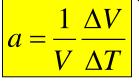
## **Thermodynamic variables: Temperature**

- 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):



• 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:  $1 \Delta I$ 

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

• 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  $\Delta T$ . 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 = 20 cm,  $S = 0.01 \text{ cm}^2$ . Temperature range  $\Delta T$  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".)