THERMAL PROPERTIES OF MATTER

TEMPERATURE SCALE

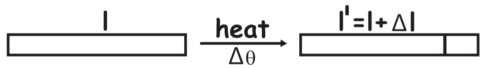
Result → $\frac{C}{5}=\frac{F-32}{9}=\frac{K-273}{5}$ (celcius-fahrenheit-kelvin conversion)

any scale conversion formula

$= \frac{\text{Reading on any scale - lower fixed point}}{\text{Upper fixed point - lower fixed point}} = \text{constant}$

THERMAL EXPANSION

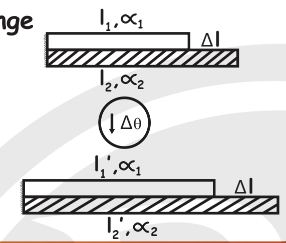
A-LINEAR



1. $\Delta l=\alpha l\Delta\theta$
2. $l'=l(1+\alpha\Delta\theta)$
3. $\alpha=\frac{\Delta l}{l\Delta\theta}$ → unit → /°c or/k, dimension-K^{-1}

Whatever be the change in temperature, the difference in length remains constant

$l_1\alpha_1=l_2\alpha_2$



APPLICATIONS OF LINEAR EXPANSION

Pendulum clock

Fact → When temperature increases, time period increases, clock runs slow

→ When temperature decreases, time period decreases, clock runs fast

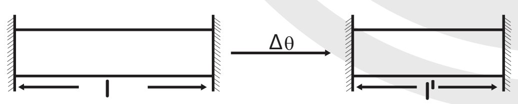
1) Loss of time in any given time interval t,

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

2) Time lost by clock in a day

$\Delta t=\frac{1}{2}\alpha\Delta\theta t=\frac{1}{2}\alpha\Delta\theta 86400=43200\alpha\Delta\theta$

Thermal Stress in a rigidly fixed rod



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

Thermal Force=$YA\alpha\Delta\theta$

Y-Young's Modulus

α-coefficent of linear expansion

Δθ -temperature change

A -Area of rod

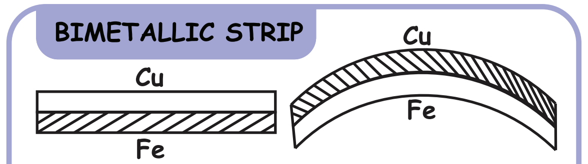
ERROR IN SCALE READING DUE TO EXPANSION OR CONTRACTION

Result → (1) At θ'>θ True value> Scale reading

At θ'<θ True value< Scale reading

$\boxed{\text{True value= Scale reading }(1+\alpha\Delta\theta)}$

BIMETALLIC STRIP



$\alpha_{cu}>\alpha_{Fe}$ → So when temperature increases

→ Δl of Cu > Δl of Fe

→ strip with higher value of α will be on convex side

EXPANSION OF CAVITY

Area of hole increases → body expands on heating.Expansion of area of body is independent of shape and size of hole

SUPERFICIAL/AREA EXPANSION

1. $\Delta A=A\beta\Delta\theta$ β -coefficant of area expansion
2. $A'=A(1+\beta\Delta\theta)$
3. $\beta=\frac{\Delta A}{A\Delta T}$ → unit — /°c or/k,dimension-$[K^{-1}]$
4. $\beta=2\alpha$

CUBICAL EXPANSION/VOLUME EXPANSION

1. $\Delta V=V\gamma\Delta\theta$
2. $V'=V(1+\gamma\Delta\theta)$
3. $\gamma=\frac{\Delta V}{V\Delta\theta}$ → unit → /°c or/K

k, dimension-$[K^{-1}]$ $\boxed{\alpha:\beta:\gamma=1:2:3}$

4. $\gamma=3\alpha$

Variation of density with temperature

Density $\propto \frac{1}{\text{Volume}}$

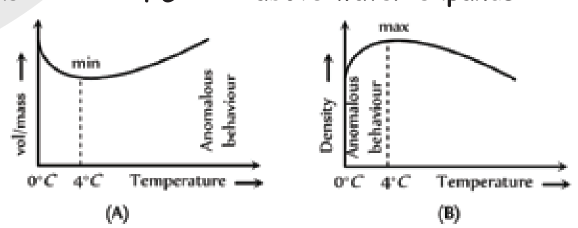
$V'=V(1+\gamma\Delta\theta)$

then $\rho'=\rho(1-\gamma\Delta\theta)$

ANOMALOUS EXPANSION OF WATER

1. Water has maximum density at 4°C (minimum volume)
2. On heating, 0°C → 4°C water contracts

4°C → above water expands
3. Graphs



REAL AND APPARENT EXPANSION OF LIQUID

1. ApparentExpansion of liquid → Real expansion of liquid - Expansion of solid in which liquid is contained
2. Apparent change in volume

1. $\Delta V_{apparent}=V_0\gamma_{apparent}\Delta\theta$
2. $\Delta V_{apparent}=V_0(\gamma_l-\gamma_s)\Delta\theta$
3. $\Delta V_{apparent}=V_0(\gamma_l-3\alpha_s)\Delta\theta$
4. $\gamma_{apparent}=\gamma_l-3\alpha_s$

γ_l -Real expansion of liquid

α_s -coefficent of linear expansion of solid

CALORIMETRY

$\boxed{1 \text{ calorie}=4.2J}$

Heat Supplied (ΔQ)

change temperature of body

1. $\Delta Q=ms\Delta T$

S-specific heat capacity

SIunit- $\frac{\text{Joule}}{\text{Kg Kelvin}}$ → $J\ Kg^{-1}K^{-1}$

2. $S_{water}=1\frac{cal}{g^oC}=4.2\frac{J}{g^oC}=4200\frac{J}{kg^oC}$

[or use Kelvin instead of °C]

$S_{ice}=\frac{1}{2}\frac{cal}{g^oC}=2.1\frac{J}{g^oC}=2100\frac{J}{kg^oC}$

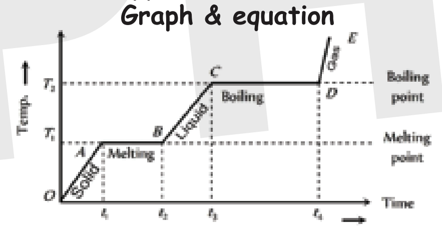
change state of body

Melting: $\Delta\theta:mL_f$, L_f-Latent heat of fusion

Boiling: $\Delta\theta:mL_v$, L_v-Latent heat of vapourisation

- $L_f=L_{ice}=80\frac{cal}{g}=80\times4.2\frac{J}{g}=80\times4200\frac{J}{kg}$
- $L_v=L_{steam}=540\frac{cal}{g}=540\times4.2\frac{J}{g}=540\times4200\frac{J}{kg}$

Heat supplied at constant rate Graph & equation



$\frac{msT_1}{\Delta t_1}=\frac{mL_f}{\Delta t_{12}}=\frac{ms(T_2-T_1)}{\Delta t_{23}}=\frac{mL_v}{\Delta t_{34}}$

if speecific heat is variable

$S=f(T)$ $T_1 \to T_2$ $\Delta Q=\int_{T_1}^{T_2} msdT$

HEAT CAPACITY

Heat capacity=mass×specific heat capacity

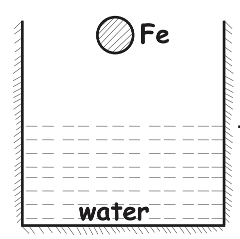
Unit= $\frac{cal}{^oC}$ ⇒ SI unit $\frac{J}{K}$

WATER EQUIVALENT

The mass of water that will absorb or lose as same quantity of heat as substance for the same changes in temperature

$m_w s_w=m_b s_b$ w=water, b=body

PRINCIPLE OF CALORIMETRY



→ Cu glass Vessel

	Cu glass Vessel	Liquid	Hot iron phere
	m_1	m_2	m_3
	s_1	s_2	s_3
initial →	T_1	T_2	T_3

Heat lost by the hotter body = Heat gained by colder bodies

$Q_3=Q_1+Q_2$

Final equilibrium temperature,

$T_{eq}=\frac{m_1s_1T_1+m_2s_2T_2+m_3s_3T_3}{m_1s_1+m_2s_2+m_3s_3}=\frac{\Sigma msT}{\Sigma ms}$

Facts : Calorimeter - A device in which the measurement of heat can be done.

ICE-WATER SYSTEM

Problem solving methodology

1. m_1 g ice $[-\theta,^oC]$ mixed with m_2g water $[-\theta_2\ ^oC]$
2. Convert $-\theta_1{}^oC$ ice → 0°C ice

$\Delta Q_1=m_1S_{ice}\theta_1$
3. Convert 0°C ice → 0°C water

$\Delta Q_2=m_1L_f$
4. Convert $\theta_2{}^oC$ water → 0°C water

$\Delta Q_3=m_2S_{water}\theta_2$

check $\Delta Q_3=,>,\text{or}<\Delta Q_1+\Delta Q_2$

$\Delta Q_3>\Delta Q_1+\Delta Q_2$

1. Whole ice melts into water
2. Additional heat is used to increase the temperature of system from 0°C
3. Final temperature can be found out by

$\Delta Q'=M_{total}S_{water}T$

where $\Delta Q'$ → additional heat

$\Delta Q_3<\Delta Q_1+\Delta Q_2$

1. Only m' g of ice melts
2. Mass of ice melts can be found by

$m'L_f=Q$
3. Final temperature is 0°C

CONVERSION OF MECHANICAL ENERGY TO HEAT ENERGY

1. Potential energy to Heat energy

$\Delta U=mgh \Longrightarrow \Delta Q=m'L_f$

When equaling multiply with 4200 for ΔQ (if L_f is in $\frac{calorie}{g}$)

ie, $mgh \Longrightarrow m'L_f\times4200$

2. Kinetic energy to Heat energy

$K.E=\frac{1}{2}mv^2 \Longrightarrow \Delta Q=m'L_f$

if L_f is in $\frac{calorie}{g}$

then

$\frac{1}{2}mv^2 \Longrightarrow m'L_f\times4200$

HEAT TRANSFER

1. Conduction

Heat flows from hot end to cold end, medium is necessary, slow process

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

Unit of 'K'= $\frac{watt}{metre^oC}$ or $\frac{watt}{metre\ K}$

'K' depends on the nature of material

$\frac{\Delta Q}{\Delta t}$ = Rate of flow of heat

A = Area of cross section

$\frac{\Delta\theta}{l}$ = Temperature gradient

K = coefficient of thermal conductivity

THERMAL PROPERTIES OF MATTER

OHM'S LAW OF CONDUCTION

Electrical Conduction

1) current, $I=\frac{dq}{dt}$

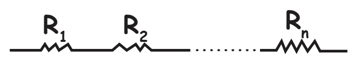
2) $I=\frac{\Delta V}{R}$ $(\Delta V=V_{high}-V_{low})$

3) electrical resistance, $R=\frac{\rho l}{A}$

4) $I=\frac{V_1-V_2}{R}=\frac{(V_1-V_2)A}{l\rho}=\frac{\sigma A}{l}(V_1-V_2)$

5) Combination of resistors

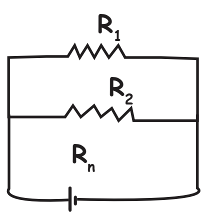
i) Series Combination



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

Here 'I' is same

ii) Parallel Combination



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

Here (V_1-V_2) is same

Thermal Conduction

1) Heat current, $H=\frac{dQ}{dt}$

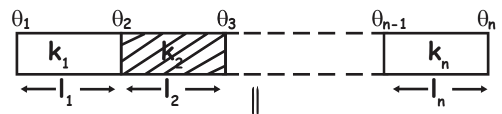
2) $H=\frac{\theta_1-\theta_2}{R}=\frac{\Delta\theta}{R}$

3) Thermal resistance, $R=\frac{l}{KA}$

4) $H=\frac{\theta_1-\theta_2}{R}=\frac{\theta_1-\theta_2}{(l/KA)}=\frac{KA}{l}(\theta_1-\theta_2)$

5) Combination of conductors

i) Series Combination



replace with resistors

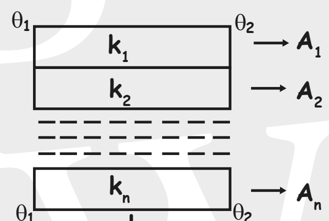
R_1 R_2

$R_1=\frac{l_1}{K_1A}$ $R_2=\frac{l_2}{K_2A}$ Find $R_{eq}=R_1+R_2.......$

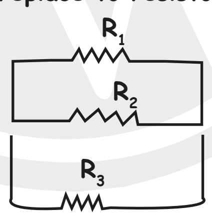
From that find 'K_{eq}'.

Here 'H' is same

ii) Parallel Combination



replace to resistors



$R_1=\frac{l}{K_1A_1}$

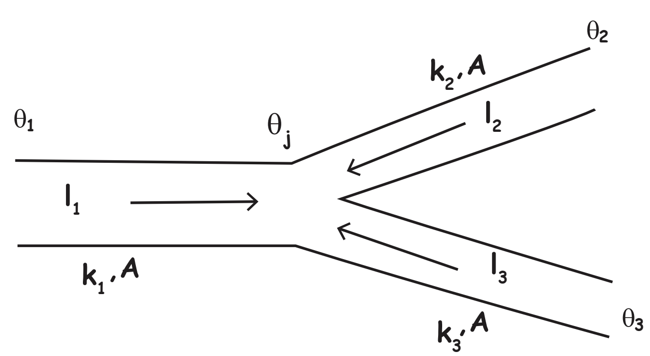
$R_2=\frac{l}{K_2A_2}$

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

from that find K_{eq}

Here, Temp Difference same

TEMPERATURE OF INTERMEDIATE JUNCTION



$I_1+I_2+I_3=0$

$\frac{\theta_1-\theta_j}{R_1}+\frac{\theta_2-\theta_j}{R_2}+\frac{\theta_3-\theta_j}{R_3}=0$

$\theta_j=\dfrac{\frac{\theta_1}{R_1}+\frac{\theta_2}{R_2}+\frac{\theta_3}{R_3}}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}}$

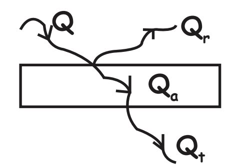
CONVECTION

- Requires a medium, actual movement of fluid, occus naturally or forced.
- Natural convection takes place due to the effect of gravity

- Sea Breeze
  Wind blows from sea to land during day time
- Land Breeze
  Wind blows from land to sea during night

RADIATION

Absorptive, reflective and Transmitted power



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

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

Reflective power(r)$=\frac{Q_r}{Q}=\frac{\text{Energy reflected}}{\text{Energy incident}}$

Transmitted power(t)$=\frac{Q_t}{Q}=\frac{\text{Energy transmitted}}{\text{Energy incident}}$

EMISSIVE POWER/INTENSITY OF THERMAL RADIATION

Emissive power(E)$=\frac{\text{Energy radiated}}{\text{area}\times\text{time}}$ unit $\longrightarrow \frac{Watt}{m^2}$

Spectral emissive power$(E_\lambda)=\frac{\text{Energy radiated}}{\text{area}\times\text{time}\times\text{wavelength}}$ unit $\rightarrow \frac{Watt}{m^3}$

Relation between E & E_λ $\Longrightarrow E=\int_0^\infty E_\lambda d\lambda$

EMISSIVITY (E)

$e=\frac{\text{Energy radiated by a general body}}{\text{Energy radiated by a black body}}$

value of e $\Longrightarrow 0<e<1$

If e=0, means general body radiates no energy

If e=1, it indicates a perfect black body

KIRCHHOFF'S LAW

Ratio of emissive power to absorptive power is same for all surfaces at the same temperature and is equal to the emissive power of a perfectly balck body at that temperature.

$\frac{E_1}{a_1}=\frac{E_2}{a_2}=.........=\frac{E}{A}=E$

STEFAN'S LAW

Emissive power of a black body $\propto$ fourth power of absolute temperature

$\boxed{E=\sigma T^4}$, $\boxed{\frac{\Delta Q}{\Delta t}=\sigma AT^4}$

$\sigma \longrightarrow$ Stefan's constant $\frac{\Delta Q}{\Delta t}\longrightarrow$ Radiant power

value of $\sigma \longrightarrow 5.67\times10^{-8}$ W/m^2K^4

Dimension $\longrightarrow [\sigma]$ $=MT^{-3}K^{-4}$

For ordinary body $E=e\sigma T^4$

$\frac{\Delta Q}{\Delta t}=eA\sigma T^4$ e=emissivity

In the presence of a surrounding (T_0) (black body)

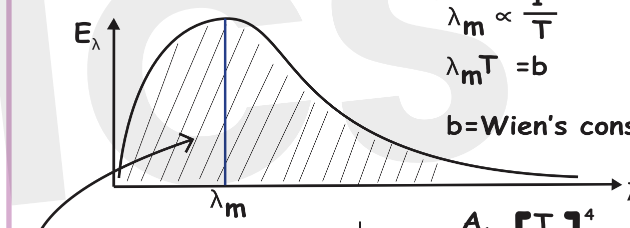
$E=\sigma(T^4-T_0^4)$ $\frac{\Delta Q}{\Delta t}=\sigma A(T^4-T_0^4)$

In the presence of a surrounding T_0) (general body)

$E=\sigma e(T^4-T_0^4)$ $\frac{\Delta Q}{\Delta t}=\sigma eA(T^4-T_0^4)$

WIEN'S LAW

Wien's displacement law



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

$\lambda_m T=b$

b=Wien's constant

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

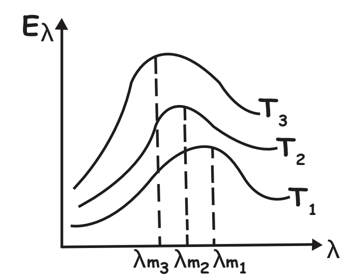
Area $=A=\int_0^\infty E_\lambda d\lambda=E=\sigma T^4$

Hence $\frac{A_1}{A_2}=\left[\frac{T_1}{T_2}\right]^4$

b $\longrightarrow$ value -2.89×10^{-3} mK

[dimension]=[b]=LK

"As the temperature of the body increases, the wavelength at which the spectral intensity (E) is maximum shift towards left."



$T_1<T_2<T_3$

$\lambda_{m_1}>\lambda_{m_2}>\lambda_{m_3}$

NEWTON'S LAW OF COOLING

$\rightarrow$ EQUATION FOR PROBLEM SOLVING

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

$\boxed{\theta_1}^{\theta_0} \xrightarrow{\Delta t} \boxed{\theta_2}^{\theta_0}$

$\theta_1>\theta_2$

Δt=time

$\theta_0\rightarrow$surrounding temperature

NEWTON'S LAW OF COOLING

Rate of cooling directly proportional to excess of temperature of the body over that of surrounding.

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

T=Temperature of body

T_0=Temperature of surounding

https://t.me/neetwallahpw