TEMPERATURE in K is a measure of the average kinetic energy of a single constituent of a system.

HEAT: is the internal energy that flows across a temperature difference from one physical system to another.

This internal energy can go into increasing the average KE of the constituents, and thus show up as $\Delta T > 0$, or it can show up as an increase of the average PE of the constituents relative to one another, that is as $\Delta V > 0$ or $\Delta \rho < 0$. It almost always shows up as a combination of both.

HEAT CAPACITY: $Q = mC\Delta T$. For most solids, C is from 100 to 1000 J/kg-K.

PHASE CHANGE: Solid to liquid, add L_f. Liquid to gas/vapor, add L_v. Note phase changes (melting, boiling) *are cooling processes,* because the system maintains constant temperature as heat is added.

unit of k W/m·K

CONDUCTION: $\mathcal{P} = (kA/L)\Delta T$.

CONVECTION: Change in ρ due to heating leads to buoyancy, which distributes the heated material throughout the cooler material.

RADIATION: $\mathcal{P} = \sigma A \epsilon T^4$. All objects not at 0 K emit electromagnetic radiation, which carries KE (photon particles) away from the object. Radiation is the only heat transfer process that can occur in a vacuum, since conduction requires matter, and convection requires liquids or gases.

An initially liquid substance has C_L of 2000 J/kg-K, and L_v of 50,000 J/kg with boiling point 90° C, and C_V of 1000 J/kg-K. If the substance starts at 50° C and ends at 130° C. How much heat per kg is needed to be input to carry the substance through this transition?

A wooden rod has $k = 0.1$ J/s-m-K. What thermal power is flowing through the rod if it has an area of 0.001 m^2 and length 1 m, with opposite ends at 10° C and 9° C?

• A 0.1 kg metal block with C = 500 J/(kg-K) is dropped into 1.0 kg of a liquid with C = 2000 J/(kg-K). What is the final temperature of the system in equilibrium, if the initial temperature of the metal is 50°C and the initial temperature of the liquid is 10° C? [Answer: 11° C.]

• A lead bullet at 65° C hits a wall hard enough to liquify completely! What was its initial speed, if all the KE goes into internal energy instead of doing work on the wall? For lead, L_f is 2.45×10^4 J/kg and C = 128 J/(kg-K), while the melting point of lead is 327° C. [Answer: 341 m/s.]

How much power does a human being of surface area 1.5 m^2 at a skin temperature of 33° C radiate to the walls of a room at 22° C, assuming human skin is a "perfect radiator," that is, having ϵ approximately 1.0?

Calculate the average temperature of the earth's surface if the earth receives a year-round average intensity of 1366 W/m^2 from the sun, and reflects only 30% back into space. [The actual measured average temperature is 15° C or 288 K.]

METHODS OF HEAT TRANSFER:

HEATING PROCESSES (heat released to surroundings)

- Freezing of liquid to solid.
- Condensation of vapor to liquid (reverse of boiling or evaporation).
- Compression of a gas.
- Condensation of vapor to solid (reverse of sublimation).

COOLING PROCESSES (heat absorbed from surroundings)

- Boiling of liquid to vapor.
- Evaporation of liquid to vapor.
- Melting of solid to liquid.
- Sublimation of solid to vapor.
- Expansion of a gas.