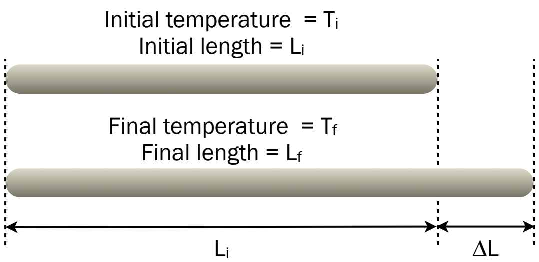
THERMAL EXPANSION

INTRODUCTION

Most objects expand when heated. You may notice that railroad tracks are not one long, solid piece, but many pieces. A gap must be left between adjacent pieces, to allow for thermal expansion. You will also see expansion gaps on bridges. If you have ever installed wood flooring, you will also remember that it is important to leave an expansion space all the way around the perimeter of the room (shame if that floor was to buckle on a hot day!).

How much an object expands depends on several parameters: what the object is made of, how big it was originally, and how much its temperature has been increased. The greater the original length, the more an object will expand. The greater the increase in temperature, the greater the expansion. But not all materials of the same size will expand by the same amount when increased by the same temperature. The coefficient of thermal expansion depends on the type of material; the greater the coefficient, the greater the expansion for a given length of material and given temperature increase. The coefficient of thermal expansion for brass is **α_{br} = 1.92x10^{-5}/°C**, and for iron **α_{Fe} = 1.14x10^{-5}/°C**. This means that the brass rod will elongate more than the same length iron rod when both temperatures are raised by the same amount.



This can be expressed mathematically as:

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

where $\Delta L = L_f - L_i$ is the change in sample length
α = coefficient of thermal expansion
L_i = original sample length
$\Delta T = T_f - T_i$ is the change in temperature

OBJECTIVES

- Observe the linear expansion of several metallic samples
- Devise an indirect method to accurately measure an expansion too small to see or record with a meter stick
- Determine the coefficient of thermal expansion for different metallic samples
- Calculate the amount of error in an experimental value

EQUIPMENT

- Hollow rods, iron and brass
- Meter stick
- Thermometer
- Steam generator
- Burner
- Dial indicator and rod support

EXPERIMENTAL PROCEDURE

- Measure and record the diameter of the dial indicator spindle, d. Then measure and record the initial length L_i of each sample rod. ***Measure only from the notch to the end of the rod.***
- Measure and record the initial temperature T_i of the metal sample (room temperature).
- Place the notched rod on the pointed support of the apparatus, and rest the other end on the spindle with the pointer. Connect the rod to the steam hose, and make sure that the open end will drain into a cup.
- Set the dial indicator to read zero before you begin to heat the water.
- Boil the water. As the steam passes through the metal rod, it will heat up the rod. Allow enough time for the rod to reach 100°, the temperature of the steam. Be very careful not to disturb the apparatus while the water heats.
- Read and record the final angular position on the dial indicator, θ.
- Repeat the experiment using the other metal rod. If you have to repeat one rod or the other, make sure to get a cold rod. Do not use the same rod a second time.

Data and Analysis

If you have not already, record your data in a neat table.

Material	d (cm)	Initial Length L_i (cm)	θ (°)	Initial Temp T_i (°C)	Final Temp T_f (°C)
Brass	0.23				100
Iron	0.23				100

1. Calculate the change in length of each rod, using:

$$\Delta L = \frac{(\pi \theta d)}{360°}$$

2. Calculate the change in temperature of each rod, using:

$$\Delta T = T_f - T_i$$

3. Calculate the coefficient of thermal expansion for each rod, using:

$$\alpha = \frac{\Delta L}{L_o \Delta T}$$

4. Calculate the percent error for each calculated value:

$$\%error = \left(\frac{(actual - experimental)}{actual} \right) \bullet 100$$

Material	ΔL (cm)	ΔT (°C)	α (/°C)	Actual value (/°C)	Percent Error (%)
Brass				1.92×10^{-5}	
Iron				1.14×10^{-5}	

Questions

5. Which would expand more, a brass rod 1m long or an iron rod 3m long, if you raised each from room temperature to 100°C? Why?
6. Calculate how much a 1m iron rod will expand if you raise its temperature from 20° to 150°C.
7. Are your values for the coefficients close to the predicted values? An acceptable margin of error would be about 5%. Did you get results within this limit? Were you more accurate with one rod than the other?
8. Did you measure the original length of each rod slightly too small or slightly too large? What is the effect of this known error on the calculated coefficient? Does it make the coefficient slightly too big or slightly too small?

You have a brass sphere and an iron ring. At room temperature (20°C), the ring can just barely slip over the sphere.

9. What happens if you heat only the sphere and try to slip the ring over?
10. What happens if you heat only the ring?
11. If you heat both the ring and sphere up, can you still slip the ring over the sphere?
12. What if you plunged both into a dewar of liquid nitrogen (−196°C)?