{\Delta T} + V_0\,\gamma_{app}\cancel{\Delta T}$$



$$V = AH$$

$$V_0(1+\gamma\Delta T) = A_0(1+2\alpha\Delta T)H$$

$$H = \frac{V_0}{A_0}\left(1+(\gamma-2\alpha)\Delta T\right)$$

$$\boxed{H = H_0\left[1+(\gamma-2\alpha)\Delta T\right]}$$

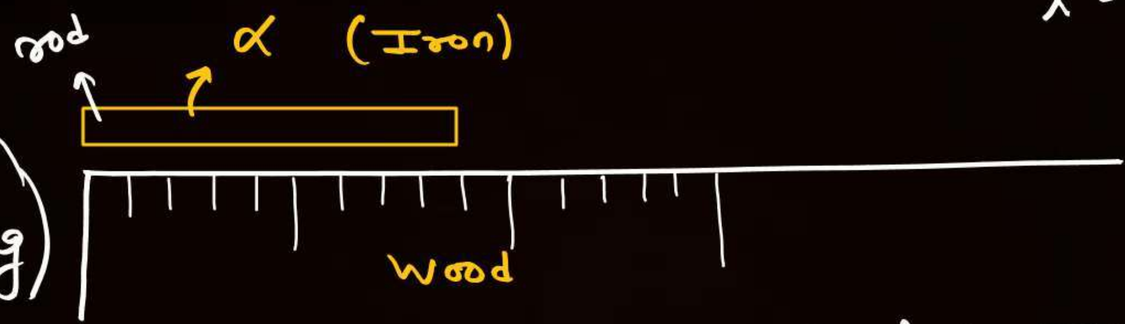
Measurement by Scale

Reading at temp. $T \rightarrow$

$$l = l_0(1 + \alpha \Delta T)$$

Case-I :-

(only rod is expanding)



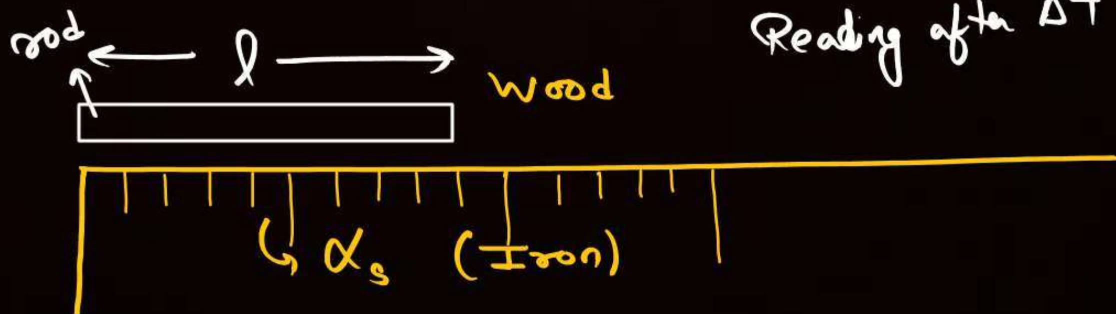
Scale is reading correctly at $T_0 \rightarrow l_0$

Reading after ΔT temp. increment $\rightarrow$

$$l = l_0(1 - \alpha_s \Delta T)$$

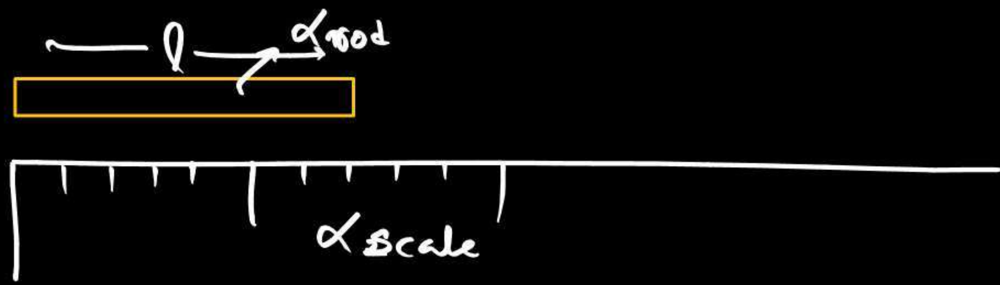
Case-II :-

(Only scale is expanding)



Case-III

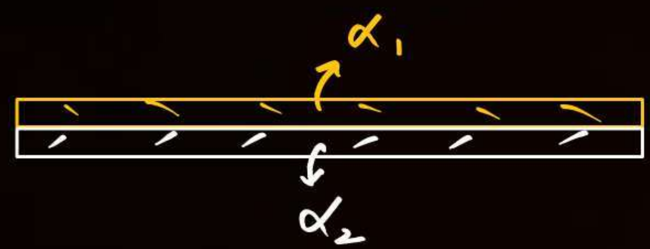
(Both rod & Scale can Expand)



Correct reading at T_0 temp. $\longrightarrow l_0$

Reading at temp $T_0 + \Delta T \longrightarrow$ $\boxed{l = l_0\left[1 + (\alpha_{rod} - \alpha_{scale})\Delta T\right]}$

Bimetallic Strip



$\alpha_1 > \alpha_2$

Strip उस side bend hogi जिस तरफ α कम होगा।

QUESTION (JEE Mains – July. 25, 2022 (I)

A unit scale is to be prepared whose length does not change with temperature and remains 20cm, using a bimetallic strip made of brass and iron each of different length. The length of both components would change in such a way that difference between their length remains constant. If length of brass is 40 cm and length of iron will be __60__ cm. ($\alpha_{iron} = 1.2 \times 10^{-5}\ K^{-1}$ and $\alpha_{brass} = 1.8 \times 10^{-5}\ K^{-1}$).

$$\Delta l_1 - \Delta l_2 = 0$$

$$l_1 \alpha_1 \cancel{\Delta t} = l_2 \alpha_2 \cancel{\Delta t}$$

$$l_1 \alpha_1 = l_2 \alpha_2$$

$$40 \times 1.8 \times \cancel{10^{-5}} = l \times 1.2 \times \cancel{10^{-5}}$$

$$l = \frac{40 \times 1.8}{1.2} = 60\,cm.$$

$$l_1 - l_2 = const$$

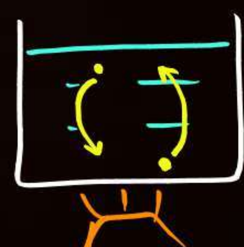
$$\Delta l_1 = \Delta l_2$$

Heat Transfer

Thermal Conduction

- Medium is required.
- only Heat transfer takes place, no matter is transferred
- In Solids.

Convection

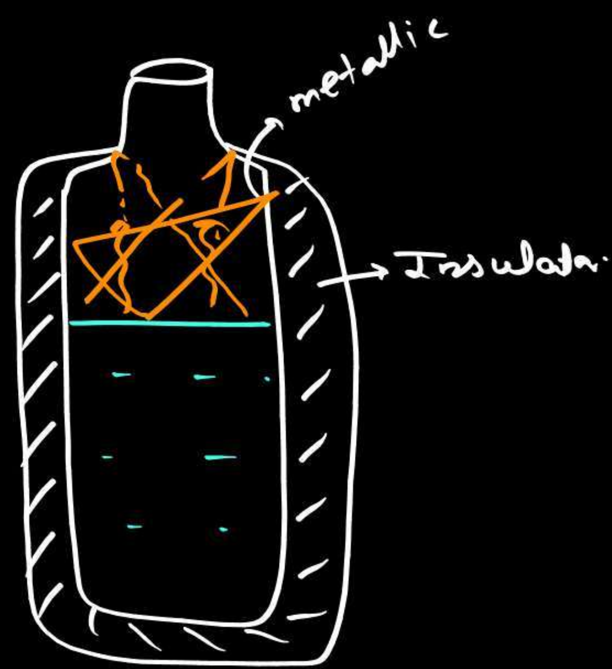


- Medium is required.
- Both mass & energy transfer takes place.
- In fluids

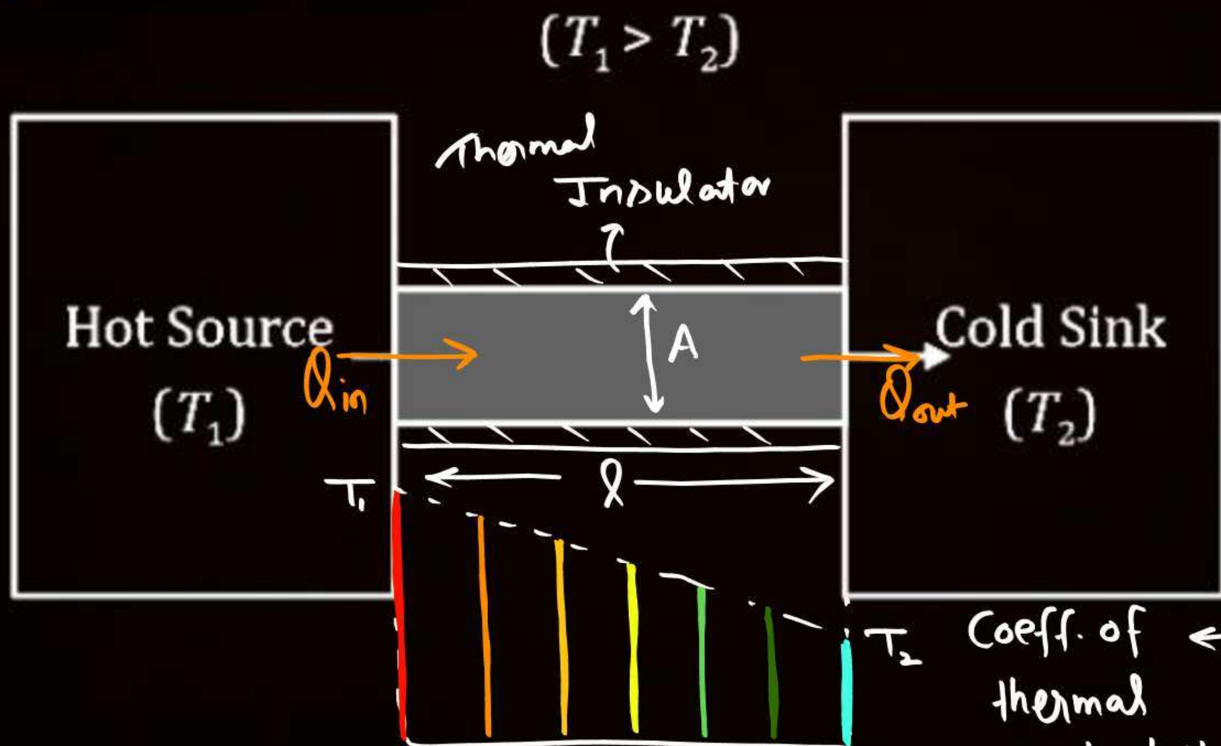
Radiation.

fastest way of energy transfer.

- Medium is not required.
- No mass transfer Happens
- Happens in all bodies, (Solid, liquid. gas)
- Happens at all temp


metallic
Insulator

Thermal Conduction



In steady state →

$$Q_{in} = Q_{out}$$

$\frac{dQ}{dt}$ = Rate of Heat flow

SI Unit : $\frac{J}{s}$ = watts.

Temp. gradient

$$\frac{dQ}{dt} \propto T_1 - T_2$$

$$\propto \frac{1}{l}$$

$$\propto A$$

$$\frac{T_1 - T_2}{l}$$

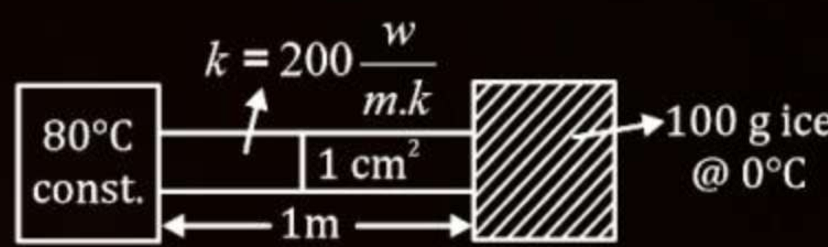
Coeff. of thermal conductivity

$$\frac{dQ}{dt} = \frac{kA}{l} \Delta T$$

QUESTION

Find time in which entire ice will melt.

$$\frac{dQ}{dt} = k\frac{A}{\ell}\Delta T \Rightarrow k = \frac{dQ/dt \cdot \ell}{A \cdot \Delta T} = \frac{\text{Watt} \cdot \cancel{m}}{m^{\cancel{2}} \cdot K}$$



$$\frac{dQ}{dt} = \frac{kA}{\ell}\Delta T$$

$$\frac{dQ}{dt} = \frac{200 \times 1 \times 10^{-4}}{1} \times 80$$

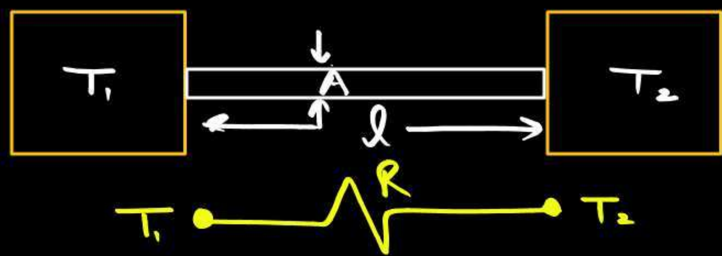
$$= 1.6\ J/s$$

$$t = \frac{Q}{dQ/dt} = \frac{mL}{(dQ/dt)}$$

$$= \frac{100 \times 80\ \text{cal}}{1.6\ J/s}$$

$$= \frac{8000 \times 4.2\ J}{1.6\ J/s}$$

$$\boxed{t = 21000\ s}\ \text{Ans}$$



$$\frac{dQ}{dt} = \frac{kA}{l}\,\Delta T$$

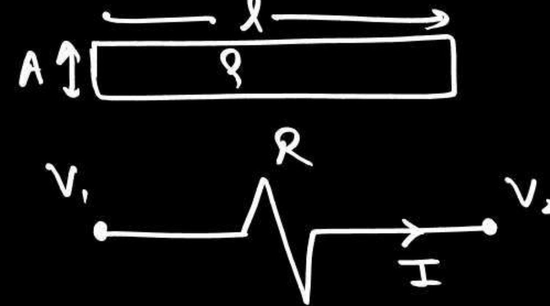
$$\frac{dQ}{dt} = \frac{\Delta T}{\left(\frac{l}{kA}\right)}$$

ΔT → Thermal potential diff

$\left(\frac{l}{kA}\right)$ → Thermal Resistance

$\frac{dQ}{dt}$ → Thermal current

$$R_{th.} = \frac{l}{kA}$$



$$V = IR$$

$$V_1 - V_2 = I \cdot R$$

$$I = \frac{V_1 - V_2}{R}$$

$$I = \frac{V_1 - V_2}{\left(\frac{\rho l}{A}\right)} = \frac{\Delta V}{\left(\frac{l}{kA}\right)}$$

ρ → Elec. Resistivity

k → Electrical conductivity.

$\left(\frac{l}{kA}\right)$ → Electric Resistance

QUESTION (JEE Mains – Jan. 10, 2019 (I))

A heat source at $T = 10^3$ K is connected to another heat reservoir at $T = 10^2$ K by a copper slab which is 1 m thick. Given that the thermal conductivity of copper is $\underbrace{0.1\ \text{WK}^{-1}\ \text{m}^{-1}}_{k}$, the energy flux through it in the steady state

(A) 90 Wm^{-2} $\frac{W}{m^2}$

(B) 120 Wm^{-2}

(C) 65 Wm^{-2}

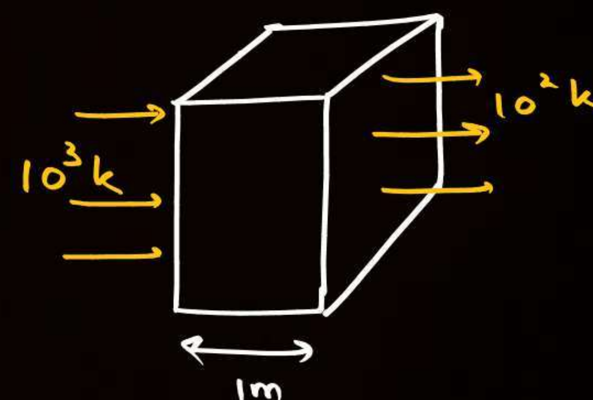
(D) 200 Wm^{-2}

$$\frac{dQ}{dt} = \frac{kA}{l}\Delta T$$

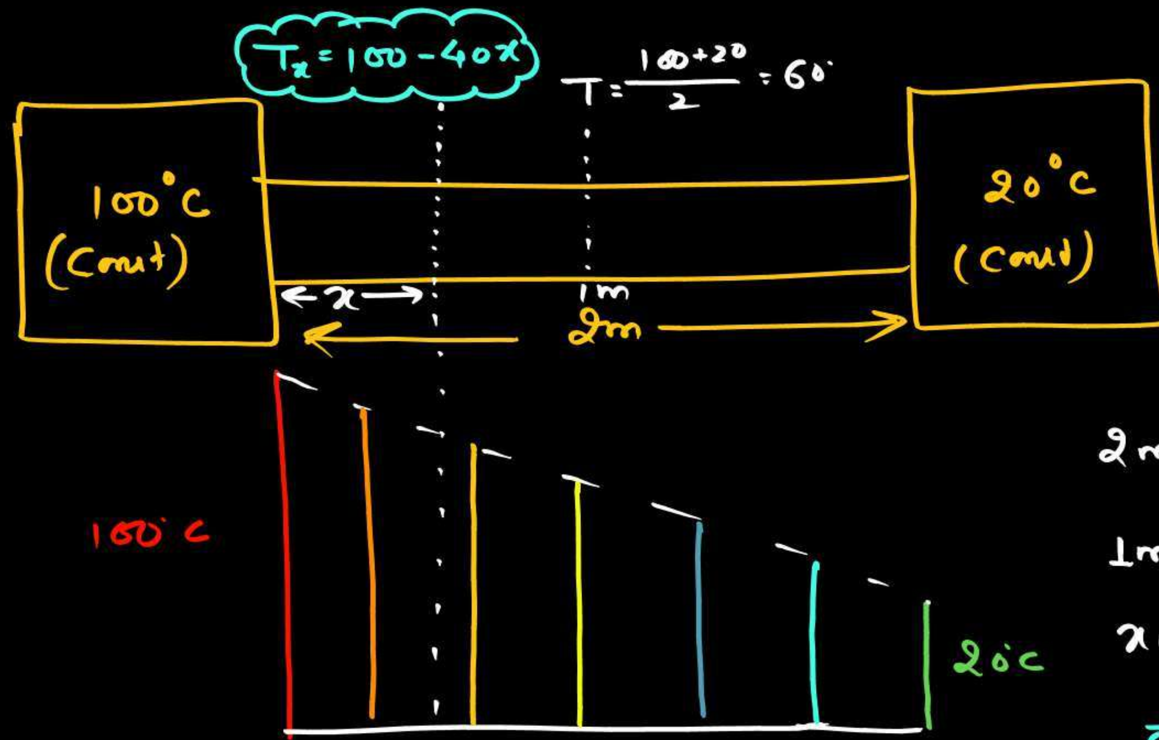
$$\frac{\frac{dQ}{dt}}{A} = \frac{k\Delta T}{l}$$

$$= \frac{0.1 \times (1000-100)}{1}$$

$$= 900 \times 0.1 = 90\ \frac{W}{m^2}.$$



Q.



ΔT

$2m \longrightarrow 80°C$

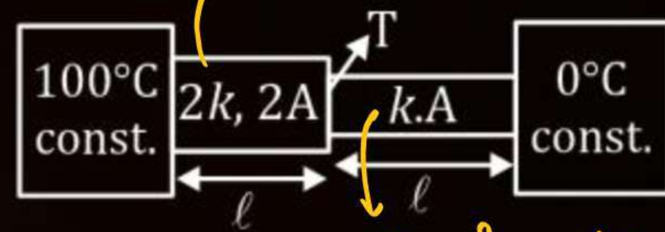
$1m \longrightarrow 40°C$

$xm \longrightarrow 40 \times x\ °C$

इतना temp. कम हुआ है।

QUESTION

Find temperature of junction between two conductors.



$R_1 = \frac{\ell}{2k \cdot 2A} = \frac{\ell}{4kA} = R$

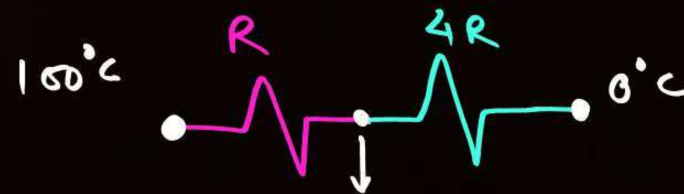
$R_2 = \frac{\ell}{kA} = 4R$

$$R = \frac{\rho \ell}{A} = \frac{\ell}{kA}$$

$$\underline{\underline{\Delta T}}$$

$$5R \longrightarrow 100^\circ C$$

$$R \longrightarrow \frac{100}{5}\,^\circ C = 20^\circ C$$



$T = 100 - 20$

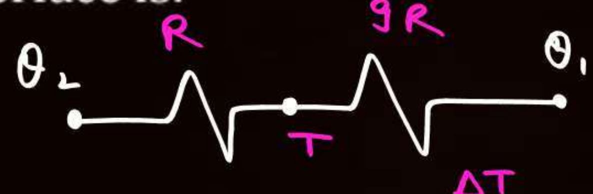
$T = 80^\circ C$ Ans

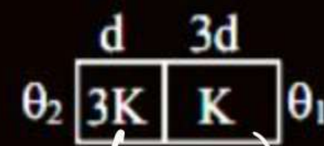
$$\frac{dQ}{dt} = \frac{V}{R_{eq}} = \frac{100}{5R} = \frac{20}{\left(\frac{\ell}{4kA}\right)}$$

$$\frac{dQ}{dt} = \frac{80kA}{\ell}$$

QUESTION (JEE Mains – Apr. 09, 2019 (II))

Two materials having coefficients of thermal conductivity '3K' and 'K' and thickness 'd' and '$3d$', respectively, are joined to form a slab as shown in the figure. The temperatures of the outer surfaces are 'θ_2' and 'θ_1' respectively, ($\theta_2 > \theta_1$). The temperature at the interface is:





(A) $\frac{\theta_2+\theta_1}{2}$

(B) $\frac{\theta_1}{3}+\frac{2\theta_2}{3}$

(C) $\frac{\theta_1}{10}+\frac{9\theta_2}{10}$

(D) $\frac{\theta_1}{6}+\frac{5\theta_2}{6}$

$10R \longrightarrow \theta_2-\theta_1$

$R \longrightarrow \frac{\theta_2-\theta_1}{10}$

$T=\theta_2-\left(\frac{\theta_2-\theta_1}{10}\right)=\frac{9\theta_2+\theta_1}{10}$

$R_1=\frac{d}{3kA}$ $\quad \frac{3d}{kA}=R_2=9R$

$R_1=R$

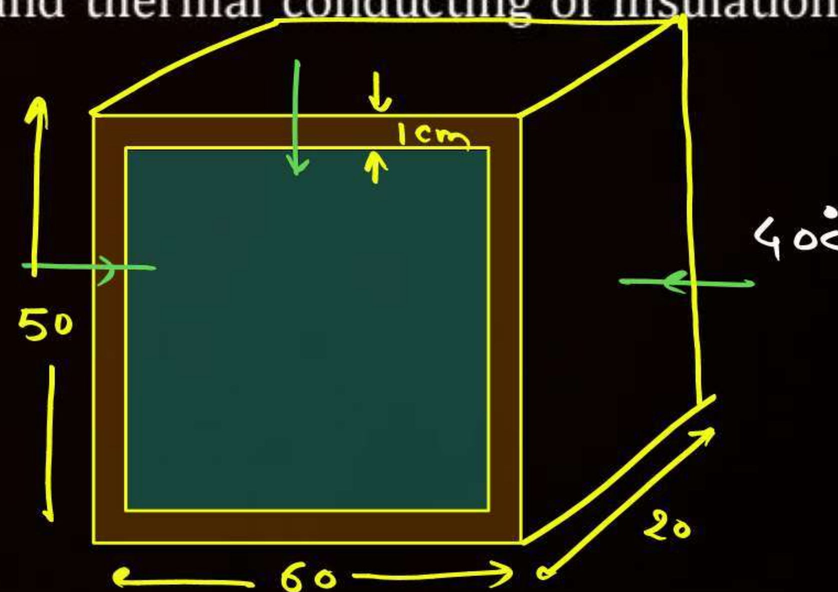
QUESTION (JEE Mains – July. 26, 2022 (II))

H.W

An ice cube of dimensions 60cm × 50cm × 20cm is placed in an insulation box of wall thickness 1 cm. The box keeping the ice cube at 0°C of temperature is brought to a room of temperature 40°C. The rate of melting of ice is approximately:

(Latent heat of fusion of ice is 3.4×10^5 J kg^{-1} and thermal conducting of insulation wall is 0.05 Wm^{-1} °C^{-1})

$\frac{dQ}{dt} =$



(A) 61×10^{-3} kg s^{-1}

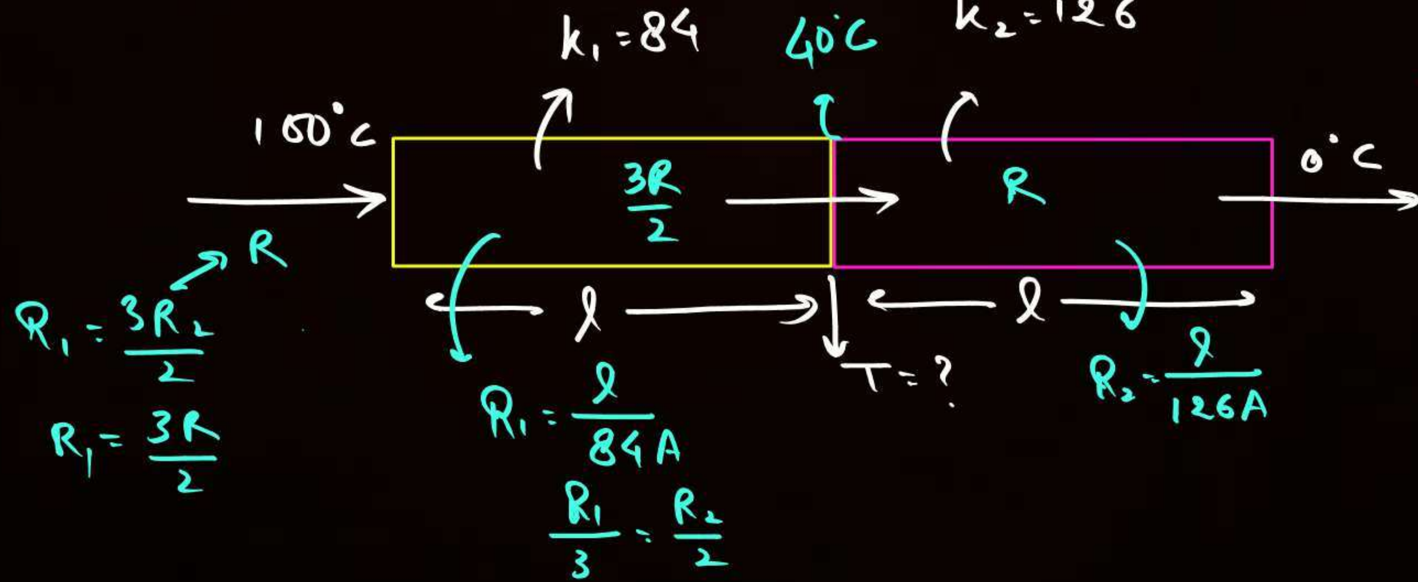
(B) 61×10^{-5} kg s^{-1}

(C) 208 kg s^{-1}

(D) 30×10^{-3} kg s^{-1}

QUESTION (JEE Mains – Apr. 13, 2023 (II))

Two plates A and B have thermal conductivities 84 $Wm^{-1}K^{-1}$ and 126 $Wm^{-1}K^{-1}$ respectively. They have same surface area and same thickness. They are placed in contact along their surfaces. If the temperatures of the outer surfaces of A and B are kept at 100° C and 0°C respectively, then the temperature of the surface of contact in steady state is 60 °C.



$\frac{5R}{2} \rightarrow 100$

$R \rightarrow \frac{100}{5/2}$

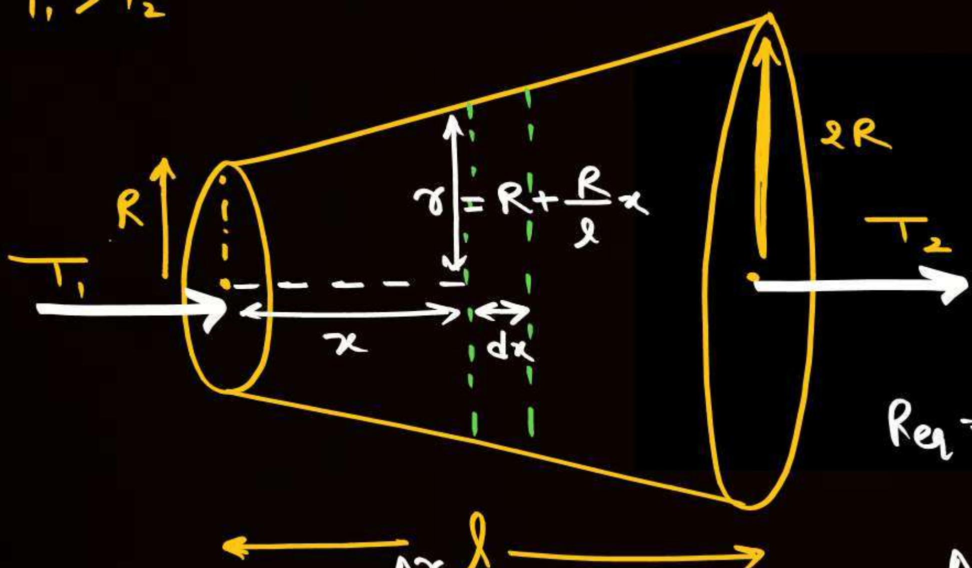
$R \rightarrow 40°C$

$\frac{3R}{2} \rightarrow 60°C$

QUESTION

Find rate of heat flow between ends of frustrum.

$T_1 > T_2$



$l \longrightarrow R$

$1 \longrightarrow \frac{R}{l}$

$x \longrightarrow \frac{R}{l}x$

$$\int dR = \int \frac{dx}{k \cdot A}$$

$$R_{eq} = \frac{1}{k} \int \frac{dx}{\pi r^2}$$

$$= \frac{1}{k\pi} \int \frac{dx}{r^2} = \frac{1}{\pi k} \int_0^l \frac{dx}{R\left[1+\frac{x}{l}\right]^2}$$

$$= \frac{1}{\pi R^2 k} \left[\frac{-\left[1+\frac{x}{l}\right]^{-1}}{\frac{1}{l}} \right]_0^l$$

$$R_{eq} = \frac{l}{\pi R^2 k}\left(1 - \frac{1}{2}\right)$$

$$R_{eq} = \frac{l}{2\pi R^2 k}$$

$$I = \frac{\Delta T}{R_{eq}} = \frac{(T_1 - T_2)\, 2\pi R^2 k}{l}$$

QUESTION (JEE Mains – Aug. 31, 2021 (II))

Two thin metallic spherical shells of radii r_1 and r_2 $(r_1 < r_2)$ are placed with their centres coinciding. A material of thermal conductivity K is filled in the space between the shells. The inner shell is maintained at temperature o the outer shell at temperature $\theta_2(\theta_1 < \theta_2)$. The rate at which heat flows radially through the material is:

(A) $\dfrac{\pi r_1 r_2(\theta_2-\theta_1)}{r_2-r_1}$

(B) $\dfrac{K(\theta_2-\theta_1)(r_2-r_1)}{4\pi r_1 r_2}$

(C) $\dfrac{K(\theta_2-\theta_1)}{r_2-r_1}$

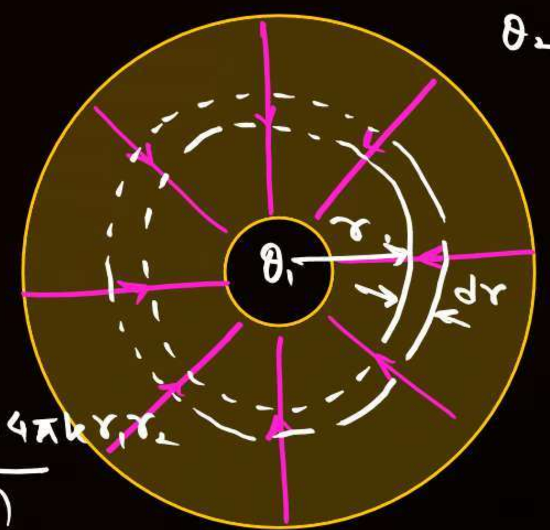
(D) $\dfrac{4\pi K r_1 r_2(\theta_2-\theta_1)}{r_2-r_1}$

$$\int dR = \int_{r_1}^{r_2} \frac{dr}{K(4\pi r^2)}$$

$$R_{eq} = \frac{1}{4\pi K}\left[-\frac{1}{r}\right]_{r_1}^{r_2}$$

$$R_{eq} = \frac{1}{4\pi K}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

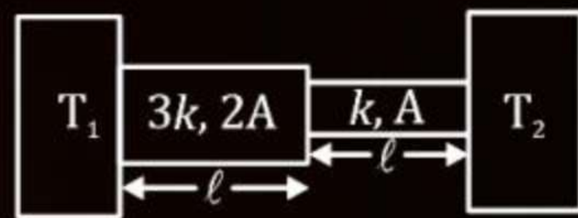
$$\frac{d\theta}{dt} = \frac{\theta_2-\theta_1}{R_{eq}} = \frac{(\theta_2-\theta_1)4\pi K r_1 r_2}{(r_2-r_1)}$$



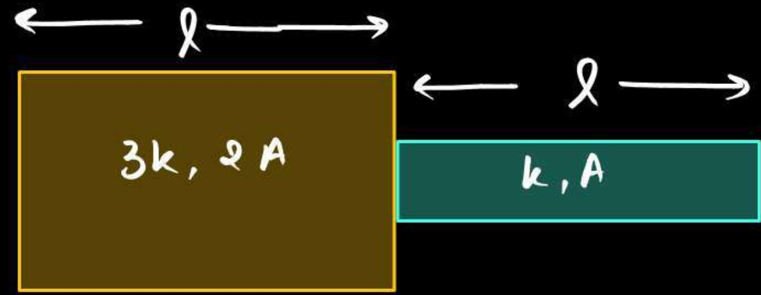
QUESTION

Find equivalent thermal conductivity-

$\frac{9k}{7}$

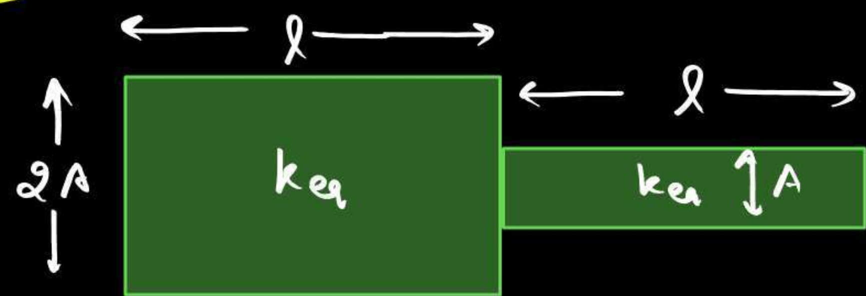


Geometry change किये बिना, ऐसा material रखो कि $R_{eq.}$ change ना हो



$$R_{eq} = R_1 + R_2 = \frac{l}{6kA} + \frac{l}{kA}$$

$$R_{eq} = \frac{7l}{6kA}$$



$$R_{eq} = \frac{l}{k_{eq}\cdot 2A} + \frac{l}{k_{eq}\cdot A}$$

$$\frac{7\cancel{l}}{\cancel{6}_{3}k\cancel{A}} = \frac{1}{k_{eq}} \times \frac{3\cancel{l}}{\cancel{2}\cancel{A}} \Rightarrow \boxed{k_{eq} = \frac{9}{7}k}$$ Ans

QUESTION (JEE Mains – March. 17, 2021 (I))

Two identical metal of thermal conductivities K_1 and K_2 respectively are connected in series. The effective thermal conductivity of the combination is:

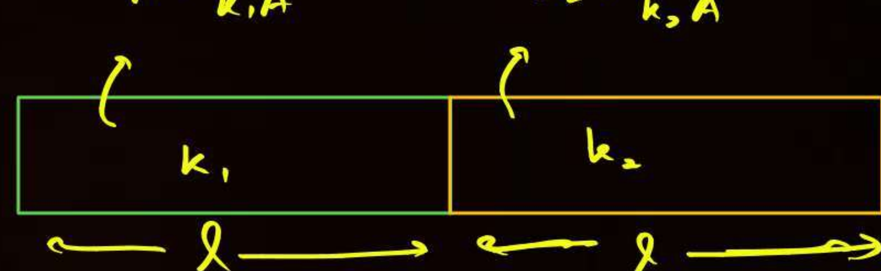
(A) $\frac{K_1+K_2}{K_1K_2}$

(B) $\frac{K_1+K_2}{2K_1K_2}$

(C) $\frac{2K_1K_2}{K_1+K_2}$ ✓

(D) $\frac{K_1K_2}{K_1+K_2}$

$R = \frac{l}{k_1 A}$ $\qquad$ $R_2 = \frac{l}{k_2 A}$



$$\frac{2\cancel{l}}{k_{eq}\cancel{A}} = \frac{\cancel{l}}{k_1\cancel{A}} + \frac{\cancel{l}}{k_2\cancel{A}}$$

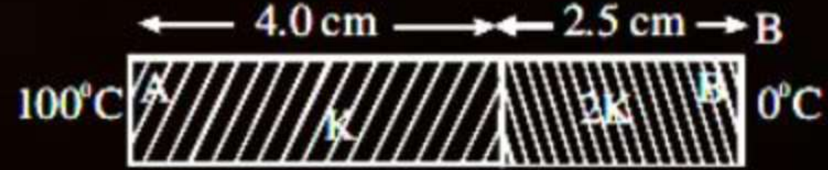
$$k_{eq} = \frac{2k_1k_2}{k_1+k_2}$$

QUESTION (JEE Mains – June. 29, 2022 (I))

H.W

As per the given figure, two plates A and B of thermal conductivity K and 2K are joined together of form a compound plate. The thickness of plates are 4.0 cm and 2.5 cm respectively and the area of cross-section is 120 cm^2 for each plate. The equivalent thermal conductivity of the compound plate is $\left(1+\frac{5}{\alpha}\right)K$, then the value of α will be

______.



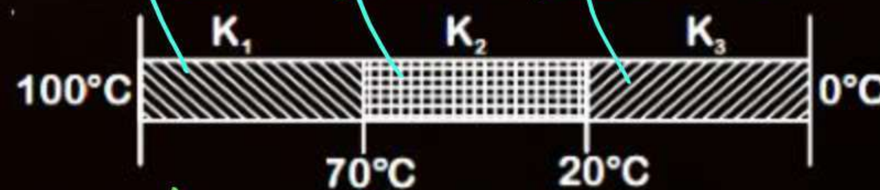
QUESTION (JEE Mains – Sep. 06, 2020 (II))

$\uparrow V = I R \uparrow$

Three rods of identical cross-section and lengths are made of three different materials of thermal conductivity K_1, K_2 and K_3 respectively. They are joined together at their ends to make a long rod (see figure). One end of the long rod is maintained at 100°C and the other at 0°C (see figure). If the joints of the rod are at 70°C and 20°C in steady state and there is no loss of energy from the surface of the rod, the correct relationship between K_1, K_2 and K_3 is

3R 5R 2R

30° 50°C 20°C



$\uparrow \Delta T = I R \uparrow$

(A) $K_1 : K_3 = 2 : 3$; $K_2 : K_3 = 2 : 5$

(B) $K_1 < K_2 < K_3$

(C) $K_1 : K_2 = 5 : 2$; $K_1 : K_3 = 3 : 5$

(D) $K_1 > K_2 > K_3$

$k_2 < k_1 < k_3$

$\uparrow R = \frac{l}{\downarrow k A}$

$$\frac{\frac{l}{k_1 A}}{\frac{l}{k_2 A}} = \frac{3R}{5R}$$

$$\frac{k_2}{k_1} = \frac{3}{5} \Rightarrow \frac{k_1}{k_2} = \frac{5}{3}$$

QUESTION

Find.

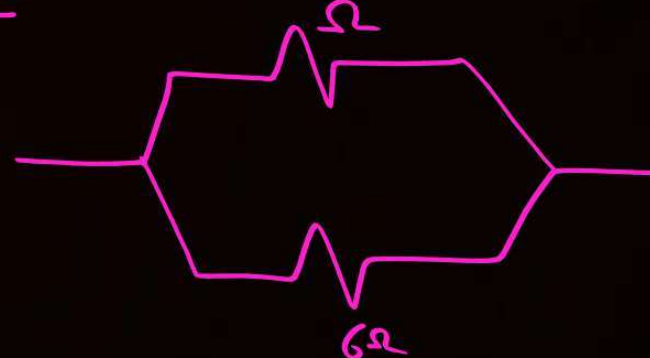
(1) Rate of heat flow

(2) Equivalent thermal conductivity. HW

$$\Omega' = \frac{l}{2k[\pi(2R)^2 - \pi R^2]}$$

$$\Omega' = \frac{l}{6k\pi R^2} = \Omega$$

$$\Omega_2 = \frac{l}{k \cdot \pi R^2} = 6\Omega$$



$$\Omega_{eq} = \frac{\Omega \times 6\Omega}{7\Omega} = \frac{6\Omega}{7}$$

$$\dot{i} = \frac{V}{R_{eq}} = \frac{5T_0 - T_0}{\frac{6}{7}\Omega}$$

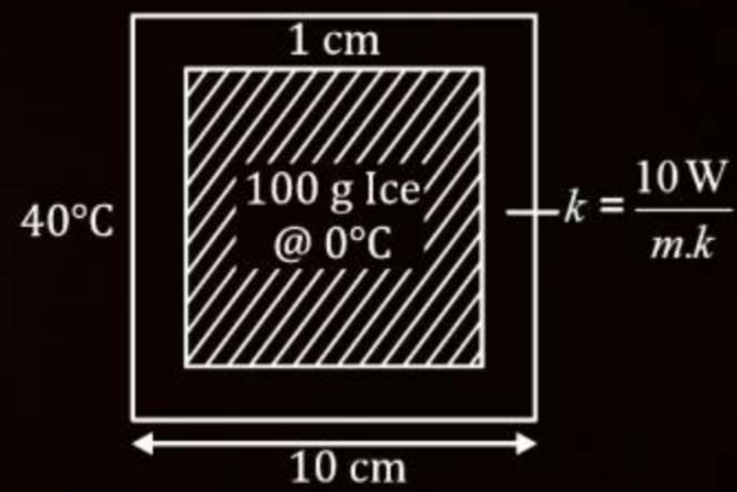
$$= 4T_0 \times \frac{7}{\cancel{6}} \times \frac{\cancel{6}k\pi R^2}{l}$$

$$= \frac{28\pi R^2 k T_0}{l}$$

QUESTION

H.W

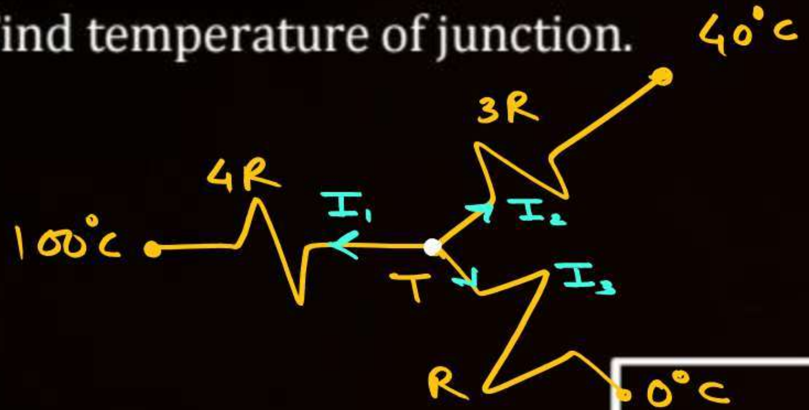
Find time in which entire ice will melt.

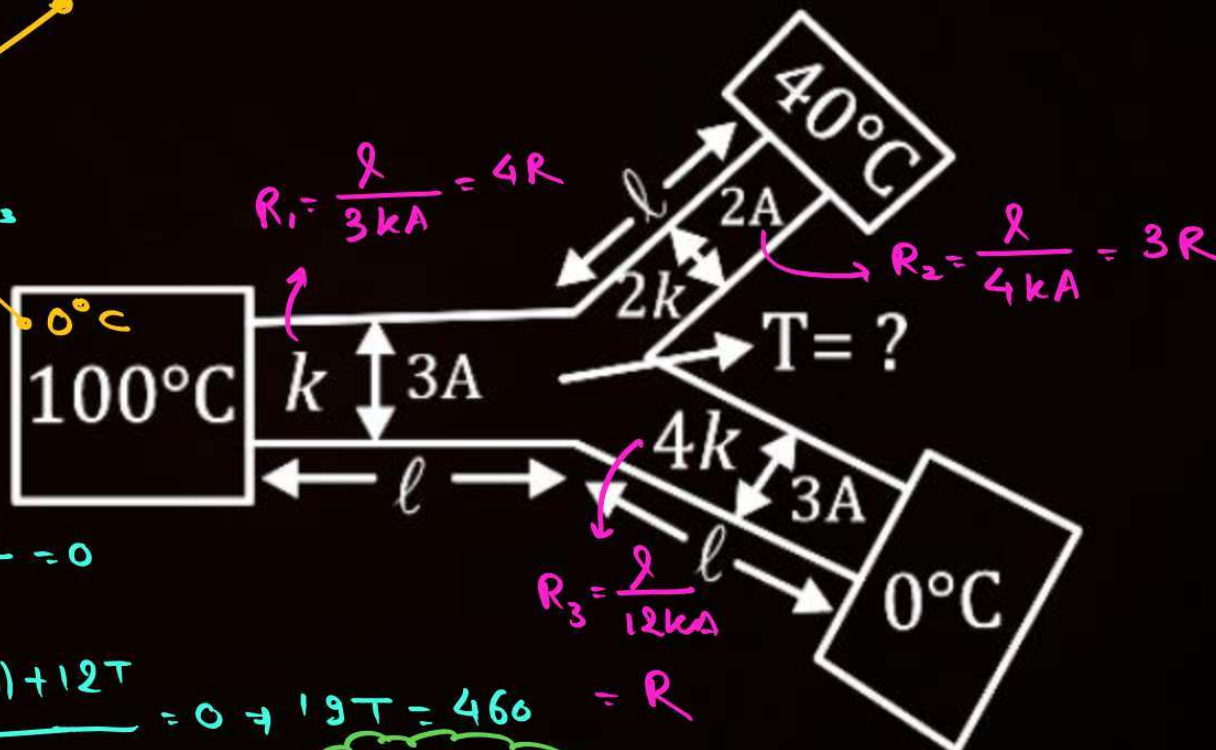


QUESTION

(KCL) $\quad I = \frac{V}{R}$

Find temperature of junction.





$$I_1 + I_2 + I_3 = 0$$

$$\frac{T-100}{4R} + \frac{T-40}{3R} + \frac{T-0}{R} = 0$$

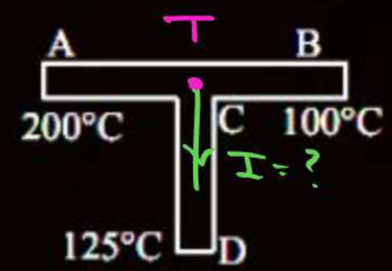
$$\frac{3(T-100) + 4(T-40) + 12T}{12R} = 0 \Rightarrow 19T = 460$$

$$\boxed{T = \frac{460}{19}\,^\circ C} \text{ Ans}$$

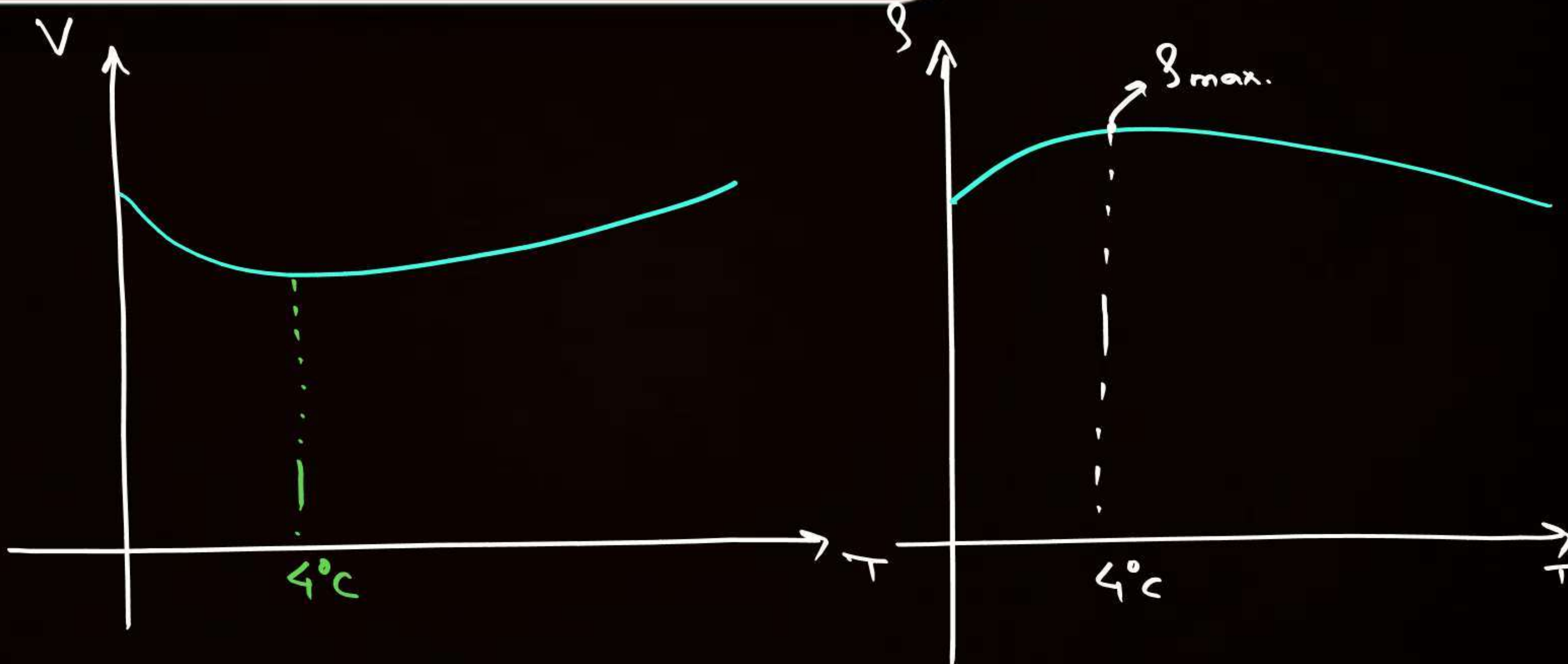
QUESTION (JEE Mains – Aug. 27, 2021 (I))

H.W

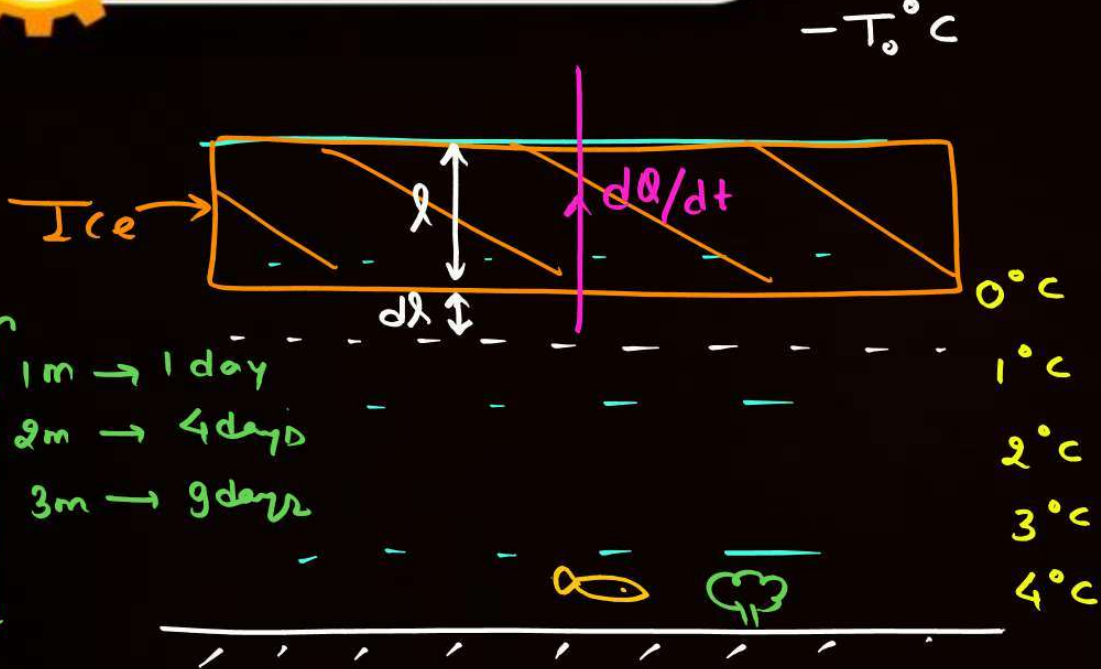
A rod CD of thermal resistance 10.0 kW^{-1} is joined at the middle of an identical rod AB as shown in figure, The end A, B and D are maintained at 200°C, 100°C and 125°C respectively. The heat current in CD is P watt. The value of P is



Anomalous Behaviour of Water



Freezing of Lake



1m → 1 day
2m → 4 days
3m → 9 days

$$\frac{dQ}{dt} = \frac{kA}{l}\Delta T$$

$$dQ = dm\,L$$

$$\frac{dm \cdot L}{dt} = \frac{kA}{l} T_0$$

$$\frac{\rho \cdot \cancel{A} \cdot dl \cdot L}{dt} = \frac{k\cancel{A}}{l} T_0$$

$$\rho L \frac{dl}{dt} = \frac{k}{l} T_0$$

$$\rho L \cdot \int l\,dl = k T_0 \int dt$$

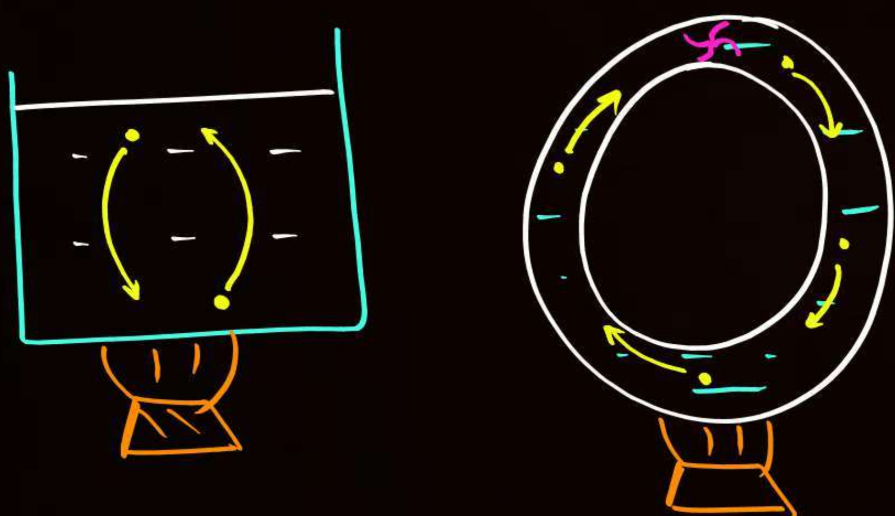
$$\frac{\rho L \cdot l^2}{2} = k T_0 t$$

$$t \propto l^2$$

Thermal Convection

Natural

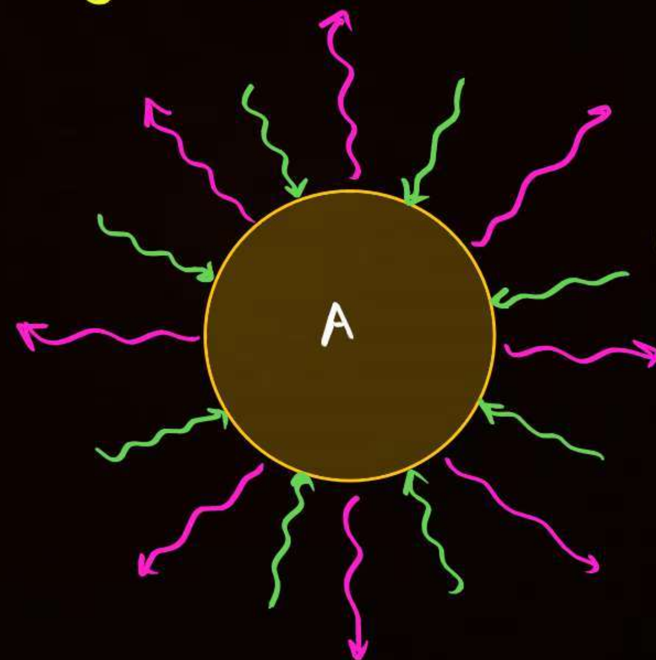
Forced.



Thermal Radiation

Prevost Theory of Heat Exchange { Heat.

Any body that has temp. of above 0 K radiates



In equillibrium →

Heat radiated per sec. = Heat absorbed per sec

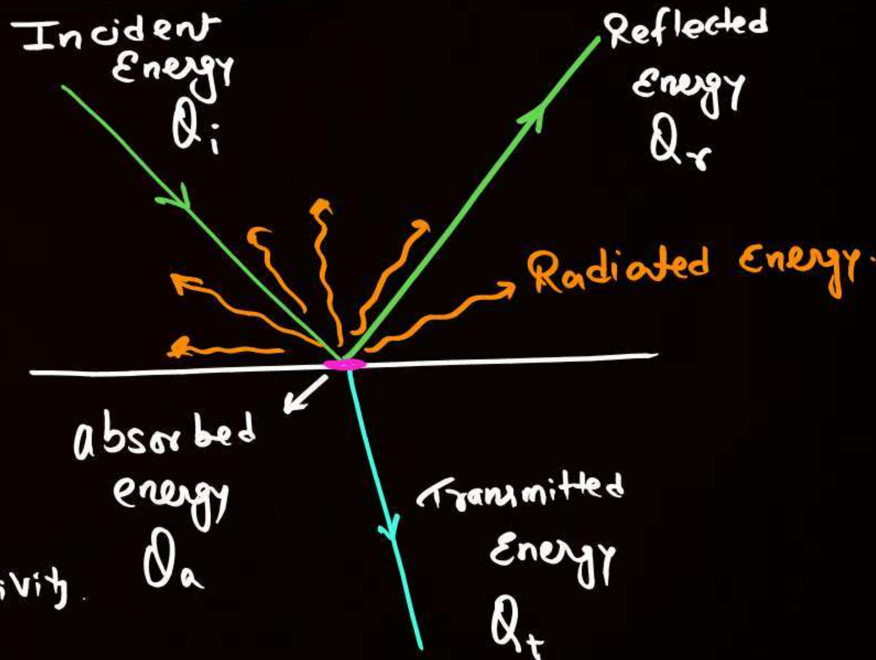
Emissive Power, Absorptive Power

$$Q_i = Q_r + Q_t + Q_a$$

$$\underbrace{\frac{Q_r}{Q_i}} + \frac{Q_t}{Q_i} + \frac{Q_a}{Q_i} = 1$$

$$r + t + \underline{\underline{a}} = 1$$

reflectivity, Transmittivity, Absorptive power/absorptivity.



$$\text{Absorptive power } (a) = \frac{\text{Total Energy absorbed}}{\text{Total Energy incident}}$$

↘ unitless

$$r + t + a = 1$$

for perfectly reflecting surface, $r = 1$, $a, e = 0$

for perfectly transparent surface, $t = 1$, $a, e = 0$

for perfectly absorptive surface (Perfect Black Body). $a = 1$, $r, t = 0$

Emissive Power, E $\longrightarrow$

Total energy radiated per unit time per unit Area.

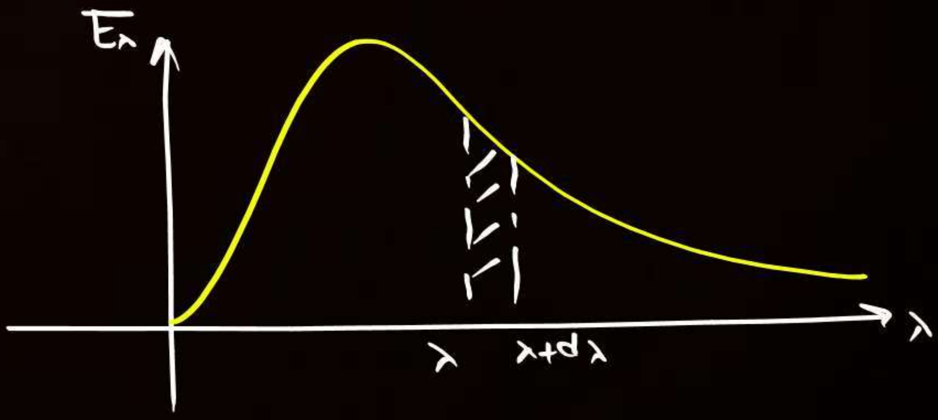
$$\boxed{E = \frac{\text{Energy radiated}}{\text{Time} \times \text{Area}}}$$

unit $= \frac{\text{Watt}}{m^2}$

Spectral Emissive Power

$$E_\lambda = \frac{dE}{d\lambda}$$

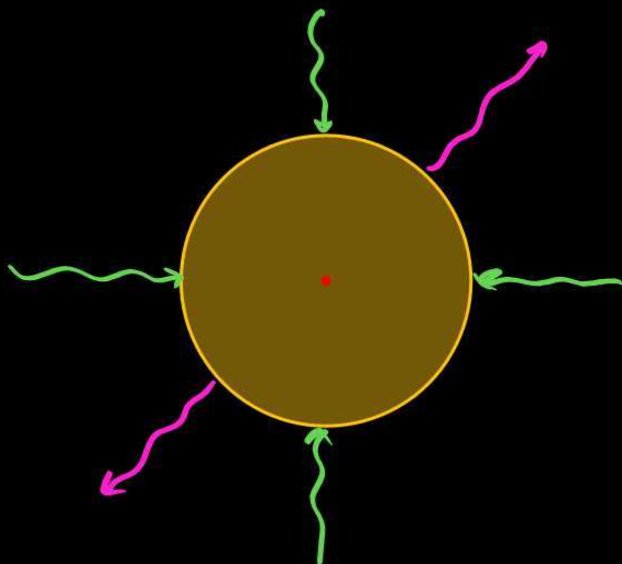
Total energy radiated per unit time per unit Area per unit wavelength

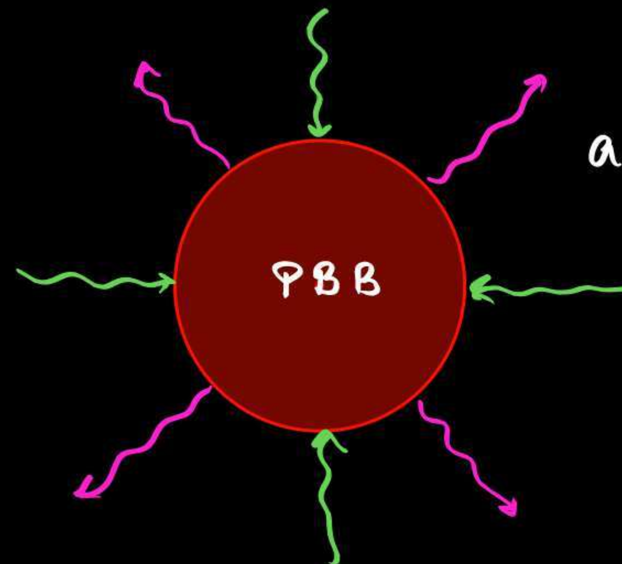


Perfect Black Body

$a = 1$

Thermal Equillibrium





$a = 1$

$E = E_0 \times a$

$E_{PBB} = E_0$

$E = E_{PBB} \times a$

Kirchhoff's Law of Radiation

Emissive power of a body is a fraction of Emissive power of PBB at same temp

$$E = E_{PBB} \times a$$

Emissivity

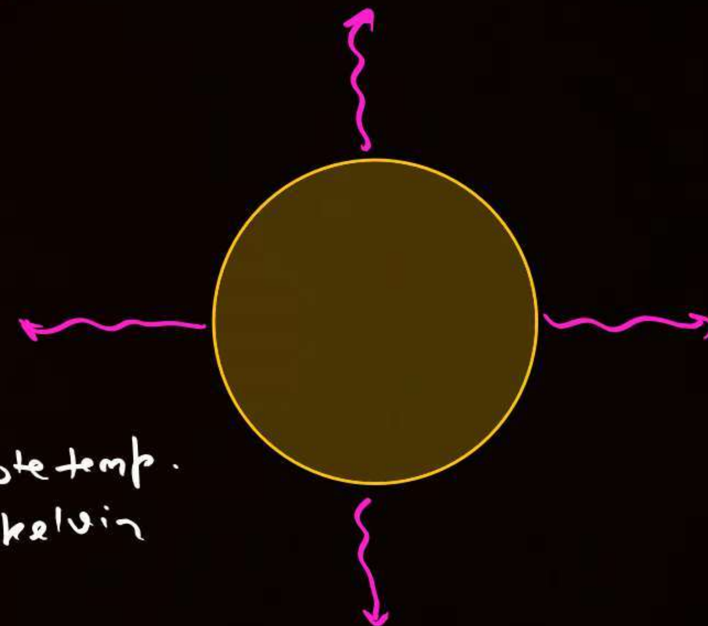
$$e = \frac{E}{E_{PBB}}$$

$$0 < e \leq 1$$

$$e = a$$

Stefan-Boltzmann Law

$$\frac{dQ}{dt} = \sigma e A T^4$$



$\frac{dQ}{dt}$ = Rate of Heat radiated per sec

T = Absolute temp. in kelvin

σ = Stefan's const

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

e = emissivity

A = Surface area of body

QUESTION (JEE Mains – 2006)

Assuming the Sun to be a spherical body of radius R at a temperature of TK, evaluate the total radiant powered incident of Earth at a distance r from the Sun

(A) $4\pi r_0^2 R^2 \sigma \frac{T^4}{r^2}$

(B) $\pi r_0^2 R^2 \sigma \frac{T^4}{r^2}$

(C) $r_0^2 R^2 \sigma \frac{T^4}{4\pi r^2}$

(D) $R^2 \sigma \frac{T^4}{r^2}$

Heat rad. by sun →

$\frac{dQ}{dt} = \sigma e A T^4$

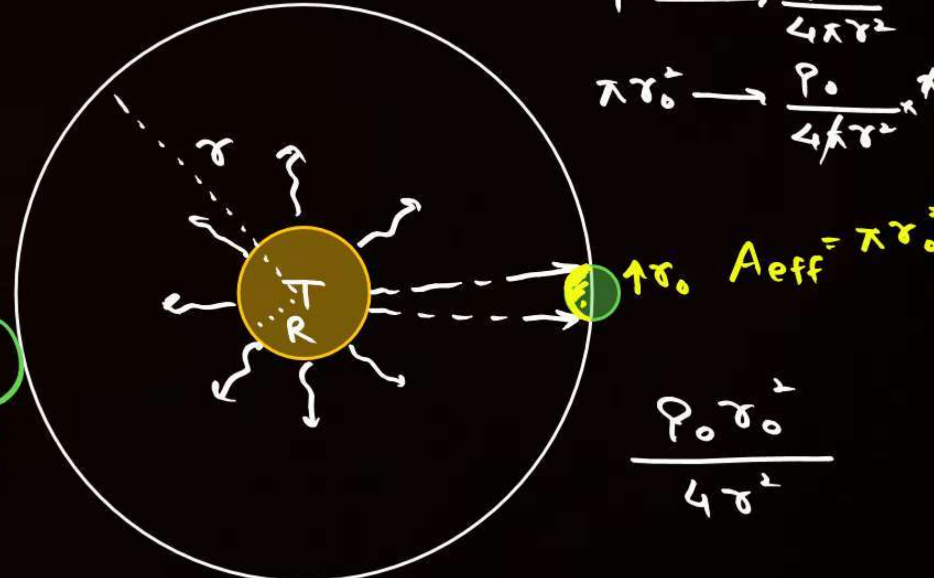
$P_0 = \frac{dQ}{dt} = \sigma(\pi R^2) T^4$

$\frac{\sigma \pi R^2 T^4 r_0^2}{4 r^2}$

$4\pi r^2 \longrightarrow P_0$

$1 \longrightarrow \frac{P_0}{4\pi r^2}$

$\pi r_0^2 \longrightarrow \frac{P_0}{4\cancel{\pi} r^2} \times \cancel{\pi} r_0^2$



$\frac{P_0 r_0^2}{4 r^2}$

where r_0 is the radius of the Earth and σ is Stefan's constant.

QUESTION (JEE Mains – Online May 7, 2012)

The heat radiated per unit area in 1 hour by a furnace whose temperature is $\underbrace{3000\text{ K}}$ is ($\sigma = 5.7 \times 10^{-8}$ W m^{-2} K^{-4})

(A) 1.7×10^{10} J

(B) 1.1×10^{12} J

(C) 2.8×10^{8} J

(D) 4.6×10^{6} J

$$\frac{\frac{dQ}{dt}}{A} = \sigma T^4$$

$$= 5.7 \times 10^{-8} \times (3 \times 10^3)^4$$

$$= 5.7 \times 10^{-8} \times 81 \times 10^{12}$$

$$= 5.7 \times 81 \times 10^4$$

$$=$$

QUESTION (JEE Mains – 2004)

If the temperature of the sun were to increase from T to $2T$ and its radius from R to $2R$, then the ratio of the radiant energy received on earth to what it was previously will be

(A) 32

(B) 16

(C) 4

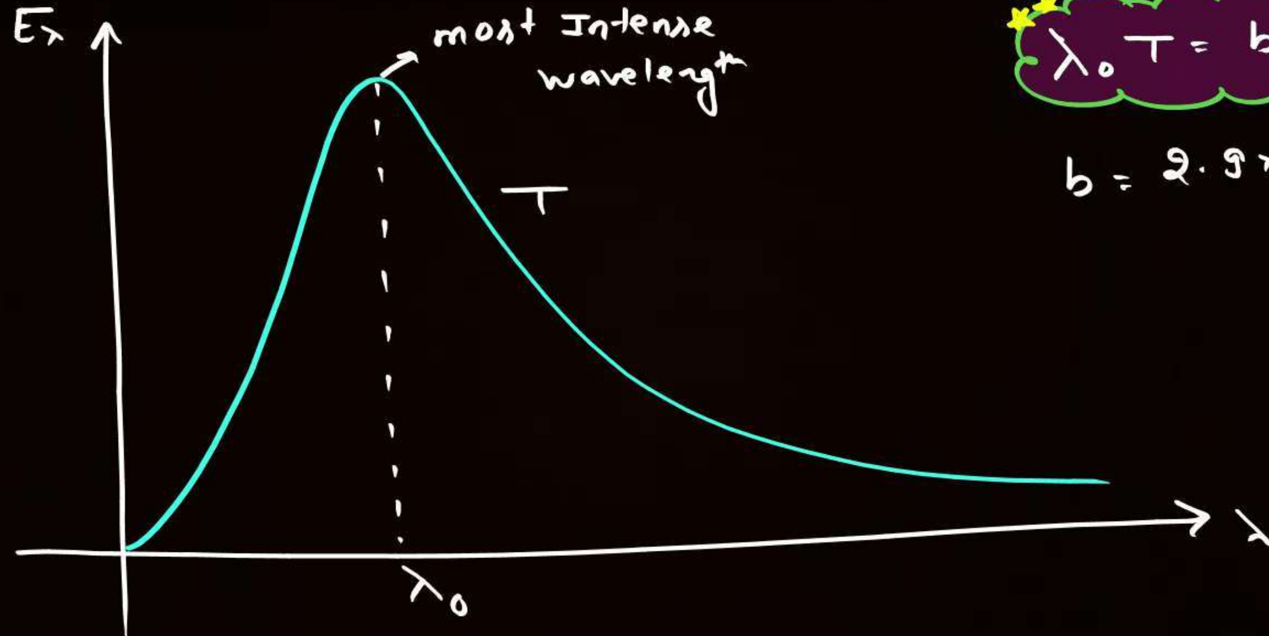
(D) 64

$$\frac{dQ}{dt} = \sigma e A T^4$$

$$\sigma e \cdot 4\pi (2R)^2 (2T)^4$$

$4\times$ $16\times$

Wein's Displacement Law



$\lambda_0 T = \text{const.}$

$$\boxed{\lambda_0 T = b}$$

$b = 2.9 \times 10^{-3}$ m.k

QUESTION (JEE Mains – JEE Adv, 2023)

$T_0 \longrightarrow 2T_0$

$P_0 \longrightarrow 2^4 P_0 = 16 P_0$

Match the temperature of a black body given in List-I with an appropriate statement in List-II, and choose the correct option. [Given: Wien's constant as 2.9×10^{-3} m-K and $hc/e = 1.24 \times 10^{-6}$ V-m]

$\lambda T = \text{const} \quad \lambda = \frac{\text{const}}{T}$

List - I	List - II
(P) 2000 K	(1) The radiation at peak wavelength can lead to emission of photoelectrons from a metal of work function 4eV.
(Q) 3000 K	(2) The radiation at peak wavelength is visible to human eye. (4000 - 7000 Å)
(R) 5000 K	(3) The radiation at peak emission wavelength will result in the widest central maximum of a single slit diffraction. $\uparrow\beta = \frac{2\lambda D}{a}$
(S) 10000 K	(4) The power emitted per unit area is 1/16 of that emitted by a blackbody at temperature 6000 K.
	(5) The radiation at peak emission wavelength can be used to image human bones. X-ray

QUESTION (JEE Mains – JEE Adv, 2023)

(A) $p \to 3, q \to 5, r \to 2, s \to 3$

(B) $p \to 3, q \to 2, r \to 4, s \to 1$

(C) $p \to 3, q \to 4, r \to 2, s \to 1$

(D) $p \to 1, q \to 2, r \to 5, s \to 3$

Rate of Heat Loss

At $T_{body} = T_0 \longrightarrow$

Heat rad. per sec. = Heat absorbed per sec

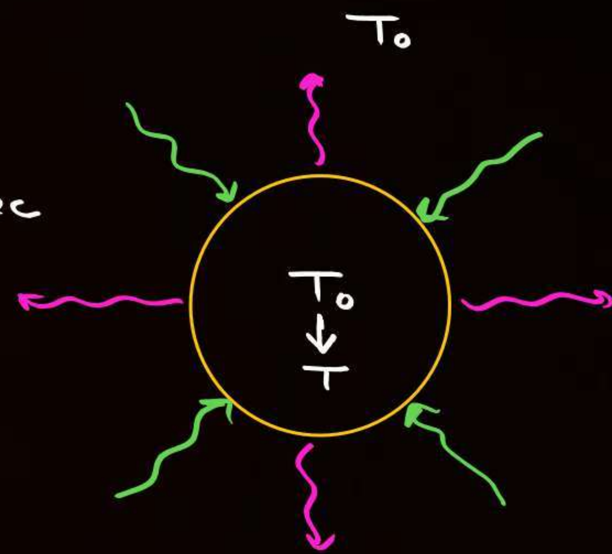
$\sigma e A T_0^4$ = Heat absorbed per sec.

At $T_{body} = T$

Heat rad./sec $= \sigma e A T^4$

Heat absorbed/sec $= \sigma e A T_0^4$

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



Rate of cooling $\left(\frac{-dT}{dt}\right)$

$$\frac{dQ_{net}}{dt} = \sigma e A (T^4 - T_0^4)$$

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

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

$$T = T_0 + \Delta T$$

$$\frac{dT}{dt} = \frac{\sigma e A}{ms}\left[(T_0 + \Delta T)^4 - T_0^4\right]$$

$$= \frac{\sigma e A}{ms}\left[T_0^4\left(1 + \frac{\Delta T}{T_0}\right)^4 - T_0^4\right]$$

$\Delta T << T_0 \rightarrow$

$$\frac{\Delta T}{dt} = \frac{\sigma e A}{ms}\left[\cancel{T_0^4}\left(1 + \frac{4\Delta T}{T_0}\right) - \cancel{T_0^4}\right]$$

$$\frac{dT}{dt} = \frac{\sigma e A}{ms} \times 4\Delta T \times T_0^3$$

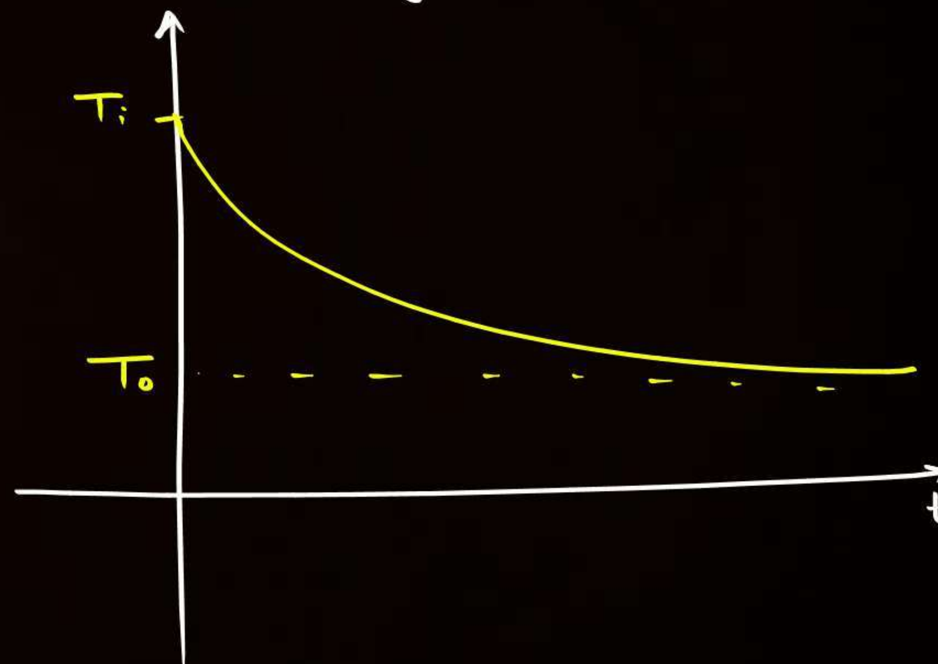
$$\frac{dT}{dt} = \left[\frac{4\sigma e A T_0^3}{ms}\right]\Delta T \Rightarrow \frac{dT}{dt} \propto \Delta T$$

Newton's Law of cooling

Newton's Law of Cooling

Temp. of surrounding

$$\underbrace{-\frac{dT}{dt}}_{\text{Rate of cooling}} = k\,(\underbrace{T}_{\text{Temp. of body}} - T_0)$$



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

$$\int_{T_i}^{T_f} \frac{dT}{T_0 - T} = \int_0^t k\,dt$$

$$\Big[-\ln(T_0 - T)\Big]_{T_i}^{T_f} = kt$$

$$\ln\left|\frac{T_i - T_0}{T_f - T_0}\right| = kt$$

QUESTION

$T_0 = 20^\circ C$

If $80°C \rightarrow 70°C = 100s$ then $70°C \rightarrow 60°C$, $t = ?$

$$\ln\left|\frac{T_i - T_0}{T_f - T_0}\right| = kt$$

$$\ln\left(\frac{80-20}{70-20}\right) = k \times 100 \Rightarrow \frac{\ln \frac{6}{5} = 100\cancel{k}}{\ln\frac{5}{4} = \cancel{k}t} \Rightarrow \frac{\ln\frac{6}{5}}{\ln 5/4} = \frac{100}{t}$$

$$\ln\left(\frac{70-20}{60-20}\right) = k \times t$$

$$t = 100\frac{\ln\frac{5}{4}}{\ln\frac{6}{5}}$$

$$t = 100\left[\frac{\ln 5 - \ln 4}{\ln 6 - \ln 5}\right]$$

Brahmastra

$T_0 = 20$

$80° \longrightarrow 70°C \;:\; 100\,s$

$70° \longrightarrow 60°C \;:\; t = ?$

$$-\frac{dT}{dt} = k\left(T_{avg} - T_0\right)$$

$$\frac{\dfrac{\cancel{80-70}}{100} = \cancel{k}\left[\left(\dfrac{80+70}{2}\right) - 20\right]}{\dfrac{\cancel{70-60}}{t} = \cancel{k}\left[\left(\dfrac{70+60}{2}\right) - 20\right]}$$

$$\frac{t}{100} = \frac{55}{45}$$

$$t = \frac{11}{9} \times 100$$

QUESTION (JEE Mains – Sep. 03, 2020 (II))

A metallic sphere cools from 50°C to 40°C in 300 s. If atmospheric temperature around is 20°C, then the sphere's temperature after the next 5 minutes will be close to :

(A) 31°C

(B) 33°C

(C) 28°C

(D) 35°C

$$\ln \frac{T_i - T_0}{T_f - T_0} = kt$$

$$\frac{\ln\left(\frac{50-20}{40-20}\right) = k \times \cancel{300}}{\ln\left(\frac{40-20}{T_f - 20}\right) = k \times \cancel{300}}$$

$$\cancel{\ln} \frac{3}{2} = \cancel{\ln} \frac{20}{T_f - 20}$$

$$\frac{3}{2} = \frac{20}{T_f - 20} \Rightarrow T_f - 20 = \frac{40}{3}$$

$$T_f = \frac{100}{3}\,°C$$

300 s

$50 \longrightarrow 40°C : 300$

$40 \longrightarrow T : 300$

$$\frac{\frac{10}{\cancel{300}} = \cancel{k}\left[45 - 20\right]}{\frac{40 - T}{\cancel{300}} = \cancel{k}\left[\frac{40+T}{2} - 20\right]}$$

$$\frac{10}{40 - T} = \frac{25}{\frac{T}{2}}$$

$$10T = 50(40 - T) \Rightarrow 60T = 2000$$

$$T = \frac{100}{3}$$ Ans.

QUESTION (JEE Mains – July. 27, 2021 (I)

H.W

A body takes 4 min. to cool from 61°C to 59°C. If the temperature of the surroundings is 30°C, the time taken by the body to cool from 51°C to 49°C is:

(A) 6 min

(B) 3 min

(C) 4 min

(D) 8 min

QUESTION (JEE Mains – 2014)

HW

Hot water cools from 60°C to 50°C in the first 10 minutes and to 42°C in the next 10 minutes. The temperature of the surroundings is:

A) 25°C

B) 10°C

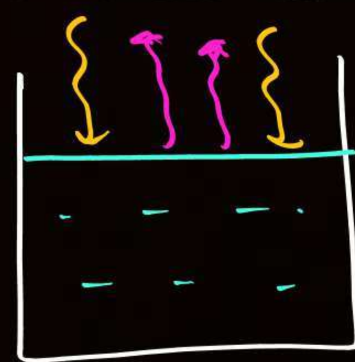
C) 15°C

D) 20°C

QUESTION (JEE Mains – JEE Adv, 2020)

A container with $\overset{m}{1\ \text{kg}}$ of water in it is kept in sunlight, which causes the water to get warmer than the surroundings. The average energy per unit time per unit area received due to the sunlight is $\underbrace{700\ \text{Wm}^{-2}}_{Q_{in}}$ and it is absorbed by the water over an effective area of $\underbrace{0.05\ \text{m}^2}$. Assuming that the heat loss from the water to the surroundings is governed by Newton's law of cooling, the difference (in °C) in the temperature of water and the surroundings after a long time will be $\underline{25/3\ °C}$. (Ignore effect of the container, and take constant for Newton's law of cooling = $\underbrace{0.001\text{s}^{-1}}_{k}$, Heat capacity of water = 4200 J kg^{-1} K^{-1})

$$Q_{in} = 7\cancel{00} \times \cancel{0.0}5$$
$$= 35\ \frac{J}{s}$$



In steady state –

$\frac{dT}{dt}$ Rate of Cooling = Rate of Heating

$$k\Delta T = \frac{35}{ms}$$

$$0.001 \times \Delta T = \frac{35}{1 \times 4200}$$

$$\Delta T = \frac{35}{42\cancel{00} \times 0.001}$$

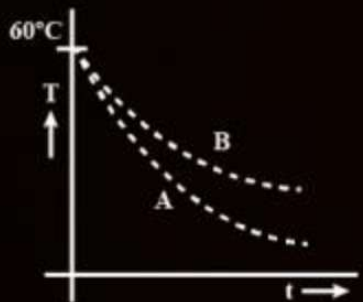
$$= \frac{\cancel{350}\ 50}{\cancel{42}\ 6}$$

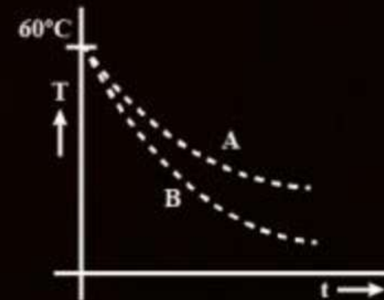
$$= \frac{25}{3}\ ^\circ C$$

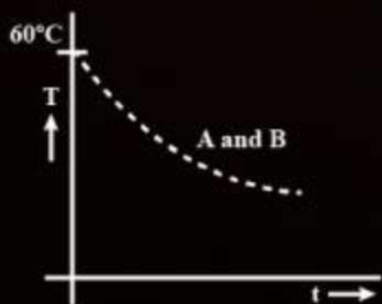
QUESTION (JEE Mains – Apr. 08, 2019 (I))

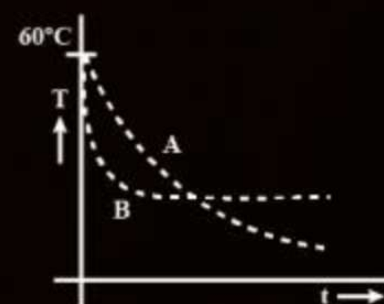
H.W

Two identical breakers A and B contain equal volumes of two different liquids at 60°C each and left to cool down. Liquid in 4 has density of 8×10^2 kg/m^3 and specific heat of 2000 J kg^{-1} K^{-1} while liquid in B has density of 10^{-3} kg m^{-3} and specific heat of 4000 J kg^{-1} K^{-1}. Which of the following best describes their temperature versus time graph schematically? (assume the emissivity of both the beakers to be the same)

(A)


(B)


(C)


(D)


Homework

DPP + Class Q.