Experiment 2
Thermal Expansion of Metals

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Synopsis

In this experiment, we try to determine the thermal expansion coefficient of different metals.

I. THEORY AND PROCEDURE

A. Apparatus

- Thermal Expansion Apparatus
- Brass, Aluminium, Copper and Steel rods
- Steam generator and electric heater
- Thermometer for temperature measurements

B. Theory

When a solid is heated, its length increases. This expansion is approximately linear for small temperature ranges:

$$L = L_0(1 + \alpha\Delta T)$$

where L is the final length, L_0 the initial length, α the coefficient of thermal expansion, and ΔT the temperature change. The above formula can simply be written as:

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

For this experiment we use thermal expansion apparatus as shown in the image:
INSERT IMAGE HERE

C. Procedure

1. Place the rod in the apparatus.
2. Fix all the screws in proper position to make the road stable.
3. Measure the temperature of the rod along the ends and the center for better accuracy.
4. Now fix the steam tubes in their proper position.
5. When everything is measured, measure the length of the road as shown int he IFGGGGG:
6. Start the induction and when the steam passes through the rod, measure the expansion of the rod using the spherometer.
7. Let the apparatus cool before putting in another rod and repeat this for different materials and different rods.

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1. Precautions

- Ensure to use thermal gloves, this helps reduce the heat flow from our hand to apparatus
- After measuring the expansion, sprinkle water or give enough time for the apparatus to cool (we used wet paper towels to cool the apparatus)
- Ensure the screws are tight enough.
- Measure the length of the rod after fixing the screws, measuring the length before may change its value when fixing the screws.
- Use different rods, when using the same material to reduce any instrumental error from material.

2. Calibration

We start by calibrating the apparatus to see weather the apparatus is working or not. For this we shall use copper rods whose thermal expansion coefficient is known; $\alpha_{\text{copper}} = 16.6{\times}10^{-6\circ}\text{C}^{-1}$[1]. We place the rods in the apparatus and measure its length (L), change in length (ΔL) and temperature across the rod, which may not be the same so we take multiple values to reduce error.

Material	T_i(°C)	L(cm))	ΔL(10^{-5}m)
Copper	24.0	59.0	75
Copper	25.5-24.5-25.5	59.7	74

Now using the known α_{copper} we calculate the temperature of rods in equilibrium as:

Material	T_i(°C)	L(cm))	ΔL(10^{-5}m)	α($10^{-6\circ}$C^{-1})	T_f(°C)
Copper	24.0	59.0	75	16.6	99.6
Copper	25.5-24.5-25.5	59.7	74	16.6	99.3

From this data we conclude that the temperature of rods in equilibrium is ≈ 100°C; which we shall take as the final temperature to calculate coefficient of thermal expansion of the other materials.

II. OBSERVATIONS

Material	T_i (°C)	Length (cm)	ΔL (10^{-5} m)
Copper	24.0	59.8	75
Copper	25.5-24.5-25.5	59.7	74
Aluminium	24.0-23.0-24.7	59.9	105
Brass	24.1-23.2-24.3	59.7	85
Steel	22.1-24.8-20.5	-	74
Aluminium	24.3-23.7-24.3	59.8	104
Brass	23.7-22.4-24.3	60.0	85
Steel	24.6-25.3	59.9	76
Brass	24.8-25.3	60.1	86
Steel	23.3-23.5	59.7	76

TABLE I. Data taken on 11 Mar 2025, the variables represents the property as described in the theory.

Least count of scale: 0.1 cm
Least count of thermometer: 0.1 °C
Least count of spherometer: 10^{-5} m

[1] Reference: alp

III. UNCERTAINTIES AND ERROR SOURCES

A. Measurement Uncertainties

- **Length Measurements:** Estimated uncertainty of ± 0.1 cm due to not proper method of viewing, expansion uncertainty of $\pm 5 \times 10^{-6}$ m.
- **Temperature Measurements:** Uncertainty of ± 0.05 K due to instrument resolution.

B. Random Errors

- Errors in the final value of α due to different rods having different material composition

C. Systematic Errors

- Errors from the uneven temperature of the rod during the initial temperature measurement
- Improper contact between the thermometer and the metal rod during temperature measurement

IV. CALCULATION AND ERROR ANALYSIS

A. Error Propagation

From the length and temperature uncertanity, the formula given in the thory the uncertanity will travel as: REFRENCE THE BOOOkThe uncertainty in α is given by the basic formula for error propagation.:

$$\sigma_\alpha = \alpha \sqrt{\left(\frac{\sigma_{\Delta L}}{\Delta L}\right)^2 + \left(\frac{\sigma_L}{L}\right)^2 + \left(\frac{\sigma_{\Delta T}}{\Delta T}\right)^2}$$

where $\sigma_{\Delta L}, \sigma_L, \sigma_{\Delta T}$ are the uncertainties in expansion length, initial length, and temperature difference, respectively.

B. Calculation

We calculate the value of α of all data points and their uncertainity from hte above formul, we get:[2]

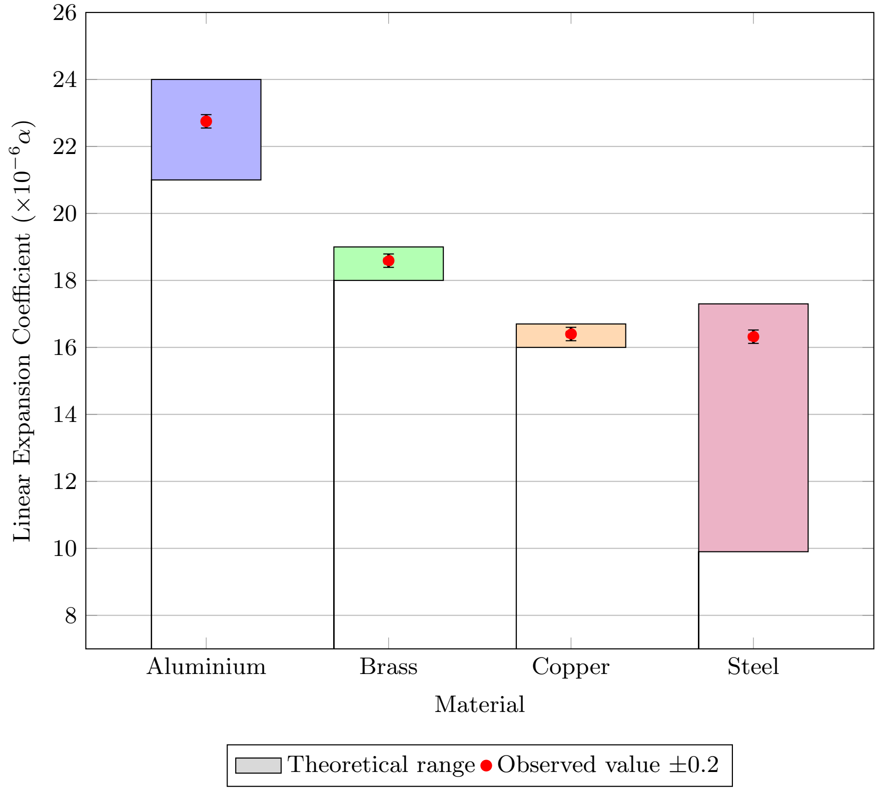
Material	α (1/°C)
Aluminium	$(2.303 \pm 0.005) \times 10^{-5}$
Aluminium	$(2.291 \pm 0.005) \times 10^{-5}$
Brass	$(1.870 \pm 0.004) \times 10^{-5}$
Brass	$(1.851 \pm 0.004) \times 10^{-5}$
Brass	$(1.909 \pm 0.004) \times 10^{-5}$
Copper	$(1.650 \pm 0.003) \times 10^{-5}$
Copper	$(1.656 \pm 0.003) \times 10^{-5}$
Steel	$(1.591 \pm 0.003) \times 10^{-5}$
Steel	$(1.691 \pm 0.003) \times 10^{-5}$
Steel	$(1.662 \pm 0.003) \times 10^{-5}$

TABLE II. Calculated expansion coefficients

[2] Refer to Cat (2025) for calculations

V. RESULT

The calculated values of α show high precision but large variations from expected values. The inconsistencies suggest experimental errors, leading to unreliable results.



Lets fucking go

Appendix A: Theoretical Values

The expected values of α in $^\circ\mathrm{C}^{-1}$ are:[3]

$$\begin{aligned}\alpha_{\text{Steel}} &\approx (1.08 - 1.25) \times 10^{-5} \\ \alpha_{\text{Brass}} &\approx (1.8 - 1.9) \times 10^{-5} \\ \alpha_{\text{Aluminium}} &\approx (2.1 - 2.4) \times 10^{-5} \\ \alpha_{\text{Copper}} &\approx 1.78 \times 10^{-5}\end{aligned}$$

REFERENCES

"Expansion coefficient of different materials," `engineeringtoolbox.com/linear-expansion-coefficients-d_95.html`, accessed: 2025-02-12.

[3] alp

Cat, L. M., “Ph2233 experiment repository,” `github.com/LAUGHINGCATMEME/PH2233` (2025).