Woodstoves

Question

- Which is more effective at heating a room:
- a black woodstove
- a white woodstove

Observations About Wood Stoves

- They burn wood inside closed fireboxes
- They often have long chimney pipes
- They are usually black
- You get burned if you touch them
- Heat rises off their surfaces
- It feels hot to stand near them

Thermal Energy

- is disordered energy
- is kinetic and potential energies of atoms
- gives rise to temperature
- does not include order energies:
  - kinetic energy of an object moving or rotating
  - potential energy of outside interactions

Heat

- is energy that flows between objects because of their difference in temperature
- is thermal energy on the move
- Technically, objects don't contain "heat"

Burning Wood

- Fire releases chemical potential energy
  - Wood and air consist of molecules
  - Molecules are bound by chemical bonds
  - When bonds rearrange, they release energy
  - Burning involves bond rearrangement

Chemical Forces Part 1

- Atoms interact via electromagnetic forces
- Large separations: atoms attract
  - Attraction is weak at great distances
  - Attraction gets stronger as atoms get closer
  - Attraction reaches a maximum strength
  - Attraction weakens as they approach further

Chemical Forces Part 2

- Medium separations: equilibrium
  - Attraction vanishes altogether at equilibrium
- Small separations: atoms repel
  - Repulsion gets stronger as atoms get closer

Chemical Bonds Part 1

- When atoms are brought together, they
  - do work
  - release chemical potential energy
- By the time they reach equilibrium, they
  - have released a specific amount of energy
  - have become bound together chemically

Chemical Bonds Part 2

- To separate the atoms,
  - you must do work on them
  - return the specific amount of energy to them

Chemical Concepts

- Molecule: atoms joined by chemical bonds
- Chemical bond: chemical-force linkages
- Bond strength: work needed to break bond
- Reactants: starting molecules
- Reaction products: ending molecules

Chemical Reactions

- Breaking old bonds takes work
- Forming new bonds does work
- If new bonds are stronger than old,
  - chemical potential energy $\rightarrow$ thermal energy
- Breaking old bonds requires energy
  - reaction requires activation energy to start

Burning Wood

- Reactants: carbohydrates and oxygen
- Products: water and carbon dioxide
- Activation energy: a burning match

Thermal Energy and Bonds

- Thermal energy causes atoms to vibrate
- Atoms vibrate about equilibrium
  - Experience restoring forces about equilibrium
  - Energy goes: potential→kinetic→potential…
  - Total energy is constant unless transferred
- Temperature set by thermal kinetic energy

Heat and Temperature

- Objects exchange thermal energy
  - Microscopic energy flows both ways
  - Average energy flows from hotter to colder
- Temperature predicts energy flow direction
  - No flow → thermal equilibrium → same temp
- Temperature is:
  - Average thermal kinetic energy per particle

Open Fire

- Burns wood to release thermal energy
- Good features:
  - Heat flows from hot fire to cold room
- Bad features:
  - Smoke enters room
  - Fire uses up room's oxygen
  - Can set fire to room

Fireplace

- Burns wood to release thermal energy
- Good features:
  - Heat flows from hot fire to cold room
  - Smoke goes mostly up chimney
  - New oxygen enters room through cracks
  - Less likely to set fire on room
- Bad features:
  - Inefficient at transferring heat to room

Woodstove

- Burns wood to release thermal energy
- Good features:
  - Heat flows from hot fire to cold room
  - All the smoke goes up chimney pipe
  - New oxygen enters room through cracks
  - Relatively little fire hazard
  - Transfers heat efficiently to room

Heat Exchanger

- Woodstove is a heat exchanger
  - Separates air used by the fire from room air
  - Transfers heat without transferring smoke

Heat Transfer Mechanisms

- Conduction: heat flow through materials
- Convection: heat flow via moving fluids
- Radiation: heat flow via light waves
- All three transfer heat from hot to cold

Conduction

- Heat flows but atoms don't
- 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

Woodstoves

- Conduction
  - moves heat through the stove's metal walls

Convection

- Fluid transports heat stored in its 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
- Natural buoyancy drives convection
  - Warmed fluid rises away from hot object
  - Cooled fluid descends away from cold object

Woodstoves

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

Radiation

- Heat flows by electromagnetic waves (radio waves, microwaves, light, …)
- Wave types depend on temperature
  - cold: radio wave, microwaves, infrared light
  - hot: infrared, visible, and ultraviolet light
- Higher temperature → more radiated heat
- Black emits and absorbs light best

Stefan-Boltzmann Law

- 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 emissivity is emission efficiency
- Emissivity
  - 0 is worst efficiency: white, shiny, or clear
  - 1 is best efficiency: black

Woodstoves

- Conduction
  - moves heat through the stove's metal walls
- Convection
  - circulates hot air around the room
- Radiation
  - transfers heat directly to your skin as light

Campfires

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

Question

- Which is more effective at heating a room:

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Summary About Wood Stoves

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