Thermodynamics

Temperature and Heat transfer

Conduction Through a Ceramic Mug
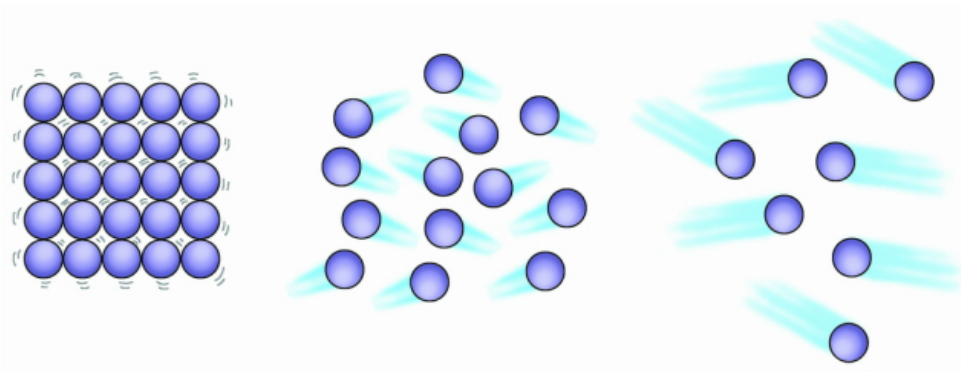
Particle model of "hot" and "cold"

Coffee particles with a higher average kinetic energy collide with the container wall and transmit their energy to the surroundings.
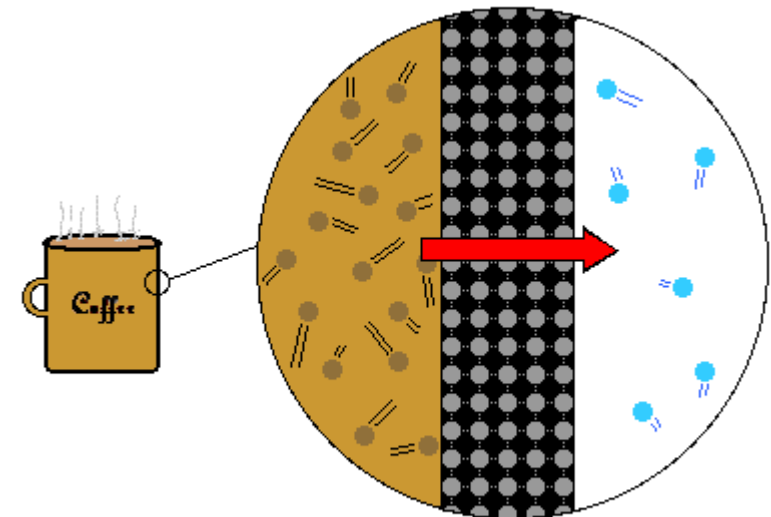
Celsius, Fahrenheit, and Kelvin
Temperature Scales
Units: C°, F°, K°

Thermodynamics

Measuring Temperature

Celsius, Fahrenheit, and Kelvin Temperature Scales
Units: C°, F°, K°

Celsius: water at 0ºC – Freezing, 100ºC – Boiling

$$T_F = T_C \times 1.8 + 32°F \qquad \Delta T_F = \Delta T_C \times 1.8$$

Absolute Temperature Scale

$$T = T_C + 273.15°K \qquad \Delta T = \Delta T_C$$

0 Kelvin is -273.15ºC or -459.67ºF

Measuring Temperature $T_F = T_C \times 1.8 + 32 \degree F$

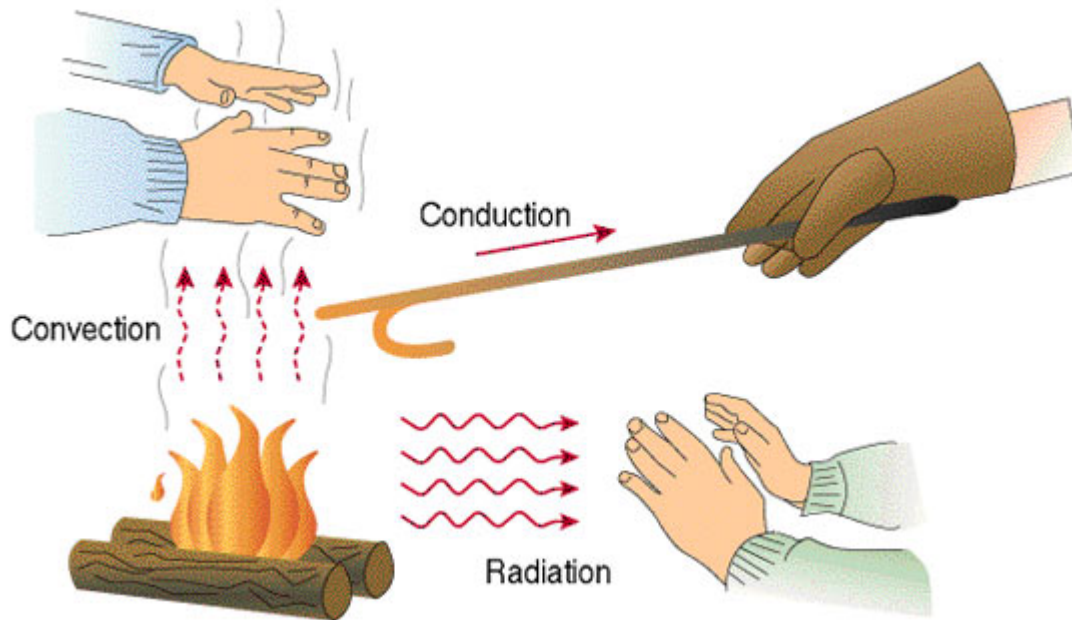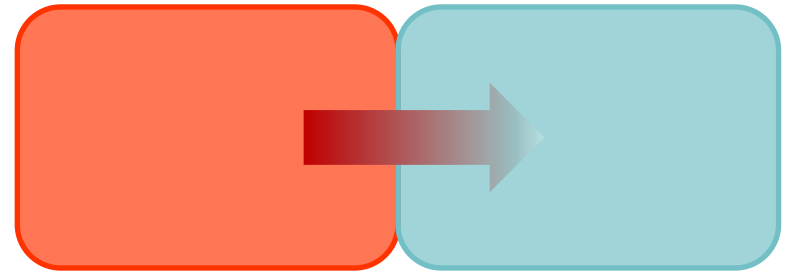*At what temperature do Celsius and Fahrenheit scale have the same value?*

$T_C = 1.8 T_C + 32 = -40\degree$

A. *0 ºC*
B. *100 ºC*
C. *-273.15 ºC*
D. *-32 ºC*
E. *-40 ºC*
F. *Not possible*

Thermodynamics

When hot meets cold – heat transfer
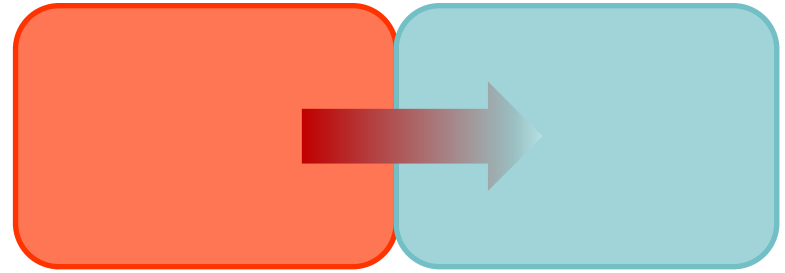
In thermal contact

Conduction

Convection

Radiation

*Radiation*

Thermodynamics

Temperature and Heat

- What is temperature?
  - A measure of how warm or cold an object is with respect to some standard
  - Related to the random thermal motion of the molecules in a substance
- What is heat?
  - The energy transferred between objects due to a temperature difference
  - Energy in transit
- How are the two concepts related?
  - Heat always flows from hotter to colder objects and heat flow changes the temperature of the object.
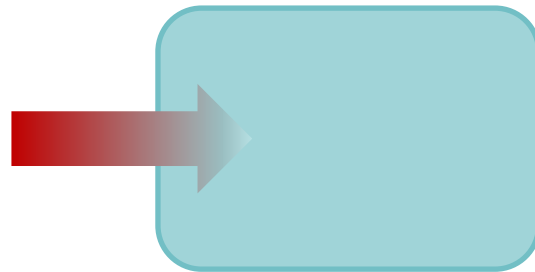
Thermodynamics

Temperature and Heat
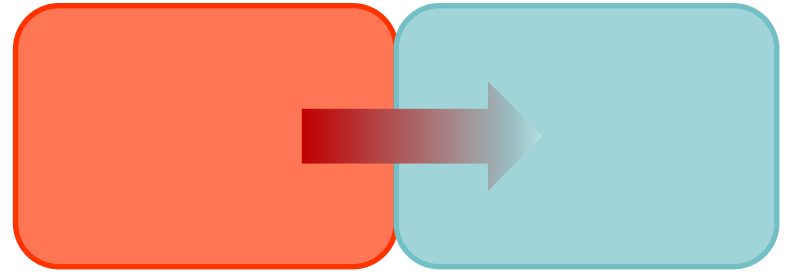
Heat flows out, temperature decreases
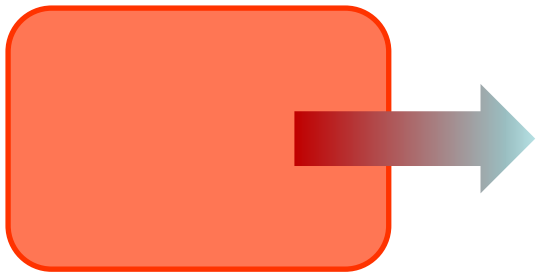
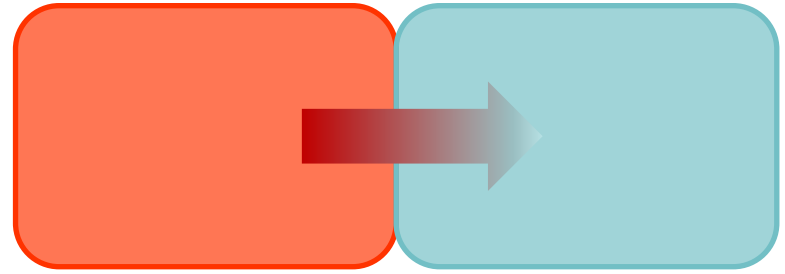*Heat flows in, temperature increases*

Thermodynamics

Heat conductivity

- How can people walk on carbon fire without getting hurt?

Thermodynamics

Heat conductivity

- How fast does heat flows through materials?

- Name some materials that conduct heat
  Fast
  Metals - iron, copper

  Slow
  Insulate - coffee cup, glass

- Applications of these materials: e.g., insulator

Thermodynamics

How to measure heat?

- SI unit is Joules
  - 4.18 Joules to change 1 gram of water +1 K
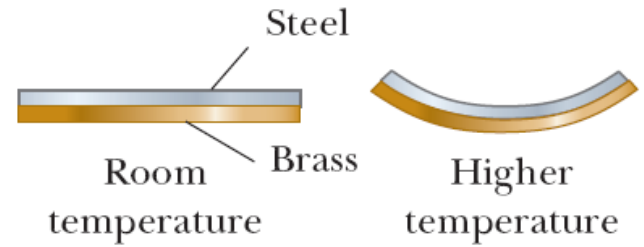 - 1 calorie to change 1 gram of water +1 K

  (note 1000 calories = 1 Calorie)
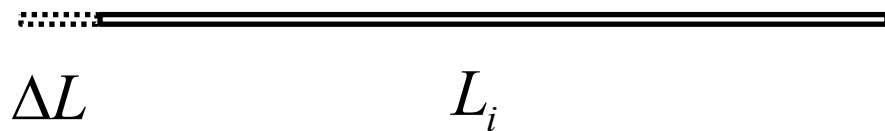 so 1 peanut contains 10 Calories or 10,000 calories

  - Our bodies metabolize (burn) food to keep us warm, to do useful work, or just goof off

Thermodynamics

Thermal Expansion of Solids and Liquids

$$\Delta L = L_f - L_i = \alpha L_i \Delta T$$

ΔL L_i

α: average coefficient of linear expansion

Material (Solids)	Average Linear Expansion Coefficient $(\alpha)(°C)^{-1}$	Material (Liquids and Gases)	Average Volume Expansion Coefficient $(\beta)(°C)^{-1}$
Aluminum	24×10^{-6}	Acetone	1.5×10^{-4}
Brass and bronze	19×10^{-6}	Alcohol, ethyl	1.12×10^{-4}
Concrete	12×10^{-6}	Benzene	1.24×10^{-4}
Copper	17×10^{-6}	Gasoline	9.6×10^{-4}
Glass (ordinary)	9×10^{-6}	Glycerin	4.85×10^{-4}
Glass (Pyrex)	3.2×10^{-6}	Mercury	1.82×10^{-4}
Invar (Ni–Fe alloy)	0.9×10^{-6}	Turpentine	9.0×10^{-4}
Lead	29×10^{-6}	Air[a] at 0°C	3.67×10^{-3}
Steel	11×10^{-6}	Helium[a]	3.665×10^{-3}

Thermodynamics

$$\Delta L = \alpha L_i \Delta T$$

α: average coefficient of linear expansion

Thermal Expansion of Solids and Liquids

$$\frac{\Delta V}{V_i} = 3\alpha\,\Delta T + 3(\alpha\,\Delta T)^2 + (\alpha\,\Delta T)^3$$

$$\Delta V \approx 3\alpha V_i \Delta T$$

$$\Delta V \approx (\alpha \cdot x_i)y_i z_i \Delta T + (\alpha \cdot y_i)x_i z_i \Delta T + (\alpha \cdot z_i)x_i y_i \Delta T$$
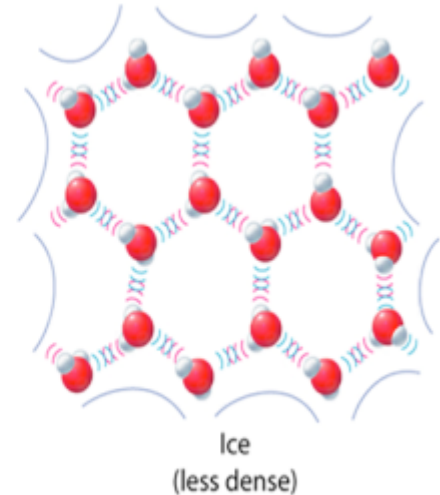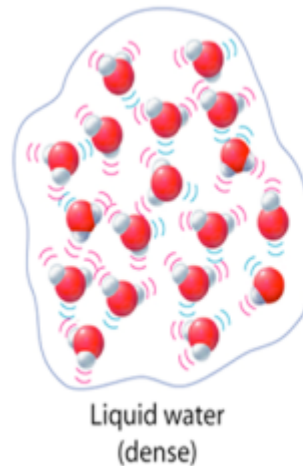
Thermodynamics

Why Does Ice Float? − Because I said so

Unlike most materials, H_2O expands as it freezes − Ice is less dense than liquid water => flotation
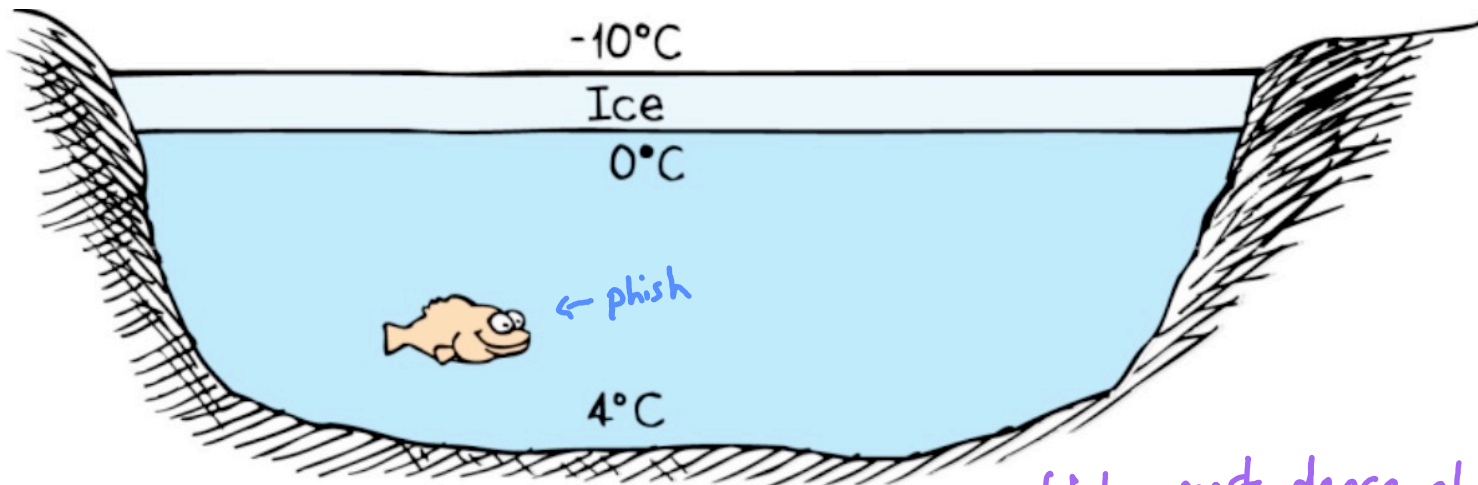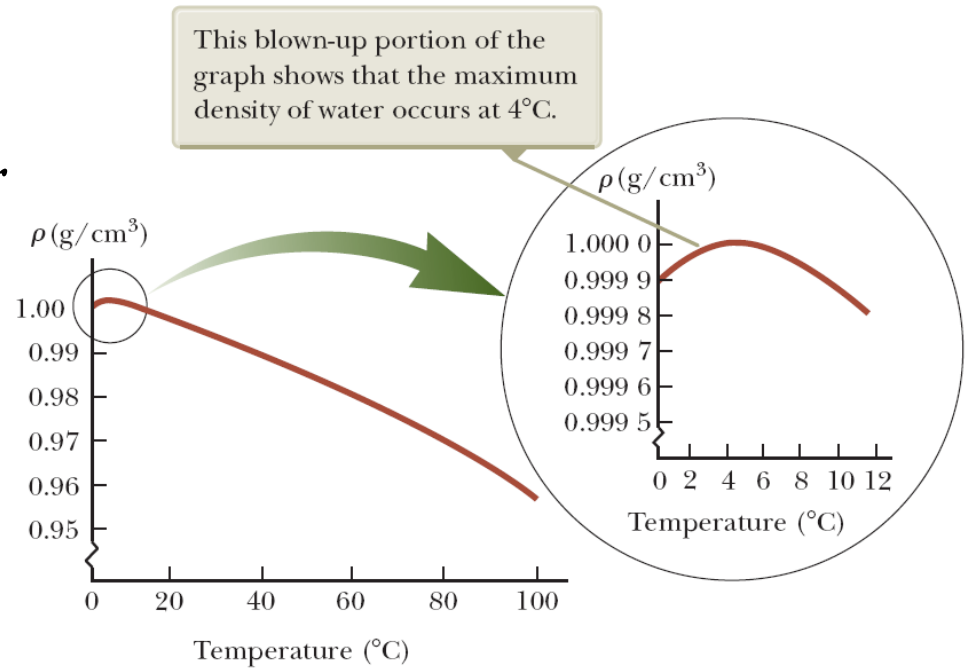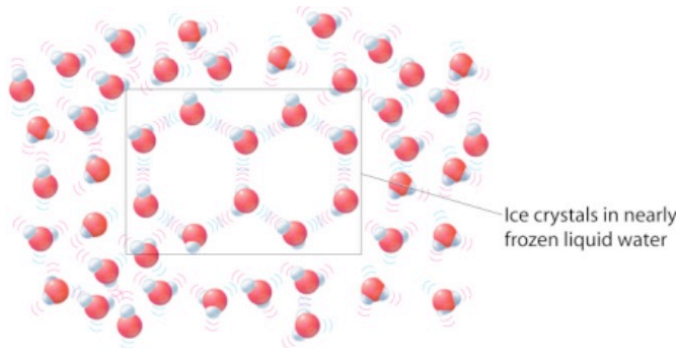
− Due to crystalline structure of ice Greater spacing between molecules than in the liquid phase

Liquid water
(dense)

Ice
(less dense)

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Thermodynamics

The Unusual Behavior of Water

This blown-up portion of the graph shows that the maximum density of water occurs at 4°C.

Ice crystals in nearly frozen liquid water

-10°C

Ice

0°C

← phish

4°C

Water most dense at 4°C