Heat And Thermometry

Topics
- Heat

Joule
Kelvin

1. Heat And Tempreture

Form of energy. (measured in joules)
(non-mechanical way of transfer of energy)

how energy is transfered?
before that:
<u>tempreture</u>: measure of hotness or coldness of a body ~~molecule~~
OR
average vibrational kinetic energy of every molecule
tempreture $\propto$ vibration $\propto$ kinetic energy.
Heat flows when diffrence in tempreture...
(energy transfers when difference in tempreture (vibrational energy of molecules))

Thermometry: branch of science that deals with measurement of heat

$$C^{\circ} = K^{\circ} - 273.15 \qquad K = C + 273.15$$

$$C^{\circ} = \frac{9}{5}(F-32) \qquad K = \frac{9}{5}(F-32) + 273.15$$

$$F = \left(\frac{5}{9}C\right) + 32 \qquad F = \left(\frac{5}{9}K - 273.15\right) + 32$$

<u>Scales</u>	<u>Icepoint (freezing)</u>	<u>Steam point (boiling)</u>
Celcius	0	100
Kelvin	273.15	373.15
Fahrenheit	32	212

this derivation is excellently explained in padhle video...

for any scale.

$$\frac{\text{Reading} - \text{Icepoint}}{\text{Steam point} - \text{Icepoint}} = \text{constant for any scale}$$

so,

$$\frac{R_c - IP_c}{SP_c - IP_c} = \frac{R_F - IP_F}{SP_F - IP_F} = \frac{R_K - IP_K}{SP_K - IP_K} = \text{constant}$$

(Celcius) (Fahrenheit) (Kelvin)

deriving the eg formulas

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

$$c = (F - 32)\frac{100}{180}$$

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

$$\frac{c - 0}{100 - 0} = \frac{K - 273.15}{373.15 - 273.15}$$

$$\frac{c - 0}{100} = \frac{K - 273.15}{100}$$

$$c = K - 273.15$$

Similarly for all...

Q Convert 50°C to Kelvin & Fahrenheit

Q On reaumer scale of temperature the melting point of ice and the boiling point of water is 0R and 80R respectively. The freezing point and boiling point of mercury in celcius are 39°C and 357°C respectively. Express them in Reamour scale.

2. Thermal Expansion

tendency of a material to change its dimensions (length, height, area, volume) when it's temprature is changed.

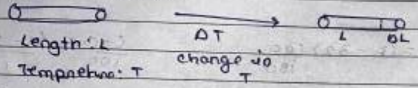
why does it happen?

- Heating: ↑ atomic vibrations
- Average distance between atoms grow
- so material expands.

+ Linear Expansion

"increase in the length of a solid material when its temprature rises"

~~why it happens:~~



ΔT causes ΔL in L

so $\Delta L \propto \Delta T$ (proportionalities)

$\Delta L \propto L$

$\Delta L \propto \Delta T L$

$\boxed{\Delta L = \alpha L \Delta T}$

coefficient of linear thermal expansion

α = increase in length per unit length per unit rise in temprature. ($\alpha = \frac{\Delta L}{L \Delta T}$)

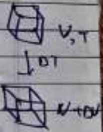
so unit = $\boxed{\frac{1}{C^\circ}}$

e.g. $\alpha_{steel} = 1.2 \times 10^{-5}\ C^{-1}$

$\alpha_{copper} = 1.7 \times 10^{-5}\ C^{-1}$

* Volume Expansion

"Increase in the ~~length~~ volume of a solid material when its tempreture is changed"



condition: works only till T < 200 K

$\Delta V \propto \Delta T$

$\Delta V \propto V$

$\Delta V \propto V \Delta T$

$\Delta V = V \gamma \Delta T$ (gemma)

* coefficient of volume expansion

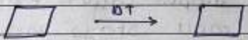
$\gamma = \frac{\Delta V}{V \Delta T}$, unit $\boxed{\frac{1}{C^\circ}}$

γ is not always linearly proportional to ΔT or T, so manier times relations are given.

e.g. $\gamma = T^4 + 2T^2$

* Area Expansion

"increase in the area of the solid material when its tempreture is changed"



A, T   A + ΔA, T+ΔT

so, $\Delta A \propto \Delta T$

$\Delta A \propto A$

$\Delta A \propto A \Delta T$

$\Delta A = A \beta \Delta T$ ← coefficient of volume expansion (Beta)

* Relation Between α, β, γ $(\gamma = 3\alpha)$ $(\beta = 2\alpha)$

$\gamma = 3\alpha$

$\beta = 2\alpha$

simple hai bhai, γ is about volume $L^{(3)}$

so α is about L, so $\gamma = 3\alpha$

same area $= L^2$, $\beta = 2\alpha$

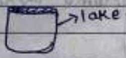
(you can mathematically prove too)

* Anomalous expansion of water

∵ it expands after 4°c
∴ but instead of being compressed at lower tem it expands too.

Mast Example.

Imagine a Lake, temp of H_2O → 70°c



1. when it goes to 9°C
the upper layer denses as volume decreases as temp decreases
$\left(d \propto \frac{1}{v}\right)$

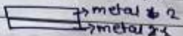
then the secound (which is at surface) cools and moves down and so on...

But at 4°C, when water expands on lower temperatures, the upper layer expands, so lighter density, and stays on top, and cools down continuously,
so you always see the frozen lakes have water beneath and only surface is frozen...

moral: water expands below 4°C too
and expands above 4°c too

* Bimetellic Strip,
when two metal strips of different expansion coefficient are bridged togther

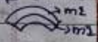
Basic mechanism

α_2 
α_1

$\alpha_2 > \alpha_1$

so metal 2 expands more than metal 1

we heated metal 2 expands more and its increase in length (Δl_2) is more but Δl_1 is less, so ends up curled on heating



* Effect on density of liquid

simply $T \propto V$ and

(density) $\rho \propto \frac{1}{V}$ so high tempretur → low density

CALORIMETRY:

branch of science that deals with the measurement of heat exchanged during physical changes

$\boxed{J/Kg^{\circ}C}$ * Specific Heat Capacity: (c, cu, s)

heat amount required to change 1°C (1K tempreture of 1kg of a material.

c of water: 4.184 J/kg°C

$$c = \frac{Q}{m\Delta T}$$

Q = heat amount (J) ΔT = change in tempreture (K/°C)

m = mass (kg)

SHC

$$Q = c\, m\, \Delta T$$

ΔT → change in tempreture; Q → heat amount; m → mass

Q Find the amount of heat required to raise the temp of 10g of water from 10°C to 50°C (c = 4.2 J/g°C)

Q A heater gives heat at the rate of 100W. It is used to heat 40g of water from 10°C → 50°C. find time taken to heat (c = 4.2 J/g°C)

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power
$\boxed{\text{watt}}$

P = work done / time

Q. A completed 1000W heater is used for 5min to heat some water from 30°C → 50°C. What is the mass of water?

* Principle of Calorimetry
"heat loss by hot body (HB) = heat gain by cold body (CB)"
based on conservation of energy.

$$Q_{HB} = Q_{CB} \qquad \because \Delta T_{HB} \,!= \Delta T_{CB}$$

$$C_{HB} m_{HB} \Delta T_{HB} = C_{CB} m_{CB} \Delta T_{CB}$$

Q. 10g of water at 80°C mixed with 50g of copper at 10°C. Find final temp of mixture. (C_w = 4.2 J/g°C, C_c = 0.42 J/g°C)

$\because \Delta T_{HB}$ = final temp − it's og temp
ΔT_{CB} = final temp + it's og temp

harder & confusing
Q. In a copper vessel we pour 20g of hot water at 80°C. Now 100g of cold water at 10°C is added. Find final temp if vessel weighs 50g (C_w = 4.2, C_c = 0.4)

* Heat Capacity : (C)
$\boxed{J/K}$
"amount of heat to raise 1°C (1°K) of a body (whole)"

$$C = \frac{Q \rightarrow \text{amount of heat}}{\Delta T \rightarrow \text{change in temp}}$$

$$C = \underset{\text{SHC}}{c}\,m \rightarrow \text{mass}$$

* Change of State

while changing state of a material heat is required.

when state is changed temprature remains same because, all the heat provided goes into change state. (↑ taken molecular space, ↓ molecular force)

i.e. (Q) ((m ΔT))

$\boxed{\text{ice}}\ 0°C \xrightarrow{\text{heat}} \approx\ 0°C$

solid ↔ liquid ↔ gas

Latent Heat $\boxed{J}$: amount of heat to change state of a material (no change in ~~[illegible]~~ temperature)

(L) $\boxed{J/kg}$ Specific Heat Latent: amount of heat to change state of 1kg of material, at constant temprature

$L_{ice} = 336\ J/g$ or $3.34 \times 10^5\ J/Kg$
(from ice → water)

$L_{water} = 2267\ J/g$ or $226 \times 10^5\ J/Kg$

$L = Q/m$

latent heat $\underbrace{Q}$ = $\underbrace{m}_{\text{mass}}$ L → specific latent heat

Heat Transfer:

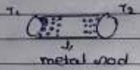
process of transfering heat energy.

↳ conduction (solid)

↳ convection (Liquid and gases)

↳ radiation (gases+light)

* Conduction



here ends of 1 metal (solid) have different tempretures, (energies) so vibrating at different rates so this vibration spreads to the side that has less temp (vibration)

∵ no flow of matter (molecules), just energy

∴ heat transfer in solid is due to molecular collisions

Variable State

(when solid can transfer heat) (not full)

Steady State

(when solid can't transfer heat, because they are full (max molecular vibration))

temp at every intersection remains constant with respect to time

rod ka change hoga because diff of temp

∴ For Steady States

K = thermal conductivity

K unit = J/mK s

= W/mK (J/s = W)

$Q \propto A \rightarrow$ area

$Q \propto 1/L \rightarrow$ length

$Q \propto t \rightarrow$ time

$Q \propto \Delta T$ (temp difference)

$Q \propto \frac{A \Delta T t}{L}$

$Q = K \frac{A \Delta T t}{L}$

↳ thermal conductivity of the substance..

Heat Current : rate of flow of heat

(H) = $H = Q/t$ (replacing $\frac{Q}{t}$ from $Q = K \frac{A \Delta T t}{l}$)

$H = \frac{KA \Delta T}{l}$

*

HEAT AND THERMOMETRY
-From JA only :)

L1

Heat: form of energy
can be converted from 1 form to another
unit SI: Joules (J)
CGS: erg
etc: calorie (cal)

Tempreture: measure of hotness or coldness
"degree of intensity of heat present in a body"
Heat transfer: when temp difference
between body or surrounding

calorie or calorie heat required to raise 1°C / 1K tempreture
of a body with mass 1g.

Kilocalorie heat require to raise 1°C / 1K of 1kg of mass
of a body (1kcal = 1000 cal)

!? (JA includes wrong definitions of heat / cal / kcal)

Thermometer device to measure tempreture using
some measuring scales

L2 Modes of Heat Transfer:

1. Conduction: heat transfer between solids
(due molecular vibrations)
(from higher temp to lower temp)
without actual molecular movement
- ✓ heat transfer - require solid medium
- × molecule transfer

2. Convection: heat transfer in fluids (liquids, gases)

- ✓ heat transfer • requires medium (fluid)
- ✓ molecular movement

types: natural (sunlight), forced (external force) (pumping etc)

13 3. Radiation: heat transfer (emission) through electromagnetic waves without requiring medium

thermal waves

- ✓ heat transfer • ✗ medium required
- ✗ molecular movement

14 Tempreture Measurement Scales

	* Celcius	* Kelvin	* Fahrient
freezing point	0°C	273.15 K	32°F
boiling point	100°C	373.15 K	212°F
Celcius		C = K - 273.15	C = (F-32) 5/9
Kelvin	K = C + 273.15		K = ((F-32) 5/9) + 273
Fahrenheit	F = (9/5 × C) + 32	F = (9/5 (K - 273.15)) + 32	

Q 50°C to K & F   Q -45°C to K & F

Q Temp at which C = = F
F = = K

Heat Capacity and Specific Heat Capacity

Heat Capacity: amount of heat transferred to the body to cause unit (1) tempreture change

Specific Heat Capacity: amount of heat transf... to every Kg (unit ma...) of a body to produce unit tempreture chan...

or H_c

Heat Capacity (rep: C, unit: J/K)

$C = Q/\Delta T$ → change in temprature

heat capacity ↓ — amount of heat ↓

so, $Q = C\Delta T$

Specific heat Capacity (rep: c, unit: J/Kg K)

$c = \frac{Q}{m\Delta T}$ → amount of heat; ΔT → change in temprature; m → mass

specific heat capacity ↓

so, $Q = cm\Delta T$

also $C = cm$ → mass

C → heat capacity; c → Specific heat capacity

∵ Heat capacity depends on specific heat capacity and mass

$H_c \propto c$

$H_c \propto m$

∴ Types of Specific Heat Capacity

↳ Specific Heat at constant volume (C_v)

amount of heat required to change the temprature of 1 mole of gas by 1K keeping its volume constant, is called specific heat C_v of the gas at constant volume

↳ Specific Heat at constant pressure (C_p)

amount of heat required to change the temprature of 1 mole of gas by 1K keeping its pressure ~~same~~ constant, is called specific heat C_p of the at constant pressure

$$C_p - C_v = R$$
R → gas constant

mole ↑

pressure ← $PV = nR_0T$ → tempreture

volume ↓ R_0 ↓ universal gas constant

(8.314 KJ / Kg mol K)

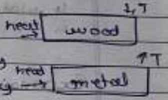
Coefficient of Thermal Conductivity & It's Thermal Applications

Thermal Conductivity: ability of the material to conduct heat (~~ability~~ capacity to allow heat current)

materials properties

↳ low thermal conductivity

↳ high thermal conductivity



* depends on

heat being transfered

1. $Q \propto A$ (cross section area)

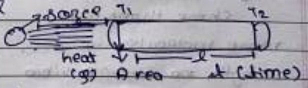
$Q \propto t$ (time)

$Q \propto \Delta T$ (tempreture difference at both ends)

$Q \propto \frac{1}{l\ (d)}$ (~~distance from the body to body~~ source length of the rod)

$$Q \propto \frac{A t \Delta T}{l}$$

$\Delta T = T_2 - T_1$



$$Q = \frac{K A t \Delta T}{l}$$

K ↓ Coefficient of thermal conductivity

K = unit: W / K m

Tempreture Gradient

the tempreture difference per unit length of the rod is called tempreture gradient

$$G = \frac{\Delta T}{d} \left(\frac{\text{temp diff}}{\text{distance}}\right) \quad \frac{K}{m}$$

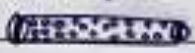
Applications

↳ POP at ceiling to reduce heat transfer (POP is less thermal conductive)
↳ metal handles of wood (↓ TC)
↳ vessel of metals (↑ TC)
↳ ice kept in wood (↓TC) so no melting (× ↑T)
↳ warm winter clothes
↳

Expansion of Solids, Coefficient of Linear Expansion

when heat provides → ↑ molecular movement
↓
increase in size

(molecular vibrates (moves) equally in all directions, but longer dimension expands more because it has more molecules in its ~~it~~ direction)

e.g. strip  metal sheet  

(here there are more molecules in length, so more vibs and movement, so length increases more than width)

here w, l are equal, but ↓ h so w, l increase causing area expansion

w, l, h are more so all increases so, volume expansion

Linear Expansion

~~Note~~ Moral of the Story:

There is always volume expansion in this 3D world, because molecules vibrates same in every direction.

but, sometimes movement in w, h is ignorable so we named it linear expansion for simplicity

when h is ignorable, we call it area expansion (refer padhle notes/video)

* Linear Expansion

when length of the object increases due to heat transfer

~~depends on ΔT~~, α,

change in length ΔL depends on,

$\Delta L \propto L$ (og length)

$\Delta L \propto \Delta T$ (change in length)

$\Delta L \propto L \Delta T$

$\Delta L = K \Delta T L$

coefficient of linear expansion (unit: $1/K$)

(constant (same) for every material)

$$K = \frac{\Delta L}{L} \times \Delta T$$