De Anza College

Thermodynamics
More Thermal Expansion

Lana Sheridan

De Anza College

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Last time

- thermal expansion

Overview

- wrap up thermal expansion

Volume Thermal Expansion

We can model volume expansion in a similar way:

$$\Delta V = \beta V_i \Delta T$$

β is the average coefficient of volume expansion.

If the material is *isotropic* (the same in all directions, symmetry wrt rotations of coordinate systems) then:

$$\beta = 3\alpha$$

using the fact that $\alpha \Delta T \ll 1$.

(This entire model is only approximately true over a restricted range of temperatures.)

Volume Thermal Expansion

Suppose $V_i = \ell wh$

$$\Delta V \approx (\Delta \ell) wh + \ell(\Delta w)h + \ell w(\Delta h)$$

Volume Thermal Expansion

Suppose $V_i = \ell w h$

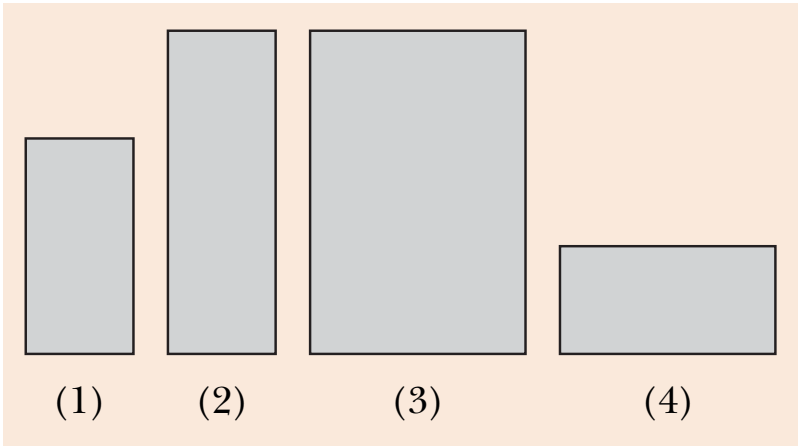
$$\begin{aligned}
\Delta V &\approx (\Delta \ell) w h + \ell (\Delta w) h + \ell w (\Delta h) \\
&= (\alpha \ell \, \Delta T) w h + \ell (\alpha w \, \Delta T) h + \ell w (\alpha h \, \Delta T) \\
&= (\alpha \, \Delta T)(3 \ell w h) \\
&= (3\alpha) V_i \, \Delta T \\
&= \beta V_i \, \Delta T
\end{aligned}$$

So, $\beta \approx 3\alpha$.

Thermal Expansion Question

The figure here shows four rectangular metal plates, with sides of L, $2L$, or $3L$. They are all made of the same material, and their temperature is to be increased by the same amount. Rank the plates according to the expected increase in

(a) their vertical heights greatest first.



(A) 1, 2, 3, 4

(B) (2 and 3), 1, 4

(C) 3, 2, (1 and 4)

(D) all the same

[1]Halliday, Resnick, Walker, page 483.

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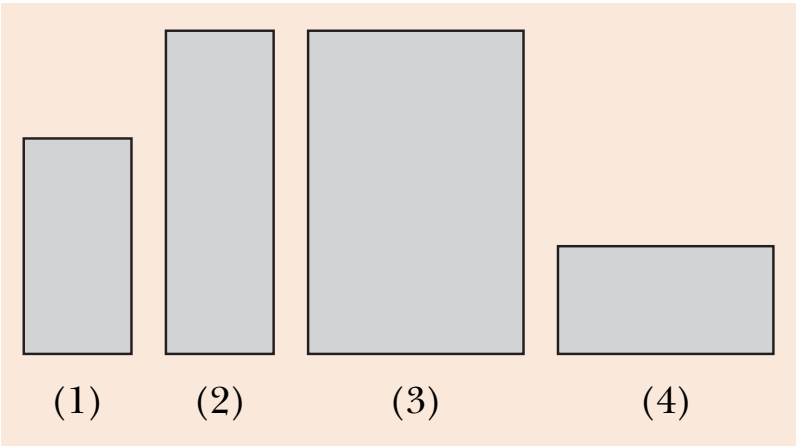

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Thermal Expansion Question

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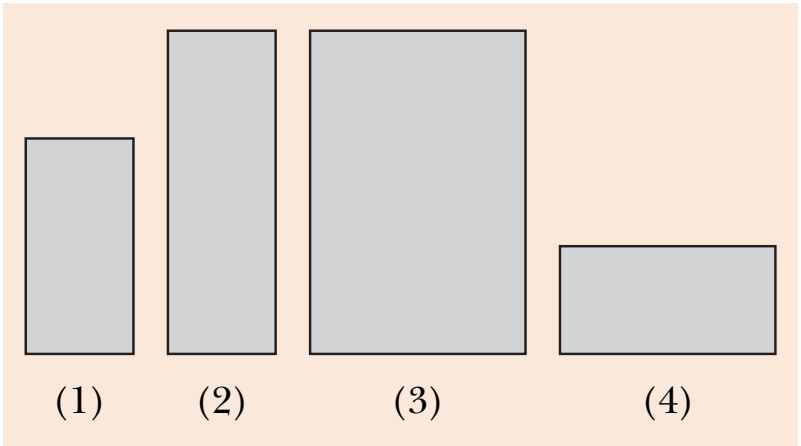

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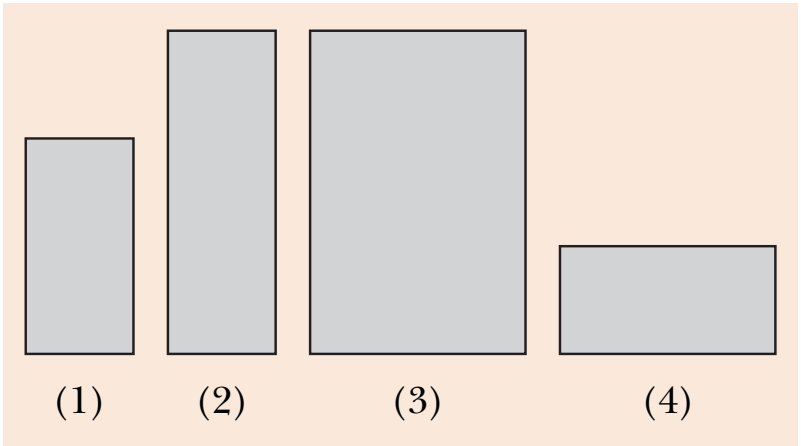

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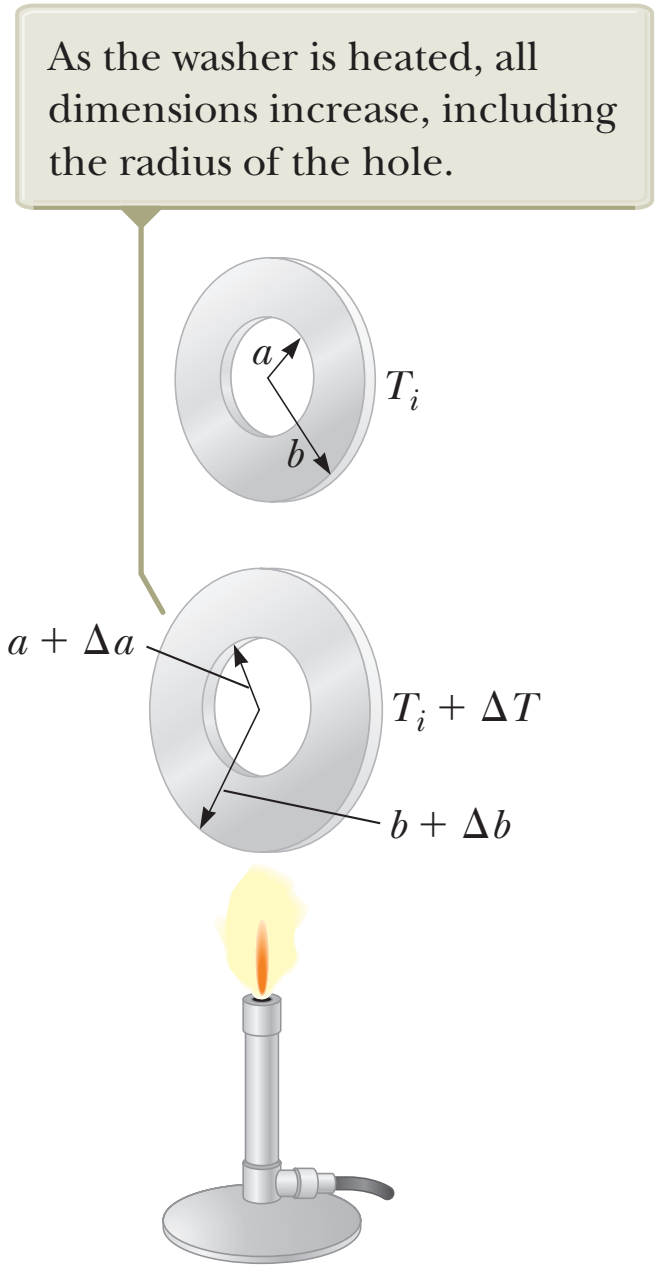
Thermal Expansion of Rings



Question

Quick Quiz 19.4[1] Two spheres are made of the same metal and have the same radius, but one is hollow and the other is solid. The spheres are taken through the same temperature increase. Which sphere expands more?

(A) The solid sphere expands more.

(B) The hollow sphere expands more.

(C) They expand by the same amount.

(D) There is not enough information to say.

[1] Serway & Jewett, pg575.

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Thermal Expansion and Water

Water has a strange behavior with temperature change.

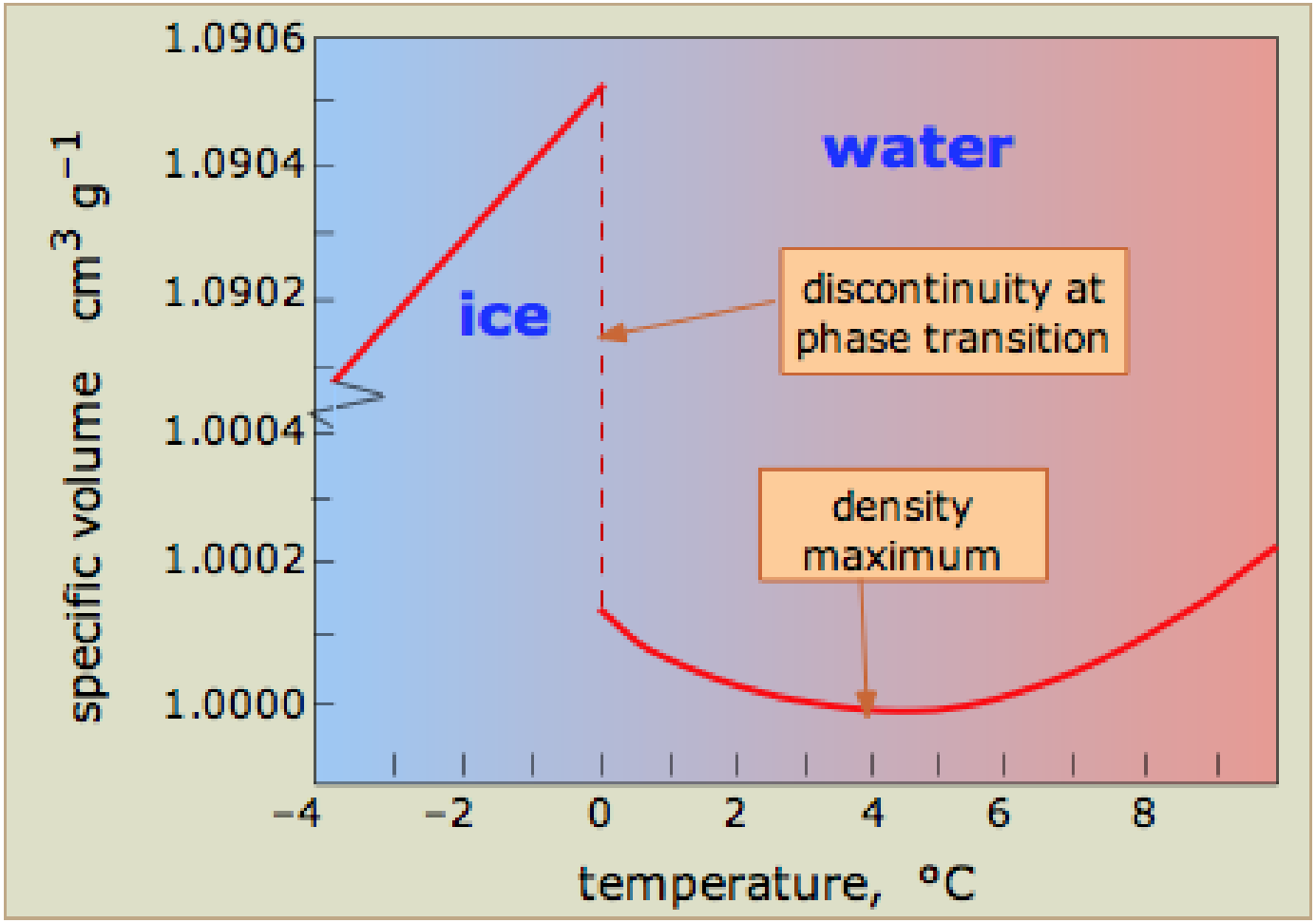
Ice is less dense than water, but even in its liquid phase, water *expands* as it cools between 4°C and 0°C.

Water forms crystals as it freezes. Those crystals have a greater volume than liquid water.

Between 4°C and 0°C some small crystals begin to form, expanding the volume of the water.

[1] Image from its.caltech.edu.

Thermal Expansion and Water



[1]Figure from Chemwiki ucdavis.edu.

Summary

- thermal expansion