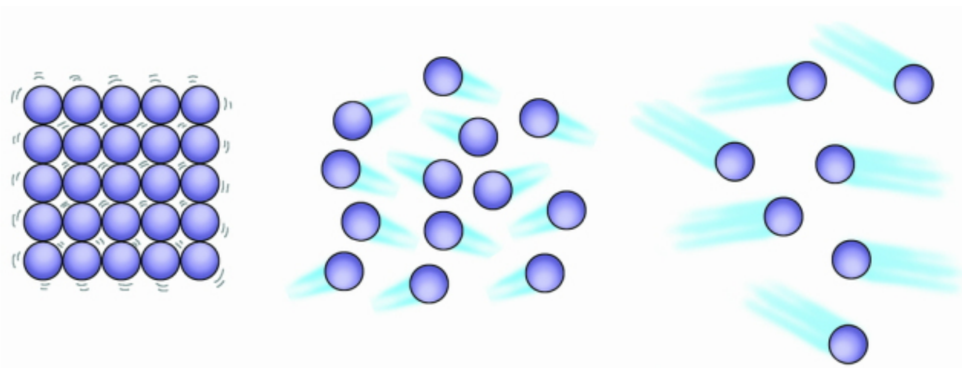
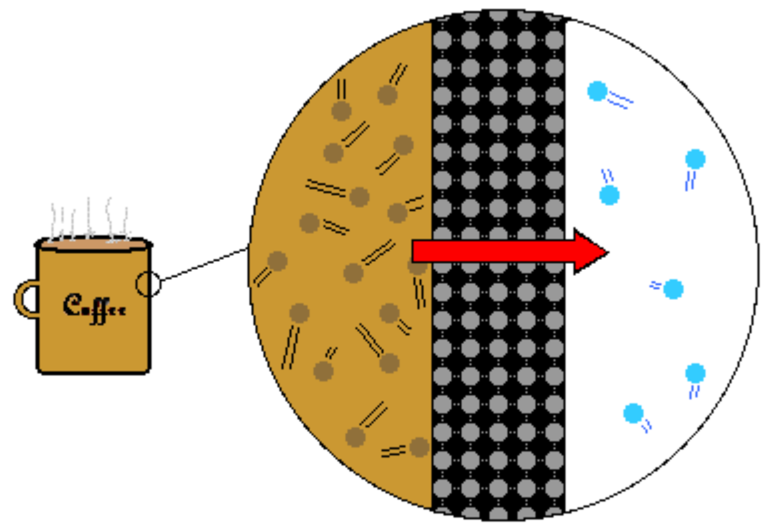
Thermodynamics

Temperature and Heat transfer



Particle model of "hot" and "cold"

Conduction Through a Ceramic Mug



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

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

0 Kelvin is -273.15ºC or -459.67ºF

Measuring Temperature

$$T_F = T_C \times 1.8 + 32°F$$

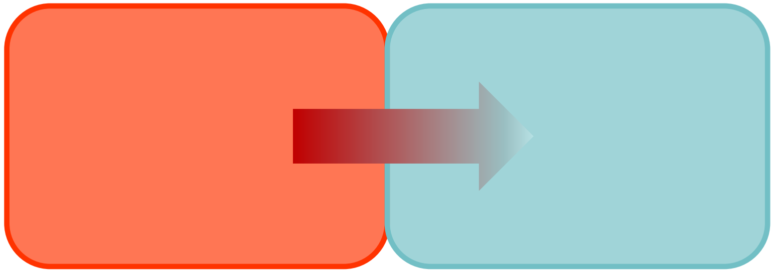
At what temperature do Celsius and Fahrenheit scale have the same value?

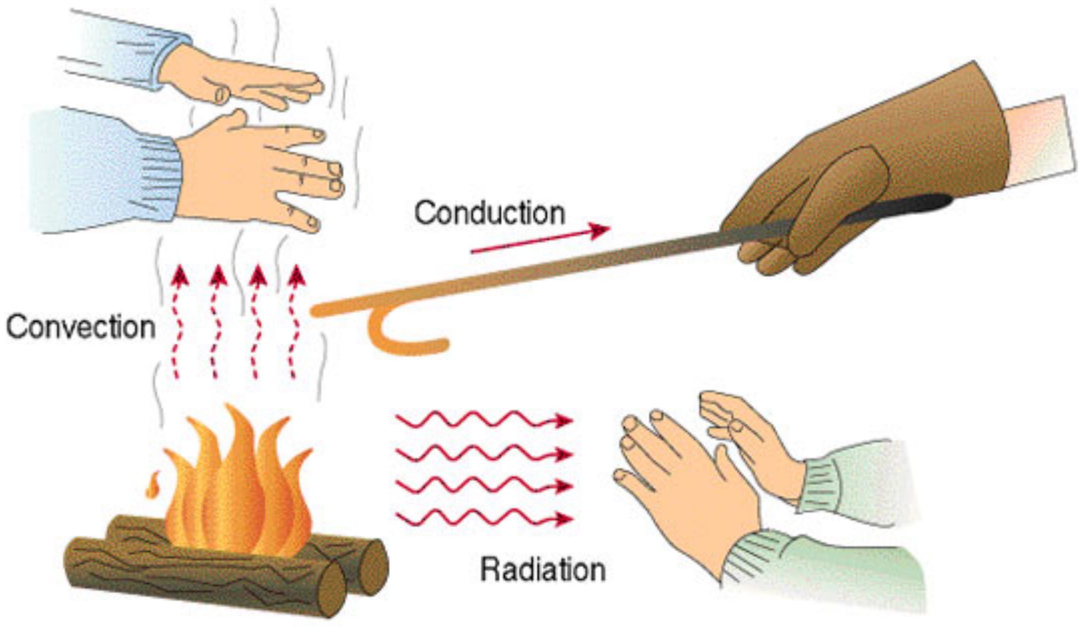
A. *0 ºC*
B. *100 ºC*
C. *-273.15 ºC*
D. *-32 ºC*
E. *-40 ºC*
F. *Not possible*

Thermodynamics

When hot meets cold – heat transfer

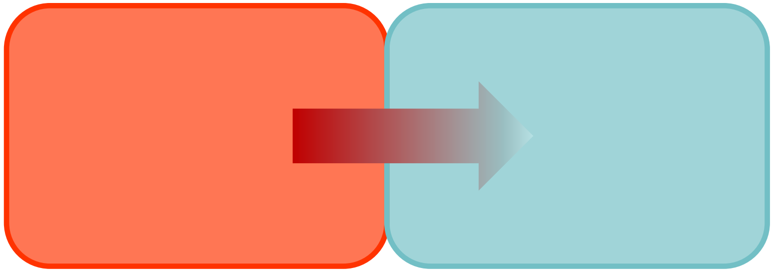
In thermal contact





Radiation

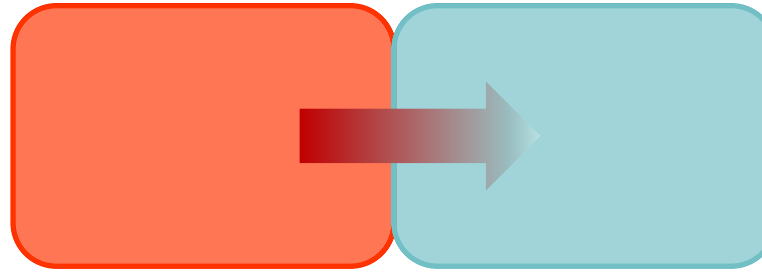
Thermodynamics



Temperature and Heat

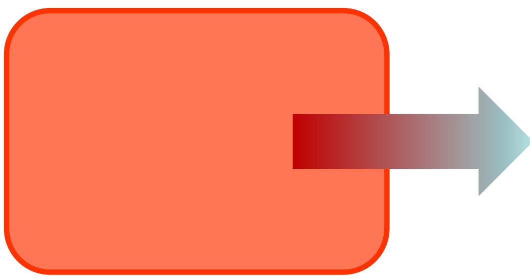
- What is temperature?
  - A measure of how warm or cold an object is with respect to some standard
  - Related to the random thermal motion of the molecules in a substance
- What is heat?
  - The energy transferred between objects due to a temperature difference
  - Energy in transit
- How are the two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

Thermodynamics

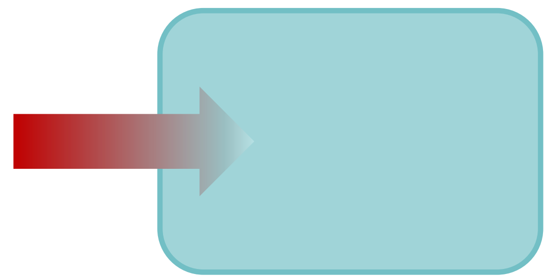


Temperature and Heat

Heat flows out, temperature decreases



Heat flows in, temperature increases

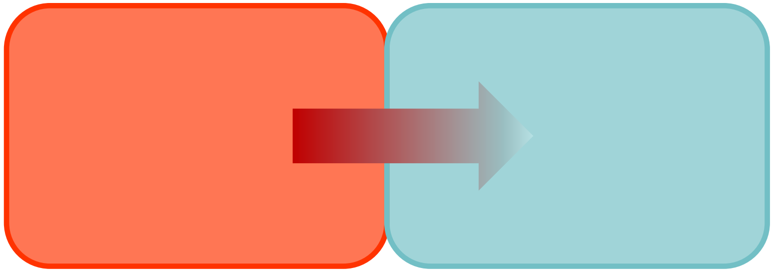


Thermodynamics

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

  Slow

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

Thermodynamics

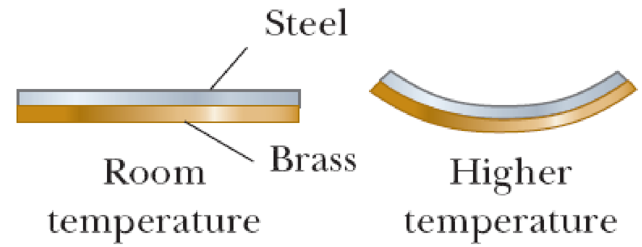
How to measure heat?

- 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

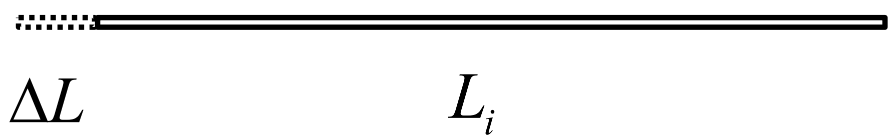
- Our bodies metabolize (burn) food to keep us warm, to do useful work, or just goof off

Thermodynamics



Thermal Expansion of Solids and Liquids

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



α: average coefficient of linear expansion

Material (Solids)	Average Linear Expansion Coefficient $(\alpha)(^\circ C)^{-1}$	Material (Liquids and Gases)	Average Volume Expansion Coefficient $(\beta)(^\circ C)^{-1}$
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}

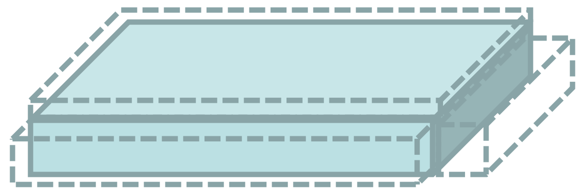
Thermodynamics

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

α: average coefficient of linear expansion

Thermal Expansion of Solids and Liquids

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



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

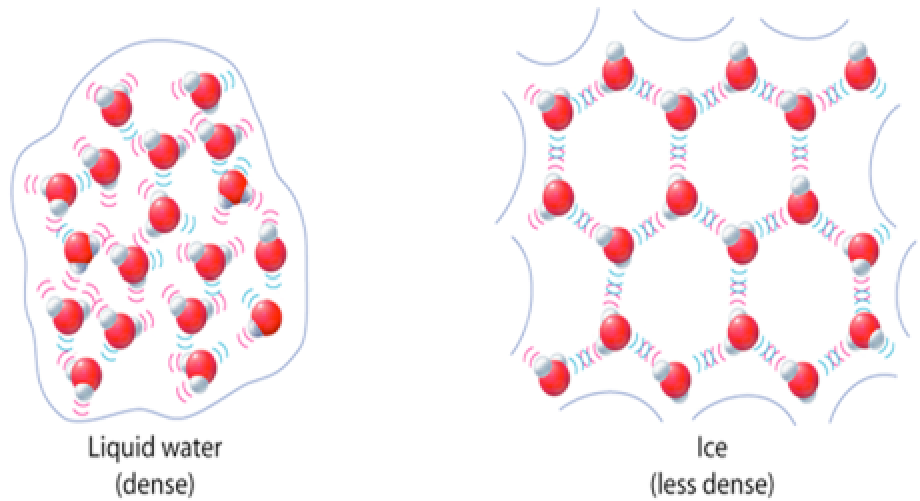
$$\Delta V \approx (\alpha \cdot x_i) y_i z_i \Delta T + (\alpha \cdot y_i) x_i z_i \Delta T + (\alpha \cdot z_i) x_i y_i \Delta T$$

Thermodynamics

Why Does Ice Float?

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



Thermodynamics

The Unusual Behavior of Water