

Heat & Temperature

(Chapter 6)

Student Learning Outcome: Relate kinetic energy to temperature, compare temperature scales, recall the laws of thermodynamics, and apply the properties of heat energy to everyday systems.

1. *What does temperature measure?*
2. *What do Fahrenheit, Celsius, and Kelvin measure?*
3. *What is heat?*
4. *What are the 3 laws of thermodynamics?*
5. *What is entropy?*
6. *What is specific heat capacity?*
7. *What causes materials to expand when heated?*

What does temperature measure?

Question: Why do we rub our hands together to warm them? What is the physics behind this practice?

- ❖ **Temperature is a measure of the average kinetic energy of the atoms and molecules in a substance.**

Go To: <http://www.youtube.com/watch?v=w1aVqKDAx6o&feature=related>
<http://www.youtube.com/watch?v=o2viSF0Pj1Y>
http://apollo.lsc.vsc.edu/classes/met130/notes/chapter2/kinetic_airmol.html

- ❖ We perceive the KE of atoms and molecules as being hot or cold.
- ❖ Objects with the same average KE are at the same temperature.
- ❖ **Materials at different temperatures reach thermal equilibrium when placed in contact. They become the same temperature.**

Examples:

- ✚ Thermometer + Person
- ✚ Person + Metal Chair

- ❖ **The total thermal energy of an object is KE + PE (stored chemical energy)**

Questions: Which has more thermal energy? How does the KE of each compare?

- a. 1/2 cup of water at 75° C b. 1 cup of water at 75 ° C)

What do Fahrenheit, Celsius, and Kelvin measure?

❖ **Fahrenheit** is based on boiling and freezing points of water.

32° → freezing at sea level

212° → boiling at sea level

❖ **Celsius** is based on boiling and freezing points of water.

0° → freezing at sea level

100° → boiling at sea level

❖ **Kelvin** is based the average KE of atoms in a gas.

$$\mathbf{K = C + 273.15}$$

$$\mathbf{F = 9/5C + 32}$$

$$\mathbf{C = 5/9F - 32}$$

❖ Absolute zero (0 Kelvin) is the lower limit for temperature.

$$\mathbf{0 \text{ Kelvin} = -237^{\circ}\text{C} = -459.4^{\circ}\text{F}}$$

- Particles would stop moving
- KE would go to zero
- Pressure would go to zero
- Volume would go to zero
- No more energy could be removed

Questions:

1. Earth's surface has an average temperature of 14 °C. What is the temperature of Earth's surface on the Fahrenheit scale?

2. The surface of the Sun is 5800 Kelvin. What is the temperature of the Sun's surface on the Fahrenheit scale?

Go To: http://solarsystem.nasa.gov/multimedia/display.cfm?IM_ID=169
<http://www2.jpl.nasa.gov/basics/Ktable.html>

What is heat?

- ❖ **Heat is energy that flows if there is a temperature difference.**
- ❖ Heat is thermal energy that is moving from one object to another.
- ❖ If there is a temperature difference, heat energy flows from hotter object to the cooler object until thermal equilibrium is reached.

HOT → COLD

- ❖ The larger the temperature difference, the faster heat energy flows.

Example: Hand on cold table

Question: If you are in a hurry to eat a very hot pizza, where should you put it to cool?

- ❖ The units for heat are Joules, calories, and Btu.
 - The **Joule** is the amount of energy it takes to change the temperature of 1 kg of water by 1 °C.
 - The **calorie** is the amount of energy it takes to change the temperature of 1 g of water by 1°C
 - The **Btu** is the amount of energy it takes to change the temperature of 1 lb of water by 1°F

What are the 3 laws of thermodynamics?

- ❖ Thermodynamics is the study of heat flow and mechanical work it can do.
- ❖ **1st Law of Thermodynamics states that the amount of heat energy transferred is equal to the change in thermal energy plus work.**

Heat Energy → Δ Energy + Work

Go To: <http://www.youtube.com/watch?v=dxVIFf4DYU4>

- ❖ **2nd Law of Thermodynamics states that heat cannot flow spontaneously from a cold substance to a substance.**
- ❖ **3rd Law of Thermodynamics states that at absolute zero, all motion would stop.**

Go To: <http://www.youtube.com/watch?v=VtEqn-5XHpU>

Questions:

1. Can you think of a situation where heated water could do work on a system?
2. What evidences do we have that heat energy flows from a hot material to a cold material?
3. If the temperature of an isolated substance is decreased, what will happen to the pressure and volume of the substance?

What is entropy?

- ❖ **Entropy is a measure of disorder, of the random motions of particles in a gas.**

Go To: <http://hyperphysics.phy-astr.gsu.edu/hbase/therm/entrop.html>

- ❖ The entropy of an isolated material never decreases; it will either increase or remain constant.

Collisions → Increase Entropy
Work → Increase Entropy
Heat added → Increase Entropy
Heat decreased → Decrease Entropy

Questions: If a balloon is filled with air, sealed, and placed in the freezer, will the entropy increase, decrease, or remain constant? What happens to entropy if I shake the balloon?

What is specific heat capacity?

Question: Does a swimming pool lose heat quickly or slowly? Why?

- ❖ **The amount of heat it takes to increase the temperature of a material by 1° C is the specific heat capacity of the material.**

$$Q = cm\Delta T$$

- ❖ A substance with a high specific heat capacity will resist changes in temperature.
 - Absorbs more heat before it changes temperature
 - Holds onto the heat longer
 - Maintain its temperature better

Questions:

1. In a standard shower, 120 kg of hot water is used during a 10 minute shower. What is the heat energy required to raise the temperature of the 120 kg of water from 15°C to 61°C? The specific heat capacity of water is 4186 J/kg°C.
2. A solid copper penny ($c = 387 \text{ J/kg}^\circ\text{C}$) with a mass of 3 grams is dropped from a height of 10 meters. If all energy is conserved within the penny, what is the temperature change of the penny when it lands on the ground?
3. Where would you expect a greater temperature change between day and night, in a humid location or a dry location? Why?

What causes materials to expand when heated?

- ❖ **Thermal expansion occurs because the motions of particles increase when temperature increases.**
- ❖ Solids tend to expand in one dimension, or linearly.
- ❖ Fluids increase volume.

Go To: http://www.youtube.com/watch?v=sRJRzF_3sd8
<http://www.youtube.com/watch?v=hX2Y2IDjuGI&feature=fvw>

Examples:

- ✚ Metal lids
- ✚ Bridge Joints
- ✚ Bimetallic strips

Go To: <http://home.howstuffworks.com/therm2.htm>
<http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/bimetal.html#c1>

Question: Do all substances expand when heated?