HEAT AND TEMPERATURE

Chapter 16

16A Defining Thermal Energy

Caloric Theory

- Scientists used to think thermal energy was a fluid which flowed from hot objects to colder ones.
- They called this fluid "caloric."
- Benjamin Thompson
  - A scientist, better known as Count Rumford, disproved the caloric theory.
  - He did this by observing the boring of cannon barrels.
  - He noticed that dull bits produced little cutting but much heat, while sharp bits produced much cutting and little heat.
  - This would mean that the amount of caloric in the same metal could change, which is impossible.
- What produces heat?
  - If heat is not a fluid, then what is it?
  - We know that heat is caused by motion.
  - The Greek word for motion is kinetos, from which we get "kinetic."
- Kinetic theory of thermal energy
  - Thermal energy = motion
  - Faster motion = "hotter"
  - Total energy = thermal energy

How Do We Measure Hot and Cold?

- What is hot to one person is not necessarily hot to someone else.
- Scientists need to measure hotness.
- They use temperature, which is measured in units called degrees.
- Temperature
  - A measure of the AVERAGE kinetic energy (motion) of the particles
  - As the particles speed up, they move up the thermometer.
- Thermometers
  - Galileo made an early one around 1600, but his was open at one end and affected by air pressure.
  - Most thermometers have either alcohol or mercury in them.
- Fahrenheit
  - The temperature scale we use in the U.S.
  - Water freezes at 32°F and boils at 212°F.
  - Fahrenheit used 0° as the coldest temperature he made, using an ice, water, and salt mixture.
- Celsius
  - The scale used by most of the world
  - 0°C is water's freezing point.
  - 100°C is water's boiling point.
  - The 100 degrees between freezing and boiling make this scale easy to use.

Kelvin
- The scale used by scientists
- It has only positive degrees.
- The coldest temperature is absolute zero: 0 K.
- The degrees are the same size as Celsius degrees, just shifted down to a colder temperature.

Celsius ←→ Kelvin
- To change from C to K, add 273.
- To change from K to C, subtract the same 273 degrees.
- Sample Problems:
  - Change 300 K to Celsius.
    27°C
  - Change -35°C to Kelvin.
    238 K
  - Change 124 K to Celsius.
    -149°C
  - Change 678°C to Kelvin.
    951 K

Absolute Zero
- The temperature at which kinetic energy is at a minimum
- It equals 0 K, which is -273°C, which is -454°F.
- That is COLD!!!

Temperature or Thermal Energy?
- Which is hotter, a glass of boiling water or a bathtub of warm water? The glass, of course.
- Which has more thermal energy? The bathtub.
- If the glass and the bathtub water were both cold, which would take more heat to warm up to their temperatures? The bathtub, because thermal energy is TOTAL kinetic energy, while temperature is AVERAGE kinetic energy.

Measuring Thermal Energy
- Since temperature and thermal energy are different, they use different units.
- Thermal energy is measured in units called calories.

calorie
- The amount of thermal energy needed to heat up 1 gram of water 1°C
- It can also measure the amount of energy a substance releases.

Food Calorie
- A food Calorie must be capitalized because it is 1000 times as large as a calorie. It is also called a kilocalorie.
- This is the thermal energy released when food is digested.
- See the Table on p. 364.

16B Heat Transfer

Transferring Thermal Energy
- The transfer of thermal energy is called heat.
- You feel heat rising from a hot oven when it transfers its thermal energy to your hand.

Therefore, heat is the flow of energy.
If too much energy is transferred too quickly, you receive a burn.
There are three different processes for thermal energy transfer:

1. Conduction
2. Convection
3. Radiation

Conduction

Heat is transferred by conduction when objects touch.
This is how a pan on a stove heats up.
The fast motion of the molecules on the stove transfers to the molecules in the pan, speeding them up.

Equilibrium

When the pan is at the same temperature as the stove, no more temperature rise occurs.
There is a balance between the temperatures: equilibrium.

Conductors

These transfer heat well by touching.
Metals are good conductors.
Solids transfer heat mainly by conduction.

Insulators

These do not transfer heat well by conduction.
Gases and non-metals are good insulators.
This is why most windows used now have two panes of glass with an air space between.

R-values

Different building materials have different amounts of insulating (R = resisting) abilities.
Combining the insulating abilities with the thickness of the material gives the R-value.

Convection

This is heating which occurs from air currents.
This is how the heat from your furnace spreads through your house.
Colder, denser gases fall, while hotter, lighter gases rise.
These are called convection currents.

Radiation

This is heat flowing WITHOUT any matter between.
This is how the thermal energy is transferred from the sun.
The light transports the energy.
Different colors absorb more or less heat.

Thermos Bottle

A thermos bottle is an excellent insulator.
Tight seals prevent convection.
Silvered surfaces reflect radiation.
The empty space between the casing and the outer "can" prevents conduction.

Specific Heat

- Does an empty pan change temperature at the same rate as a pan with a little water in it?
- Why not? Because water takes quite a lot of heat (calories) to change its temperature.
- This is a high specific heat.
- See the Table on p. 376.

Thermal Energy Transfers

- Heat of Fusion
  - This is the heat that must be removed from water at 0°C to make it freeze.
  - This energy goes to form the bonds of the solid.
  - Water has a high heat of fusion, which is why a little ice can cool so much water.
- Heat of Vaporization
  - This is the heat that must be added to a liquid at its boiling temperature to make it boil.
  - This energy goes to break the bonds of the liquid.

Thermal Expansion

- Objects expand when heated and contract when cooled. This is called thermal expansion.
- When heated, the molecules move faster and take up more space, causing the expansion.
- They do NOT grow bigger.
- Cooling slows them down, and they take up less space.
- Bimetallic strips use this to change the shape of the strip.
- Pyrex© glassware has a very low expansion rate, so it can stand sudden temperature changes.
- Water expands as it finishes cooling to freezing and as it freezes.

Thermodynamics

- This is the study of heat flow.
- Joule studied how heat (steam) engines change heat to work.
- There are two very important laws of thermodynamics:
- First Law
  - This is the law of energy conservation.
  - It states that no energy can be created or destroyed but can only change form.
  - This law went into effect at the end of creation.
- Second Law
  - This is the law of degeneration.
  - It states that whenever heat is transferred, some of it cannot be used.
  - It is lost as "waste heat."
  - This means things run down and wear out.
  - This law started at the fall of man.
- Entropy
  - This is the measure of the amount of unusable energy. It is always increasing.
  - This means that the universe is running out of energy.
  - Therefore, it must have had a time when the energy was "put in."