Absolute Zero and Coefficient of Linear Expansion

Temperature

- How do we define a temperature scale?
  - We need to use a device whose physical properties change linearly with temperatures (e.g., length of a metal rod, volume of a liquid, volume or pressure of a gas, resistance of a conductor, change in color of very hot object, infrared radiation)?
  - Such properties are called thermometric properties.

- We also need two reference points, the ice point (freezing) and the steam point (boiling) of water.
  - Both are measured at standard atmospheric pressure.
  - Then draw equally spaced lines between the ice point and the steam point.

- When you place a mercury thermometer in an ice bath, the length of the mercury column will decrease until thermal equilibrium is reached. Then the temperature is read by comparing the height of the mercury column with a scale on the glass.

- Constant Volume Thermometer
  - Any gas at a given volume and at low pressure will yield a pressure vs. temperature graph (same slope and y-intercept) below.

- CAUTION
  - Two different thermometers based on different thermometric properties (such as ethanol and mercury thermometers) might not agree with each other when they are used to precisely measure the temperature of a body.

  - Reason: Change in physical properties not truly linear and the range in which these are approx. linear is limited.
Temperature

• For a given pressure, a constant volume thermometer will always reproduce the corresponding temperature value independent of any physical properties of the system. This allows one to define a more precise method of measuring temperature. It is called the ideal-gas temperature scale.

• The units for this scale is the Kelvin and the reference point is the triple point of water 0.01°C at 610 Pa.

Coefficient of Expansion

Show that $\beta = 3\alpha$.

$V = LWH$

$\frac{dV}{dT} = LW \frac{dH}{dT} + WH \frac{dL}{dT} + LH \frac{dW}{dT}$

$\frac{dV}{dT} = LWaH + WHaL + LHaW$

$\frac{\Delta V}{\Delta T} = L_a W_a H_o + W_o H_a L_o + L_o H_o W_o = 3a_o H_o W_o$

$\therefore \beta = 3\alpha = \frac{1}{V} \frac{dV}{dT}$

Example

• You want to construct a device that has two points whose separation $L$ remains the same regardless of temperature. A design is shown below. What are the conditions on $L_A$, $\alpha_A$, $L_B$, $\alpha_b$?

Coefficient of Expansion

Show that $\beta = 3\alpha$. Method 2

If $V_o = L_o^3$, then $V = (L_o + a L_o \Delta T)^3$

$\Delta V = V - V_o = (L_o + a L_o \Delta T)^3 - L_o^3$

$\Delta V = L_o^3 + 3a L_o \Delta T + \text{higher order terms in } \Delta T$ - $L_o^3$

$\Delta V = 3a L_o \Delta T$

$\therefore \beta = 3\alpha$

Example

• A steel I-beam in a structure expands by a distance $\Delta L$ due to an increase in temperature. What is the tensile force produced by the expansion?