Thermo!

Chapter 8
Temperature

- a number that corresponds to the warmth or coldness of an object
- measured by a thermometer
- is a per-particle property
- no upper limit
- definite limit on lower end
Temperature Scale

- **Celsius scale** named after Anders Celsius (1701–1744)
  - zero °C for freezing point of water to 100°C for boiling point of water
- **Fahrenheit scale** named after G. D. Fahrenheit (1686–1736)
  - 32°F for freezing point of water to 212°F for boiling point of water
- **Kelvin scale** named after Lord Kelvin (1824–1907) for freezing point of water to 373 K for boiling point of water
  - zero at absolute zero, same size degrees as Celsius scale
  - Kelvins, rather than degrees are used
Temperature

Temperature is proportional to the average translational kinetic energy per particle in a substance.

- gas—how fast the gas particles are bouncing to and fro
- liquid—how fast particles slide and jiggle past one another
- solid—how fast particles move as they vibrate and jiggle in place
• Gas Particles are in constant RANDOM motion
• Particles have different speeds
• Pressure is given by the momentum transferred by particles colliding
• Average KE of each particle is $\sim T$
The Internal Energy of a system is a measure of the total Energy due to ALL random molecular motions: (Translations KE, Rotational KE, Vibrational KE) and internal POTENTIAL energies due to interactive forces (electromagnetic, strong, weak, gravitational).

Mechanical Energy is due to the kinetic and potential energies of the system itself in an external reference frame.

Temperature is a measure of the AVERAGE Translational KE ONLY!

Heat is a flow of thermal energy from hotter to colder because of a difference in temperature. (think water fall!)
There is twice as much molecular kinetic energy in 2 liters of boiling water as in 1 liter of boiling water. Which will be the same for both?

A. temperature
B. thermal energy
C. both A and B
D. neither A nor B
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A. temperature
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Explanation:
Average kinetic energy of molecules is the same, which means temperature is the same for both.
To say that body A has a higher temperature than body B is to say that body A has more

A. thermal energy.
B. mass.
C. kinetic energy per particle.
D. potential energy.
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Heat

Heat
• internal energy transferred from one thing to another due to a temperature difference
• internal energy in transit

Flow of Internal Energy
• from a high-temperature substance to a low-temperature substance until thermal equilibrium is reached
• internal energy never flows unassisted from a low-temperature to a high-temperature substance
If a red hot thumbtack is immersed in warm water, the direction of heat flow will be from the

A. warm water to the red hot thumbtack.
B. red hot thumbtack to the warm water.
C. no heat flow
D. not enough information
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Heat
CHECK YOUR ANSWER
Quantity of Heat

Energy ratings of foods and fuels are determined from energy released when they are burned.
Unit of energy, the Calorie, is common for foods.

4.18 joules = 1 calorie

- 4.18 joules of heat are required to change the gram of water by 1 Celsius degree
- kilocalorie or 1000 calories called a Calorie
- heat needed to change the temperature of 1 kg of water by 1°C
The same quantity of heat is added to different amounts of water in two equal-size containers. The temperature of the smaller amount of water

A. decreases more.
B. increases more.
C. does not change.
D. not enough information
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A. decreases more.
B. increases more.
C. does not change.
D. not enough information
You heat a half-cup of tea and its temperature rises by 4°C. How much will the temperature rise if you add the same amount of heat to a full cup of tea?

A. 0°C  
B. 2°C  
C. 4°C  
D. 8°C
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Specific Heat:  *Thermal Inertia*

The Specific Heat of a substance is the amount of Energy it requires to raise the temperature of 1 gram, 1 degree Celsius.

\[ Q = mc\Delta T \quad c = \frac{Q}{m\Delta T} = \frac{J}{kg \cdot ^\circ C} \]

• The higher the specific heat, the more energy it takes and the longer it takes to heat up and to cool off.

• The lower the specific heat, the less energy it takes and the quicker it takes to heat up and cool off.

• Substances with HIGH specific heat STORE heat energy and make good thermal moderators. (Ex: Water, Oceans)
Specific Heat

\[ c_{\text{water}} = 4186 \frac{J}{kg \cdot ^{\circ}C} \]

\[ c_{\text{glycerin}} = 2410 \frac{J}{kg \cdot ^{\circ}C} \]

\[ c_{\text{iron}} = 452 \frac{J}{kg \cdot ^{\circ}C} \]

Why does water have such a high specific heat?

Heat goes into other modes of energy so that temperature changes slowly.
Which has the higher specific heat capacity, water or land?

A. Water.
B. Land.
C. both of the above are the same
D. neither of the above
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A. Water.
B. Land.
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Explanation:
A substance with small temperature changes for large heat changes has a high specific heat capacity. Water takes much longer to heat up in the sunshine than does land. This difference is a major influence on climate.
The Laws of Thermodynamics

Thermodynamics
• movement of heat

First law of thermodynamics
• states that the heat added to a system transforms to an equal amount of some other form of energy
• more specifically, heat added = increase internal energy + external work done by the system
• Energy can neither be created nor destroyed.
Zeroeth Law

- Two systems individually in thermal equilibrium with a third system (such as a thermometer) are in thermal equilibrium with each other.
- That is, there is no flow of heat within a system in thermal equilibrium
1st Law of Thermo

• The change of internal energy of a system due to a temperature or phase change is given by (next chapter):
  
  Temperature Change: $Q = mc\Delta T$
  Phase Change: $Q = mL$

• $Q$ is positive when the system GAINS heat and negative when it LOSES heat.
2nd Law of Thermo

• Heat flows spontaneously from a substance at a higher temperature to a substance at a lower temperature and does not flow spontaneously in the reverse direction.
• Heat flows from hot to cold.
• Alternative: Irreversible processes must have an increase in Entropy; Reversible processes have no change in Entropy.
• Entropy is a measure of disorder in a system
3rd Law of Thermo

It is not possible to lower the temperature of any system to absolute zero.
Absolute Zero

As temperature of a gas changes, volume of a gas changes.

- at zero degrees with pressure constant, volume changes by $1/273$ for each degree Celsius

Absolute Zero

- lowest limit of temperature
- molecules have lost all available kinetic energy
Thermal Expansion: Linear

To furnace

(a) Heated
(b) Cooled
 Thermal Expansion

Thermal expansion

- due to rise in temperature of a substance, molecules jiggle faster and move farther apart
- most substances expand when heated and contract when cooled
  - railroad tracks laid on winter days expand and buckle in hot summer
  - warming metal lids on glass jars under hot water loosens the lid by more expansion of the lid than the jar
Thermal Expansion

Thermal expansion (continued)

• plays a role in construction and devices

  example:

  • use of reinforcing steel with the same rate of expansion as concrete—expansion joints on bridges

  • gaps on concrete roadways and sidewalks allow for concrete expansion in the summer and contraction in the winter
Thermal Expansion

Thermal expansion (continued)

- different substances expand at different rates

example:

- when the temperature of a bimetallic strip of brass and iron is increased, greater expansion occurs for the brass strip that bends to turn a pointer, to regulate a valve, or to close a switch

Bimetallic strips are used in heaters, oven thermometers, refrigerators, and electric toasters.
When stringing telephone lines between poles in the summer, it is advisable to allow the lines to

A. sag.
B. be taut.
C. be close to the ground.
D. allow ample space for birds.
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C. be close to the ground.
D. allow ample space for birds.

Explanation:
Telephone lines are longer in a warmer summer and shorter in a cold winter. Hence, they sag more on hot summer days than in winter. If the lines are not strung with enough sag in summer, they might contract too much and snap during the winter—especially when carrying ice.
Thermal Expansion

\[ \Delta L = \alpha L_0 \Delta T \quad \Delta V = \beta V_0 \Delta T \]

- Coefficients determined experimentally!
- Liquids expand more than solids!
- \( \beta \sim 3\alpha \)
Thermal Expansion: Linear

The coefficient of linear expansion of steel is $12 \times 10^{-6}/°C$. A railroad track is made of individual rails of steel 1.0 km in length. By what length would these rails change between a cold day when the temperature is -10 °C and a hot day at 30 °C?

\[
\Delta L = \alpha L_0 \Delta T
\]

\[
\Delta L = (12 \times 10^{-6} \, /°C)(10^3 \, m)(30°C – (-10°C))
\]

\[
\Delta L = .48 \, m
\]
Thermal Expansion

When the temperature of a metal ring increases, does the hole become larger? Smaller? Or stay same?
Circle Expansion

The coefficient of linear expansion of aluminum is \(23 \times 10^{-6}/\text{C}^\circ\). A circular hole in an aluminum plate is 2.725 cm in diameter at 0°C. What is the diameter of the hole if the temperature of the plate is raised to 100°C?

\[
\Delta L = \alpha L_0 \Delta T
\]

\[
= (23 \times 10^{-6} / \text{C}^\circ)(2.725cm)100\text{C}^\circ
\]

\[
= 6.3 \times 10^{-3} \text{ cm}
\]

\[d = 2.731 \text{ cm}\]
Thermal Expansion: Water

Water Expands when it cools below 4 °C!
Thus, the solid state is less dense than the liquid state:

Ice Floats!

Maximum density at 4 °C

Graph showing density vs temperature.
When a sample of 0°C water is heated, it first

A. expands.
B. contracts.
C. remains unchanged.
D. not enough information
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B. contracts.
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*Explanation:*
Water continues to contract until it reaches a temperature of 4°C. With further increase in temperature beyond 4°C, water then expands.
When a sample of 4°C water is cooled, it

A. expands.
B. contracts.
C. remains unchanged.
D. not enough information
When a sample of 4°C water is cooled, it

A. expands.
B. contracts.
C. remains unchanged.
D. not enough information

Explanation:
Parts of the water will crystallize and occupy more space.