Linear Expansion of Materials

As the temperature of a material increases, it begins to expand. For instance, a metal rod or beam will increase its length by an amount ΔL. The value of ΔL depends on the original length (L_o) at the original temperature (T_o), the temperature to which it is heated (T) and the coefficient of linear expansion (α). The equation relating these variables is shown in **Figure 1**. The amount of expansion depends upon the material; each material has its own unique coefficient of linear expansion. Coefficients for a variety of materials are shown in **Table 1**. Note that the left column includes metals and metal alloys and the right column includes non-metals.

Figure 1

$$\Delta L = \alpha \bullet L_o \bullet (T - T_o)$$

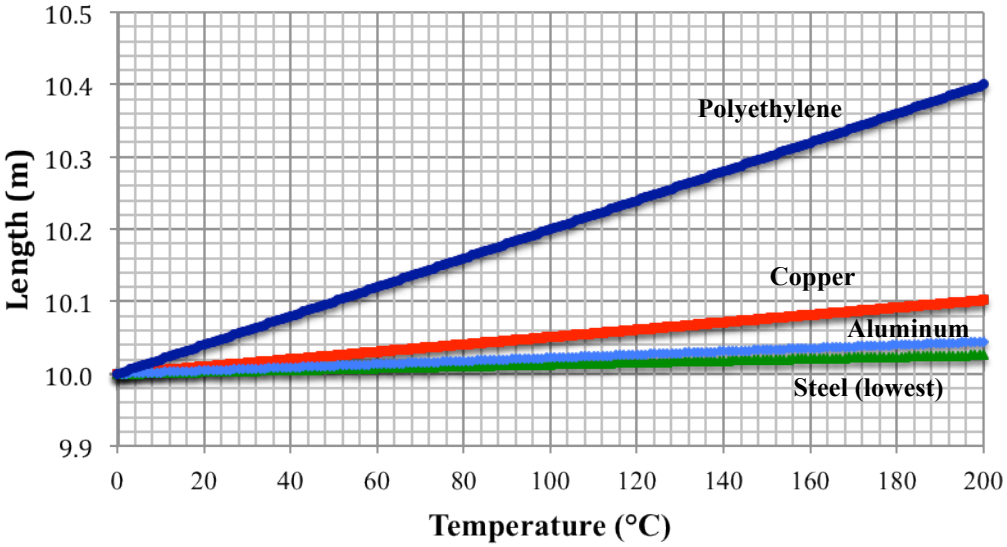
Table 1

Material	α (m/°C/m)
Copper	$5.1 \bullet 10^{-5}$
Steel	$1.3 \bullet 10^{-5}$
Aluminum	$2.2 \bullet 10^{-5}$
Brass	$1.9 \bullet 10^{-5}$

Material	α (m/°C/m)
Wood	$5.0 \bullet 10^{-6}$
Polyethylene	$2.0 \bullet 10^{-4}$
Polystyrene	$7.0 \bullet 10^{-5}$
Polyvinyl chloride	$5.0 \bullet 10^{-5}$

The expansion of a rod or beam in one dimension as described by **Figure 1** is known as **linear expansion**. Linear expansion causes the length of a rod or beam to change with temperature. **Figure 2** shows how the length of a beam varies as a function of temperature for four different materials.

Figure 2



Questions:

1. The equation in **Figure 1** would suggest that the amount of expansion (ΔL) of a material would be _____.
   a. directly proportional to the temperature of the material
   b. directly proportional to the temperature change of the material
   c. inversely proportional to the temperature of the material
   d. inversely proportional to the temperature change of the material

2. Which one of the following quantitative conclusions regarding the relationship between temperature and length is consistent with the equation in **Figure 1**?
   a. The length of a rod will be twice as long at twice the temperature.
   b. As the temperature change is doubled, the length of the metal rod doubles.
   c. A mere doubling of temperature is enough to cause a rod to double its length.
   d. The amount of expansion of a rod is twice as much for twice the temperature change.

3. According to **Table 1** and the **Figure 1** equation, which one of the listed materials has the lowest tendency to expand when heated?
   a. Brass
   b. Polyethylene
   c. Steel
   d. Wood

4. Use the **Figure 1** equation and the **Table 1** to determine which of the following situations would result in the greatest amount of expansion (ΔL).
   a. Increase the temperature of a 10.0-m length copper rod from 20°C to 30°C.
   b. Increase the temperature of a 5.0-m length copper rod from 120°C to 130°C.
   c. Increase the temperature of a 10.0-m length brass rod from 20°C to 30°C.
   d. Increase the temperature of a 5.0-m length brass rod from 120°C to 130°C.

5. Use the **Figure 1** equation and the **Table 1** to determine which of the following situation would result in the greatest amount of expansion (ΔL).
   a. Increase the temperature of a 5.0-m length copper rod from 50°C to 100°C.
   b. Increase the temperature of a 5.0-m length copper rod from 50°C to 200°C.
   c. Increase the temperature of a 10.0-m length copper rod from 50°C to 100°C.
   d. Increase the temperature of a 10.0-m length copper rod from 50°C to 200°C.

6. The amount that a 2-meter length copper rod expands for an increase in temperature from 25°C to 35°C is hardly noticeable. Use the **Figure 1** equation and the **Table 1** to identify the correct explanation for this observation.
   a. The α value is quite small for copper; the expansion would be much more noticeable for wood with its larger α value.
   b. The 25°C to 35°C range is low on the temperature scale; it would be more noticeable for a change from 125°C to 135°C.
   c. The α values of the materials in **Table 1** are very small; larger temperature changes are required to notice the expansion.
   d. The expansion is very small compared to the length of the rod; it would be a more noticeable expansion when it occurs for a shorter rod.

7. Each line in **Figure 2** is sloped with a different slope. The slopes of the lines are representative of the _____.
   a. rate at which the beam is heated
   b. the molar mass of the different materials
   c. the original length of the different beams
   d. coefficient of linear expansion of the material

8. If each of the beams in **Figure 2** were cooled to -50°C, the shortest beam would be ____.
   a. aluminum
   b. copper
   c. polyethylene
   d. steel

9. Which description best describes the origin of the four plotted lines in **Figure 2**?
   a. Beams of four different materials and having different lengths were obtained at 0°C. The beams were heated to 200°C; their length was measured at various temperatures.
   b. Beams of four different materials were obtained at 0°C and measured to be the same length. They were heated to 200°C; their length was measured at various temperatures.
   c. Beams of four different materials with random lengths were obtained at 200°C. The beams were cooled until they reached the same length; this occurred at a temperature of 0°C.
   d. Four equal length beams were obtained at room temperature. They were heated and cooled between the temperature range of 0°C and 200°C; their length was measured at various temperatures.

10. Suppose a 10.0-meter length polypropylene pipe at 0°C were heated to 100°C. According to **Figure 2**, what is the amount of expansion (ΔL) of the beam?
    a. 0.30 m
    b. 0.40 m
    c. 10.30 m
    d. 10.40 m

11. Suppose a 10.0-meter length polyvinyl chloride (PVC) pipe at 0°C were heated to 50°C. Based on the values in **Table 1** and the plots of **Figure 2**, what would be the amount of expansion (ΔL) of the PVC pipe?
    a. Approximately 0.01 m
    b. Approximately 0.05 m
    c. Approximately 0.10 m
    d. Approximately 0.50 m

12. Suppose a 10.0-m length brass beam at 0°C were heated to 200°C and its length as a function of temperature was plotted – similar to **Figure 2**. Where would the line be located on the graph?
    a. Below the steel line.
    b. Between the steel and the aluminum line.
    c. Between the aluminum line and the copper line.
    d. Between the copper line and the polypropylene line.

13. Suppose a 5.0-m length copper pipe at 0°C were heated to 200°C. Based on the equation in **Figure 1** and the plots of **Figure 2**, what would be its new length at this temperature?
    a. Approximately 5.05 m
    b. Approximately 10.1 m
    c. Approximately 15.1 m
    d. Approximately 20.2 m