HEAT AND TEMPERATURE
Heat vs. Temperature

- Both heat and temperature are related to the Kinetic Energy of molecules in a substance
  - Often called “thermal energy”

- Temperature is the average KE of the molecules
  - It is something a physical system has

- Heat refers to the total amount of energy transferred from one system to another
  - It is something a physical system does
Heat Transfer

- When two objects come in contact:
  - Heat is given from the hotter object to the colder one
  - Until both objects reach the same temperature

- The amount of heat exchange depends on:
  - Starting temperatures (bigger difference → more heat)
  - Size of objects
Specific Heat

• Different materials respond differently to heat
  – Some change temperature easily (little heat required)
  – Others absorb heat with only a small temperature change

• A material's “Specific Heat”:
  – Translates heat to temperature change
  – Small Specific Heat: temperature changes easily
  – Large Specific Heat: much heat required to change temp

• Water has a very high specific heat
  – Very good at cooling objects → it “eats” heat energy
  – Temperature near the ocean is usually mild
Thermal Expansion

• Hot substance $\rightarrow$ Large motions of molecules
  - Causes the substance to expand
  - Amount of expansion depends on the material

• Must be considered in buildings and devices
  - Often expand and contract with changes in temperature
Example: Thermostat

- Uses a coiled “bimetallic strip”
  - Two strips of metals with different expansion tendencies
  - Temperature increases → coil gets tighter
  - Temperature decreases → coil unwinds

- When temperature reaches a certain value:
  - Can connect a circuit to turn a heater on/off
  - Allows for automated control of temperature
Thermal Expansion of Water

- Water has very unusual thermal properties
  - Freeze water → it expands (most substances compress)
  - So ice at 0° C is less dense than water at 0° C

- As a result, ice floats in water

- Expansive force of freezing water is very strong
  - Water in small cracks can tear apart roads... and mountains!
Methods of Heat Transfer

- **Conduction**
  - Two substances in physical contact → direct heat exchange
  - Different materials → very different heat conductivity
  - Metals are often good heat conductors

- **Convection**
  - Motion of a fluid (liquid or gas) carries heat with it
  - Evident in the “churning” motion of boiling water

- **Radiation**
  - Hot objects give off energy as electromagnetic waves
  - The hotter the object, the more energy it gives off
Heat Transfer Examples

● (40° F air) vs. (40° F water)
  – Which is more damaging to humans?
  – Water is 30 times more conductive of heat
  – Hypothermia sets in very quickly in cold water

● Winds near the shore
  – Water and land heat at different rates
  – Convection currents move the heat
  – Winds blow onshore during day...
  – ...and offshore at night
The Greenhouse Effect

- Earth's energy balance:
  - Input: Absorption of sunlight (incident energy – reflected energy)
  - Output: Earth gives off radiation (due to temperature)

- If energy input = energy output:
  - Earth's average temperature stays the same

Ways to change Earth temperature:

1) Reflect more/less energy
   - Ice and clouds reflect sunlight

2) Radiate more/less energy
   - Greenhouse gases block radiation
     - \( \text{CO}_2 \), Methane, etc.
Phase Change

- Solid, Liquid, Gas, Plasma
  - The 4 “phases” of matter

- To change the phase of a substance:
  - Must change the temperature and/or pressure
Latent Heat

• “Extra” heat is exchanged during a phase change
  - This heat does **NOT** cause a change in temperature

• $0^\circ \text{C} \rightarrow$ Ice melts to become water...
  - ...but before the water raises to $1^\circ \text{C} \rightarrow$ Need **latent heat**
  - This makes phase change a **slow** process

Latent heat needed for phase change:

Can be large compared to the heat required for temperature change
Latent Heat Example: Sweat

- Mechanism to avoid body overheating
  - Uses Latent Heat of Evaporation to cool body

- How does it work?
  - Heat conducts from skin to liquid sweat until it evaporates
  - Evaporation process pulls heat out of the body quickly

- So is sweat “boiling” off the body?
  - No (not hot enough), but some evaporation still occurs at temperatures below the boiling point
  - Boiling is not the same thing as evaporation
Summary

- Heat moves from hot substances to cold ones
  - 1) Conduction, 2) Convection, 3) Radiation

- Hot objects expand, cold objects contract

- Latent Heat is required to change phase
  - In addition to the necessary temperature and pressure