DON BOSCO CATHOLIC SECONDARY AND PREPARATORY SCHOOL

GRADE 9: PHYSICS HANDOUT(3)

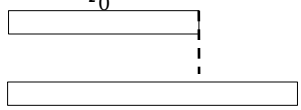
Thermal expansion of a substance

- Change in shape as temperature changes.

Thermal expansion of solid

Solid has definite shape and volume. Then its thermal expansion can be described in terms of length, area or volume.

Linear expansion - change in length.



initial length l_0 at initial temperature, T_0.

final length l_1 at final tempetrature, T_1.

Thermally, change of length, Δl is directly proportional to change in temperature (ΔT).

$$\Delta l \propto \Delta T$$

$$\Rightarrow \Delta l = k\Delta T$$

The proportionality constant, K is experimentally determined as $k = l_0\alpha$

Then $\Delta l = l_0\alpha\Delta T$ where α - coefficient of linear expansion.

$$\Delta l = l_1 - l_0$$

$$\Rightarrow l_1 - l_0 = l_0\alpha\Delta T$$

$$\therefore\ l_1 = l_0 + l_0\alpha\Delta T \quad , \quad \Delta T = T_1 - T_0$$

Example: A certain rod is 1m long at $20℃$ and 1.002m at $60℃$. What is its coefficient of linear expansion? What is its length at $10℃$?

Solution: i) $\Delta l = l_0\alpha\Delta T$

$$\Rightarrow \alpha = \frac{\Delta l}{l_0 \Delta T} = \frac{l_1 - l_0}{l_0 (T_1 - T_o)} = \frac{1.002 - 1}{1 \times (60 - 20)} = \frac{0.002}{1 \times 40} /℃$$

$$\therefore \quad \alpha = 5 \times 10^{-5} /℃$$

ii) $l_1 = l_0 + l_0 \alpha \Delta T$

$= 1 + 1 \times 5 \times 10^{-5} \times (10 - 20)$

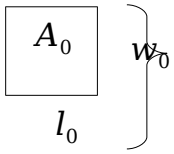
$l_1 = 1 + 5 \times 10^{-5} \times (-10)$

$l_1 = 1 - 5 \times 10^{-4} = 1 - 0.0005 m$

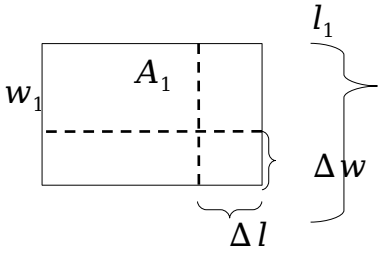
$\therefore \quad l_1 = 0.9995 m$

Areal expansion

- change in area as temperature changes.



Initial area, A_1 at final temperature, T_0.



Final area, A_1 at final temperatures, T_1.

Area of an object expands in two directions linearly.

$A_1 = l_1 w_1$

$\Rightarrow \quad A_1 = (l_0 + l_0 \alpha \Delta T)(w_0 + w_0 \alpha \Delta T)$

$\Rightarrow \quad A_1 = l_0 w_0 + 2 l_0 w_0 \alpha \Delta T + l_0 w_0 \alpha^2 \Delta T^2$

Since α is very small, then $\alpha^2 \approx 0$.

This implies $l_0 w_0 \alpha^2 \Delta T^2 \approx 0$.

$A_1 = l_0 w_0 + l_0 w_0 2\alpha\Delta T$, $l_0 w_0 = A_0 - initial\ area\ at\ initial\ temperature\ T_0$

$\Rightarrow$ $\boxed{A_1 = A_0 + A_0\beta\Delta T}$ Where β - coefficient of expansion of area of a substance.

$\beta = 2\alpha$

Example: A square metal sheet has 40cm side a $0\,℃$. If its coefficient of linear expansion is $3\times10^{-3}/℃$, what is the area at $20\,℃$?

Solution: $A_1 = A_0 + A_0\beta\Delta T$, $A_0 = S^2$

$\Rightarrow$ $A_1 = A_0 + A_0 2\alpha\Delta T$

$\Rightarrow$ $A_1 = 1600 + 1600\times2\times3\times10^{-3}(20-0)$

$\Rightarrow$ $A_1 = 1600 + 9600\times20\times10^{-3}$

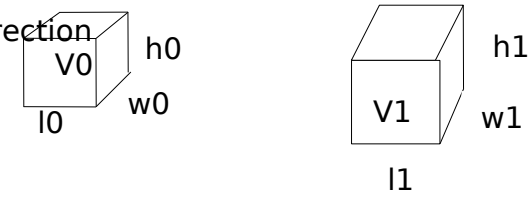
$\Rightarrow$ $A_1 = 1600 + 192$

$\therefore$ $A_{1=¿1792cm^2¿}$

Problem: Area of a substance at $20℃$ is $0.95\,m^2$ and $1\,m^2$ at $70\,℃$. What is coefficient of linear expansion of the substance?

Volume expansion of solid substance

A solid substance expands linearly in three direction



$V_0 = l_0 w_0 h_0$

$V_1 = l_1 w_1 h_1$

$V_1 = (l_0 + l_0\alpha\Delta T)(w_0 + w_0 + w_0\Delta T)(h_0 + h_0\Delta T)$

$V_1 = l_0 w_0 h_0 + 3 l_0 w_0 h_0\alpha\Delta T + 3 l_0 w_0 h_0\alpha^2\Delta T^2 + l_0 w_0 h_0\alpha^3\Delta T^3$

Since α is very small, the terms with $\alpha^2 \wedge \alpha^3$ are zero.

$V_1 = l_0 w_0 h_0 + 3 l_0 w_0 h_0\alpha\Delta T \Longrightarrow$ $V_1 = l_0 w_0 h_0 + l_0 w_0 h_0 3\alpha\Delta T$

$\boxed{V_1 = l_0 w_0 h_0 + l_0 w_0 h_0\gamma\Delta T}$ Equation of volume expansion of solid substance

where γ _coefficient of volume expansion. $\gamma = 3\alpha - ¿$ only for the solid substance.

eg. Side a cube is 20cm at 0^0C. If its confidents of linear expansion is $4x10^{-4}/^0$C, is its

volume at 60^0C?

Solution:- $V_{1=}V_0+V_0\gamma T$, $S^3=20^3=8000cm^3$ and $\gamma=3\alpha=3x4x10^{-4}=12x10^{-4}/^0$C.

$V_1=8000+8000x12x10^{-4}(60-10)=8000+9.6x50$

$\therefore V_1=8480\,cm^3$

H.W **2.** Volume of a substance is $500cm^3$ at 0^0C and $590cm^3$ at 25^0C. What is its coeffient of

linear expansion of the substance?