Lecture 2

Thermal expansion and contraction

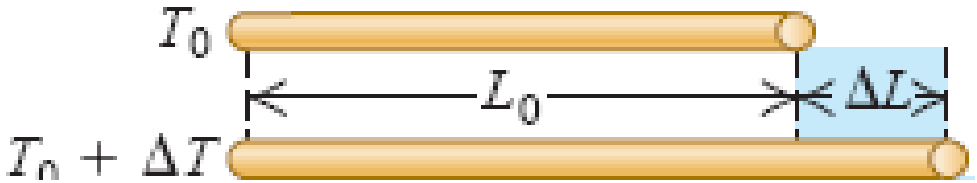
Pre-reading: §17.4

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:

$$\Delta L = \alpha L_o \Delta T$$

Linear expansion

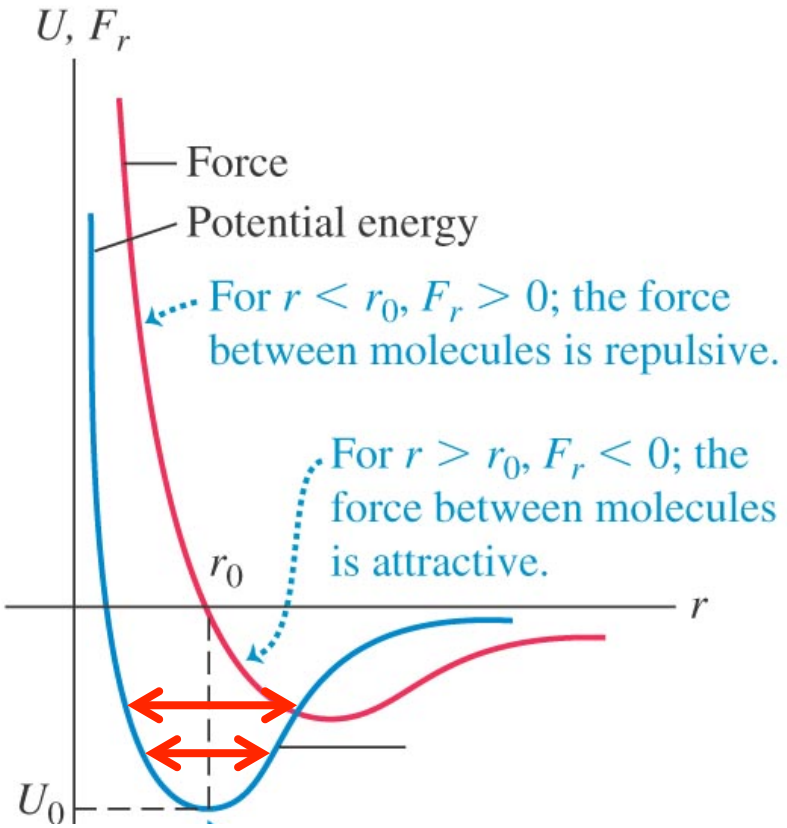
- α is the coefficient of linear expansion.

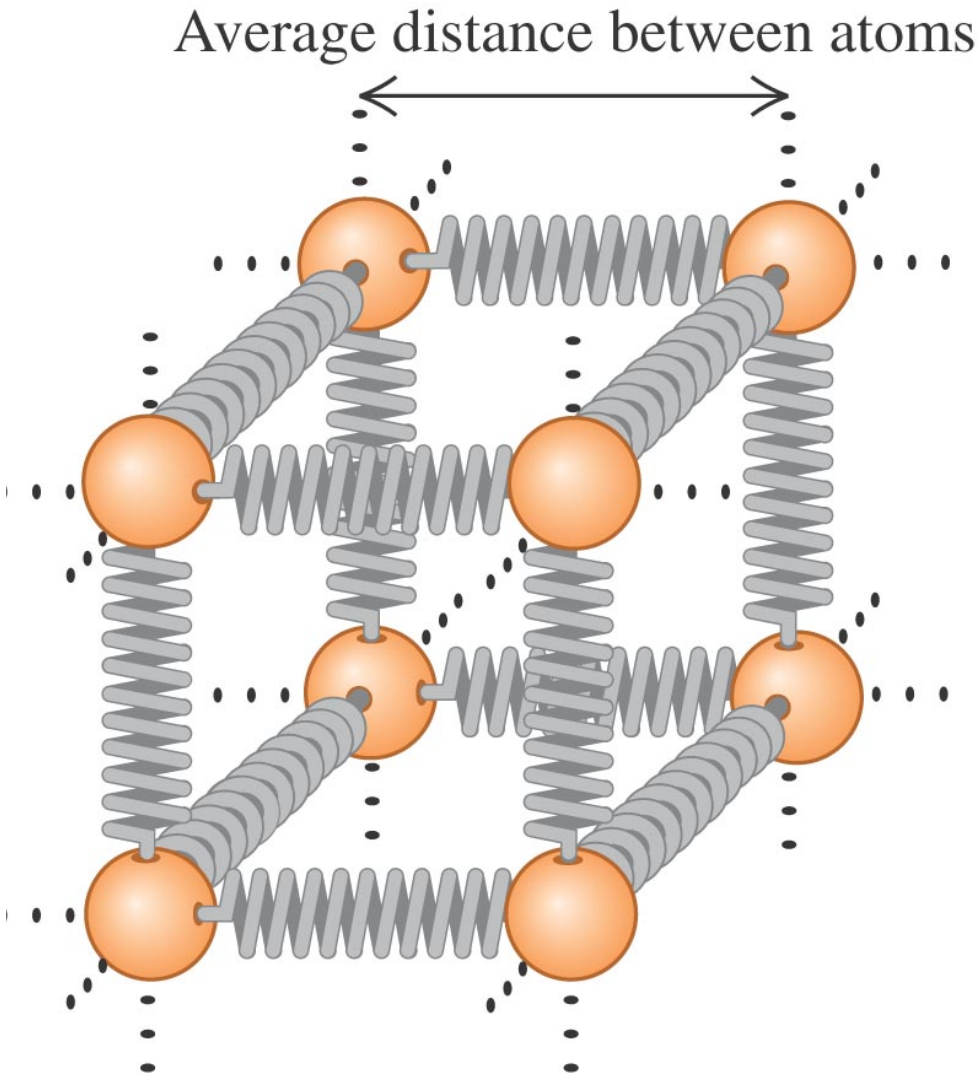
  Units: K^{-1}, $°C^{-1}$

Table 17.1 Coefficients of Linear Expansion

Material	α [K^{-1} or $(C°)^{-1}$]
Aluminum	2.4×10^{-5}
Brass	2.0×10^{-5}
Copper	1.7×10^{-5}
Glass	$0.4–0.9 \times 10^{-5}$
Invar (nickel–iron alloy)	0.09×10^{-5}
Quartz (fused)	0.04×10^{-5}
Steel	1.2×10^{-5}

Why do solids expand?





KJF §18.2

Question

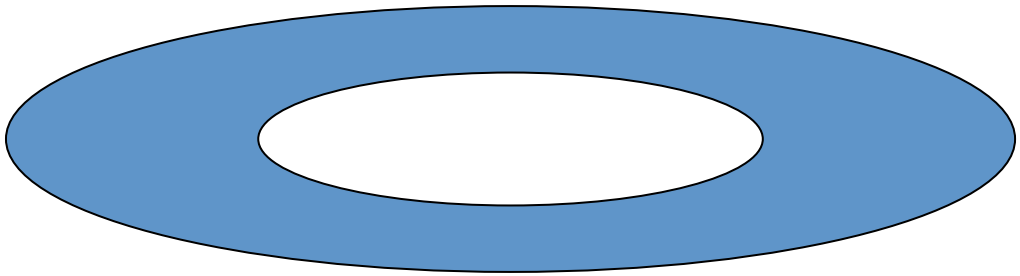
A metal disc with a hole in it is heated.

Will the diameter of the hole

(a) increase,

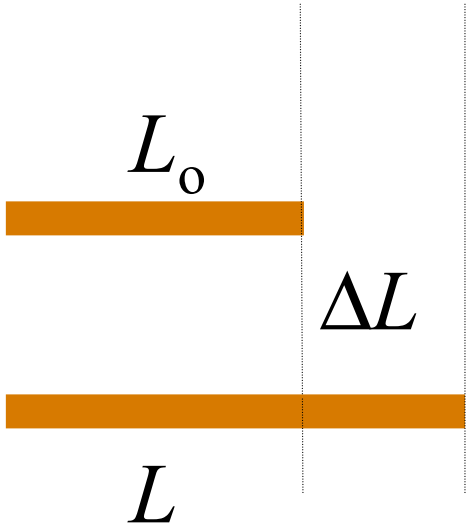
(b) decrease or

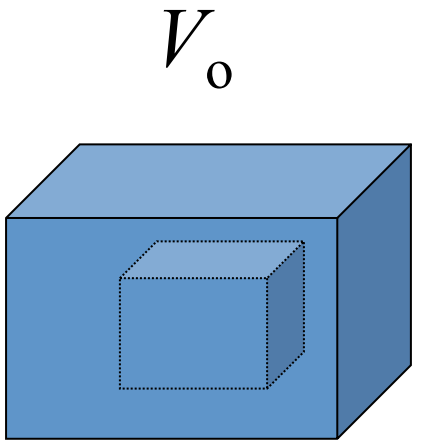
(c) not change?



Volume expansion

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





$$\Delta L = \alpha L_o \Delta T$$

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

Question

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

(a) 2 pm

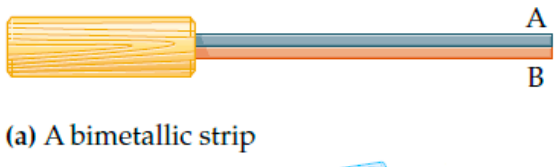
(b) 2 am

Question

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

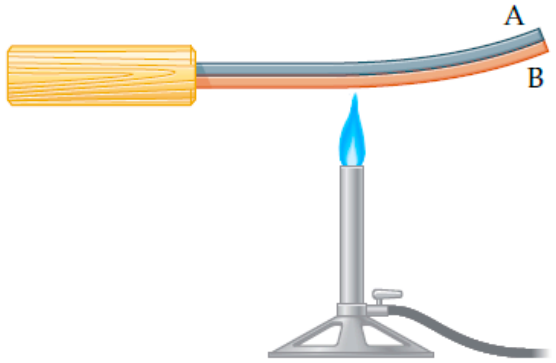
(a) A

(b) B



(a) A bimetallic strip

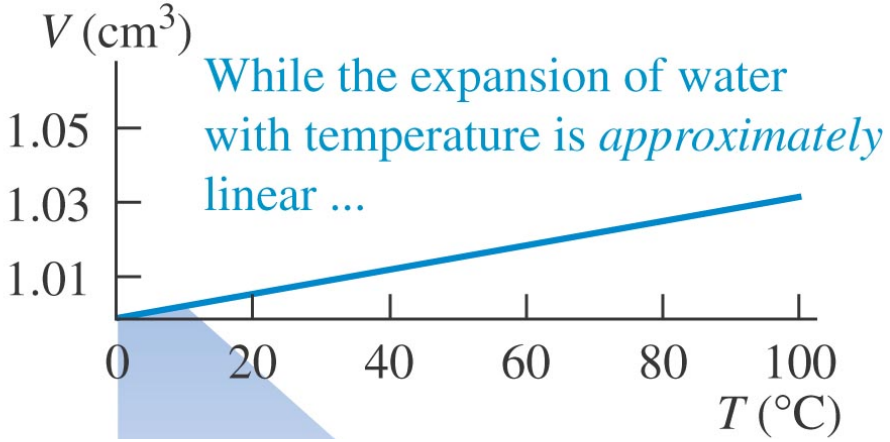
(b) Chilling the strip

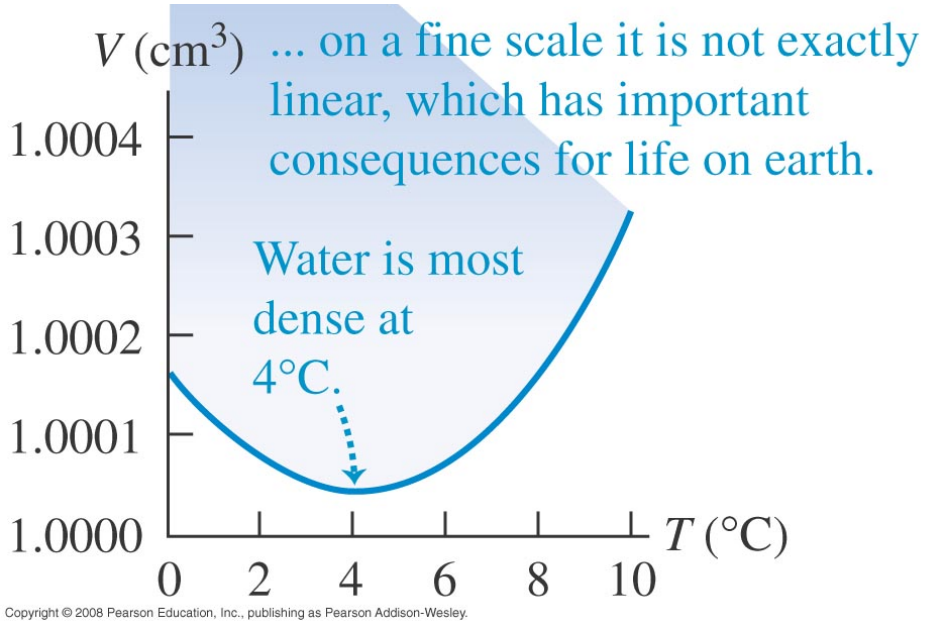


(c) Heating the strip

Thermal expansion of water

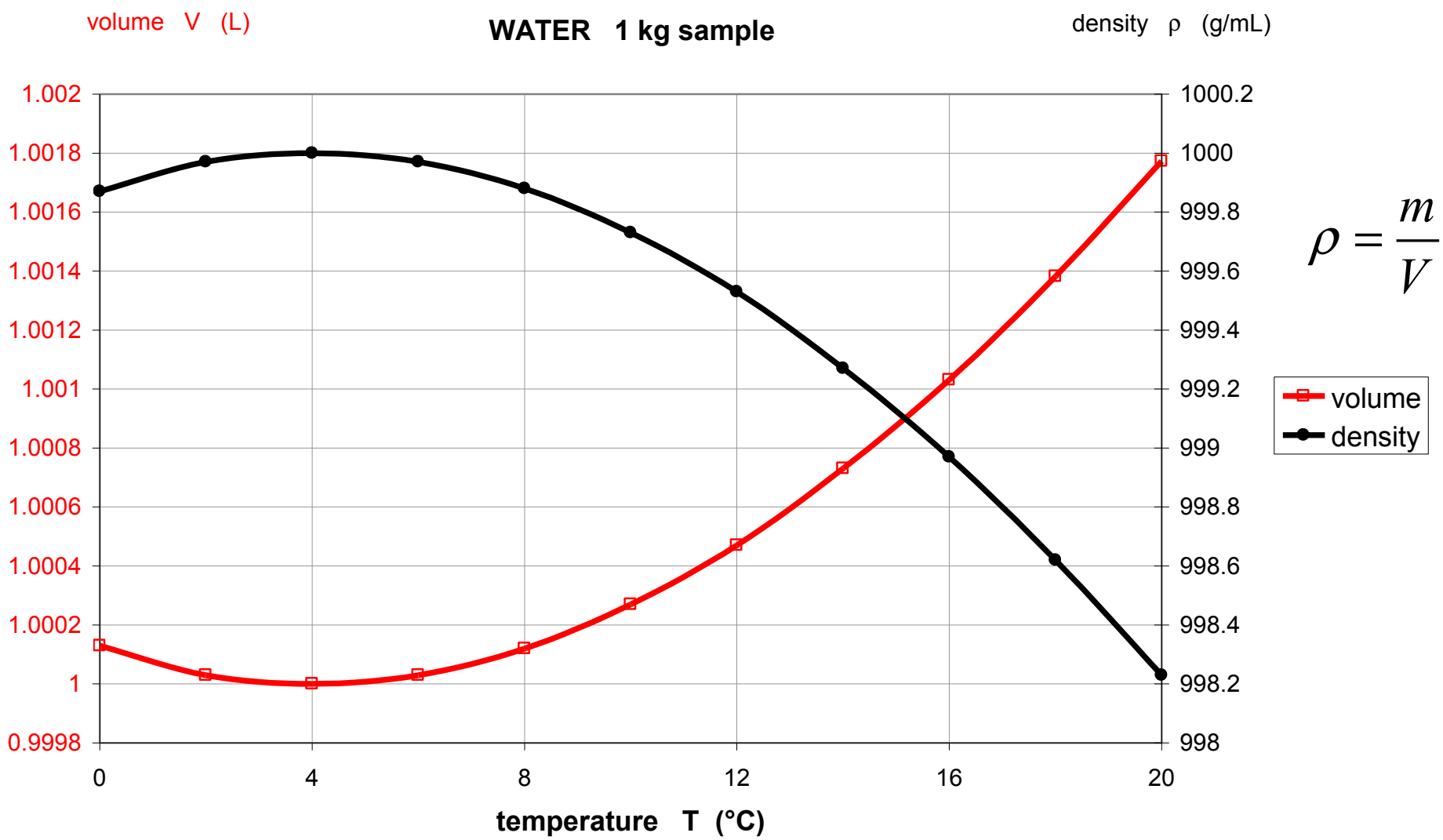
Water has an anomalous property: between 0 °C and 4 °C its coefficient of expansion is *negative*.





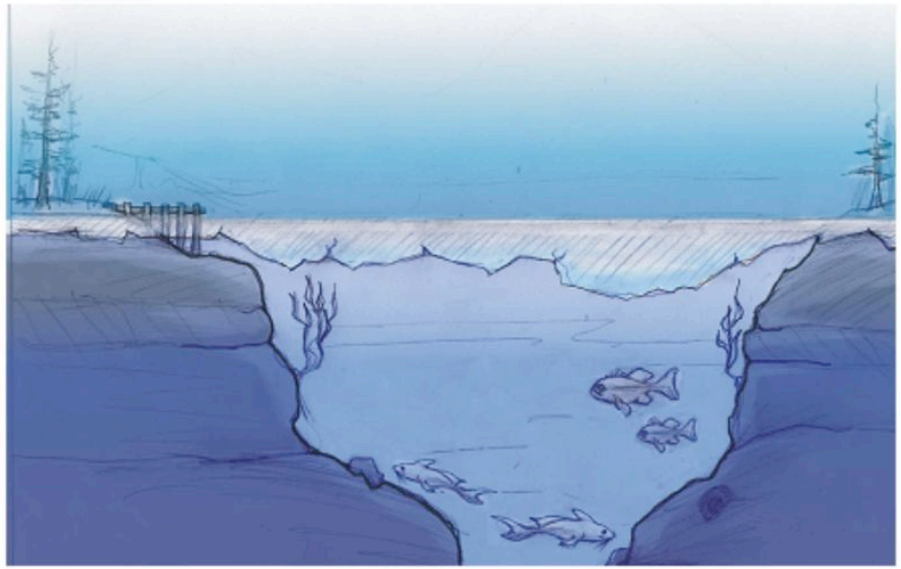
Water has its maximum density near 4 °C.

KJF §17.4


volume V (L)
WATER 1 kg sample
density ρ (g/mL)
1.002
1.0018
1.0016
1.0014
1.0012
1.001
1.0008
1.0006
1.0004
1.0002
1
0.9998
1000.2
1000
999.8
999.6
999.4
999.2
999
998.8
998.6
998.4
998.2
998
0
4
8
12
16
20
temperature T (°C)
volume
density
$\rho = \frac{m}{V}$

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? ($\alpha_{steel} = 1.2 \times 10^{-5}\ K^{-1}$)

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

KJF §17.3

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?

$\beta_{\text{petrol}} = 9.5\times10^{-4}\ \text{K}^{-1}$ and $\alpha_{\text{steel}} = 1.2\times10^{-5}\ \text{K}^{-1}$

KJF §17.3

Next lecture

Phase change and heat capacity

Read: KJF §17.6, 18.4