Thermodynamics

7 – Thermal Expansion

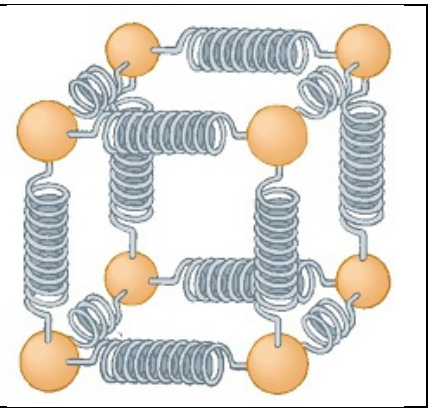
Thermal expansion results from a change in the average separation between the constituent atoms in a solid, liquid or gas.

Imagine that the atoms are connected by stiff springs. (*See to the right*)

At ordinary temperatures the average spacing between the atoms is about 10^{-10} m while oscillating about their equilibrium positions with an amplitude of approximately 10^{-11} m at a frequency of approximately 10^{13} Hz.

As the temperature of the solid increases, the atoms oscillate with greater amplitudes; as a result, the average separation between them increases.

Consequently, the object expands.



We can quantify both the linear and the volume expansion of materials using the following formula's:

$$\Delta L = \alpha L_o \Delta T$$

$$\Delta V = \beta V_o \Delta T$$

Where: $\Delta L/\Delta V$ = Change in Length/Volume (m/m^3)
α/β = Linear/volume expansion coefficient
L_o/V_o = Initial Length/Volume
ΔT = change in Temperature

Material	Coefficient of Linear Expansion, α $(C°)^{-1}$	Coefficient of Volume Expansion, β $(C°)^{-1}$
Solids		
Aluminum	25×10^{-6}	75×10^{-6}
Brass	19×10^{-6}	56×10^{-6}
Copper	17×10^{-6}	50×10^{-6}
Gold	14×10^{-6}	42×10^{-6}
Iron or steel	12×10^{-6}	35×10^{-6}
Lead	29×10^{-6}	87×10^{-6}
Glass (Pyrex®)	3×10^{-6}	9×10^{-6}
Glass (ordinary)	9×10^{-6}	27×10^{-6}
Quartz	0.4×10^{-6}	1×10^{-6}
Concrete and brick	$\approx 12 \times 10^{-6}$	$\approx 36 \times 10^{-6}$
Marble	$1.4–3.5 \times 10^{-6}$	$4–10 \times 10^{-6}$
Liquids		
Gasoline		950×10^{-6}
Mercury		180×10^{-6}
Ethyl alcohol		1100×10^{-6}
Glycerin		500×10^{-6}
Water		210×10^{-6}
Gases		
Air (and most other gases at atmospheric pressure)		3400×10^{-6}

Example:

A steel railroad track has a length of 30.000 m when the temperature is 0.0 °C. What is its length when the temperature increases to 40.0 °C?

$\Delta L = \alpha L_o \Delta T$

$\Delta L = (12 \times 10^{-6})(30.000\,m)(40.0°C)$

$\Delta L = 0.014$

$L_f = L_o + \Delta L = 30.000m + 0.014m$

$L_f = 30.014m$

Examples:

A glass (*made of glass*) filled water with ***EXACTLY*** 1.0 liter is ***completely*** filled at 5°C. How much water will spill out of the glass when the temperature is raised to 85°C? Glass EXPANDS!

$\Delta V = \Delta V_{water} - \Delta V_{glass}$

$\Delta V = \beta_{water} V_o \Delta T - \beta_{glass} V_o \Delta T$

$\Delta V = (210 \times 10^{-6})(1.0)(80.) - (27 \times 10^{-6})(1.0)(80.)$

$\Delta V = 0.015L$

15mL will spill out!