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 ΔT= 10°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 **a**.

a) Obtain the general formula, and compute the result for Ethanol-based thermometer, with dimensions **L = 20cm** , **S = 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 ℃) than on cold winter day (-5℃)? 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".)