FORMULAE SHEET

1. Type of thermal expansion

		Coefficient of expansion	For temperature change Δt change in
(i)	Linear	$\alpha = \lim_{\Delta t \to 0} \frac{1}{\ell_0}\frac{\Delta \ell}{\Delta t}$	Length $\Delta \ell = \ell_0 \alpha \Delta t$
(ii)	Superficial	$\beta = \lim_{\Delta t \to 0} \frac{1}{A_0}\frac{\Delta A}{\Delta t}$	Area $\Delta A = A_0 \beta \Delta t$
(iii)	Volume	$\gamma = \lim_{\Delta t \to 0} \frac{1}{V_0}\frac{\Delta V}{\Delta t}$	Volume $\Delta V = V_0 \gamma \Delta t$

- For isotropic solids $\alpha_1 = \alpha_2 = \alpha_3 = \alpha$(let) so $\beta = 2\alpha$ and $\gamma = 3\alpha$
- For anisotropic solids $\beta = \alpha_1 + \alpha_2$ and $\gamma = \alpha_1 + \alpha_2 + \alpha_3$ Here α_1, α_2 and α_3 are coefficient of linear expansion in X, Y, and Z directions.

Variation in density: With increase of temperature volume increases so density decreases and vice-versa.

$$\rho = \frac{\rho_0}{(1+\gamma \Delta t)} \approx \rho_0 (1 - r\,\Delta T)$$

Thermal Stress: A rod of length ℓ_0 is clamped between two fixed walls with distance ℓ_0.

If temperature is changed by amount Δt then stress= $\frac{F}{A}$ (area assumed to be constant)

Strain= $\frac{\Delta \ell}{\ell_0}$; so, $Y = \frac{F/A}{\Delta \ell / \ell_0} = \frac{F\ell_0}{A\Delta \ell} - \frac{F}{A\alpha\Delta t}$ or F=YA $\alpha \Delta t$

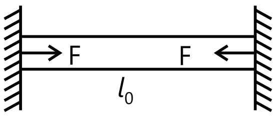

Figure 15.6

- $\Delta Q = mc\Delta T$ where c: Specific heat capacity
- $\Delta Q = nC\Delta T$ C: Molar heat capacity
- Heat transfer in phase change : $\Delta Q = mL$ L: latent heat of substance
- 1 Calorie= 4.18 joules of mechanical work
- Law of Calorimetry: heat released by one of the substances = Heat absorbed by other substances.

Solved Examples

JEE Main/Boards

Example 1: Calculate the amount of heat required to convert 1.00kg of ice at -10°C into steam at 100°C at normal pressure. Specific heat capacity of ice = 2100 Jk^{-1} K^{-1}, latent heat of fusion of ice=3.36×10^5 $JKg^{-1}K^{-1}$, specific heat capacity of water= 4200 $JKg^{-1}K^{-1}$ and latent heat of vaporization of water =2.25×10^6 JKg^{-1}.

Sol: Here the temperature of ice and water changes along with change in phases. i. e. ice to water and then water to steam.

Heat required to take the ice from -10 °C to $0^0C = (1kg)(2100\ JKg^{-1}K^{-1})(10K) = 21000\,J$.

Heat required to melt the ice at 0 °C to water = $(1kg)(3.36\times10^5\ JKg^{-1}) = 336000\,J$.

Heat required to take 1 kg of water from 0 °C to 100 $= (1kg)(4200 JKg^{-1}K^{-1})(100K) = 420000J$.

Heat required to convert 1kg of water at 100°C into steam $= (1kg)(2.25\times10^6\ JKg^{-1}) = 2.25\times10^6$ J.