Lecture 2

Thermal expansion and contraction

Pre-reading: §17.4
Question

How does a change in temperature affect the dimensions of a system?
Linear expansion

Most materials expand when their temperatures increase.

The increase in length is found to be proportional to the temperature increase, and to the length of the object:

$$\Delta L = \alpha L_0 \Delta T$$
Linear expansion

- $\alpha$ is the coefficient of linear expansion.
  Units: $K^{-1}$, $°C^{-1}$

### Table 17.1 Coefficients of Linear Expansion

<table>
<thead>
<tr>
<th>Material</th>
<th>$\alpha [K^{-1} \text{ or } (°C)^{-1}]$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>$2.4 \times 10^{-5}$</td>
</tr>
<tr>
<td>Brass</td>
<td>$2.0 \times 10^{-5}$</td>
</tr>
<tr>
<td>Copper</td>
<td>$1.7 \times 10^{-5}$</td>
</tr>
<tr>
<td>Glass</td>
<td>$0.4-0.9 \times 10^{-5}$</td>
</tr>
<tr>
<td>Invar (nickel–iron alloy)</td>
<td>$0.09 \times 10^{-5}$</td>
</tr>
<tr>
<td>Quartz (fused)</td>
<td>$0.04 \times 10^{-5}$</td>
</tr>
<tr>
<td>Steel</td>
<td>$1.2 \times 10^{-5}$</td>
</tr>
</tbody>
</table>
Why do solids expand?

For \( r < r_0 \), \( F_r > 0 \); the force between molecules is repulsive.

For \( r > r_0 \), \( F_r < 0 \); the force between molecules is attractive.
A metal disc with a hole in it is heated.

Will the diameter of the hole
(a) increase,
(b) decrease or
(c) not change?
Volume expansion

Similarly, an increase in temperature causes an increase in *volume* for both solids and liquids.

\[ \Delta L = \alpha L_0 \Delta T \]

\[ \Delta V = \beta V_0 \Delta T \]
Question

You have enough money to buy 10 L of petrol. When should you buy it?

(a) 2 pm
(b) 2 am
Question

When a bimetallic strip is heated and cooled, it behaves as in the following diagram. Which substance has the larger coefficient of expansion?

(a) A
(b) B
Thermal expansion of water

Water has an anomalous property: between 0 °C and 4 °C its coefficient of expansion is negative.

Water has its maximum density near 4 °C.

While the expansion of water with temperature is approximately linear ...

... on a fine scale it is not exactly linear, which has important consequences for life on earth.

Water is most dense at 4°C.
WATER 1 kg sample

\[ \rho = \frac{m}{V} \]
Consequence: lakes freeze from the top down

- Above 4 °C water cools at surface and sinks (greater density)
- Below 4 °C, water cools but stays at surface
- Water at bottom stays warmer.
- Below 0 °C ice forms; ice is also less dense than water.
- Life can remain alive under the ice.
Problem

A surveyor uses a steel measuring tape that is exactly 50.000 m at a temperature of 20 °C.

a) What is the length on a hot summer day when the temperature is 35 °C? ($\alpha_{\text{steel}} = 1.2 \times 10^{-5} \text{ K}^{-1}$)

b) On this day, when the tape reads 35.794 m, what is the true distance?
Problem

A petrol tanker loads 40,000 L of fuel in Darwin and drives it to Sydney, where the temperature is 25° lower. How many litres of petrol does he deliver?

\[ \beta_{\text{petrol}} = 9.5 \times 10^{-4} \text{ K}^{-1} \text{ and } \alpha_{\text{steel}} = 1.2 \times 10^{-5} \text{ K}^{-1} \]
Next lecture

Phase change and heat capacity

*Read:* KJF §17.6, 18.4