Woodstoves

Turn off all electronic devices

Observations about Woodstoves

- They burn wood in enclosed fireboxes
- They often have long chimney pipes
- Their surfaces are usually dark in color
- They'll burn you if you touch them
- Heat rises off their surfaces
- They warm you when you stand near them

5 Questions about Woodstoves

1. What are thermal energy and heat?
2. How does a woodstove produce thermal energy?
3. Why does heat flow from the stove to the room?
4. Why is a woodstove better than an open fire?
5. How does a woodstove heat the room?

Question 1

Q: What are thermal energy and heat?

A: Disordered energy and its transfer mechanism

- Thermal energy is
  - disordered energy within an object's particles
  - the kinetic and potential energies of those particles
  - responsible for temperature
- Heat is energy flowing between objects
  - due to a difference in their temperatures

Question 2

Q: How does a woodstove produce thermal energy?

A: It converts chemical energy into thermal energy

- Fire releases chemical potential energy
  - Wood and air consist of molecules
  - Molecules are bound by chemical bonds
  - When bonds rearrange, they can release energy
  - Burning rearranges bonds and releases energy!

Chemical Forces and Bonds

- Atoms interact via electromagnetic forces
- The chemical forces between two atoms are
  - attractive at long distances
  - repulsive at short distances
  - zero at a specific equilibrium separation
- Atoms at their equilibrium separation
  - are in a stable equilibrium
  - are bound together by an energy deficit
- Their energy deficit is a chemical bond

Woodstoves 7

A Few Names

- Molecule: atoms joined by chemical bonds
- Chemical bond: a chemical-force linkage
- Bond strength: the work needed to break bond
- Reactants: starting molecules
- Products: ending molecules

Woodstoves 8

Chemical Reactions

- Breaking old bonds takes work
- Forming new bonds does work
- If new bonds are stronger than the old bonds,
  - chemical potential energy → thermal energy
- However, breaking old bonds requires energy
  - reaction requires activation energy to start

Woodstoves 9

When Wood Burns…

- When you ignite wood,
  - the reactants are carbohydrates and oxygen
  - the products are water and carbon dioxide
  - the activation energy comes from a burning match
- This reaction releases energy as thermal energy

Woodstoves 10

Question 3

Q: Why does heat flow from the stove to the room?

A: Because the stove is hotter than the room

- Heat naturally flows from hotter to colder
  - Microscopically, thermal energy moves both ways
  - Statistically, the net flow is from hotter to colder
- At thermal equilibrium, temperatures are equal
  - no heat flows between those objects
- Temperature measures the average thermal kinetic energy per particle (slightly oversimplified)

Woodstoves 11

Question 4

Q: Why is a woodstove better than an open fire?

A: It releases heat, but not smoke, into the room

- An open fire is energy efficient, but has problems
  - Smoke is released into the room
  - Fire uses up the room's oxygen
  - Can set fire to the room
- A fireplace is cleaner, safer, but less efficient
- A woodstove can be clean, safe, and efficient
  - A woodstove is a heat exchanger
  - It separates air used by the fire from room air
  - It transfers heat without transferring smoke

Woodstoves 12

Question 5

Q: How does a woodstove heat the room?

A: It uses all three heat transfer mechanisms

- Those heat transfer mechanisms are
  - conduction: heat flows through materials
  - convection: heat flows via moving fluids
  - radiation: heat flows via electromagnetic waves
- All three transfer heat from hot to cold

Woodstoves 13

Conduction and Woodstoves

- In conduction, heat flows but atoms stay put
- In an insulator,
  - adjacent atoms jiggle one another
  - atoms do work and exchange energies
  - on average, heat flows from hot to cold atoms
- In a conductor,
  - mobile electrons carry heat long distances
  - heat flows quickly from hot to cold spots
- Conduction moves heat through stove's walls

Woodstoves 14

Convection and Woodstoves

- In convection, heat flows with a fluid's atoms
  - Fluid warms up near a hot object
  - Flowing fluid carries thermal energy with it
  - Fluid cools down near a cold object
  - Overall, heat flows from hot to cold
- Buoyancy drives natural convection
  - Warmed fluid rises away from hot object
  - Cooled fluid descends away from cold object
- Convection circulates hot air around the room

Woodstoves 15

Radiation and Woodstoves

- In radiation, heat flows via electromagnetic waves (radio waves, microwaves, light, …)
- Range of waves depends on temperature
  - cold: radio wave, microwaves, infrared light
  - hot: infrared, visible, and ultraviolet light
- Higher temperature → more radiated heat
- Blacker surface → more radiated heat
- Black emits and absorbs radiation perfectly

Woodstoves 16

Stefan-Boltzmann Law

- Emissivity is a surface's emission-absorption efficiency
  - 0 → perfect inefficiency: white, shiny, or clear
  - 1 → perfect efficiency: black
- The amount of heat a surface radiates is

$$\text{power} = \text{emissivity} \cdot \text{Stefan-Boltzmann constant} \cdot \text{temperature}^4 \cdot \text{surface area}$$

where temperature is measured on an absolute scale

Woodstoves 17

What About Campfires?

- No conduction, unless you touch hot coals
- No convection, unless you are above fire
- Lots of radiation:
  - your face feels hot because radiation reaches it
  - your back feels cold because no radiation reaches it

Woodstoves 18

Summary about Wood Stoves

- Use all three heat transfer mechanisms
- Have tall chimneys for heat exchange
- Are dark-coated to encourage radiation
- Are sealed to keep smoke out of room air