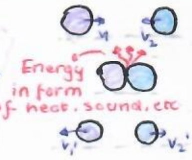
THERMAL PHYSICS.

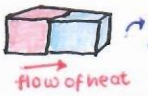
HEAT ENERGY

- Energy that is transfered from one body to another without mechanical work involed is called Heat.



→ vibration of atom causes to heat energy.

Heat ∝ Internal Energy.



Energy of body changes although no mechanical work done.

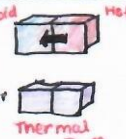
*THERMODYNAMICS

Branch of physical science that deals with relation betn heat and other forms of energy and, by extension, of the relatn-ships betn all forms of energy.

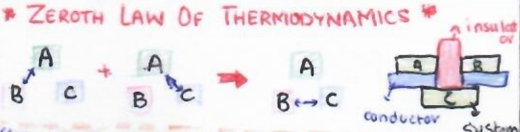
*THERMAL EQUILIBRIUM

→ Two systems in thermal contact with each other are in thermal equilibrium if they do not transfer heat betn each other.

→ Heat is transferred from high temp. to lower temperature.



* ZEROTH LAW OF THERMODYNAMICS *



"If two systems are each in thermal eqm with a third system, they are also in thermal eqm with each other"

→ This law gives the concept of temperature scale.

*TEMPERATURE

↳ measure of hotness or coldness of an object.

→ objects in thermal eqm have same temperature

→ heat flows from higher temp. to lower.

→ Science of measuring temp. is called Thermometry.

→ temperature is measured with the help of other measurable properties of substance that change with change of heat flow.

e.g. volume, pressure, resistance.

*CENTIGRADE SYSTEM

→ In this system, various lengths of mercury in thermometer are assigned values for temp. as follows:

$0°C$ → ice point (melting ice)

$100°C$ → steam point (boiling water)

$t = \alpha l + b$, α, b are constant.

∴ temp. is measured with help of length of Hg.

*FAHRENHEIT SCALE

→ Here, 180 divisions are taken betn ice point & steam point and values are assigned as:

$32°F$ → ice point ($0°C$)

$212°F$ → steam point ($100°C$)

$98.6°F$ → Human body temp. ($37°C$)

$$°F = 32 + \frac{9}{5}°C.$$

CONSTANT VOLUME GAS THERMOMETER

$PV = nRT$ ⟶ constant volume, then $p \propto T$

$T = cP$ $\quad T_{ref} = cP_{ref}$.

Dividing,

$$T = \frac{P}{P_{ref}} \times T_{ref}.$$

Reference point is taken as triple point of water (ice, water, vapour are in eqm)

$$T = \frac{P}{P_{ref}} \times 273.16\,K \qquad T = \frac{P - P_0}{P_{100} - P_0} \times 100°C.$$

CALORIE

Unit of Heat energy.

Amount of heat required to raise the temp. of one gram of water from $14.5°C$ to $15.5°C$.

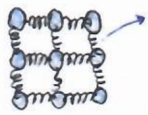
1 calorie = 4.186 Joule.

*MECHANICAL EQUIVALENT OF HEAT.

Mechanical work can be done to change the temperature of water.

$$\underbrace{W}_{\text{work done}} = \underbrace{J}_{\text{Mechanical equivalent of Heat}}\underbrace{H}_{\text{Heat given}}$$

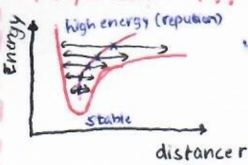
*MOLECULAR BASIS OF THERMAL EXPANSION



→ Intermolecular forces are just like spring forces. On both, stretching and compressing a force acts.

Thus, due to high vibrational energy they move apart and expansion occurs.

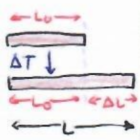
Why expansion only ??



Here the avg. distance betn molecules keeps on increasing because $U - r$ graph is unsymmetric parabola.

*LINEAR EXPANSION

$\Delta L \propto \Delta T$, $\quad \Delta L \propto L_0$



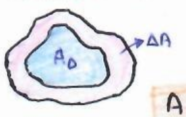
$\Delta L = \alpha L_0 \Delta T$; α → coefficient of Linear expansion.

Unit: $°C^{-1}$ or K^{-1}

$L_0 + \Delta L = L_0(1 + \alpha \Delta T)$

$$L = L_0(1 + \alpha \Delta T)$$

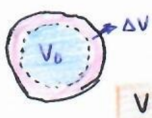
*AREAL EXPANSION / SUPERFICIAL EXPANSION



$\Delta A = \beta A_0 \Delta T$; β → coefficient of Areal Expansion

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

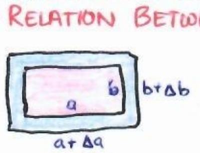
*VOLUME EXPANSION / CUBICAL EXPANSION



$\Delta V = \gamma V_0 \Delta T$; γ → coefficient of volumetric expansion

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

*RELATION BETWEEN α, β, γ



$\Delta a = \alpha a \Delta t \quad \Delta b = \alpha b \Delta t.$

$\Delta A = (a + \Delta a)(b + \Delta b) - ab$

$\Delta A = a\Delta b + \Delta a\, b + \underbrace{\Delta a \Delta b}_{<<1}$

$\Delta A = ab\alpha\Delta t + ab\alpha\Delta t.$

$\Delta A = ab(2\alpha)\Delta T$

$\Delta A = A\underbrace{(2\alpha)}_{\beta}\Delta T$

$\beta = 2\alpha$

∴ similarly,

$\gamma = 3\alpha$

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

→ only if bodies are uniform isotropic.

*EXPANSION IN CAVITIES.

cavity also expands

Both will expand similarly. (same size)

*CHANGE IN TIME PERIOD OF PENDULUM.

$$T_0 = 2\pi\sqrt{\frac{L_0}{g}} \qquad T = 2\pi\sqrt{\frac{L_0(1 + \alpha\Delta\theta)}{g}}$$

$$\frac{T}{T_0} = \sqrt{1 + \alpha\Delta\theta} = (1 + \alpha\Delta\theta)^{1/2}$$ ∵ small

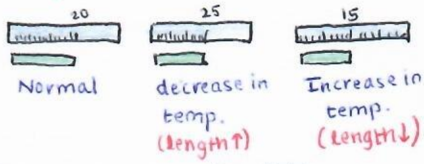
$$T = T_0\left(1 + \frac{1}{2}\alpha\Delta\theta\right)$$

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

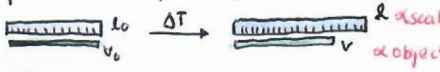
For decrease in temp. $\Delta\theta < 0$, then clock runs faster & gains time.

For increase in temp. $\Delta\theta > 0$, then clock runs slower & loses time.

*DEFECT IN METALLIC SCALES.



If both are expanding then,



Consider only stick: $V = V_0(1 + \alpha_{obj}\Delta T)$

Now, new extension: $\Delta l = \alpha_{scale}\Delta T)$.

$\Delta l = V_0(1 + \alpha_{obj}\Delta T)(\alpha_{scale}\Delta T)$

∴ Reading + extension = Actual.

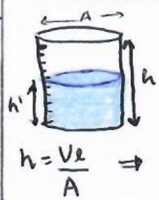
$R = V - V_0(1 + \alpha_{obj}\Delta T)(\alpha_{scale}\Delta T)$

$R = V_0(1 + \alpha_{obj}\Delta T)(1 - \alpha_{scale}\Delta T)$

$R = V_0(1 + \alpha_{obj}\Delta T - \alpha_{scale}\Delta T - \underbrace{\alpha_{obj}\alpha_{scale}\Delta T^2}_{\text{very small}})$

$$\therefore R = V_0\left(1 + (\alpha_{obj} - \alpha_{scale})\Delta T\right)$$

*EXPANSION OF LIQUID IN CONTAINER



$V_{cont} = V_{con(0)}(1 + \gamma_{con}\Delta T)$

$V_{liq} = V_{liq(0)}(1 + \gamma_{liq}\Delta T)$

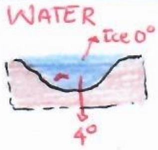
$$h = \frac{V_l}{A} \Rightarrow h' = \frac{V_{l0}(1 + \gamma_l \Delta T)}{A_{c0}(1 + \beta_c \Delta T)}$$

*ANOMALOUS BEHAVIOUR OF WATER

Upon heating water,

$0° - 4°$, volume↓ density↑

$4°$ - above, volume↑ density↓



*CHANGE IN DENSITY

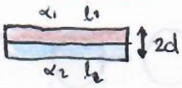
$m_0 = m$

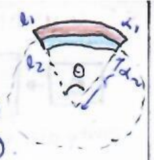
$\rho_0 V_0 = \rho V$

$\rho_0 V_0 = \rho V_0(1 + \gamma\Delta T)$

$$\rho = \frac{\rho_0}{1 + \gamma\Delta T}$$

* BIMETALLIC STRIP





$\alpha_1 > \alpha_2$

$l_1 = l_0(1+\alpha_1\Delta T)$

$l_2 = l_0(1+\alpha_2\Delta T)$

$$\theta = \frac{l_1}{R+d} = \frac{l_2}{R-d} \Rightarrow \boxed{\frac{R}{d} = \frac{l_1+l_2}{l_1-l_2}}$$

* THERMAL STRESS

Stress $= \frac{F}{A}$

Strain $= \frac{\Delta L}{L_0}$

$$Y \text{ (young's modulus)} = \frac{\text{Stress}}{\text{Strain}} = \frac{F \; L_0}{A\,(\Delta L)}$$

$$Y = \frac{F\,L_0}{A\,(L_0 \alpha \Delta T)} = \frac{F}{A \alpha \Delta T}$$

$$\therefore \boxed{F = YA\alpha\Delta T}$$