Module-4(b)

Thermal Expansion of solid material

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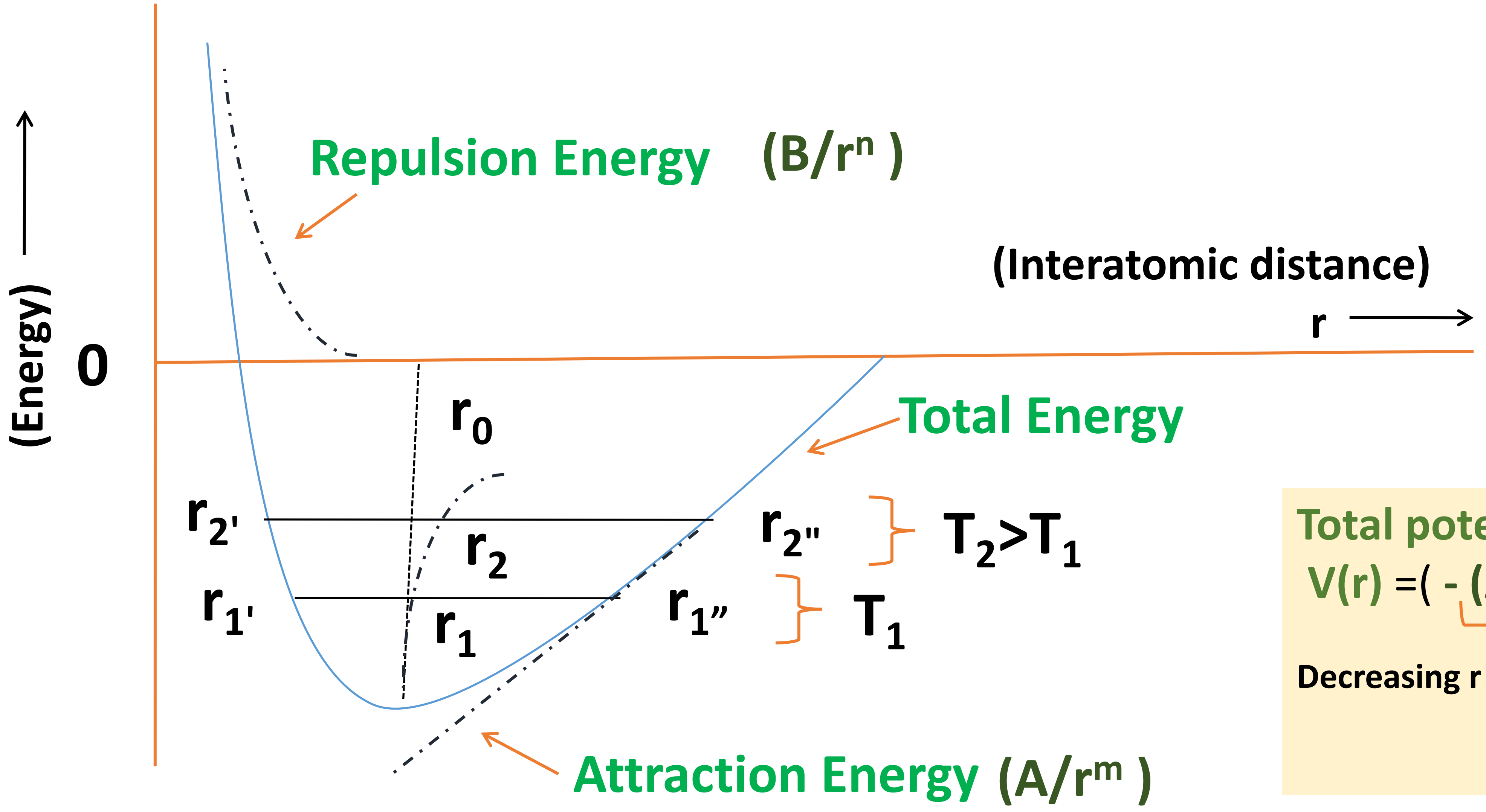
Aim:

To study the thermal expansion behavior of solid materials using a dial gauge dilatometer.

Theory:



Total potential energy

$$V(r) = \left(-\underbrace{(A/r^m) + (B/r^n)} \right)$$

Decreasing r lowers the energy

Figure: Potential energy Vs Interatomic distance

- **Asymmetric shape** of the potential energy curve can be noticed.

- Degree of asymmetry is a function of the values of the exponent of **m** and n in equation.

- **$m<n$**

- In ionic crystals, m ~1 and n ~ 12, here m = 1 corresponds to coulomb attraction between two point charges.

- In molecular crystals, m ~ 6.

- At temperature T_1 and energy E_1, the r oscillates from r_1' to r_1''.
  $r_1 = (r_1' + r_1'')/2$

- At temperature $T_2 > T_1$ and energy E_2, r oscillates from r_2' to r_2''.
  $r_2 = (r_2' + r_2'')/2$

- At T_2, $r_2 > r_1$ leads to thermal expansion.

•**Asymmetric shape of the potential energy curve** (due to anharmonic nature of the lattice vibrations) **is responsible for the thermal expansion.**

- **Large binding energy** $\longrightarrow$ **high melting point of a material**

$\downarrow$

Have a deep potential energy minimum

$\downarrow$

At T<<<Tm, asymmetry of the curve exist only to a small extent.

- A material with a high melting point (T ° K) would, near room T shows low thermal expansion.

- **Isotropic materials (ex: metals, glass, plastics):**
Exhibit the same thermal expansion in all directions.

- **Non isotropic crystals (ex: wood, composites):**
Possess different Th. Exp. values in various directions.

- **Poly crystalline specimen (ex: ceramics, ice)** :
Has randomly oriented non isotropic crystals so possess avg of expansion coefficient of all the directions.

- **Multiphase material (ex: Steels, composites)**
Has weighted average of the expansion coefficients of its component phases.

Thermal expansion coefficient can be measured by knowing two physical quantities:

Displacement

Temperature

Objective

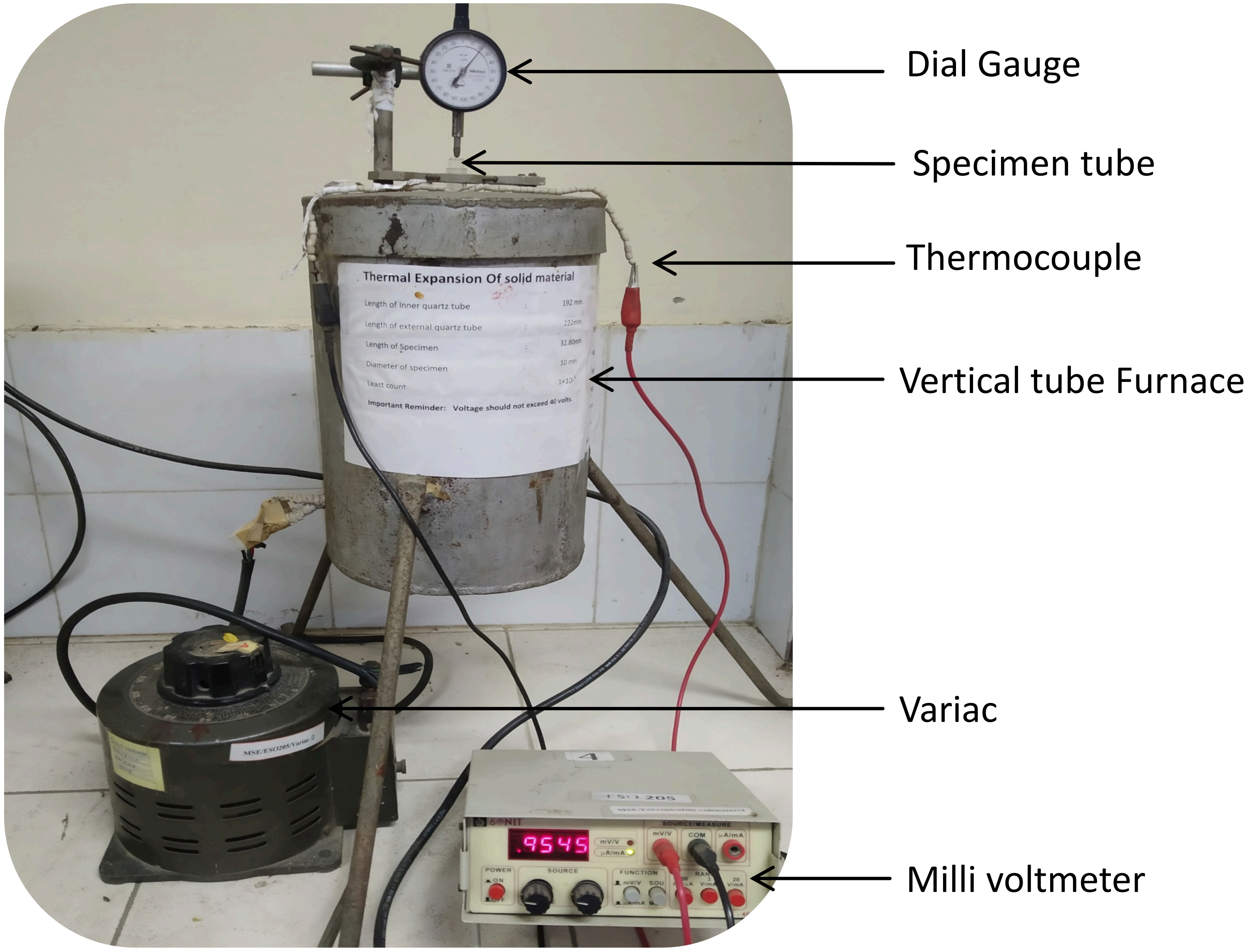
To study the thermal Expansion behaviour of solid material using a dial gauge dilatometer

Apparatus

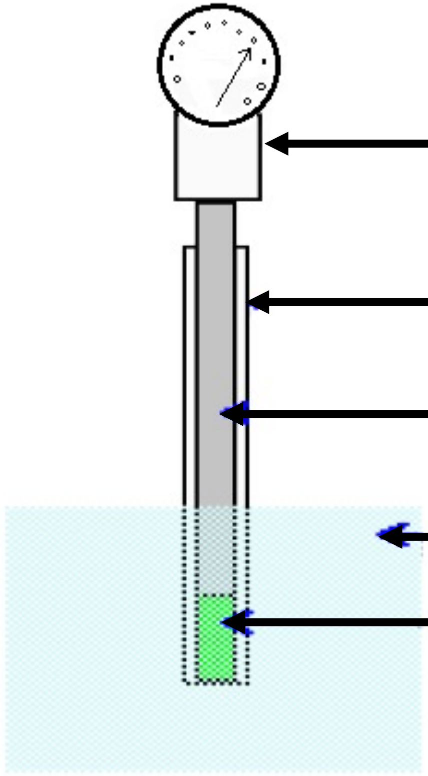
- Fused silica tube
- Dial gauge dilatometer
- Vertical Tube Furnace
- Variac (Auto transformer) for power supply
- Temperature Controller
- Potentiometer
- K-type Thermocouple (Chromel-Alumel) and
- Specimen (Aluminium), Fireclay bricks

Dial gauge (mechanical magnification)

Experimental Setup



Schematic Diagram & Dilatometer Assembly Experimental Setup



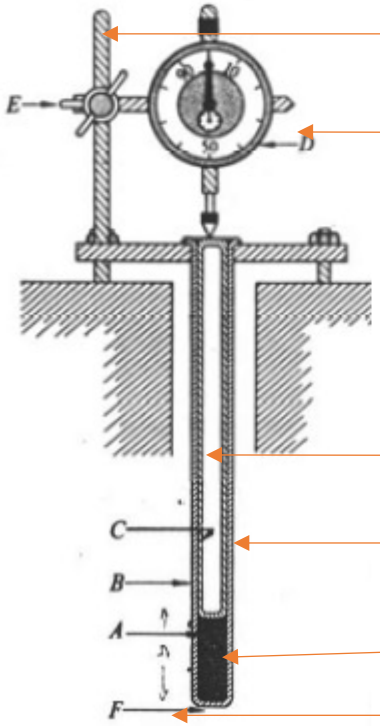
Dial Gauge
(Least count=0.001mm)

Fused Silica Tube

Fused Silica Rod

Heat Transfer Fluid

Specimen



Tighten with clamp

Dial gauge

Nut bolt tighten
with Inconel plate

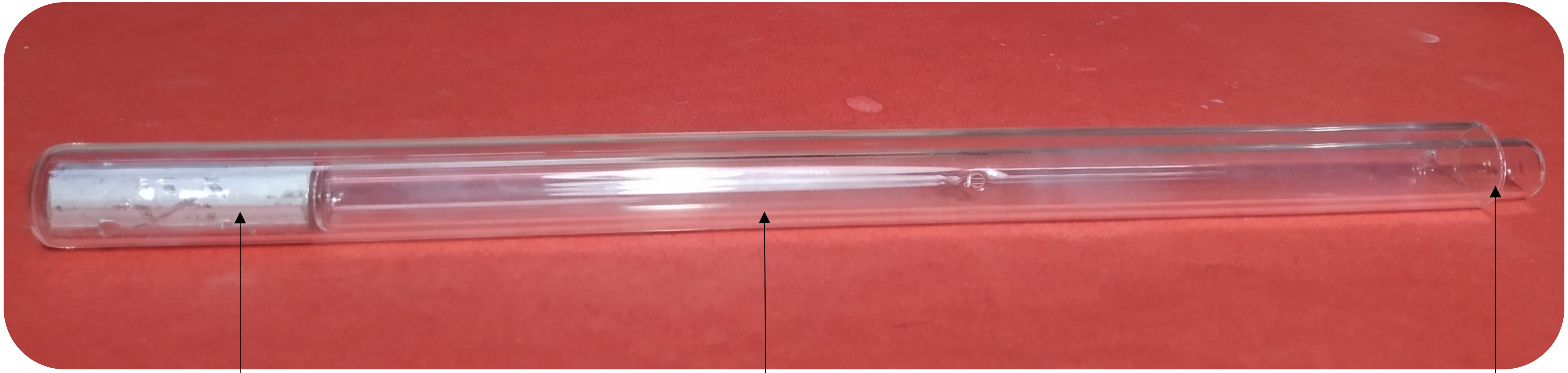
Fused Silica Rod

Fused Silica Tube

Specimen

Alumina tube
Bottom End closed

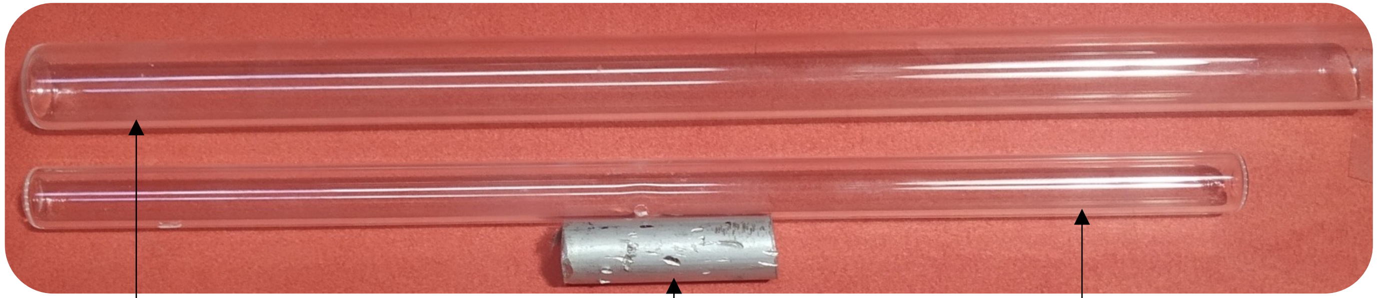
Internal Experimental Design



Specimen(Aluminium)

Outer Tube

Inner tube



Silica Tubes

Outer tube

Specimen

Inner tube

Methodology

1. Take pure aluminium (why Al?)
2. Mount one of the samples at the bottom of the quartz tube which is closed at one end
3. Place the quartz tube on the top of specimen
4. Attach the dial gauge on the top of outer quartz tube by Inconel clamp
5. Insert the whole assembly in tube furnace
6. Read the dial gauge reading at different temperature

Linear thermal expansion coefficient

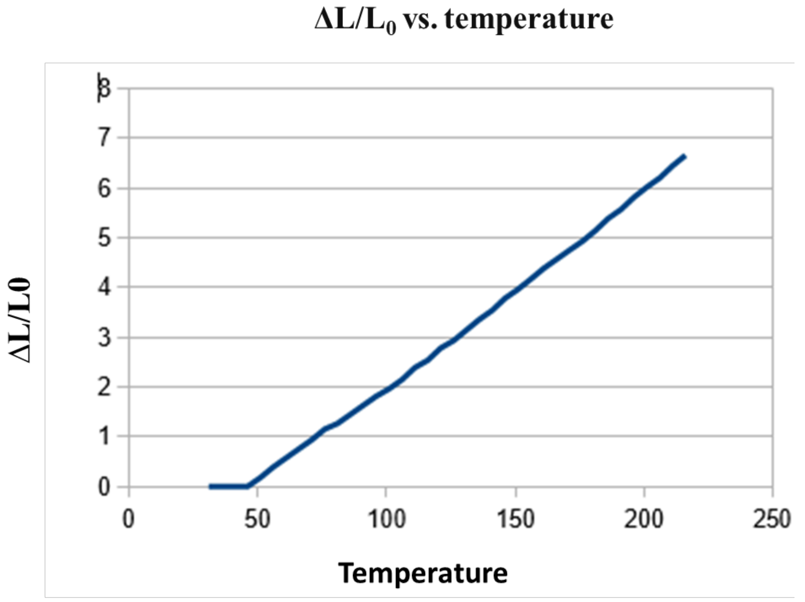
The change in length with temperature for solid material can be expressed as follows:

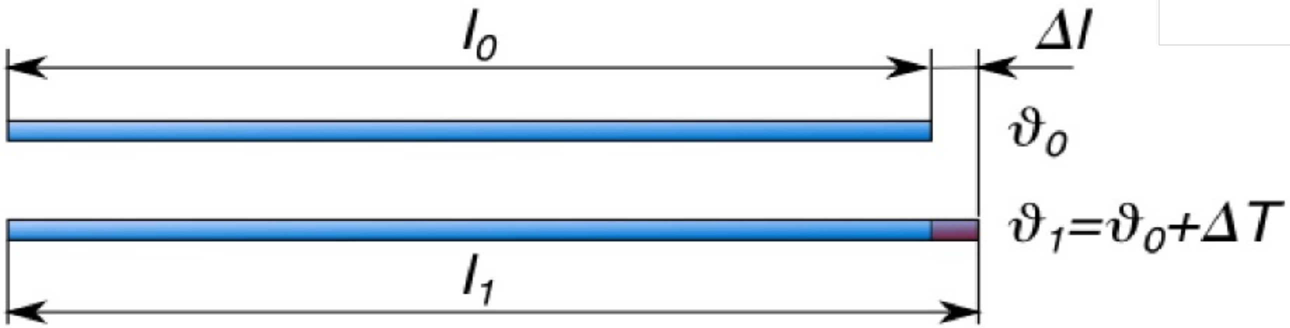
$$\alpha * \Delta T = (L_f - L_o)/L_o$$

Or

$$\alpha = (\Delta L)/(\Delta T * L_o)$$

- L_o and L_f are the initial and final length (after heat treatment), respectively.
- α is linear thermal expansion coefficient.
- $\Delta T = T_f - T_o$





Change in length of a rod due to thermal expansion.

Question:

1. Show one adverse effect of differential dilatation (thermal expansion mismatch). Check out your surrounding if you can find any such example (Don’t forget to post a picture of whatever you have observed with proper explanation).

THANK YOU