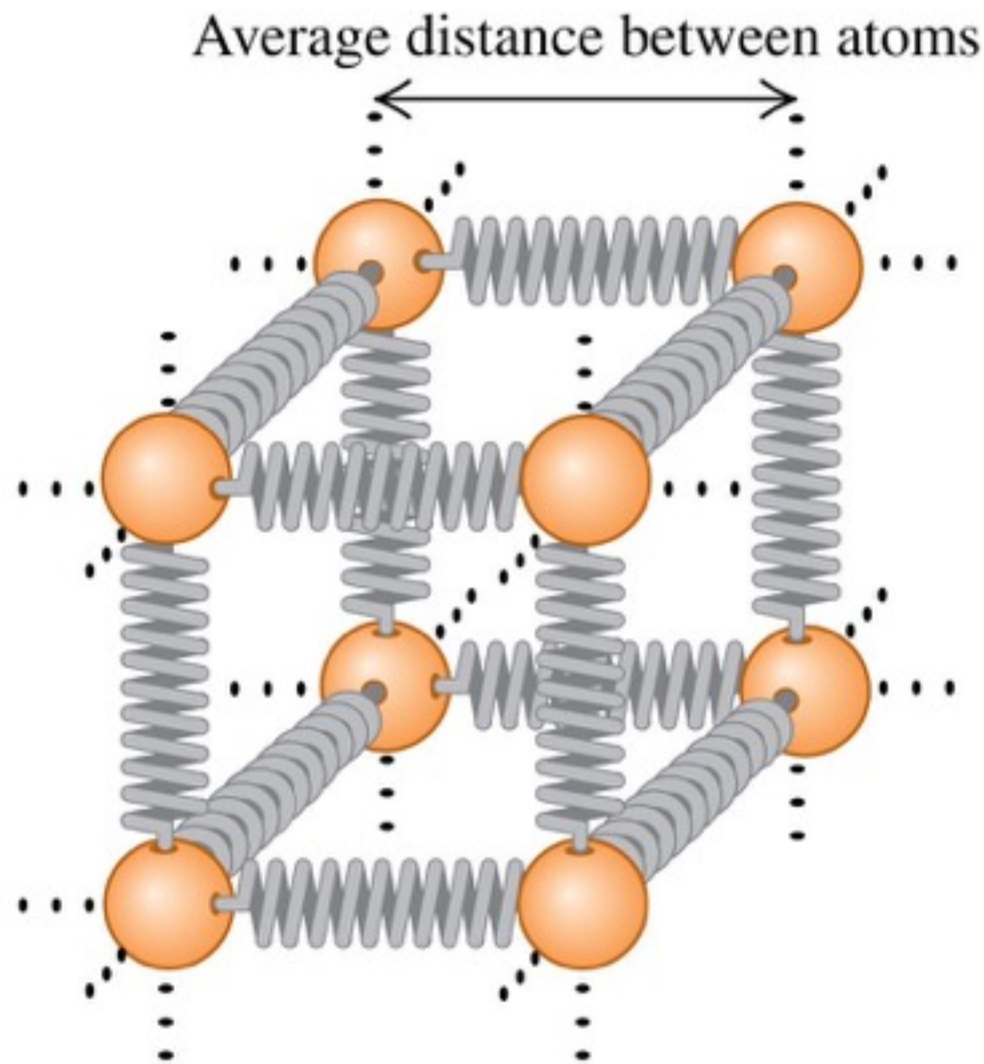
Lecture 2

PHYC 161 Fall 2016

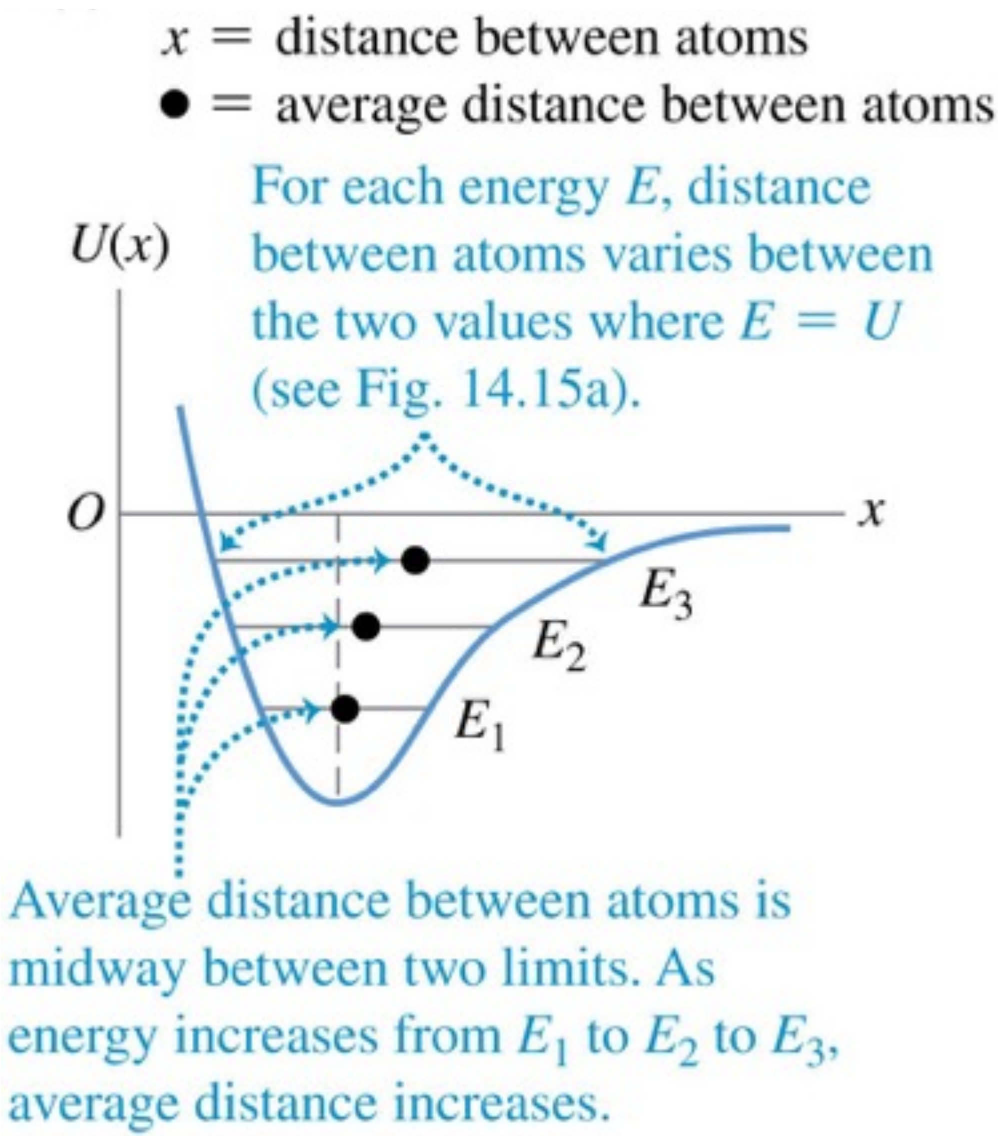
Molecular basis for thermal expansion

- We can understand linear expansion if we model the atoms as being held together by springs.
- When the temperature increases, the average distance between atoms also increases.
- As the atoms get farther apart, every dimension increases.



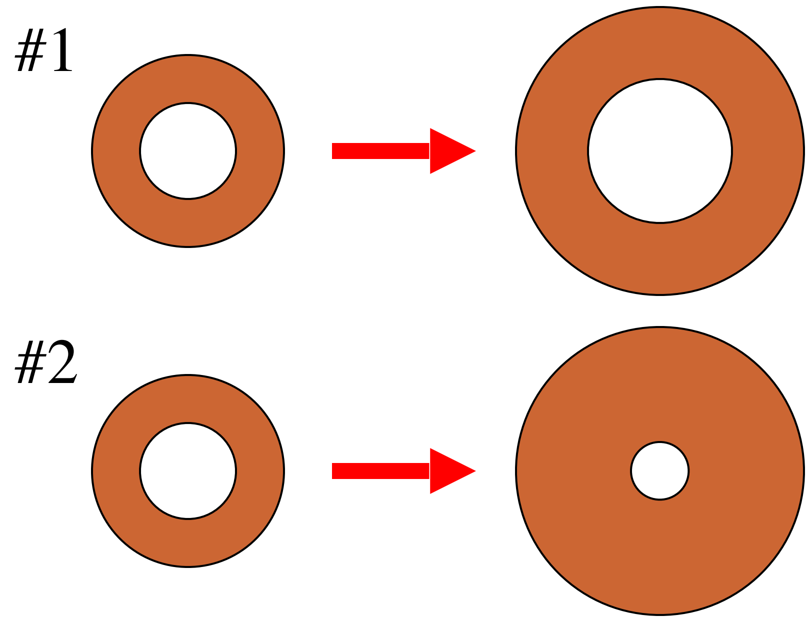
Molecular basis for thermal expansion

- A graph of the "spring" potential energy versus distance between neighboring atoms is not symmetrical.
- As the energy increases and the atoms oscillate with greater amplitude, the average distance increases.



Q17.3

A solid object has a hole in it. Which of these illustrations more correctly shows how the size of the object and the hole change as the temperature increases?



A. illustration #1

B. illustration #2

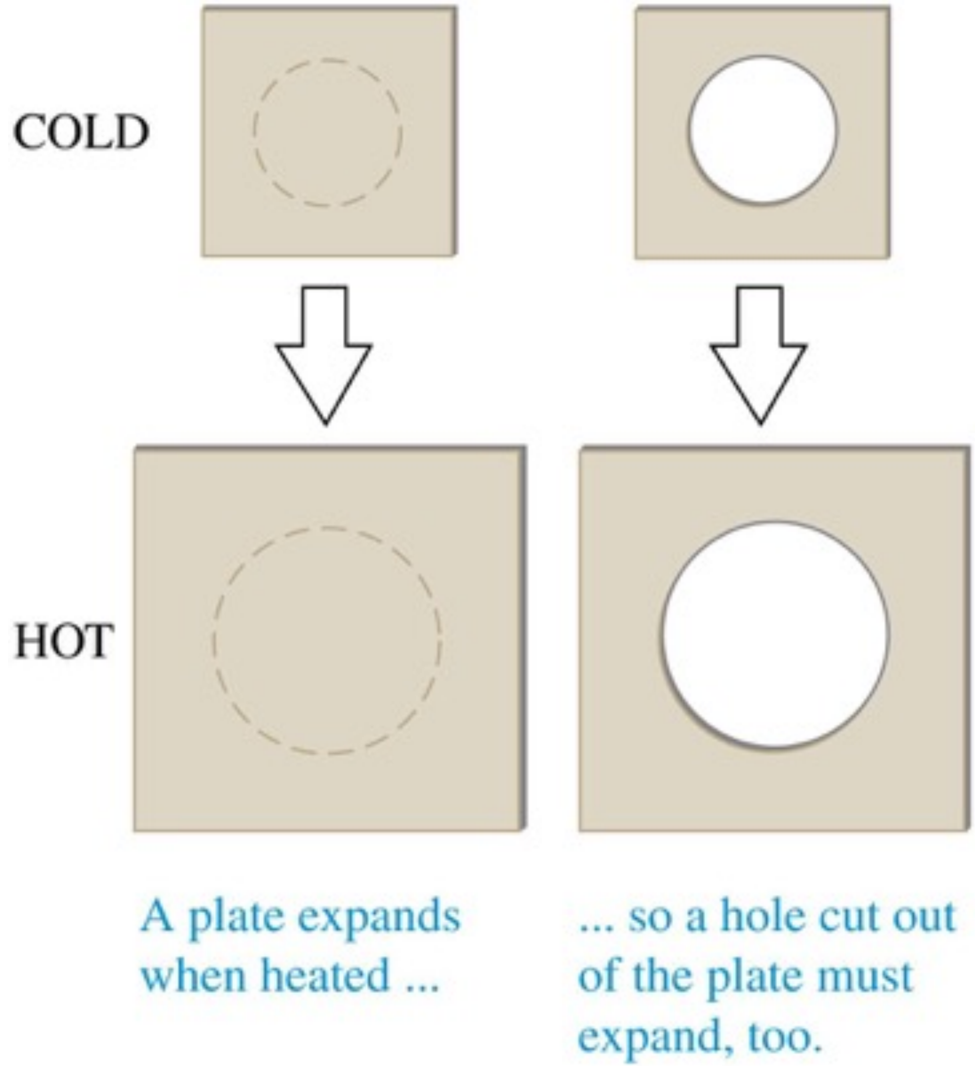
C. The answer depends on the material of which the object is made.

D. The answer depends on how much the temperature increases.

E. Both C and D are correct.

Expanding holes and volume expansion

- If an object has a hole in it, the hole also expands with the object, as shown.
- The hole does *not shrink*.
- The change in volume due to thermal expansion is given by $\Delta V = \beta V_0 \Delta T$, where β is the **coefficient of volume expansion** and is equal to 3α.

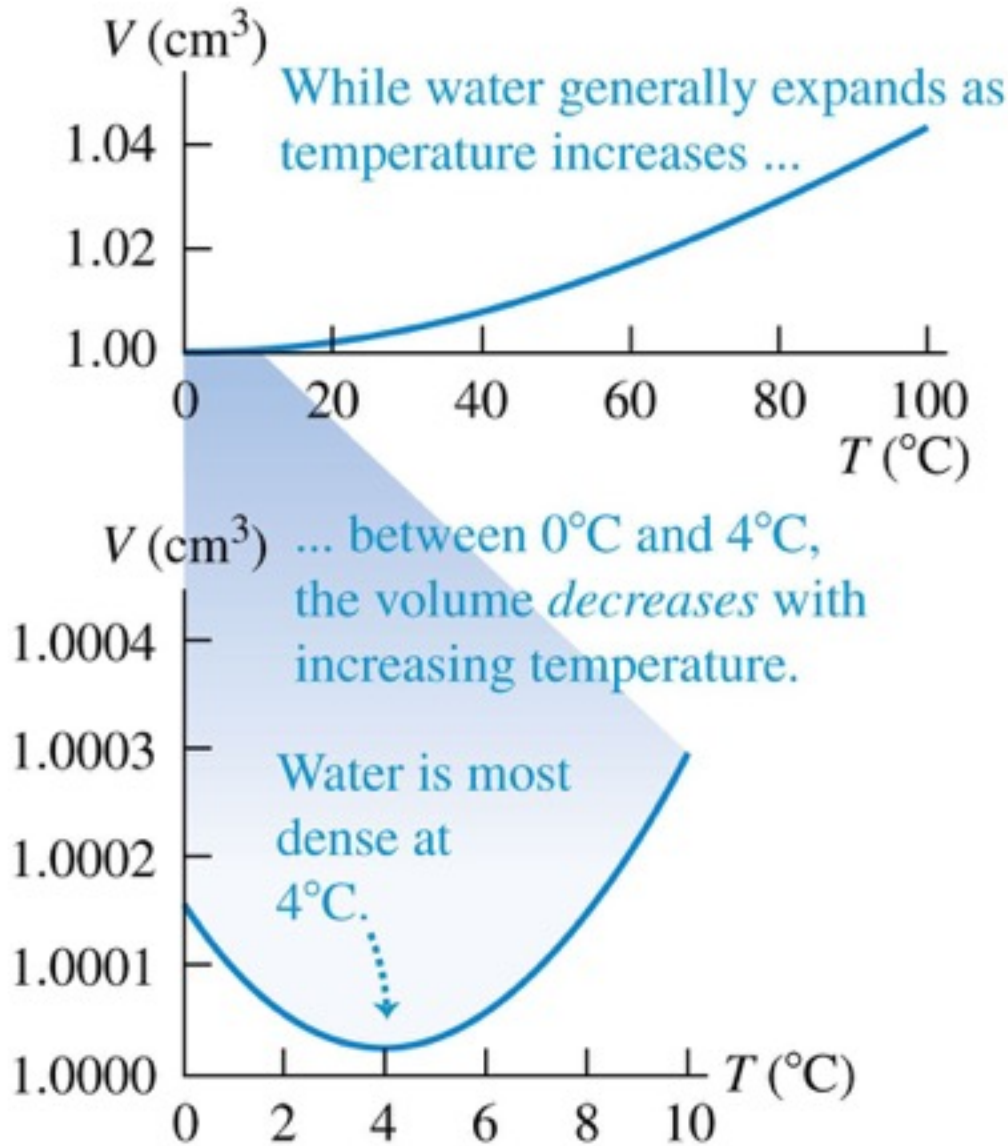


Example of thermal expansion

- This railroad track has a gap between segments to allow for thermal expansion.
- On hot days, the segments expand and fill in the gap.
- If there were no gaps, the track could buckle under very hot conditions.

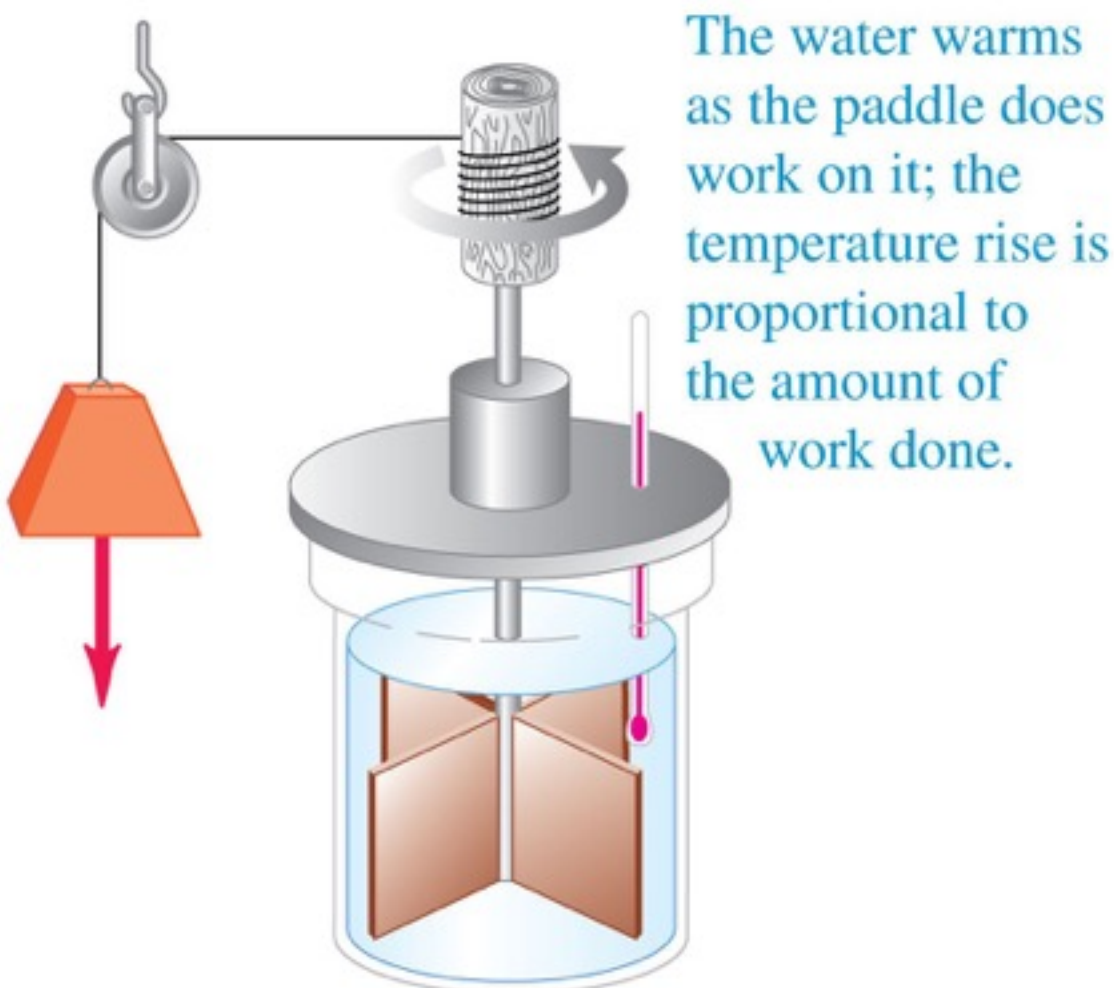
Thermal expansion of water

- Between 0°C and 4°C, water *decreases* in volume with increasing temperature.
- Because of this anomalous behavior, lakes freeze from the top down instead of from the bottom up.



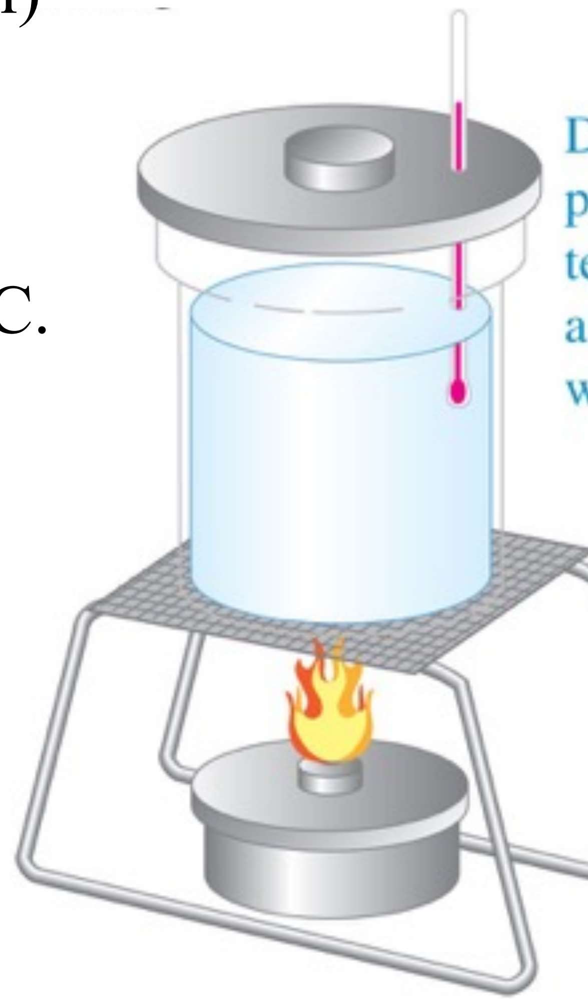
Quantity of heat

- Sir James Joule (1818–1889) studied how water can be warmed by vigorous stirring with a paddle wheel.



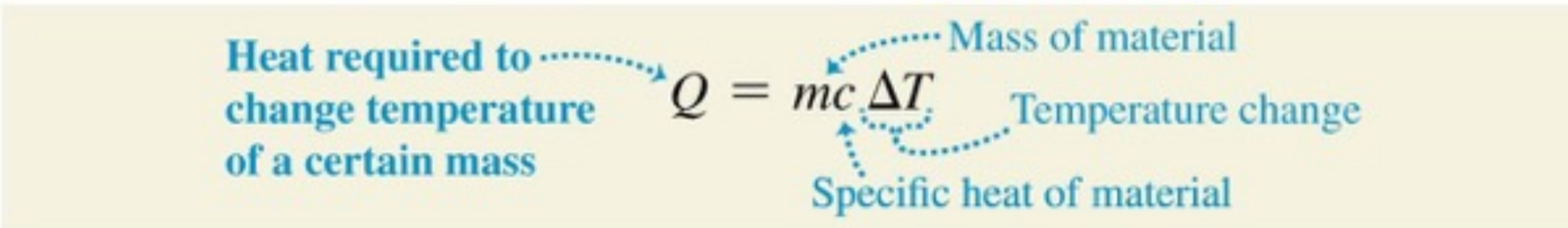
Quantity of heat

- The same temperature change caused by stirring can also be caused by putting the water in contact with some hotter body.
- The **calorie** (abbreviated cal) is the amount of heat required to raise the temperature of 1 gram of water from 14.5°C to 15.5°C.



Specific heat

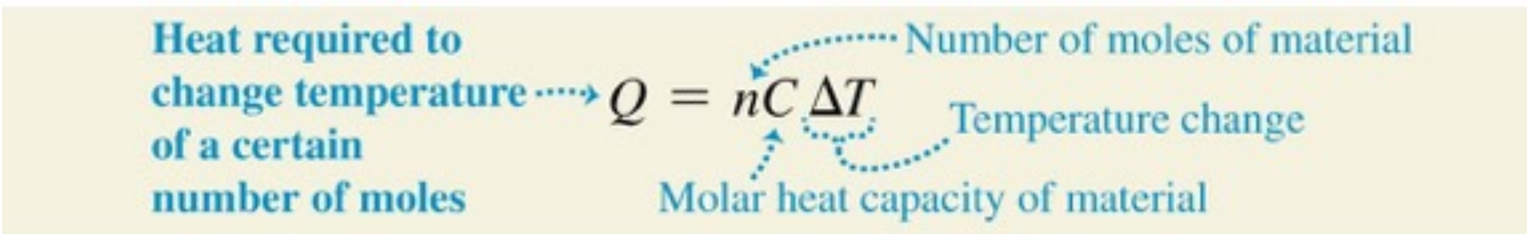
- The quantity of heat Q required to increase the temperature of a mass m of a certain material by ΔT is:



- The **specific heat** c has different values for different materials.
- The specific heat of water is approximately 4190 J/kg · K.

Molar heat capacity

- The quantity of heat Q required to increase the temperature of n moles of a certain material by ΔT is:

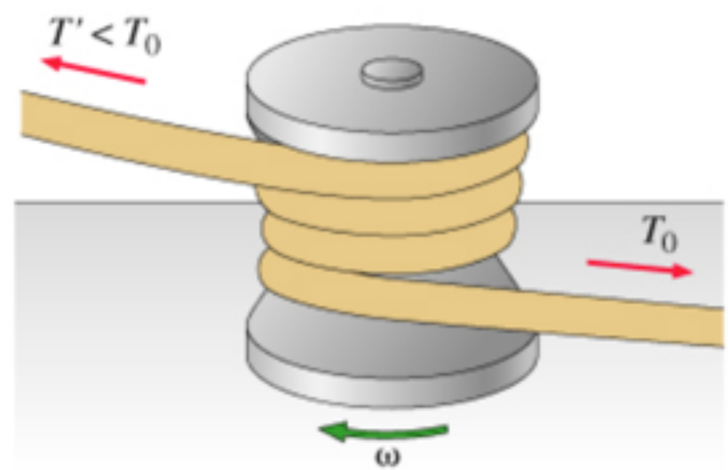


- The **molar heat capacity** C has different values for different materials.
- The molar heat capacity of water is approximately 75.4 J/mol · K.

HW 3: Thermal energy due to friction on a rope

Description: This problem looks at the power lost to heat due to friction of a rope moving about a cylinder and the subsequent temperature rise of the cylinder (using its heat capacity).

A capstan is a rotating drum or cylinder over which a rope or cord slides to provide a great amplification of the rope's tension while keeping both ends free . Since the added tension in the rope is due to friction, the capstan generates thermal energy.



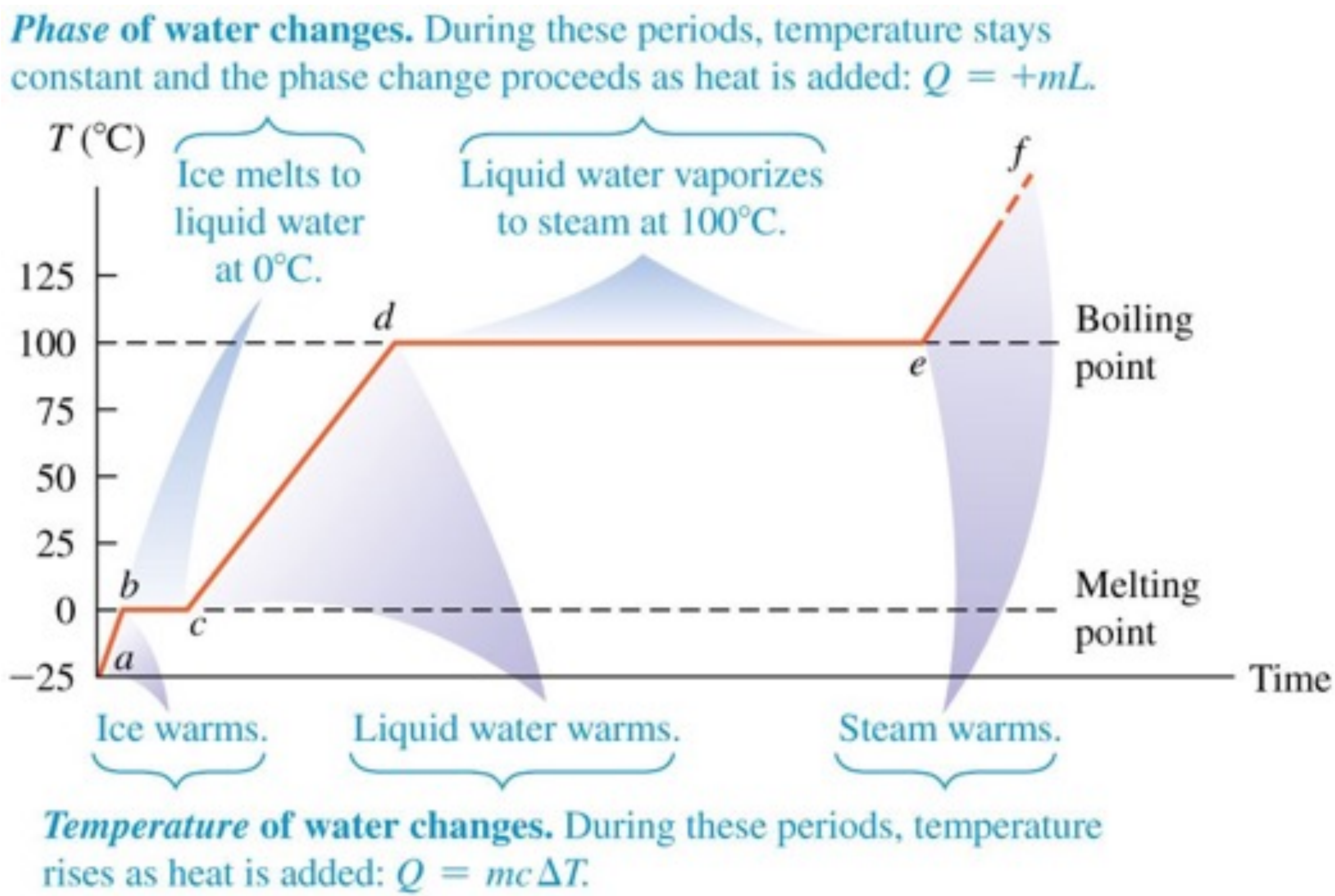
Phase changes

- The **phases** (or states) of matter are solid, liquid, and gas.
- A **phase change** is a transition from one phase to another.
- The temperature does not change during a phase change.
- The **latent heat**, L, is the heat per unit mass that is transferred in a phase change.

$$Q = \pm mL$$

- Heat transfer in a phase change: Q
- m: Mass of material that changes phase
- L: Latent heat for this phase change
- $\pm$: + if heat enters material, − if heat leaves

Heat added to ice at a constant rate



Q17.6

A pitcher contains 0.50 kg of liquid water at 0°C and 0.50 kg of ice at 0°C. You let heat flow into the pitcher until there is 0.75 kg of liquid water and 0.25 kg of ice. During this process, the temperature of the ice-water mixture

A. increases slightly.

B. decreases slightly.

C. first increases slightly, then decreases slightly.

D. remains the same.

E. The answer depends on the rate at which heat flows.

Heat of fusion

- The metal gallium, shown here melting in a person's hand, is one of the few elements that melts at room temperature.
- Its melting temperature is 29.8°C, and its **heat of fusion** is $L_f = 8.04 \times 10^4$ J/kg.

Heat of vaporization

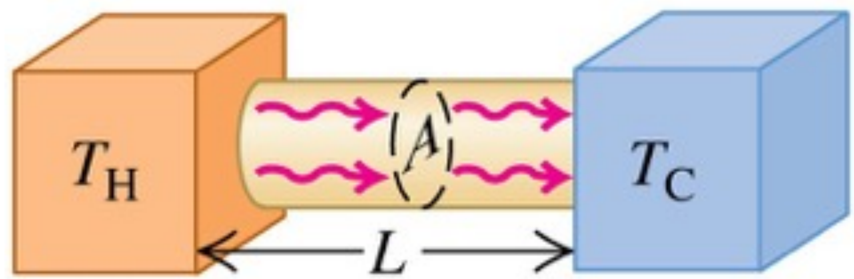
- The water may be warm and it may be a hot day, but these children will feel cold when they first step out of the swimming pool.
- That’s because as water evaporates from their skin, it removes the **heat of vaporization** from their bodies.
- To stay warm, they will need to dry off immediately.

Mechanisms of heat transfer

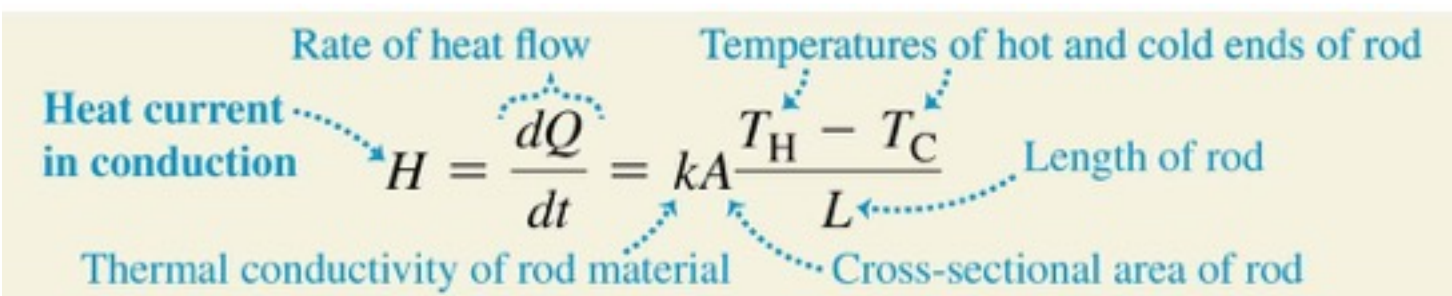
- In nature, energy naturally flows from higher temperature objects to lower temperature objects; this is called **heat transfer**.
- The three mechanisms of heat transfer are **conduction**, **convection**, and **radiation**.
- *Conduction* occurs within a body or between two bodies in contact.
- *Convection* depends on motion of mass from one region of space to another.
- *Radiation* is heat transfer by electromagnetic radiation, such as sunshine, with no need for matter to be present in the space between bodies.

Conduction of heat

- In conduction, heat flows from a higher to a lower temperature.
- Consider a solid rod of conducting material with cross-sectional area A and length L.
- The left end of the rod is kept at a temperature T_H and the right end at a lower temperature T_C.



- The rate that heat is transferred is:



$$H = \frac{dQ}{dt} = kA\frac{T_H - T_C}{L}$$

Thermal conductivities of some common substances

Substance	***k* (W/m · K)**
Silver	406
Copper	385
Aluminum	205
Wood	0.12 – 0.04
Concrete	0.8
Fiberglass	0.04
Styrofoam	0.027

Q17.7

A chair has a wooden seat but metal legs. The chair legs feel colder to the touch than does the seat. Why is this?

A. The metal is at a lower temperature than the wood.

B. The metal has a higher specific heat than the wood.

C. The metal has a lower specific heat than the wood.

D. The metal has a higher thermal conductivity than the wood.

E. The metal has a lower thermal conductivity than the wood.