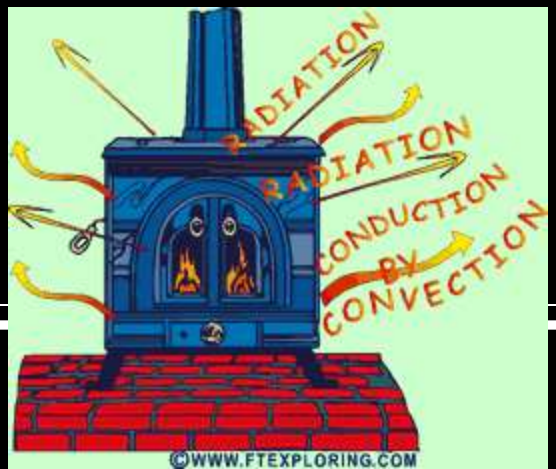
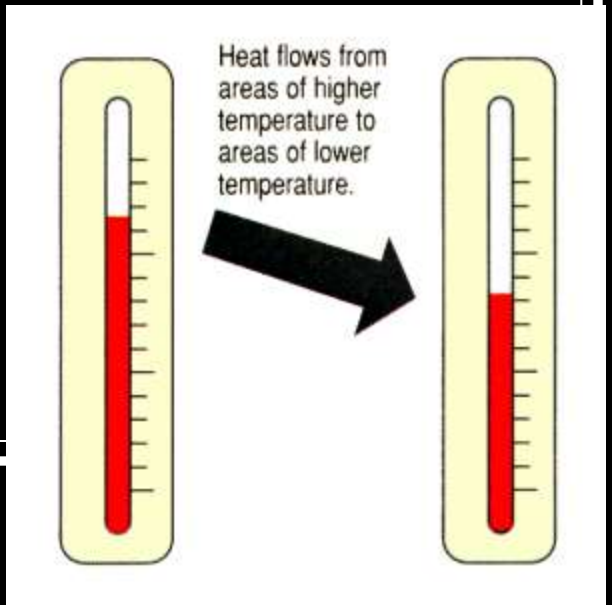
Chapter 16: Thermal Energy and Heat

16.1 – Thermal Energy and Matter

Work and Heat

- **Heat** is the transfer of thermal energy from one object to another because of temperature differences
- Heat flows spontaneously from hot objects to cold objects



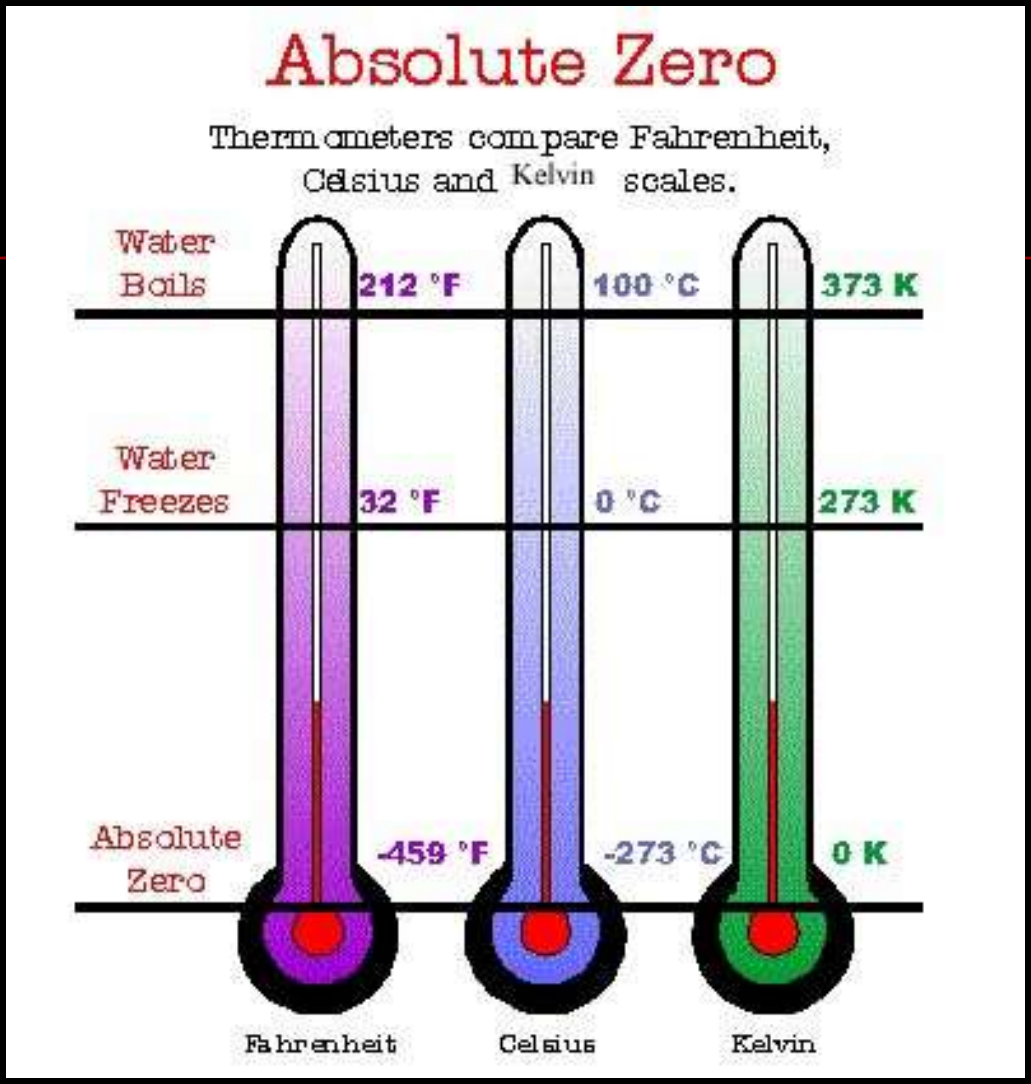


- Imagine two glasses with differing amounts of water in them at the same temperature
- The glass with more water has more heat energy than the glass with less water, even though they are at the same temperature

Work and Heat

- **Temperature** is the measure of how hot or cold something is compared to a reference point.
- The **Celsius scale** has reference points of freezing and boiling points of water
- On the **Kelvin scale** the reference point is absolute zero
  - **Absolute Zero** is the temperature at which molecules essentially stop (no kinetic energy)

Absolute Zero



Converting Between Celsius and Farhrnheit

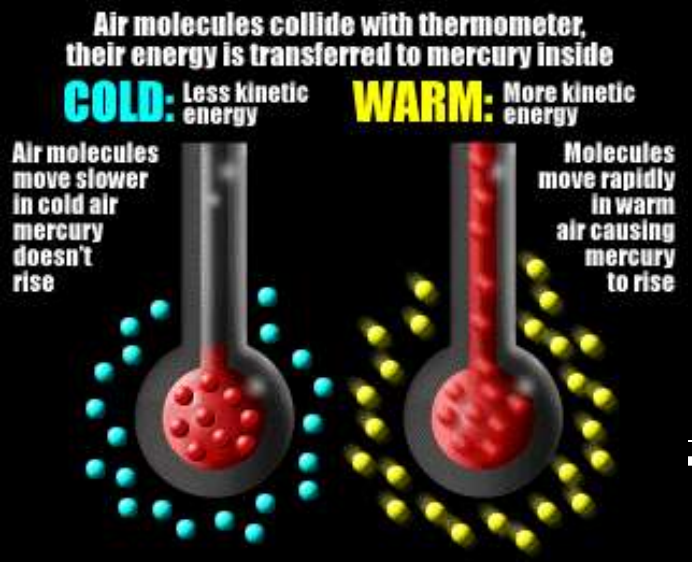
- $T_c = (T_f - 32) / 1.8$
- $T_f = (1.8 \times T_c) + 32$
- What is 212 F in Celsius?

Celsius-Kelvin Conversion

- $T_k = T_c + 273$
- What is 32 Celsius in Kelvin?

Work and Heat

- Temperature is related to the average kinetic energy of the particles in an object due to their random motions through space
- As an object heats up, its particles move faster



Thermal Energy

- Thermal energy depends on mass, temperature, and phase (solid, liquid or gas) of an object.

Thermal Contraction and Expansion

- **Thermal expansion** is an increase in the volume of a material due to a temperature increase
- Thermal expansion occurs when particles of matter move farther apart as temperature increases.

Thermal Contraction and Expansion

- Slower particles collide less often and exert less force, this is called **thermal contraction**

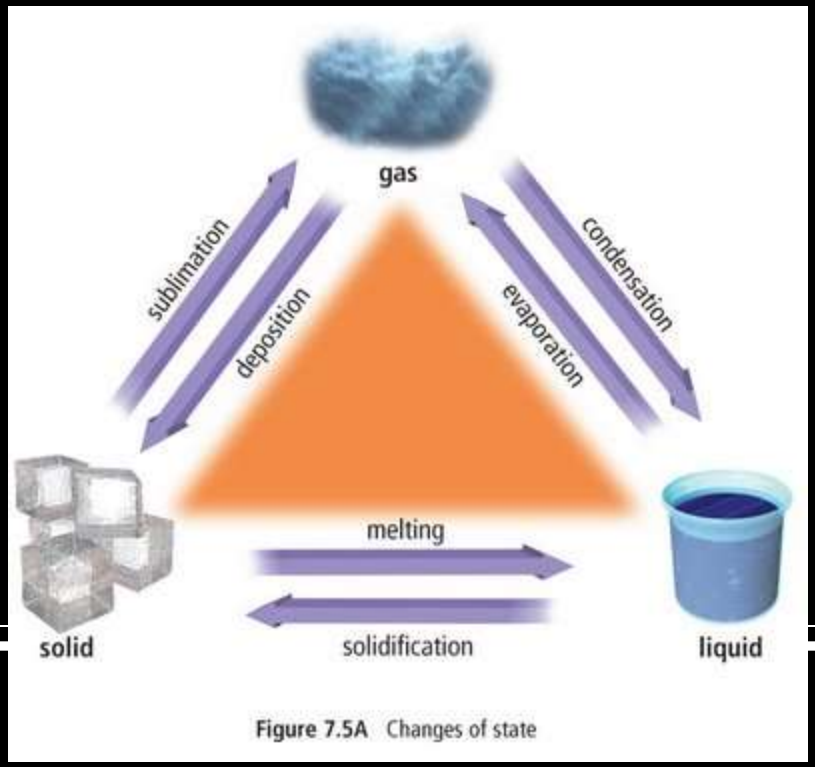


Figure 7.5A Changes of state

Specific Heat

- **Specific heat** is the amount of heat needed to raise the temperature of one gram of material by one degree Celsuis
- The lower a material's specific heat, the more its temperature rises when a given amount of energy is absorbed by a given mass

Specific Heat

- Specific heat is often measured in **Joules** per gram per degree Celsius
  - J/G*C
- It takes 4.18 J of energy to raise the temperature of 1.00 gram of water by 1.00 degree Celsius

Substance	Specific Heat (J/ g °C)
copper	0.3845
granite	0.7953
lead	0.1276
ice	2.06
water	4.184

Measuring Heat Changes

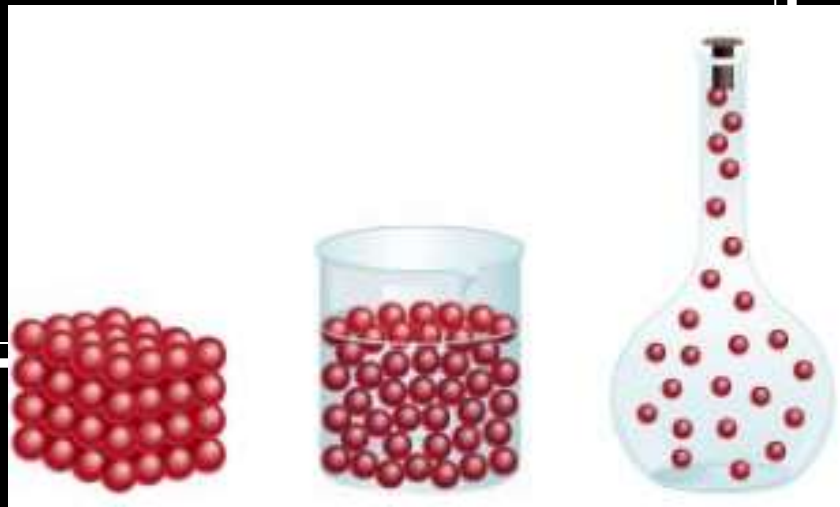
- A **calorimeter** is an instrument used to measure changes in thermal energy
- A calorimeter uses the principle that heat flows from a hotter object to a colder object until both reach the same temperature

Chapter 16: Thermal Energy and Heat

16.2 – Heat and Thermodynamics

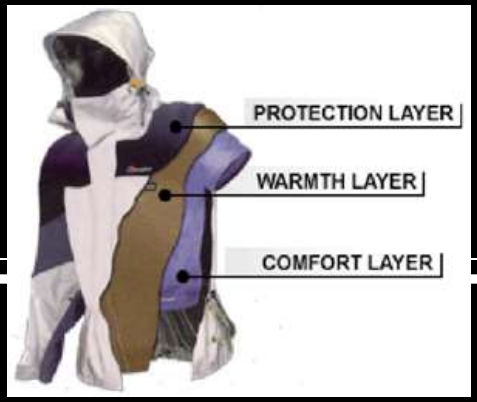
Conduction

- **Conduction** is the transfer of thermal energy with no overall transfer of matter
- Conduction in gases is slower than conduction in liquids and solids because the particles in a gas collide less often



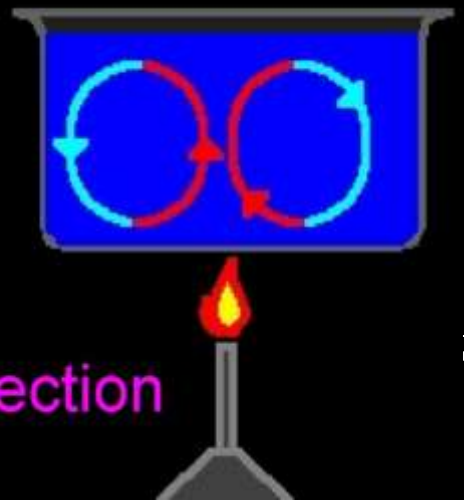
Conduction continued

- **<u>Thermal conductors</u>** are materials that conduct thermal energy well. A wire rack in a hot oven is an example. Pots/pans and copper/aluminum are good conductors
- A material that conducts thermal energy poorly is called a **<u>thermal insulator</u>**



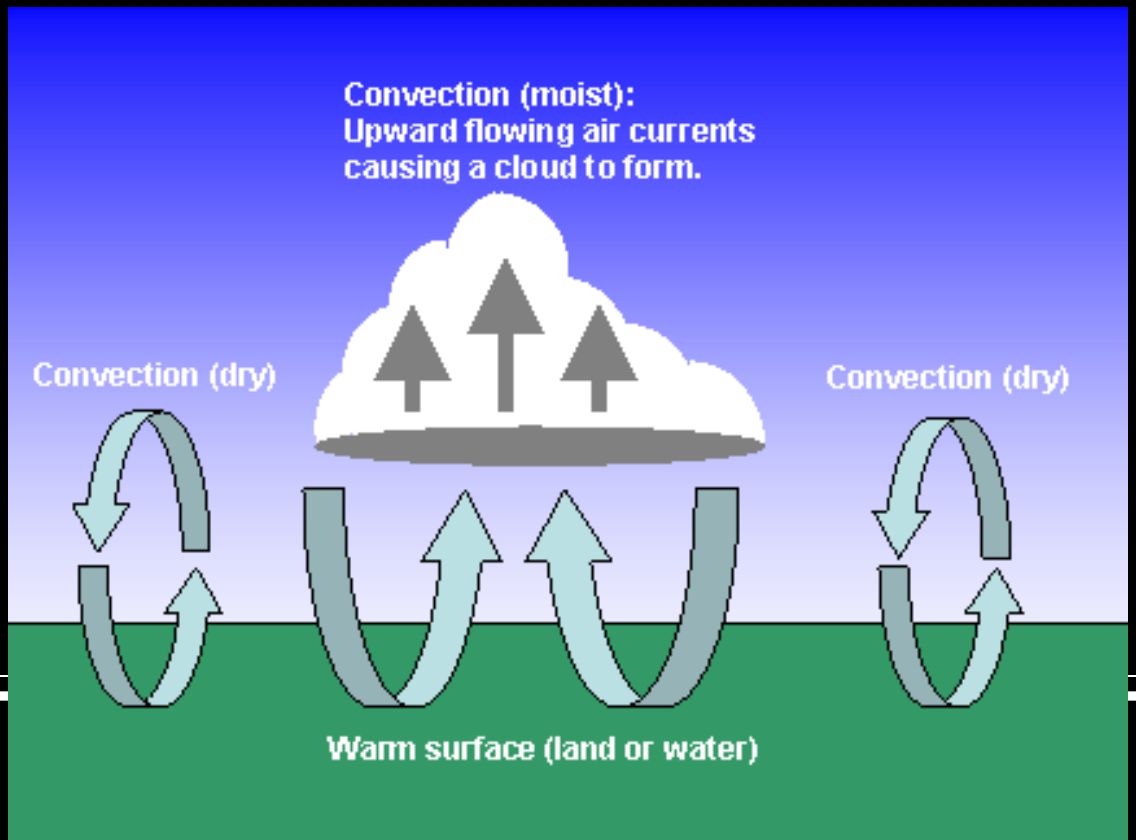
Convection

- **Convection** is the transfer of thermal energy when a particle of a fluid moves from one place to another
- **Convection currents** occur when a fluid circulates in a loop as it alternately heats up and cools down



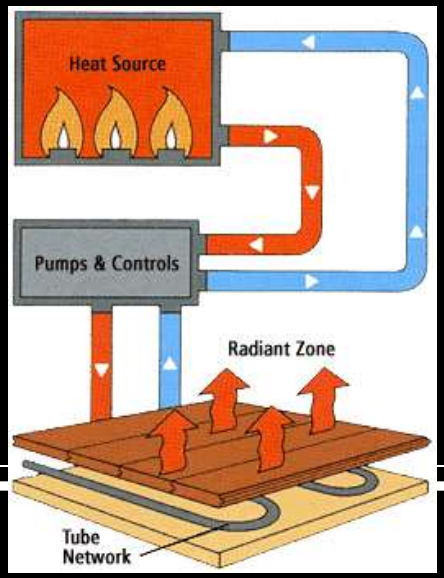
Convection continued

- Convection currents are important in many natural cycles such as ocean currents, weather systems, and movements of hot rock into Earth's interior



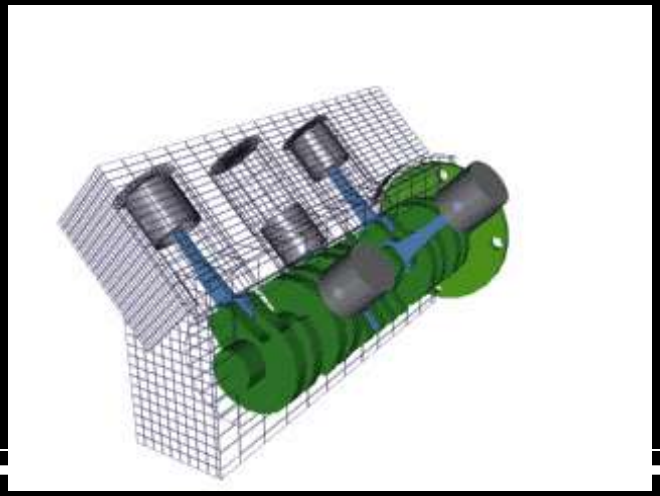
Radiation

- **<u>Radiation</u>** is the transfer of energy by waves moving through space
- All objects radiate energy. As an object's temperature increases, the rate at which it radiates energy increases



Thermodynamics

- The study of conversions between heat and other forms of energy is called **thermodynamics**
- The **first law of thermodynamics** states that energy is conserved



Thermodynamics continued

- The **second law of thermodynamics** states that thermal energy can flow from colder objects to hotter objects only if work is being done on the system

Thermodynamics continued

- A **heat engine** is any device that converts heat into work
- Thermal energy that is not converted into work is called **waste heat**

Thermodynamics continued

- The **third law of thermodynamics** states that absolute-zero cannot be reached

Chapter 16: Thermal Energy and Heat

16.3 – Using Heat

Heat Engines

- **Steam engines** played a key role in the development of the modern industrial world
- A steam engine is an **external combustion engine** – an engine that burns fuel outside the engine

Heat Engines

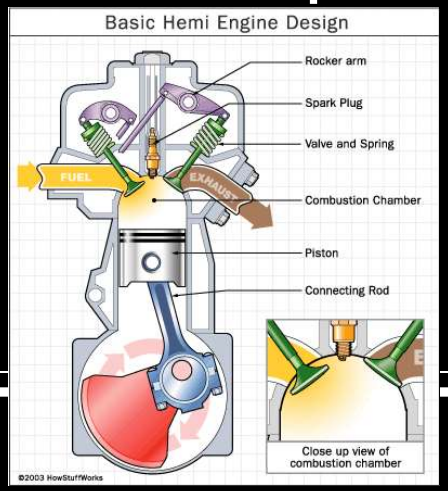
- Thomas Newcomen developed the first practical steam engine in 1712
- In 1765 James Watt designed an engine that was more efficient, in part because it operated at a higher temperature

Heat Engines

- How it works:
  - Hot steam enters the cylinder on the right side
  - When the valve slides to the left hot steam is trapped in the cylinder
  - The steam expands and cools as it pushes the piston to the left
  - Heat is converted into work
  - The piston moves back and forth as hot steam enters on one side and then the other side
  - How steam engine works

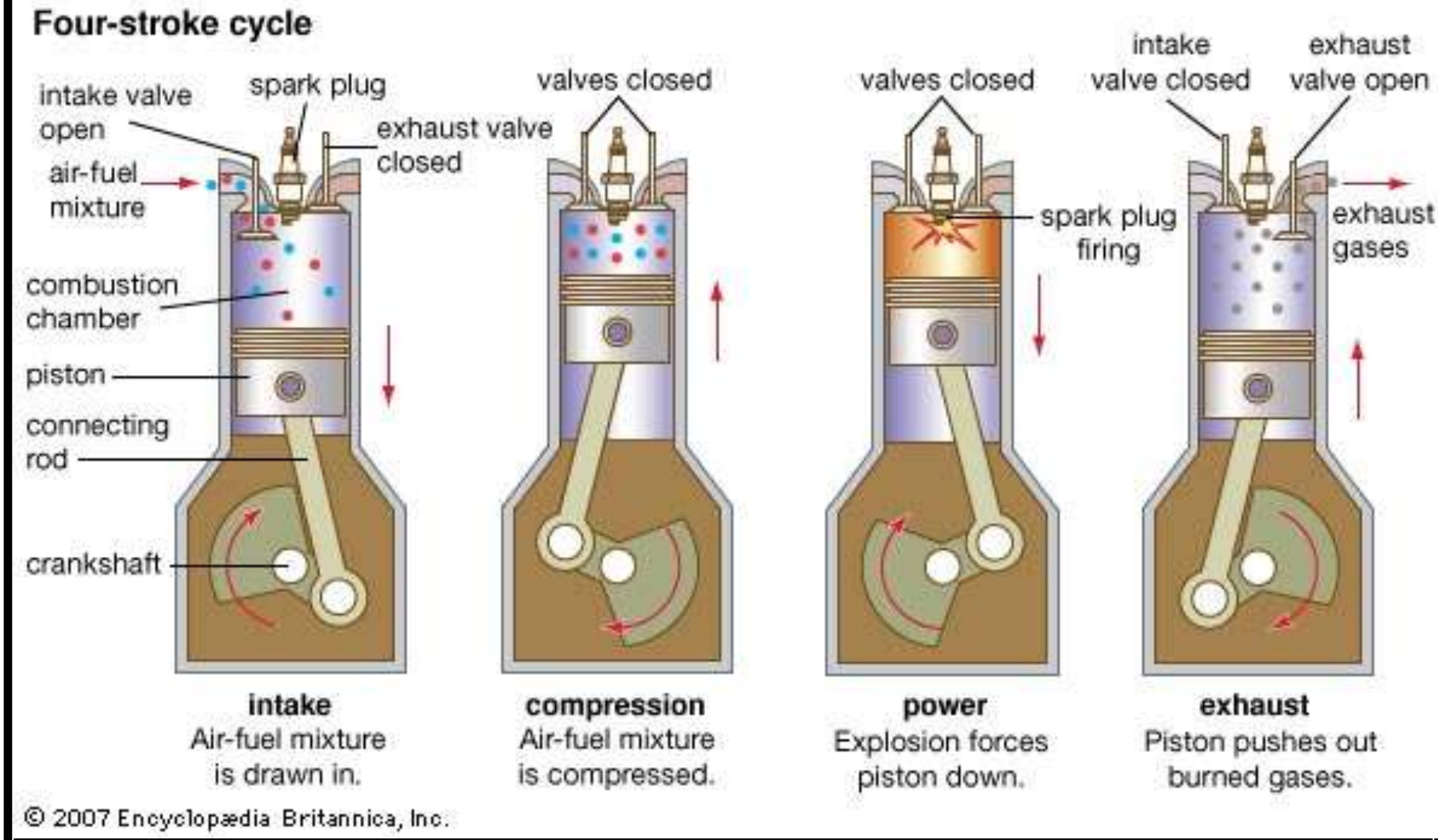
Internal Combustion Engine

- An **internal combustion engine** is a heat engine into which the fuel burns inside the engine
- Most internal combustion engines use pistons that move up and down inside cylinders



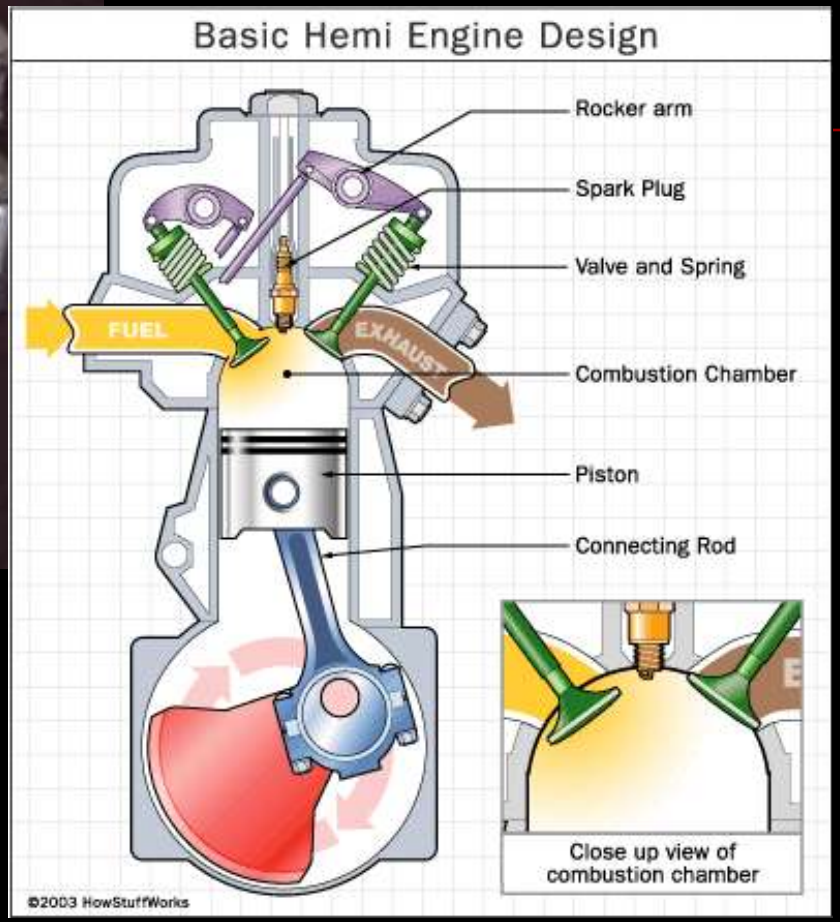
Internal Combustion Engine

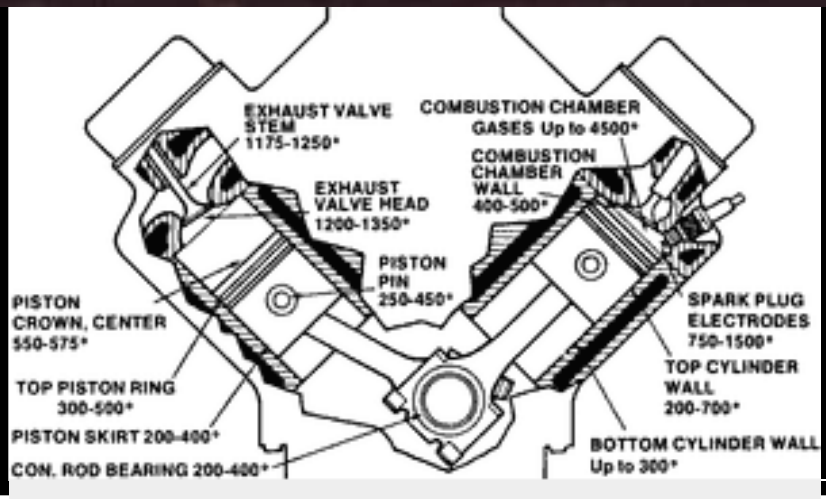
- Each upward and downward motion is called a **stroke**
- Four strokes
  1. Intake – Fuel and air is drawn into the cylinder through the intake valve
  2. Compression – Fuel/air mixture is compressed
  3. Power – A spark ignites the mixture, forcing the piston back down
  4. Exhaust – The exhaust gas is forced out the exhaust valve



http://www.alchemical.org/thermo/other/4%20Cycle%20Engine.swf


HIPERFORMER
remanufactured auto and marine engines

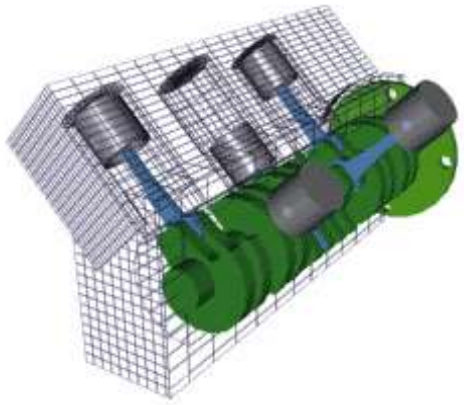

Basic Hemi Engine Design
Rocker arm
Spark Plug
Valve and Spring
FUEL
EXHAUST
Combustion Chamber
Piston
Connecting Rod
Close up view of combustion chamber
©2003 HowStuffWorks


EXHAUST VALVE STEM 1175-1250°
COMBUSTION CHAMBER GASES Up to 4500°
COMBUSTION CHAMBER WALL 400-500°
EXHAUST VALVE HEAD 1200-1350°
PISTON PIN 250-450°
PISTON CROWN, CENTER 550-575°
SPARK PLUG ELECTRODES 750-1500°
TOP CYLINDER WALL 200-700°
TOP PISTON RING 300-500°
PISTON SKIRT 200-400°
CON. ROD BEARING 200-400°
BOTTOM CYLINDER WALL Up to 300°

Internal Combustion Engine

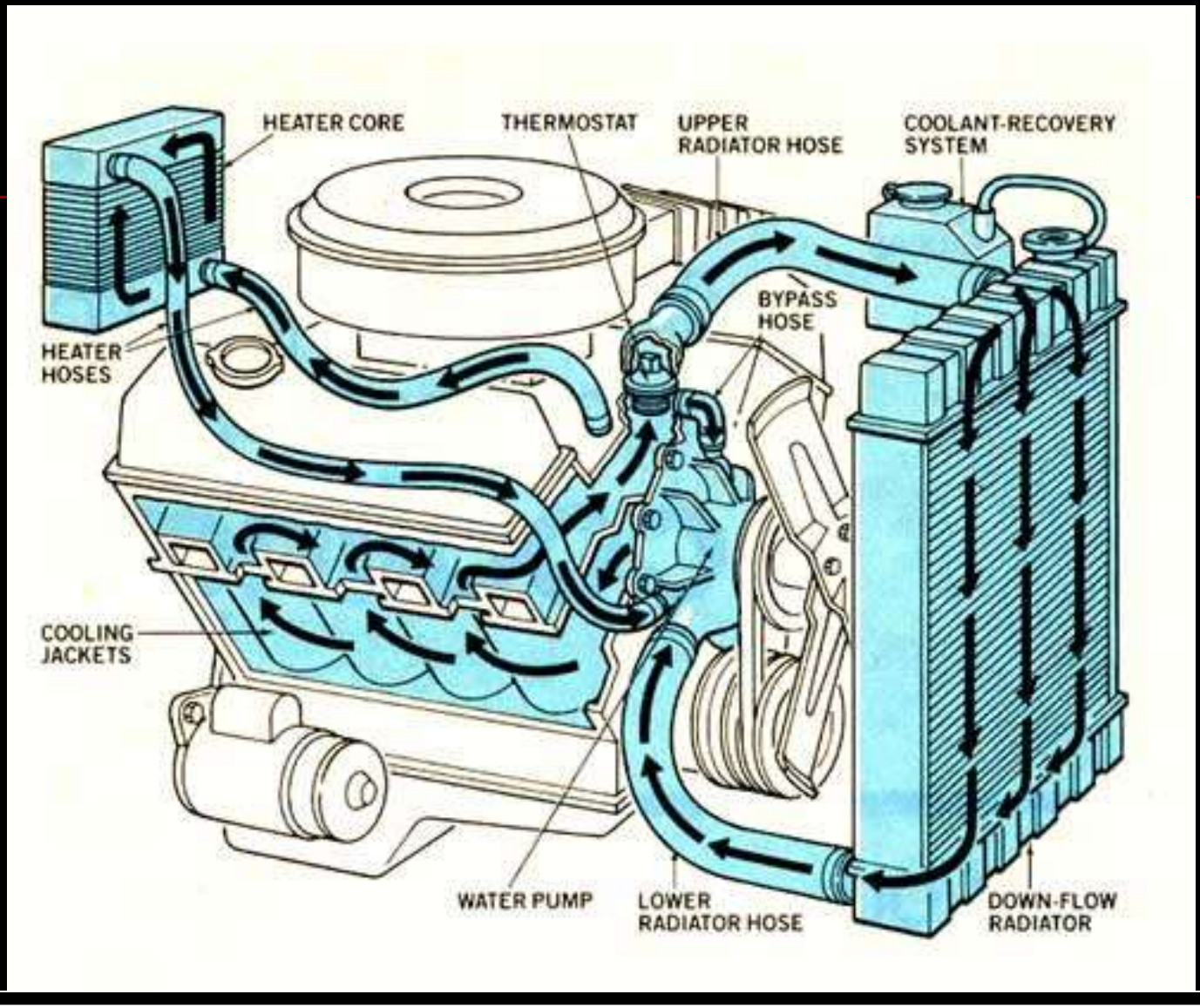
- The linear motion of each stroke is converted into rotary motion by the **crankshaft**. The crankshaft is connected to the transmission, which is linked to the vehicles wheels through the drive shaft

4 cyl vs V-6 vs Opposed
http://auto.howstuffworks.com/engine2.htm



Internal Combustion Engine

- In an internal combustion engine, the cooling system and exhaust transfer heat from the engine to the environment
- A coolant – usually water and antifreeze – absorbs some thermal energy from the engine and passes through the radiator


HEATER CORE
THERMOSTAT
UPPER RADIATOR HOSE
COOLANT-RECOVERY SYSTEM
BYPASS HOSE
HEATER HOSES
COOLING JACKETS
WATER PUMP
LOWER RADIATOR HOSE
DOWN-FLOW RADIATOR

Internal Combustion Engine

- Gasoline engines are more efficient than old-fashioned steam engines, but they are still not very eficient. About one third of the fuel energy in a gasoline engine is converted to work.

- The rest is lost as waste heat!

Heating Systems

- Hot-water Heating
  - Boiler
  - At the boiler, heating **oil** or **natural gas** burns and heats the water. The circulating pump carries the **hot water** to **radiators** in each **room**. The hot water transfers **thermal** energy to the **radiator** by **conduction**. As the pipes heat up, they heat the room air by **conduction** and **radiation**
  - **Temperature** is controlled by a **thermostat**

Heating Systems

- Steam Heating
- The transfer of heat from the steam-heated radiator to the room occurs by conduction and radiation
- Steam heating often is used in older buildings or when many buildings are heated from one central locations

Heating Systems

- Electric baseboard heating
- An electric baseboard heater uses electrical energy to heat a room. A conductor similar to the heating element in an electric stove is used to convert electrical energy to thermal energy. The hot coil heats the air near it by conduction and radiation

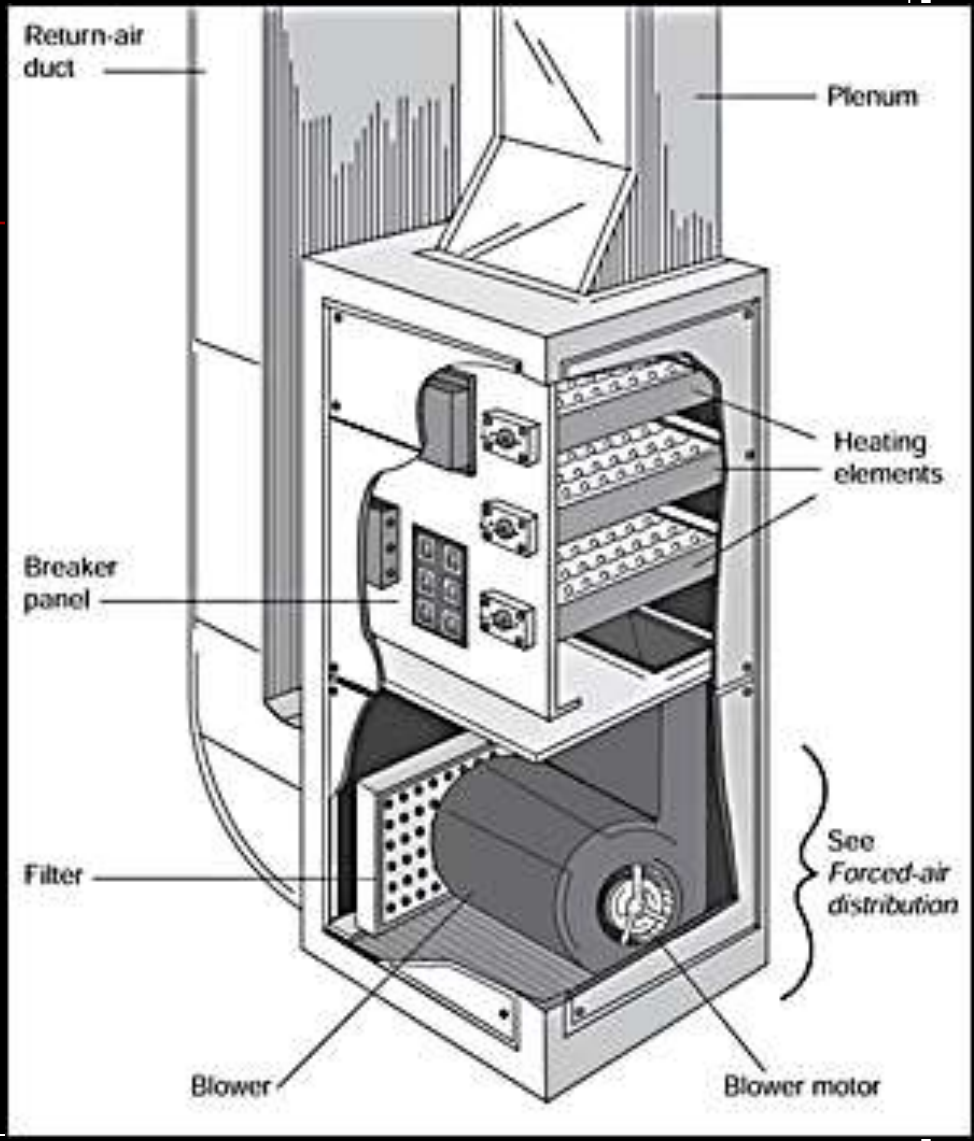
Heating Systems

- Radiant heaters are similar to electric baseboard heating. They are often sold as small portable units. These “space heaters” are easy to turn on and off.

Heating Systems

- Forced-Air Heating
- Forced air heating systems use fans to circulate warm air through ducts to the rooms of a building
- In a forced air heating system, convection circulates air in each room
- One advantage of forced-air heating is that the air is cleaned as it passes through filters located near the furnace


Perfect Heat
PLUS 90t
Air Flow


Return-air duct
Plenum
Heating elements
Breaker panel
Filter
See Forced-air distribution
Blower
Blower motor

Cooling Systems

- A heat pump is a device that reverses the normal flow of thermal energy
- A refrigerant is a fluid that vaporizes and condenses inside the tubing of the heat pump

Cooling Systems

- Heat pumps must do work on a refrigerant in order to reverse the normal flow of thermal energy. In this process, a cold area, such as the inside of a refrigerator, become even colder

Cooling Systems

- Refrigerators
- A refrigerator is a heat pump – it transfers thermal energy from the cold food compartment to the warm room
- A motor must do work to move refrigerant through tubing inside the refrigerator walls

Cooling Systems

- Air Conditioners
- The compressor raises the temperature and pressure of the refrigerant, turning it into a hot, high-pressure gas. The temperature of the condenser coil is higher than the outside air temperature, so heat flows from the coils spontaneously to the outside. A fan increases the rate at which it flows
- As thermal energy is removed from the coil, the refrigerant cools and condenses into a liquid