PHYS101: Thermal Expansion
Instructor: James Cutright

Instructions: Everything that you do in the lab can be submitted as a group in the provided excel sheet. Make sure to follow the procedure carefully.

Equipment Needed:

Computer and 850 UI	Metal Tongs
Rod Stand and Metal Rod	2 Micrometers (0-25 mm and 25-50 mm)
Spring Right Angle Clamp	String
Large and small Right Angle Clamp	2 Rectangular Metal Samples: 1 Brass and 1 Aluminum.
1 Hot Plate	
Test Tube Clamp	1 Stainless Steel Thermometer
1 Large Beaker	

Part 1: Linear Expansion of a Material

Theory: Any material that undergoes an increase in temperature will see an increase in the average velocity of the constituent particles which make up the object. As the average velocity of the individual particles increases the average distance between the particles will increase as well. This microscopic process can be observed indirectly: as the temperature of the object increases, it will expand in proportion. In short, if you heat something up it expands. The equation governing this is usually given as:

$$\Delta l = \alpha L_0(\Delta T)$$

In this expression, Δl is the increase in length of the object, L_0 is the starting length of the sample, and ΔT is the net change in temperature. The coefficient of linear expansion, α, is a characteristic property of the material, like density. If a material has a high α it will tend to expand more than a material with a smaller α. A table of coefficients of linear expansion is given on the next page.

A material can also expand in three dimensions. Since three dimensional expansion is just one dimensional expansion happening in three different directions, the coefficient, β, that describes the change in volume of a sample as it heats up is roughly three times the α for that material:

$$\beta \cong 3\alpha$$

The net change in volume that you would see in a sample, ΔV, is calculated in the same way that you calculate the linear change. In this case you would use the coefficient of bulk expansion, β, the initial volume of the sample, V_0, and the change in temperature, ΔT:

$$\Delta V = \beta V_0(\Delta T)$$

TABLE 13–1 Coefficients of Expansion, near 20°C

Material	Coefficient of Linear Expansion, α $(\mathrm{C}^\circ)^{-1}$	Coefficient of Volume Expansion, β $(\mathrm{C}^\circ)^{-1}$
Solids		
Aluminum	25×10^{-6}	75×10^{-6}
Brass	19×10^{-6}	56×10^{-6}
Copper	17×10^{-6}	50×10^{-6}
Gold	14×10^{-6}	42×10^{-6}
Iron or steel	12×10^{-6}	35×10^{-6}
Lead	29×10^{-6}	87×10^{-6}
Glass (Pyrex®)	3×10^{-6}	9×10^{-6}
Glass (ordinary)	9×10^{-6}	27×10^{-6}
Quartz	0.4×10^{-6}	1×10^{-6}
Concrete and brick	$\approx 12 \times 10^{-6}$	$\approx 36 \times 10^{-6}$
Marble	$1.4\text{–}3.5 \times 10^{-6}$	$4\text{–}10 \times 10^{-6}$
Liquids		
Gasoline		950×10^{-6}
Mercury		180×10^{-6}
Ethyl alcohol		1100×10^{-6}
Glycerin		500×10^{-6}
Water		210×10^{-6}
Gases		
Air (and most other gases at atmospheric pressure)		3400×10^{-6}

Procedure and Data Collection:

1) For this lab, you will need to be able to use a metric micrometer to make your measurements. Make sure you ask the instructor if you aren't sure how to use a micrometer.
2) Measure the temperature of the room.
3) Measure the initial dimensions of each sample. That means you need the length, width, and height of each sample. Each group should measure each sample once, so that you get a good average for each sample.
4) The given table has the coefficients of thermal expansion for aluminum and brass. You are going to use them to predict the net change in length you expect to see for each dimension of the sample.
5) Fill a beaker with water, and start it boiling on the hot plate. This will likely take a little while.
6) Connect your stainless-steel thermometer to the 850 UI and open the program "Thermometer.cap". If you hit record and leave it on the thermometer will give you a continual reading of the temperature. Make sure to measure the temperature of the room and record it. Note: if the thermometer is not calibrated it will read weird values. Inform your instructor if this happens. Room temperature should be close to 22°C.
7) Suspend a sample of metal in the beaker using the rod stand and spring right angle clamp. Along with the metal sample, you should put a thermometer in the water by suspending it with the test tube clamp. **Caution: Hot Pyrex is more brittle than cool Pyrex. If it comes in contact with the metal sample while hot it may shatter. The same goes for the thermometer.**
8) Experimental note: Pyrex warms faster than water. The thermometer should not be in contact with the Pyrex, as it will be warmer than the water. Have the thermometer somewhere in the middle with the sample. Don't let the sample and thermometer run into each other.
9) Leave the sample of metal in the boiling water for 5 minutes, so the metal has time to warm up. Confirm the temperature of the water with the thermometer.
10) Each member of the group will now pick a job: using the micrometer, holding the sample for measurements, and recording data.
11) Have one member of your group use the tongs to hold the metal sample (I suggest cradling it, not pinching). Have one person measure the sample while it is still hot, literally right when it leaves the water. The third member will record your data. **Note: Do not wait too long. If the sample cools off it will start to contract and ruin the measurement. You need to submerge the sample in the water for about a minute between each measurement. You can't measure two or three dimensions each time you pull the sample out of the water, only one!**
12) Measure the dimensions of the hot sample three times, and then take the average of each. Make sure that your measurements are consistent.

13) Fill out the spreadsheet with your data and calculations. At the end of the lab, you will need to compare the data that you collected with the predicted values that you calculated with the equations given in the theory section.
14) Make sure to answer the questions at the end of the lab on the spreadsheet. There is a spot for that to the right of the data collection section.

Questions:

1) Compare the measurements that you made with the two micrometers. Each micrometer has the same resolution (0.01 mm). Is one device clearly superior to the other for this experiment? How could you improve this experiment? *Hint: think about micrometer resolution.*
2) Brass and Copper have very similar coefficients of linear expansion. Why? *Hint: Look brass up online, and see how it is made.*
3) Suppose your micrometers were also submerged in the water for the same length of time that the metal samples were submerged. How would this change the results of your measurements?