Thermal Energy

- Disordered
- Kinetic and potential energies of individual atoms
- Presence of thermal energy gives an object temperature

Thermal Energy

- Ordered motion doesn't contribute to thermal energy
  - total kinetic energy - whole object moves
  - lift object up - all atoms acquire gravitational potential energy

Chemical Bonds

- Bring two atoms together - large separation
  - attractive force (electromagnetic)
  - stronger force as atoms get closer

Chemical Bonds

- Bring two atoms together - small separation
  - repulsive force
- Equilibrium separation
  - distance where attraction ends an repulsion begins

Chemical Bonds

- Bring two atoms together
  - they do work on you
  - give up chemical potential energy

Chemical Bonds

- Pull two atoms apart
  - you do work on them

Chemical Bonds

- Molecule
  - a collection of atoms held together by chemical bonds
- Bond Strength
  - work needed to separate atoms from their equilibrium position

Thermal Energy in Chemical Bonds

- Move atoms away from their equilibrium separation
  - the atoms vibrate
  - potential to kinetic to potential to . . .
  - Total energy constant unless transferred elsewhere

Thermal Energy in Chemical Bonds

- Large molecules
  - vibrate and rotate in a complicated way
  - energy can move around within the molecule
  - Total energy still constant unless transferred elsewhere

Thermal Energy in Chemical Bonds

- Solid
  - huge assembly of atoms and molecules held together by chemical bonds
  - random vibrations and wiggles - **thermal motion**
  - associated energy - **thermal energy**

Thermal Energy in Chemical Bonds

- Form of thermal energy changes, kinetic to potential
- Energy moves as atoms do work on each other
- Work done by individual atoms and molecules is small and unorganized

Generating Thermal Energy

- Sliding friction
- Electricity
- Chemical reaction

Chemical Reactions

- Reactants - molecules you start with
- Reaction products - molecules you end up with

Chemical Reactions

- Breaking bonds takes work
- Forming bonds does work

Chemical Reactions

- If bonds in reaction products are stronger than bonds in reactants
- then energy is released
- Chemical potential energy is converted to thermal energy

Chemical Reactions

- Activation energy - energy needed to break old chemical bonds

Chemical Reactions

- Burning wax
  - reactants: wax (carbon and hydrogen) and oxygen
  - Reaction products: water and carbon dioxide

Heat and Temperature

- When two objects touch they exchange thermal energy
- On a microscopic level energy flows both ways
- On average energy flows one way

Heat and Temperature

- Define temperature to predict direction of energy flow
- Energy flows from hotter object to colder object
- No energy flow -> thermal equilibruim -> equal temperatures

Heat and Temperature

- Heat is thermal energy on the move
- Heat flows from high temperature to low temperature

Heat and Temperature

- Standard temperature scale
  - average thermal kinetic energy per particle
- Ideal gas
  - no interactions - no potential energy
  - average kinetic energy per atom

Heat and Temperature

- High temperature
- Lots of microscopic kinetic energy
- Lots of microscopic ability to do work
- Lots of macroscopic heat transfer
- Microscopic work transfers heat

Open Fire

- Burn wood to produce heat
- Heat flows from high to low temperature

- Smoke
- Uses up oxygen
- Unsafe

Fireplace

- Burn wood to produce heat
- Heat flows from high to low temperature

- Gets rid of smoke
- New oxygen enters through cracks in room
- Safer

- Inefficient at transferring heat

Wood Stove

- Burn wood to produce heat
- Heat flows from high to low temperature

- Gets rid of smoke
- New oxygen enters through cracks in room
- Safer

- Efficient heat exchanger

Heat Exchanger

- Separates air used to burn from air in room
- Transfers heat efficiently without transferring particles

Mechanisms of Heat Transfer

- Conduction
- Convection
- Radiation

Conduction

- Heat goes from high to low temperature, but atoms and molecules don't move

Conduction in insulators

- Interaction between neighboring atoms and molecules
- Microscopic exchanges of energy as particles do work on one another
- Atoms fixed, energy moves
- On average energy flows from hot to cold until thermal equilibrium

Conduction in metals

- Metals: electrons not bound to particular atoms, they travel almost freely
- Microscopic exchanges of energy as electrons collide with atoms and molecules
- Electrons can travel long distances before colliding - fast heat transfer
- On average energy flows from hot to cold until thermal equilibrium

Wood Stove

- Conduction
  - moves heat through metal walls of stove

Convection

- Fluid transports heat

Convection

- Fluid heats up near hot object
- Fluid moves away from hot object carrying heat with it
- Fluid cools down near cold object

Convection

- Natural circulation of fluid
  - buoyancy causes hot air to rise
  - as heated air cools it descends
  - cool air is reheated by stove
- Forced circulation makes convection more effective

Wood Stove

- Conduction
  - moves heat through metal walls of stove
- Convection
  - circulates hot air around the room

Radiation

- Heat transferred by electromagnetic waves

Radiation

- Electromagnetic waves travel through empty space at the speed of light
  - radio waves
  - microwaves
  - infrared light
  - visible light
  - ultraviolet light
  - gamma rays

Radiation

- Heat transferred through empty space, not by atoms and molecules
- Type of waves depends on temperature of object
  - cold - radio wave, microwaves, infrared light
  - hot - cold + visible light, ultraviolet light
- High temperature emits more radiation
- Black emits and absorbs well

Campfire

- No conduction - if you don't touch the hot coals
- No convection - unless you are above the fire
- All radiation - face hot, back cold

Wood Stove

- Conduction
  - moves heat through metal walls of stove
- Convection
  - circulates hot air around the room
- Radiation
  - transfers heat using electromagnetic waves