Woodstoves

Question

Which is more effective at heating a room:

1. a black woodstove
2. a white woodstove

Thermal Energy

- is disordered energy
- is the 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 the energy that flows between objects because of their difference in temperatures
- Heat is thermal energy on the move
- Technically: object's don't *contain* heat

Burning Wood

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

Chemical Forces

- Atoms exert electromagnetic forces on each other
- At large separations, atoms attract
  - Attraction is weak at great distances
  - Attraction gets stronger as atoms get closer
  - Attraction eventually reaches a maximum strength
  - Attraction weakens as they approach further
- At medium separations, atoms are in equilibrium
  - Attraction vanishes altogether at equilibrium
- At close separations, atoms repel
  - Repulsion gets stronger as atoms get closer

Chemical Bonds

- When two 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
- To separate the two atoms,
  - you must do work on them
  - return that 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 bonds takes work
- Forming bonds does work
- If reaction-product bonds are stronger than reactant bonds, then
  - chemical potential energy → thermal energy
- Breaking reactant bonds requires energy
  - reaction may require activation energy to start

Burning Wood

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

Thermal Energy and Bonds

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

Heat and Temperature

- Touching objects exchange thermal energy
  - Microscopically, energy flows both ways
  - On average, energy flows one way
- Temperature predicts energy flow direction
  - Energy flows from hotter to colder
  - No flow → thermal equilibrium → same temp
- Temperature turns out to be
  - 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 to 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 to burn wood 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 through material but atoms don't
- In an insulator,
  - adjacent atoms jiggle one another
  - microscopic exchanges of energy; atoms do work
  - on average, heat flows from hot to cold atoms
- In a conductor,
  - mobile electrons help carry heat long distances
  - heat flows quickly from hot to cold via electrons

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
  - Fluid flows away, carrying 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 transferred 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
  - ranges from 0 (bad) to 1 (good)
  - 0 is white, shiny, or clear; 1 is 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 hot, back cold

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