Fluids, Thermodynamics, Waves, & Optics
Thermodynamics
Lab 3
Thermal Expansion

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Overview

- Purpose & Theory
- Equipment
- Procedure

Purpose of the Lab

To investigate thermal expansion in three metals and find the coefficient of linear expansion, α, for each one.

You will measure the change in length ΔL of each metal tube as the temperature of the tube is increased by ΔT.

Use the equation for linear thermal expansion to deduce α for each tube.

Calculate the absolute uncertainty using the partial derivative method for each α obtained and compare to the accepted values.

Theory

Thermal expansion:

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

Therefore, α can be calculated from:

$$\alpha = \frac{\Delta L}{L_i \, \Delta T}$$

Micrometer Gauge

Each increment on the dial gauge is equivalent to 0.01 mm of tube expansion.

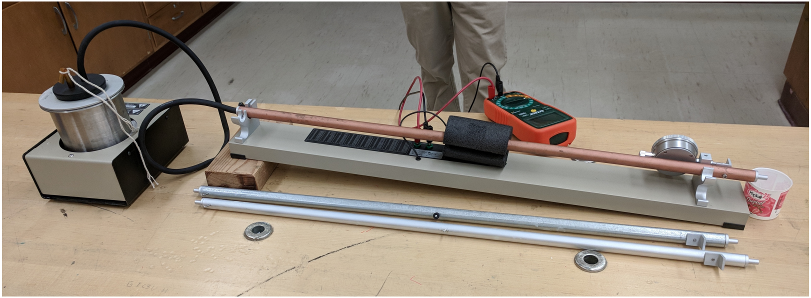
Thermistor

The thermistor was used to measure the resistance of the tube. From the resistance measurement, you can determine the temperature using the conversion table.

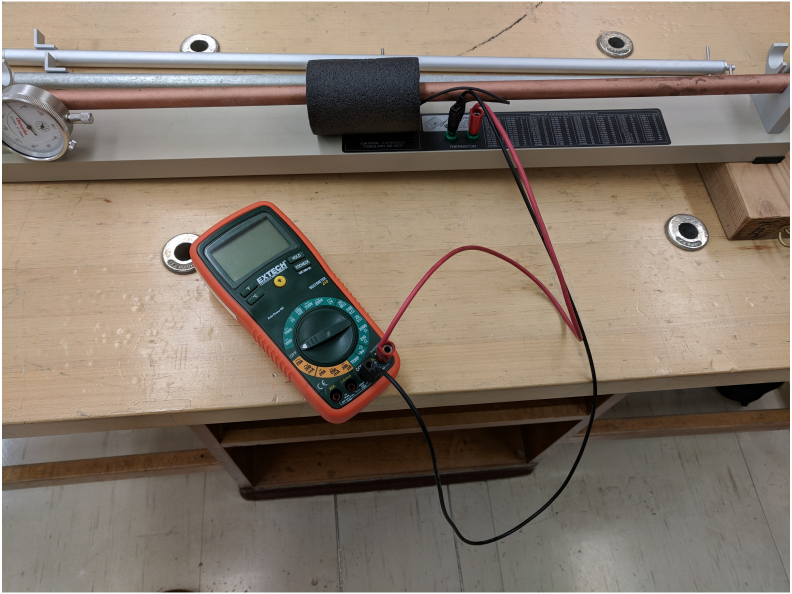
Steam Generator

Switched on, but not connected (using the rubber hose) to the tube until after you zero the micrometer and take the first (cold) resistance reading.

The Setup



Connecting the Ohmmeter



The Ohmmeter

Thermistor

A thermistor is a special type of resistor. Its resistance depends on temperature more strongly than ordinary resistors.

In this setup, it is the small piece at then end of the black lead. Use the thumbscrew to secure it to the long tube.

Cover this part of the tube with the foam insulator.

Micrometer Gauge

As the rod expands, the needle will turn counterclockwise. Refer to the numbers in red on the dial.

Experimental Procedure

Experiment happened like this:

1. The length of the tube was measured with a meterstick and record the uncertainty also.

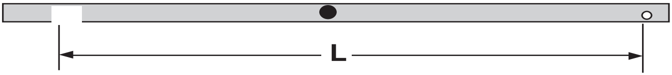


Figure: Measured from the inside of the angle bracket to the inside of the pin.

2. The tube fits into the expansion base. The stainless steel pin on the tube fits into the slot and the bracket is snug against the spring arm of the dial gauge.

3. The thermistor lug was attached to the thumbscrew to ensure maximum contact with the tube. The foam insulator was put over the thermistor lug.

Experimental Procedure

4. The ohmmeter was used to measure and record R_i for the resistance at room temperature.

5. A cup was used to collect condensation at the gauge end of the tube and a wood block propped up the opposite end, so the tube sloped downward toward the cup.

6. The outer casing of the dial gauge was rotated to zero the scale when the tube was cold.

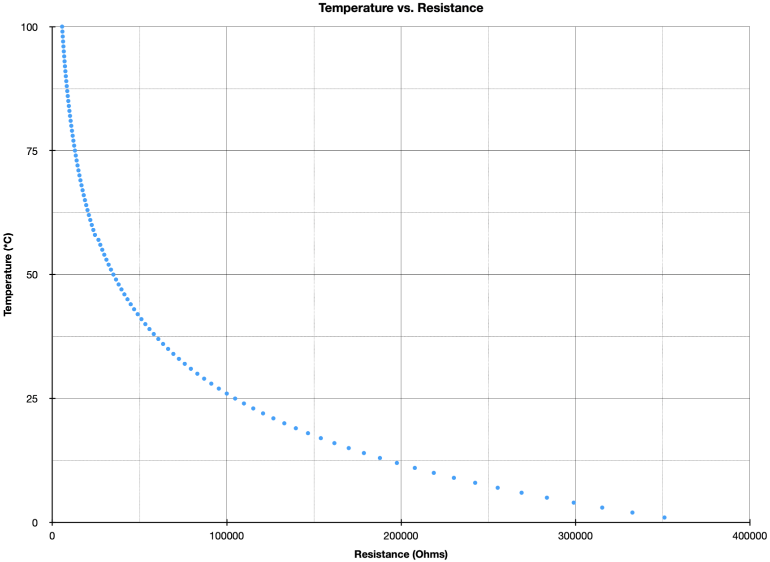
7. The steam generator was connected using the black tubing. When the thermistor resistance stabilized, R_f and ΔL were recorded. Each increment on the dial gauge is equivalent to 0.01 mm of tube expansion.

8. This was repeated with the other two tubes.

Your Lab Activity

1. JOIN YOUR LAB GROUP IN CANVAS (People $>$ Lab3, you need to do this every week)
2. Record all group members' names on the document you will submit
3. Convert resistance readings to temperatures.
4. Calculate α and do an error analysis using the partial derivative method.
5. Compare to the accepted values of α.
6. Answer the questions in the Conclusions section of the instruction sheet.

Converting Resistances to Temperatures



Converting Resistances to Temperatures

Take the resistance value, and find the range it fits into. Then interpolate between the two points to find the temperature to 3 significant figures (1 decimal place).

Example:
Resistance value is $R = 81.5$ kΩ.

That falls in the range:
83,124 $\Omega \rightarrow 29^\circ$C ($T_1$)
79,422 $\Omega \rightarrow 30^\circ$C ($T_2$)

Approximate this interval on the plot with a line. Slope of line connecting those 2 points:

$$m = \frac{T_2 - T_1}{R_2 - R_1} = \frac{30 - 29}{79,422 - 83,124} = -2.7012 \times 10^{-4}$$

Converting Resistances to Temperatures

$$\begin{aligned}(T - T_1) &= m(R - R_1)\\ T &= m(R - R_1) + T_1\\ T &= (-2.7012 \times 10^{-4})(81,500 - 79,422) + 29\\ T &= 29.4^\circ\text{C} \quad \text{(3 s.f.)}\end{aligned}$$

Error Propagation function (Random errors)

Suppose f is a function of the measured values x, y, and z.

$$\delta f = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 (\delta x)^2 + \left(\frac{\partial f}{\partial y}\right)^2 (\delta y)^2 + \left(\frac{\partial f}{\partial z}\right)^2 (\delta z)^2}$$

δx, δy, and δz are uncertainties in x, y, and z respectively.

In this case, you have the function: $\alpha(\Delta L, L, \Delta T)$.

Don't forget that $\delta(\Delta T) \neq \delta T$.

Error Propagation function (Random errors)

Don't forget that $\delta(\Delta T) \neq \delta T$.

One last thing...

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