Absolute Zero and Coefficient of Linear Expansion

Physics 4C Lab 1

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*.**

Temperature

- **How do we define a temperature scale?**
  - **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.**

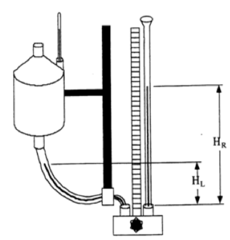
Temperature

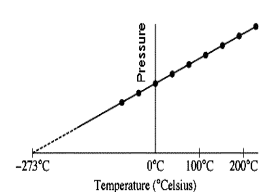
- **How do we define a temperature scale?**
  - **When you place a mercury thermometer in an ice bath, then length of the mercury column will decrease until thermal equilibrium is reached. Then the temperature is read by comparing the height of the mercury column with a scale on the glass.**

Temperature

- **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.**

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





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 610Pa.

Coefficient of Expansion

Linear: $L-L_o=\Delta L = \alpha L_0 \Delta T$

α_{avg} = average coefficient of linear expansion

Area: $A-A_o = \Delta A = 2\alpha A_0 \Delta T = \gamma A_0 \Delta T$

γ_{avg} = average coefficient of area expansion

Volume: $V-V_o = \Delta V = 3\alpha V_0 \Delta T = \beta V_0 \Delta T$

β_{avg} = average coefficient of volume expansion

***True for a limited temperature range*

Coefficient of Expansion

Show that $\beta=3\alpha$.

$$V = LWH$$
$$\frac{dV}{dT} = LW\frac{dH}{dT} + WH\frac{dL}{dT} + LH\frac{dH}{dT}$$
$$\frac{dV}{dT} = LW\alpha H + WH\alpha L + LH\alpha W$$
$$\frac{\Delta V}{\Delta T} = L_oW_o\alpha H_o + W_oH_o\alpha L_o + L_oH_o\alpha W_o = 3\alpha L_oH_oW_o$$
$$\therefore \beta = 3\alpha = \frac{1}{V}\frac{dV}{dT}$$

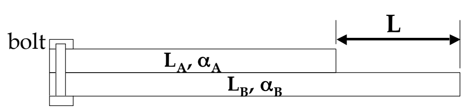
Coefficient of Expansion

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

$$If\ V_o = L_o^3,\ then\ V = (L_o + \alpha L_o \Delta T)^3$$
$$\Delta V = V - V_o = (L_o + \alpha L_o \Delta T)^3 - L_o^3$$
$$\Delta V = (L_o^3 + 3\alpha L_o \Delta T + higher\ order\ terms\ in\ \Delta T) - L_o^3$$
$$\Delta V = 3\alpha L_o \Delta T$$
$$\therefore \beta = 3\alpha$$

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, α_A, L_B, α_B?



Example

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