University of Science and Technology

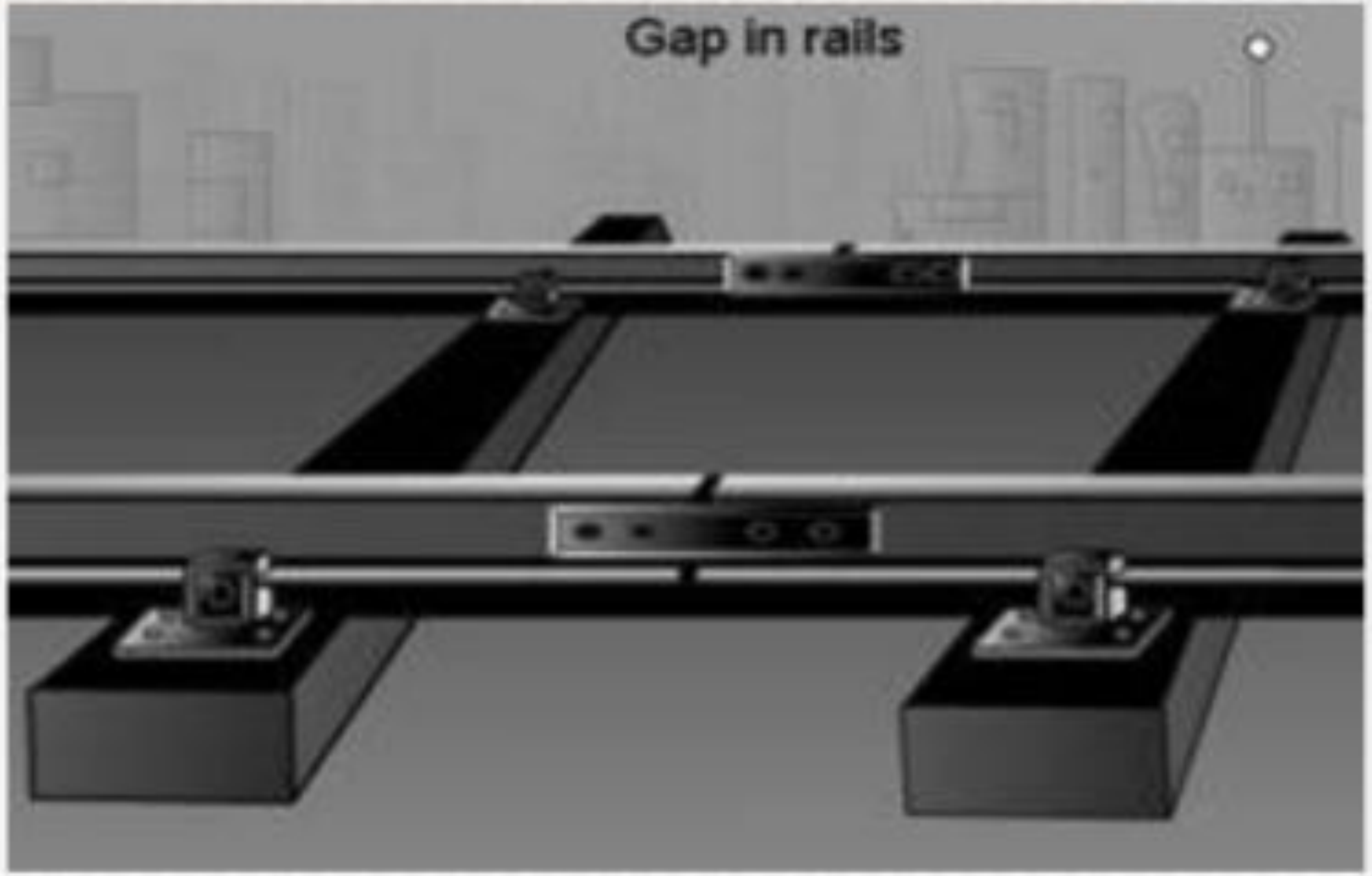
Faculty of Engineering

First Year - Semester One - Academic Year:2025-2026

Physics (1)

Lec (9)

Thermal Expansion


Gap in rails

1. Definition of Thermal Expansion : Thermal expansion is **the increase in dimensions or volume of a material due to an increase in temperature**.

- When a material is heated, its particles move faster, increasing the distance between them, which causes **length, area, or volume to increase**.
- Cooling a material causes the opposite effect, known as **thermal contraction**.

Types of Thermal Expansion

A) Linear (Length) Expansion

- Occurs in **solid objects with a definite shape** (rods, wires, beams).
- Depends on the original length, the linear expansion coefficient, and the temperature change.

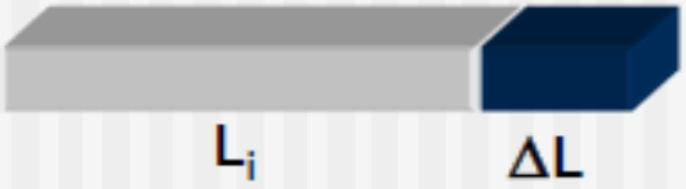
Formula: $\Delta L = L_0 \cdot \alpha \cdot \Delta T$

Where:

- ΔL = change in length
- L_0 = original length
- α = linear expansion coefficient ($°C^{-1}$)
- ΔT = temperature change

Linear Expansion Formula

$$\Delta L = \alpha L_i \Delta T$$



Numeric Example:

- Metal rod: $L_0=2$ m
- Linear expansion coefficient: $\alpha=12\times10^{-6}/°C$
- Temperature increase: $\Delta T=50°C$

$$\Delta L=2\cdot12\times10^{-6}x50=0.0012\ m=1.2\ mm$$

Interpretation: The rod length increases by 1.2 mm.

Thermal Expansion

Linear Expansion

Amount of linear expansion (ΔL) depends on the following:

1. ΔT ($T_{final} - T_{initial}$) : Change in temperature (°C)
2. L_i : Original length
3. α (alpha) : Coefficient of thermal expansion

Units for Coefficient of Thermal Expansion

α units: 1/°C

Linear Expansion Formula

$$\Delta L = \alpha \, L_i \, \Delta T$$

Change
In
Temperature
(Final – Initial)

Original
Length

Coefficient
Of Thermal
Expansion

Change
In
Length

Linear Expansion Example #1

A Brass strip is 3 cm long at 0ºC. How long will it be at 100ºC if the coefficient of linear expansion for Brass is $1.8 \times 10^{-5}/^{\circ}C$?

$\Delta L = (\alpha)(L_i)(\Delta t)$
$\Delta L = (1.8 \times 10^{-5}/^{\circ}C)(3\ cm)(100^{\circ}C - 0^{\circ}C)$
$\Delta L = 0.0054\ cm$

$L_f = \Delta L + L_i$
$L_f = 0.0054\ cm + 3\ cm$
$L_f = 3.0054\ cm$

B) Area Expansion

- Occurs when the **surface area of a solid object** increases.
- Often used for plates, sheets, or surfaces.

Formula: $\Delta A = 2\alpha \cdot A_0 \cdot \Delta T$

Where:

- A_0 = original area
- α = linear expansion coefficient

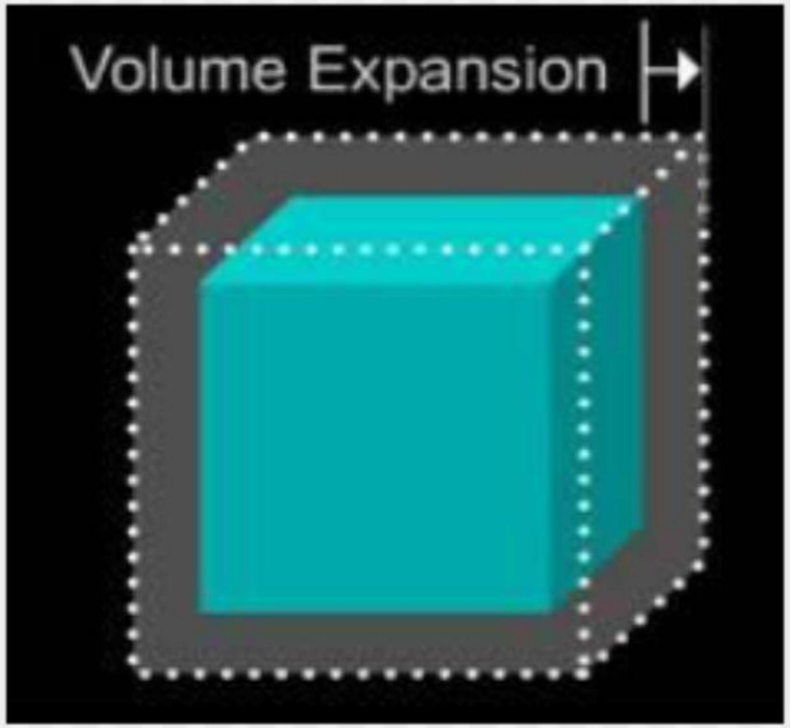
Numeric Example:

- Metal plate area: $A_0=1\ m^2$
- Linear expansion coefficient: $\alpha=12\times10^{-6}/°C$
- Temperature increase: $\Delta T=50°C$

$\Delta A=2x12\times10^{-6}x1x50=0.0012\ m^2$

Interpretation: The plate's area increases by $0.0012\ m^2$.

Volumetric Expansion



C) Volumetric Expansion

- Occurs when the **volume of a substance increases**, applicable for solids, liquids, or gases.

Formula: $\Delta V = \beta \cdot V_0 \cdot \Delta T$

Where:

- V_0 = original volume
- β = volumetric expansion coefficient ($°C^{-1}$)

Volumetric Expansion

Volumetric Expansion

Amount of volume expansion (ΔV) depends on the following:

1. **ΔT ($T_{final} - T_{initial}$) : Change in temperature (°C)**
2. **V_i : Original volume**
3. **Beta (β): Coefficient of volumetric expansion**

Units for Coefficient of Volumetric Expansion:

β units: 1/°C

Volumetric Expansion Formula

$$\Delta V = \beta \, V_i \, \Delta T$$

Change In Temperature
Final - Initial

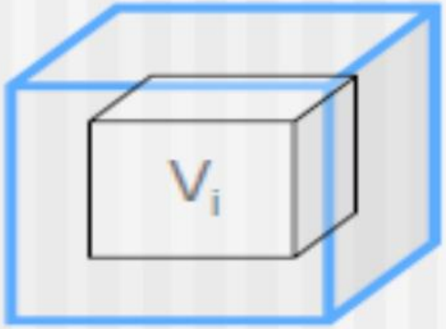
Original Volume

Coefficient Of Volumetric Expansion

Change In Volume

Volumetric Expansion Formula

$$\Delta V = \beta V_i \Delta T$$



$V_i + \Delta V$

Numeric Example:

- Volume of liquid: $V_0 = 10$ L
- Volumetric expansion coefficient: $\beta = 0.0002/°C$
- Temperature increase: $\Delta T = 50°C$

$\Delta V = 0.0002 x 10 x 50 = 0.1$ L

Interpretation: The liquid volume increases by 0.1 L.

Volumetric Thermal Expansion Example #1

The coefficient of volumetric expansion of mercury is 1.8×10^{-4} /°C. If the temperature of 10 L of mercury increases by 30 °C, how much volume will the mercury increase by?

$$\Delta V = (\beta)(V_i)(\Delta t)$$

$$\Delta V = (1.8 \times 10^{-4})(10\ L)(30\ ^\circ C)$$

$$\Delta V = 0.054\ L$$

3. Relationship Between Expansion Coefficients

For most solids: $\beta \approx 3\alpha$ $\Delta A \approx 2\alpha A_0 \Delta T$

- α = linear expansion coefficient
- β = volumetric expansion coefficient
- ΔA = area expansion
- ΔV = volume expansion

Meaning:

- The volumetric expansion coefficient is approximately **three times the linear expansion coefficient**.
- The area expansion coefficient is approximately **two times the linear expansion coefficient**.

. Practical Notes

1. **Metal structures:** Leave small gaps between rods or rails to prevent bending or cracking when heated.
2. **Glass objects:** Have small expansion coefficients but may crack under rapid temperature changes.
3. **Liquids:** Used in thermometers (mercury/alcohol) because expansion is easily measurable.
4. **Gases:** Expand significantly with temperature, following the ideal gas law $V \propto T$ at constant pressure.