

Thermodynamic variables: Temperature

- Temperature T determines the direction of heat transfer. Heat between two objects in contact flows from the hotter one to colder one. Eventually, their temperatures will equilibrate: $T_1 = T_2$.
- The most common is Celsius temperature scale. $T = 0^\circ\text{C}$ is the melting point of ice, and $T = 100^\circ\text{C}$ is the boiling temperature of water at atmospheric pressure.
- Many properties of matter depend on temperature. For most substances, volume increases upon heating (exception: water near freezing point, between 0°C and 4°C).
- Thermal Expansion Coefficient (units $1/^\circ\text{C}$):

$$a = \frac{1}{V} \frac{\Delta V}{\Delta T}$$

- Example: $a = 1.8 \cdot 10^{-4} \text{ } 1/^\circ\text{C}$ for Mercury (Hg). This means that as temperature increases by $\Delta T = 10^\circ\text{C}$, a mercury droplet of initial volume V will grow by the amount $\Delta V = aV \Delta T = 1.8 \cdot 10^{-3} V$, or by 0.18%.
- Another way to characterize thermal expansion is to use Linear Thermal Expansion coefficient, a_L . It tells how much linear dimensions (say, length) changes with temperature:

$$a_L = \frac{1}{L} \frac{\Delta L}{\Delta T}$$

- For all liquids and many solids, $a_L = a/3$.

Homework

Problem 1

Please design a thermometer that will be able to measure temperature in a range ΔT . You may use glass capillary with length L and cross-section area S , connected to a glass reservoir that contains certain liquid. What should be the volume V of the reservoir, to make the thermometer maximally accurate? Thermal expansion coefficient of the liquid is α .

- a) Obtain the general formula, and compute the result for Ethanol-based thermometer, with dimensions $L = 20\text{cm}$, $S = 0.01\text{cm}^2$. Temperature range ΔT must be sufficient to monitor weather in Long Island. Thermal expansion coefficient of ethanol can be *googled*.
- b) Estimate the best possible accuracy of such thermometer.

Problem 2

How much taller is the Eiffel Tower on the hot summer day (30 °C) than on cold winter day (-5°C)? The tower is 324 m tall measured from the top of the flagpole. Assume the tower is built of structural steel. (It's actually made of "puddle iron".)