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°C is the melting point of ice, and T= 100°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/°C):

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

- Example: a = $1.8 \cdot 10^{-4}$ 1/°C for Mercury (Hg). This means that as temperature increases by $\Delta T = 10^{\circ}$ 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:

• 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 a.

- a) Obtain the general formula, and compute the result for Ethanol-based thermometer, with dimensions $\mathbf{L} = \mathbf{20cm}$, $\mathbf{S} = \mathbf{0.01cm^2}$. 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".)