

Woodstoves 1

Woodstoves

Woodstoves 2

Question

Which is more effective at heating a room:

- a black woodstove
- a shiny chrome-plated woodstove

Woodstoves 3

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

Woodstoves 4

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

Woodstoves 5

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"

Woodstoves 6

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 → 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 stable 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:

- a black woodstove
- a shiny chrome-plated woodstove

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