Physics Lab 211

Experiment No. 8

The Thermal Expansion Coefficient of Brass

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Abstract:

-Aims: To determine the coefficient of linear expansion of a brass rod, and learning how to calibrate an instrument .

-Methods: By recording the scale readings as the thickness and temperature changes .

-Main Result:

$$\bar{\alpha} = (\mathbf{18} \pm \mathbf{4})\mathbf{10^{-6}}\ \ \mathbf{1/C^0}$$

Theoretical Background:

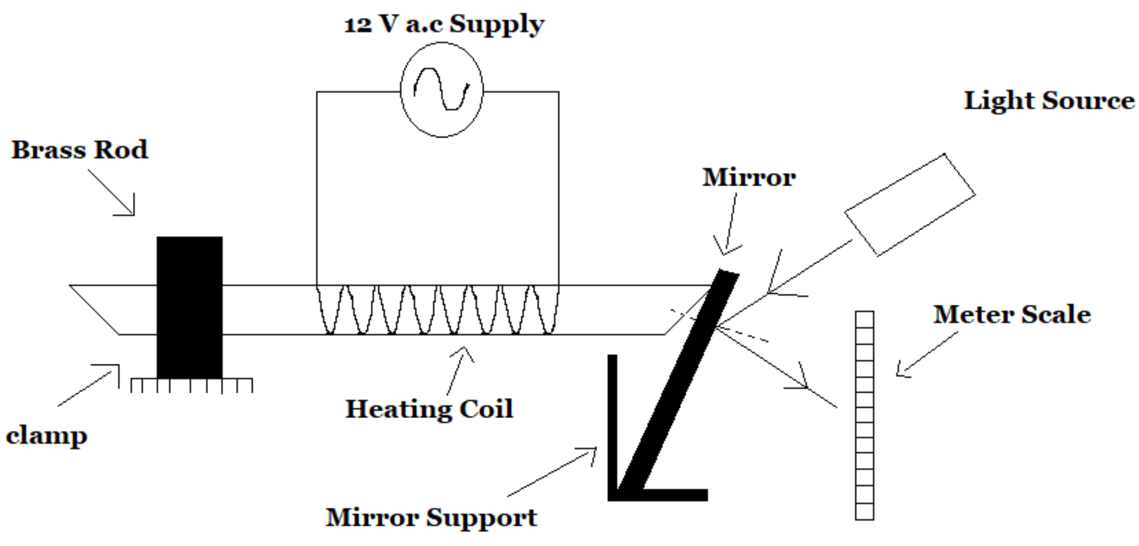
The expansion of metals when heated is linear over wide ranges of temperatures. The relation describing the new length of a metallic rod when heated is as follows:

$$L(T) = L_0(1 + \alpha(T - T_0))$$

Where T_0 is the room temperature, L_0 is the length of the metallic rod at T_0, and α is called the linear coefficient of thermal expansion.

Procedure:

The brass rod is fixed at one end, and the other end is allowed to be expanded and pushed against the back of a mirror. In the first part, plenty of identical pieces of plastic are inserted between the brass rod and the mirror one by one, then the total thickness of the inserted papers versus the scale reading was recorded. In the second part, the length of the rod from the point of clamping to the point where it touched the mirror was measured after removing all the plastic slips of course. After that, the heating transformer was turned on, and the scale readings were recorded as temperature rose. After the temperature stopped rising, the heater was turned off and the scale readings were recorded again as the temperature was lowering, until it stopped.



Data Sheet:

$\boldsymbol{L_0 = (0.50 \pm 0.01)m}$

Part I:

Thickness (m)	**Scale Reading (m)**
0.000076	0.148
0.000152	0.150
0.000228	0.153
0.000304	0.156
0.000380	0.159
0.000456	0.162
0.000532	0.165
0.000608	0.168
0.000684	0.171
0.000760	0.176

Part II:

Temperature (C^0)	Heating		
	Scale Reading (m)	Thickness (m)	Length (m)
30	0.148	9.952380952E-05	0.5000995
35	0.152	1.990476190E-04	0.5001990
40	0.154	2.488095238E-04	0.5002488
45	0.155	2.736904762E-04	0.5002737
50	0.157	3.234523810E-04	0.5003235
55	0.159	3.607738095E-04	0.5003608
59	0.160	3.980952381E-04	0.5003981

Temperature (C^0)	Cooling		
	Scale Reading (m)	Thickness (m)	Length (m)
59.0	0.160	3.980952381E-04	0.5003981
55.0	0.157	3.110119048E-04	0.5003110
50.0	0.154	2.488095238E-04	0.5002488
45.0	0.152	1.990476190E-04	0.5001990
40.0	0.150	1.492857143E-04	0.5001493
35.0	0.149	1.119642857E-04	0.5001120
30.0	0.147	7.464285714E-05	0.5000746

Calculations:

From the first part we obtain the calibration curve. By using this curve we can convert temperature scale data into temperature-length data, in order to use for measuring the thermal expansion coefficient, by plotting the length vs. the temperature.

For finding the length at any temperature we use the equation:

$L = L_0 + Thickness$. Where the $Thickness = \frac{scale\ reading - y\_intercept}{slope}$

Here, we have $L_0 = 0.5\ m$, $y\_intercept_{(calibration\ curve)} = 0.144\ m$, and the $slope_{(calibration\ curve)} = 40.191\ m$.

By substituting the above equation with every scale reading we can plot length vs. temperature and from the equation:

$$L(T) = L_0\big(1 + \alpha(T - T_0)\big) \to L(T) = \alpha L_0 T + (L_0 - \alpha L_0 T_0)$$

We obtain a slope of value "αL_0", and $y\_intercept$ of value "$(L_0 - \alpha L_0 T_0)$".

The second part is divided into two sections:

1- Heating:

From the heating graph:

$$\boldsymbol{a} - Slope = \alpha_{11} L_0 \to \alpha_{11} = \frac{slope}{L_0} = \frac{9.455 \times \frac{10^{-6} m}{C^0}}{0.5\ m}$$

$$\to \boldsymbol{\alpha_{11} = 1.89 \times 10^{-5}\ 1/C^0}$$

$$\boldsymbol{b} - y\_intercept = L_0(1 - \alpha T_0) \to \alpha_{12} = \frac{1 - \frac{y\_intercept}{L_0}}{T_0} = \frac{1 - \frac{0.4998}{0.5}}{30}$$

$$\to \boldsymbol{\alpha_{12} = 1.33 \times 10^{-5}\ 1/C^0}$$

$$\overline{\alpha_1} = \frac{(\alpha_{11} + \alpha_{12})}{2} = \frac{(1.89 + 1.33) \times 10^{-5}}{2} = 16 \times 10^{-6}\ 1/C^0$$

$$\Delta\bar{\alpha}_1 = \sigma_m = 4 \times 10^{-6}\ 1/C^0$$

$$\boldsymbol{\overline{\alpha_1} = (16 \pm 4)10^{-6}\ 1/C^0}$$

2- Cooling:

From the cooling graph:

$$\boldsymbol{a} - Slope = \alpha_{21} L_0 \rightarrow \alpha_{21} = \frac{slope}{L_0} = \frac{1.067 \times \frac{10^{-5} m}{C^0}}{0.5\ m}$$

$$\rightarrow \boldsymbol{\alpha_{21} = 2.13\ \times 10^{-5}\ 1/C^0}$$

$$\boldsymbol{b} - \ y\_intercept = L_0(1 - \alpha T_0) \rightarrow \alpha_{22} = \frac{1 - \frac{y\_intercept}{L_0}}{T_0} = \frac{1 - \frac{0.4997}{0.5}}{30}$$

$$\rightarrow \boldsymbol{\alpha_{22} = 2.00\ \times 10^{-5}\ 1/C^0}$$

$$\overline{\alpha_2} = \frac{(\alpha_{11} + \alpha_{12})}{2} = \frac{(2.13 + 2.00) \times 10^{-5}}{2} = 21 \times 10^{-6}\ 1/C^0$$

$$\Delta\overline{\alpha_2} = \sigma_m = 0.9 \times 10^{-6}\ 1/C^0$$

$$\boldsymbol{\overline{\alpha_2} = (21 \pm 0.9)10^{-6}\ \ 1/C^0}$$

$$\bar{\alpha} = \frac{(\alpha_1 + \alpha_2)}{2} = \frac{(16 + 21) \times 10^{-6}}{2} = 18.5 \times 10^{-6}\ 1/C^0$$

$$\Delta\bar{\alpha} = \sigma_m = 4\ 1/C^0$$

$$\boldsymbol{\bar{\alpha} = (18 \pm 4)10^{-6}\ \ 1/C^0}$$

Results & Conclusions:

$$\overline{\boldsymbol{\alpha_{exp}}} = (\mathbf{18} \pm \mathbf{4})\mathbf{10^{-6}}\ \ \mathbf{1/C^0}$$

The thermal expansion coefficient of Brass: $\alpha_{theo} = 19 \times 10^{-6}\ 1/C^0$

$Discrepancy = |\alpha_{theo} - \alpha_{exp}| = |19 - 18| \times 10^{-6} = 1 \times 10^{-6}\ 1/C^0$

$2 \times \Delta\alpha\ >?\ Discrepancy$

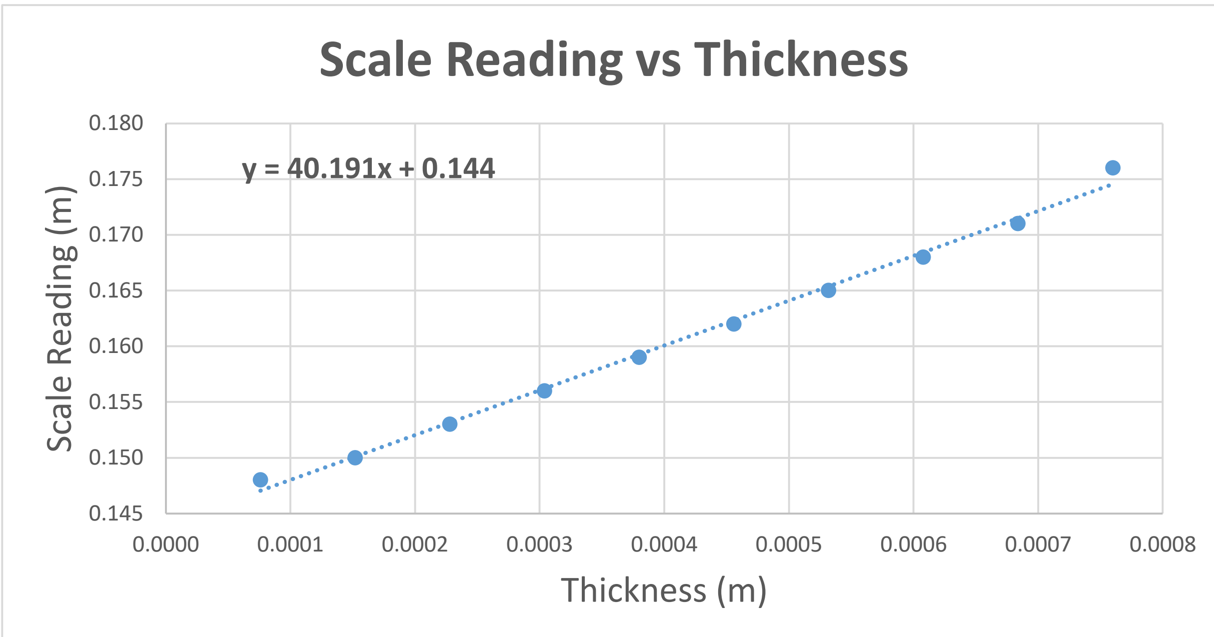
$2 \times 4 \times 10^{-6}\ >?\ 1 \times 10^{-6}$

$8 \times 10^{-6} > 1 \times 10^{-6}$

So, it is clear that our obtained value is accepted within the random errors considered.

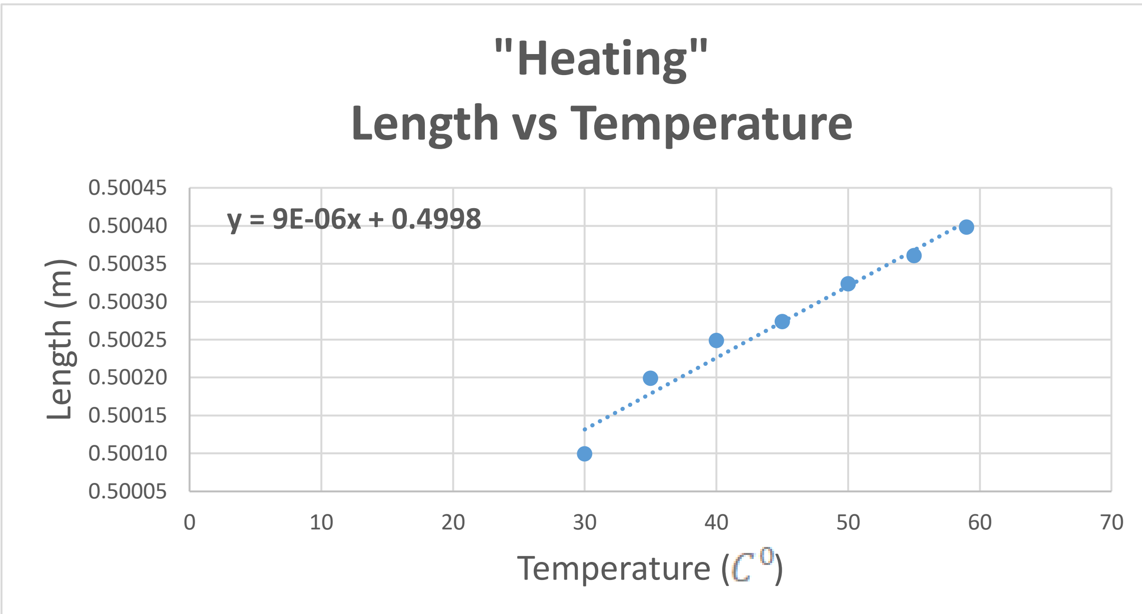
Some random errors may have occurred while practicing this experiment. Most commonly, the reading of the scale was not accurate since the beam was thick and not precise. As well as, the brass rod is old and its thermal coefficient may change with time due to corrosion.

Graph I



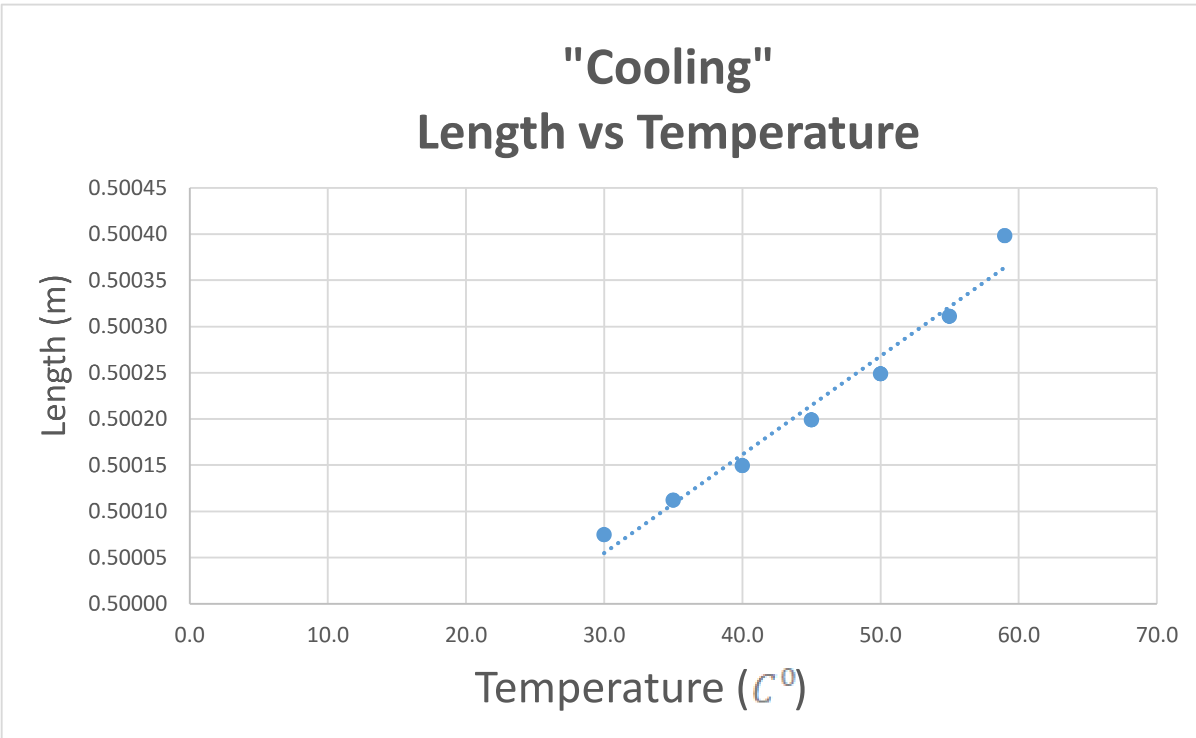
	slope	y-intercept
	40.191388	0.144000
error	1.005544	0.000474

Graph II



	slope	y-intercept
	9.454868E-06	4.998478E-01
error	7.851678E-07	3.604938E-05

Graph III



	slope	y-intercept
	1.066554E-05	4.997348E-01
error	8.530770E-07	3.916729E-05