Phys 111: Lecture 25

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The 25th Day: "Too Hot!"

Homework Wk #13 Due Thursday

Today's Topics

1. Temperature Scales
2. Heat (Transfer of Thermal Energy)
3. Linear Thermal Expansion

Motivation

How can we prevent pipes from bursting in the winter?

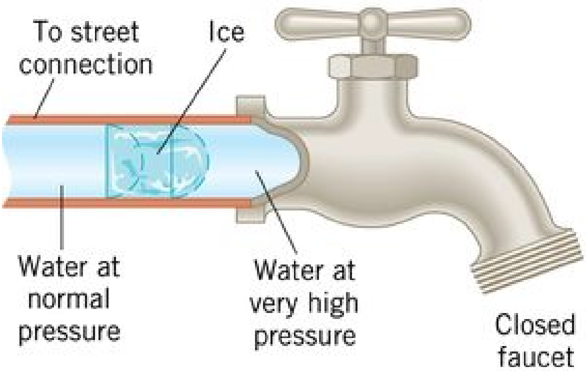


Figure: 25.1 Water freezes and then expands[1]

[1] C&J Figure 12.21

Temperature

Temperature (T) is a measure of the average kinetic energy of a system. High kinetic energy means high temperature.

Usually we discuss how 'hot' the system is.

Rank the following from highest temperature to lowest:

- liquid nitrogen
- boiling water
- iced tea
- hot coffee

Common Temperature Scales

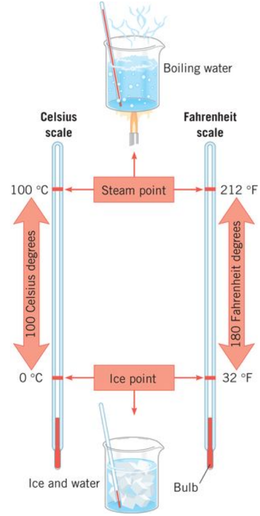


Figure: 25.2 Celsius and Fahrenheit temperature scales[2]

[2] C&J Figure 12.1

Temperature Scales in Science

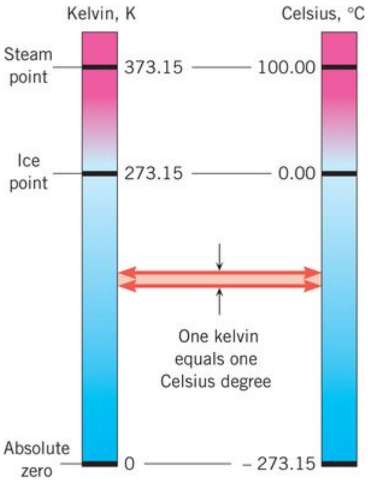


Figure: 25.2 Celsius and Kelvin temperature scales[2]

[2] C&J Figure 12.2

Why Kelvin?

Below is an ideal version of the trendline Sir William Thompson (Lord Kelvin) extrapolated from pressure data measured when cooling gases.

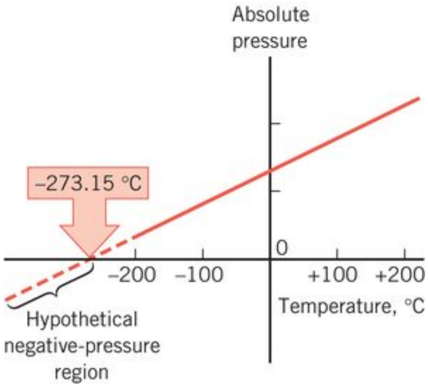


Figure: 25.2 Pressure as temperature changes[3]

[3] C&J Figure 12.4

Temperature Scales Summary

Quantities	Fahrenheit	Celsius	Kelvin
Water Boiling	$212.0°F$	$100°C$	$373.15\ K$
Water Freezing	$32.0°F$	$0°C$	$273.15\ K$
Equal ΔT	$1.8°F$	$1.0°C$	$1.0\ K$

$$T_K = \left(\frac{1\ K}{1°C}\right) T_C + 273.15\ K$$

$$T_C = \left(\frac{5°C}{9°F}\right)\left(T_F - 32.0°F\right)$$

$$T_F = \left(\frac{9°F}{5°C}\right) T_C + 32.0°F$$

Electrical Thermometers: Thermocouples

"Thermocouples are used to measure temperatures as high as $2300°C$ or as low as $-270°C$." C&J pg. 329

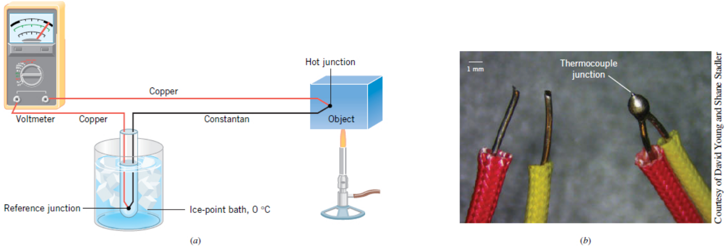


Figure: 25.3 Diagram for a thermocouple measurement[4]

[4] C&J Figure 12.5

Exercise #1

C&J 12.1 Suppose you are hiking down the Grand Canyon. At the top, the temperature early in the morning is a cool $3°C$. By late afternoon, the temperature at the bottom of the canyon has warmed to a sweltering $34°C$. What is the difference between the higher and lower temperatures in

a. Fahrenheit degrees and

b. kelvins?

Exercise #1 Translation

C&J 12.1 Determine how to report a change of $\Delta T = 31°C$ in $°F$ and kelvins.

Strategy: Use the conversions for changes in temperature, not the equations for finding temperatures in different scales.

$$1°C = 1.8°F$$

$$1°C = 1\ K$$

Exercise #1 Answer

C&J 12.1 A change of $\Delta T = 31^\circ C$ is equal to

a. $\Delta T = 55.8^\circ F$ and

b. $\Delta T = 31\ K$

Exercise #2

C&J 12.5 Dermatologists often remove small precancerous skin lesions by freezing them quickly with liquid nitrogen, which has a temperature of $77\ K$. What is this temperature on the

a. Celsius and

b. Fahrenheit scales?

Exercise #2 Translation

C&J 12.5 Determine how to report a temperature of $T = 77\ K$ in $^\circ C$ and $^\circ F$.

Strategy: Use the conversions for temperatures, meaning the equations for finding temperatures in different scales.

$$T_K = T_C + 273.15$$

$$T_F = \left(\frac{9}{5}\right) T_C + 32.0$$

Exercise #2 Answer

C&J 12.5 A temperature of $T = 77\ K$ is equal to

a. $T = -196^{\circ}C$ and

b. $T = -383^{\circ}F$

Linear Thermal Expansion

In general most objects expand when heated and contract when cooled and the change depends on the original length (L_o) as well as the material (α)

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

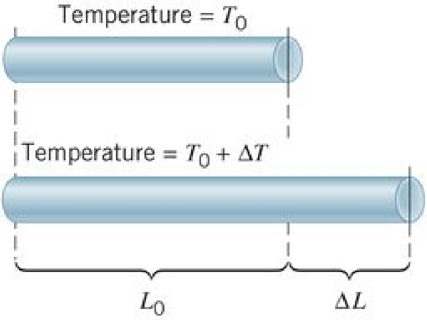


Figure: 25.4 Thermal expansion of 'normal' solids[5]

[5] C&J Figure 12.9

Linear Expansion Demo

In this context, α is used for the coefficient of linear expansion and is recorded with units of $1/°C$.

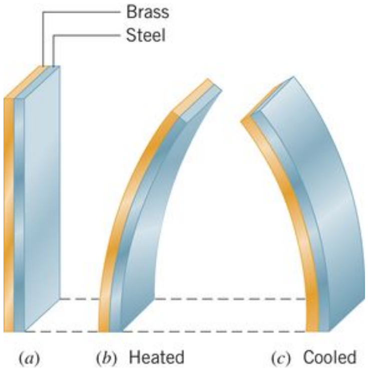


Figure: 25.5 Thermal expansion of two different metals[6]

[6] C&J Figure 12.15

Linear Expansion Application

Thermal expansion used in product engineering

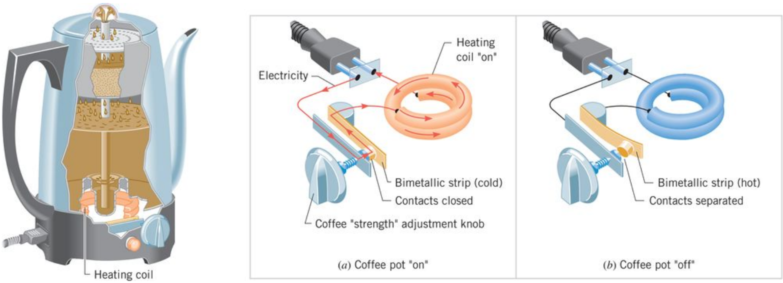


Figure: 25.6 Thermal expansion used in a water kettle[6]

[6] C&J Figure 12.16

C&J 12.10 A steel section of the Alaskan pipeline had a length of $65\ m$ and a temperature of $18°C$ when it was installed. What is its change in length when the temperature drops to a frigid $-45°C$?

We need to know the linear coefficient for steel: $\alpha = 12 \times 10^{-6}\ (°C)^{-1}$.

Exercise #3 Answers

C&J 12.10 The linear coefficient for steel is $\alpha = 12 \times 10^{-6}\ (^\circ C)^{-1}$, the original length was measured to be $L_o = 65\ m$, and the temperature change was measured to be $\Delta T = -63^\circ C$. What is the change in length for such a temperature change?

We need to use the reported values with the relationship

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

$$\Delta L = -4.9\ cm$$

$$\% \Delta L = \left(\frac{\Delta L}{L_o} \right) \times 100\% = (\alpha \Delta T) \times 100\% = 0.756\%$$

Ex. 4 Thinking About Possible Applications

C&J 12.19 The brass bar and the aluminum bar in the drawing are each attached to an immovable wall. At $28°C$ the air gap between the rods is $1.3 \times 10^{-3}\ m$. At what temperature will the gap be closed?

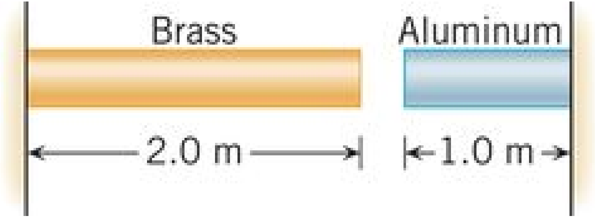


Figure: 25.7 Thermal expansion based device[7]

[7] C&J Figure for Problem 12.19

Motivation

How can we prevent pipes from bursting in the winter? *Loosen the faucet just enough to leak a little bit so pressure doesn't build up.*

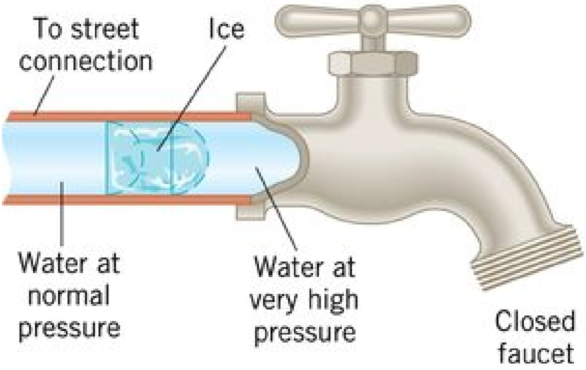


Figure: 25.1 Water freezes and then expands[1]

[1] C&J Figure 12.21

Heat

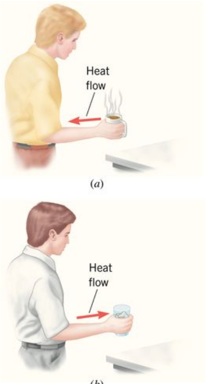
Heat (Q) is energy that flows from a higher-temperature object to a lower-temperature object because of the difference in temperatures.

SI units are joules (J) because it's energy.

Heat flows from a hotter object to a cooler object when the two are placed in contact.

'Heat Flow'

Why is it that a cup of hot coffee feels hot to the touch, while a glass of ice water feels cold?



(a)
(b)

Figure: 25.8 Two common instances of 'heat transfer'[8]

[8] C&J Figure 12.22

Necessary for Thursday

Knowledge of how to use the following relationships

- $T_K = T_C + 273.15$
- $T_C = \left(\frac{5}{9}\right)\left(T_F - 32.0\right)$
- $\Delta L = \alpha L_o \Delta T$
- $Q = mc\Delta T$