Experiment 8
Michelson's Interferometer

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Synopsis

In this experiment reflective index of glass and air is measured.

I. THEORY AND PROCEDURE

A. Apparatus

- Lee's Apparatus
- Bad conductor discs
- Two thermometers
- Boiler and Induction
- Stop watch
- Weighing balance
- Vernier Caliper
- Screw gauge

B. Theory

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

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

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:

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 between the two clamps.
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}°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 and Appendix-B and we conclude that the temperature of rods in equilibrium is $= 99 \pm 1$ °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. The '-' value is assumed to be 60.0 cm.

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

[1] Reference: **?**

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.

IV. CALCULATION AND ERROR ANALYSIS

A. Error Propagation

From the length and temperature uncertainty, and using Equation-1 uncertainty in α, by the basic formula for error propagation[1] will propogate as .:

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

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 (Refer to [3] for calculations):

Material	α (1/°C)
Aluminium	$(2.33 \pm 0.02) \times 10^{-5}$
Aluminium	$(2.32 \pm 0.02) \times 10^{-5}$
Brass	$(1.90 \pm 0.02) \times 10^{-5}$
Brass	$(1.88 \pm 0.02) \times 10^{-5}$
Brass	$(1.92 \pm 0.02 \times 10^{-5}$
Copper	$(1.67 \pm 0.02) \times 10^{-5}$
Copper	$(1.68 \pm 0.02) \times 10^{-5}$
Steel	$(1.61 \pm 0.02) \times 10^{-5}$
Steel	$(1.71 \pm 0.02) \times 10^{-5}$
Steel	$(1.68 \pm 0.02) \times 10^{-5}$

TABLE II. Calculated expansion coefficients

V. RESULT

The final expansion values by weighted average[1] are:

Material	**α (1/°C)**	**Uncertainty (1/°C)**	χ^2_ν
Aluminium	2.328×10^{-5}	6.1×10^{-8}	0.15
Brass	1.90×10^{-5}	1.73×10^{-7}	2.70
Copper	1.674×10^{-5}	3.60×10^{-8}	0.10
Steel	1.67×10^{-5}	3.07×10^{-7}	11.14

Appendix A: Theoretical Values

The expected values of α in $^\circ\mathrm{C}^{-1}$ are [4]:

$$\begin{aligned}
\alpha_{\mathrm{Steel}} &= (0.99 - 1.73) \times 10^{-5} \\
\alpha_{\mathrm{Brass}} &= (1.8 - 1.9) \times 10^{-5} \\
\alpha_{\mathrm{Aluminium}} &= (2.1 - 2.4) \times 10^{-5} \\
\alpha_{\mathrm{Copper}} &= (1.6 - 1.67) \times 10^{-5}
\end{aligned}$$

Appendix B: Temperature of rod

The temperature of rod measured with the application of thermal paste is found to be ranging between 98 $^\circ$C $-$ 99 $^\circ$C (measured on 19 Mar 2025)