Thermal Expansion

1. Co-efficients of expansion:

   1. Linear expansion: \( \alpha \)

   \[ (L_2 - L_1) = \alpha L_1 (t_2 - t_1) \]

   \[ \alpha = \frac{\Delta L}{L_1 \Delta t} \text{ / } ^\circ \text{C} = \frac{1}{L} \frac{dL}{dt} / ^\circ \text{C} \]

   2. Superficial expansion: \( \beta \)

   \[ (A_2 - A_1) = \beta A_1 (t_2 - t_1) \]

   \[ \beta = \frac{\Delta A}{A_1 \Delta t} / ^\circ \text{C} = \frac{1}{A} \frac{dA}{dt} / ^\circ \text{C} \]

   3. Volume expansion: \( \varepsilon \)

   \[ (V_2 - V_1) = \varepsilon V_1 (t_2 - t_1) \]

   \[ \varepsilon = \frac{\Delta V}{V_1 \Delta t} / ^\circ \text{C} = \frac{1}{V} \frac{dV}{dt} / ^\circ \text{C} \]

* Relation between \( \alpha, \beta, \varepsilon \):

\[ 2\varepsilon = 3\beta = 6\alpha \quad \Rightarrow \quad \varepsilon = 3\alpha \quad \beta = 2\alpha \]

* Variation of density with temp:

\[ \rho_1 = \rho_2 (1 + \varepsilon t) \Rightarrow \rho_2 = \rho_1 (1 - \varepsilon t) \]

* Thermal Stress: \( \frac{F}{A} = Y \alpha t \)

\[ [Y \text{ = Young’s Modulus}] \]

* Error due to thermal expansion:

1. Measurement of length by a scale:

   \[ l_t = l_0 [1 + \alpha (t_1 - t_0)] \]

   \[ l_0 = l_2 [1 + \alpha (t_0 - t_2)] \]
2. Clock going fast or slow: \( T_0 = 2\pi \sqrt{\frac{10}{g}} \)

\[ T_t = 2\pi \sqrt{\frac{10}{g} \left[ 1 + \alpha (t - t_0) \right]} \]

* Bucking of bimetallic strips:

\( \alpha_A > \alpha_B \quad 10^\circ C \quad t_1^\circ C > t_0^\circ C \quad t_2^\circ C < t_0^\circ C \)

* Thermal expansion of liquid: Liquid has only coefficient of volume expansion.

- Coefficients of real & apparent expansion of liquid in a glass flask:

\[ \delta_r = \delta_a \times \delta_g \]

\[ \delta_r \text{ real expansion coef.} \quad \delta_a \text{ apparent expansion coef.} \quad \delta_g \text{ volume expansion coef. of glass} \]

- Variation of density of liquid with temp.

\[ \rho_1 = \rho_2 \left( 1 + \delta_r t \right) \]

* Apparent weight of a body immersed in a liquid at different temp.

\[ M_2 = M_1 \left[ 1 - (\delta_1^L - \delta_1^S) t \right] \]

\[ M_2 \to \text{app. loss in weight in temp } t_2 \quad \delta_1^L \to \text{ for liquid} \]

\[ M_1 \to \text{app. loss in weight in temp } t_1 \quad \delta_1^S \to \text{ for solid} \]

\[ m' = [m_1 + \rho_1 V_1 (\delta_1^L - \delta_1^S) t] \]

\[ M_2 = m - m' \]

\[ M_1 = m - m_1 \]
Thermal expansion

* Temperature correction in barometer reading:
  i) Scale Correction: \( H = h(1 + \alpha \theta) \).
     \( h \rightarrow \) observed height of barometer at \( 0^\circ C \)
     \( H \rightarrow \) correct height at the temp. \( 0^\circ C \)
     after scale correction.
  ii) Density correction: \( \rho_0 = \rho(1 + \beta \theta) \).

Considering both corrections,

\[ H_0 = h \left[ 1 - (\delta - \alpha) \theta \right]. \]

\[ H_0 \rightarrow \] correct height,

\( h \rightarrow \) observed height.