Thermal Properties of Matter

@anjit

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1 TEMPERATURE

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- Heat transfer takes place between system and surrounding medium until they are at same temperature.
- Measure of temperature is obtained using a thermometer.
- Some properties of material change with temperature to be used as basis of constructing thermometer.
- For standard scale a fixed reference point is taken.
- A relationship for conversion between Fahrenheit and Celsius temperature scale is

$$\frac{t_F - 32}{180} = \frac{t_c}{100}$$

- A temperature −273.15°C is designated as absolute zero. This is foundation of Kelvin temperature scale.
- Size of unit of Kelvin and Celsius temperature scales is the same. Relation between scales is

$$T_K = t_c + 273.15$$

2 HEAT

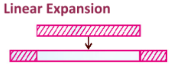
- A form of energy transferred between two or more systems by virtue of temperature difference.

Thermal Expansion

- A change in temperature of a body causes change in its dimensions.

Three types of expansion

1. Linear Expansion



$$\alpha_l = \frac{\Delta l}{l} \times \frac{1}{\Delta T}$$

2. Area Expansion

$$\alpha_a = \frac{\Delta A}{A} \times \frac{1}{\Delta T}$$

$\alpha_a = 2\alpha_l$

For anisotropic solid = $\alpha_V = \alpha_{l_1} + \alpha_{l_2}$

3. Volume Expansion

$$\alpha_V = \frac{\Delta V}{V} \times \frac{1}{\Delta T}$$

- α_V is constant only at high temperature
- Pyrex glass and invar has low .
- Alcohol has high volume expansion coefficient than mercury.
- $\alpha_V = \frac{1}{T}$ for ideal gases

$(\alpha_V)_{gases} > (\alpha_V)_{liquid} > (\alpha_V)_{solids}$

- When a solid rod has its ends rigidly fixed, it results in thermal stress in material which is proportional to temperature change.

Thermal Stress $= Y \cdot \alpha_l \cdot \Delta T$

3 CALORIMETRY

- Heat lost by a part at higher temperature is equal to heat gained by the part at lower temperature.
- Calorimetry means measurement of heat.
- A device in which heat measurement can be done is called a calorimeter.

4 HEAT CAPACITY

The change in temperature of a substance, when a given quantity of heat is absorbed or rejected is characterised by a quantity called heat capacity.

$$S = \frac{\Delta Q}{\Delta T}$$

Specific heat capacity

This is unique value of heat absorbed or given off, to change unit mass of it by one unit temperature change.

$$s = \frac{S}{m} = \frac{1}{m}\frac{\Delta Q}{\Delta T}$$

Molar specific heat

If the amount of substance is specified in terms of moles we define heat capacity per mole

$$C = \frac{S}{\mu} = \frac{1}{\mu}\left(\frac{\Delta Q}{\Delta T}\right) \text{ Jmol}^{-1}\text{K}^{-1}$$

For gases two molar specific heat capacities

- Molar specific heat capacity at constant pressure
- Molar specific heat capacity at constant volume

$C_P - C_V = R$ (for ideal gases)

5 CHANGE OF STATE

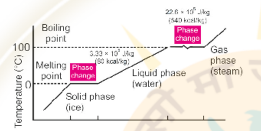
- Change of state from solid to liquid is called melting or fusion.
- Change of state from liquid to vapour is called vaporisation
- The temperature at which the liquid and vapour states of substance coexist is called its Boiling point.
- Boiling point increases with increase in pressure and vice versa.
- The change from solid state to vapour state without passing through the liquid state is called sublimation and substance is said to sublime.

Latent heat

- Amount of heat transferred during change of state of substance is called its latent heat.

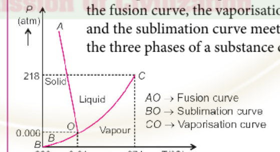
$$L = \frac{\Delta Q}{M} \text{ Jkg}^{-1}$$

- L depends on pressure.
- Solid-liquid state change → Latent heat of fusion (L_f)
- Liquid-gas state change Latent heat of vaporisation (L_v)



6 TRIPLE POINT

The temperature and pressure at which the fusion curve, the vaporisation curve and the sublimation curve meet and all the three phases of a substance coexist



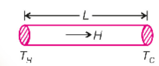
Pressure-temperature phase diagrams for water

HEAT TRANSFER MODES

7 CONDUCTION

- It is a mechanism of heat transfer between adjacent parts of a body due to temperature difference.
- At steady state, the temperature of bar, through which heat is flowing, decreases with distance, and heat starts flowing at a constant rate.
- The rate of flow of heat

$$H = KA\left(\frac{T_H - T_C}{L}\right)$$



T_H = Hot end Temperature
T_C = Cold end Temperature
L = Length of rod
A = Cross - section of rod
K is called thermal conductivity of material.

- Greater value of K for a material, more rapidly will it conduct heat. Its SI units are $\text{Wm}^{-1}\text{K}^{-1}$

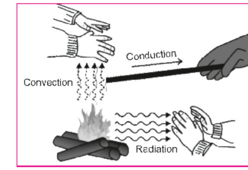
9 RADIATION

- This heat transfer mechanism needs no medium.
- Energy transferred by waves is called radiant energy.
- Heat transferred from sun to earth is by radiation.
- Radiations emitted by hot bodies are called thermal radiations.

8 CONVECTION

In convection mode heat transfer by actual motion of matter occurs.

- Convection occurs in fluids only.
- Two types of convections are
  1. Natural convection
  2. Forced convection
- Trade winds is example of natural convection in which gravity plays an important role.
- In forced convection material is forced to move by a pump. Human circulatory system, cooling system of automobile engine are forced convection method.



LAWS OF RADIATION

10 WIEN'S DISPLACEMENT LAW

Wavelength for which radiation energy is maximum decreases with increasing temperature.

$$\lambda_m T = \text{constant}$$

Value of constant (Wien's constant) is 2.9×10^{-3} m K.

- This law is used to measure surface temperature of celestial bodies like stars, moon and sun.

11 STEFAN – BOLTZMANN'S LAW

For a black body which is perfect radiator energy emitted per unit time is given as

$$H = A\ \sigma T^4$$

A is area, T is absolute temperature of body, σ is called Stefan Boltzmann's constant

$\sigma = 5.67 \times 10^{-8} \text{Wm}^{-2}\text{K}^{-4}$

- But if a body is surrounded by surroundings at temperature For perfect radiator net rate of heat radiated

$$H = \sigma A(T^4 - T_s^4)$$

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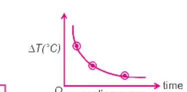
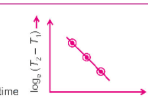
12 NEWTON'S LAW OF COOLING





Rate of heat loss of a body is directly proportional to difference of temperature of body and surroundings.

- This law holds for small temperature difference only.

$$-\frac{dQ}{dt} = k(T_B - T_S)$$

$$\log_e (T_2 - T_1) = -kt + C$$

Average method

$$\frac{\text{Change in temperature}}{\text{time}} = k\Delta T$$

$$\Delta T = (T_{av} - T_s)$$

13 GREENHOUSE EFFECT

The absorption of infrared waves by greenhouse gases such as CO_2, methane (CH_4) nitrous dude (N_2O) chloroflurocarbons (CF_xCl_x) and ozone (O_3). Heating of atmosphere → More energy to earth → Warmer surface. Without Greenhouse effect temperature of earth would have been −18°C

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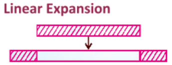

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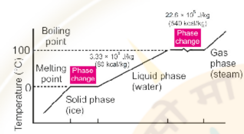

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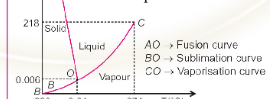

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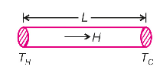

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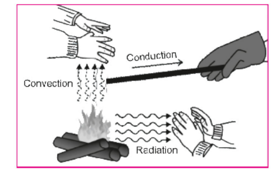

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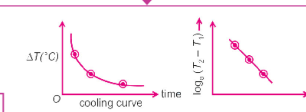

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