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 atoms bound together by chemical bonds
- When molecules rearrange, they can release chemical potential energy

When materials burn in air,
- reactant molecules are converted into product molecules
- chemical potential energy is converted into thermal energy!

Chemical Forces and Bonds

Atoms interact with one another via electromagnetic forces that are
- attractive at long distances
- repulsive at short distances
- zero at a specific equilibrium separation

Atoms in molecules normally reside near their equilibrium separations
- They are in stable equilibrium
- They are bound together by energy deficits—separating them requires energy

Their energy deficits are their chemical bonds
- Bond strength is the energy required to break a specific chemical bond

Chemical Reactions

Breaking old bonds takes work, forming new bonds does work

When wood burns in air,

- the reactants are carbohydrates and oxygen
- the products are water and carbon dioxide
- the new bonds are stronger than the old bonds,
- so chemical potential energy is transformed into thermal energy

However, energy is required to break the old bonds,

- wood does not burn at room temperature
- wood must be heated to high temperature before it begins burning
- because activation energy is required for combustion to occur
- the initial activation energy comes from a burning match

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 actually moves both ways
- Statistically, however, the net flow of heat is from hotter to colder

At thermal equilibrium, no heat flows between objects

- Objects in thermal equilibrium have equal temperatures

Temperature controls the direction in which heat flows

- measures the average thermal kinetic energy per particle (slightly oversimplified)

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

- releases smoke into the room
- consumes some of the room's oxygen
- can set fire to objects in the room

A fireplace is cleaner and safer, but less energy efficient

A woodstove can be clean, safe, and energy efficient

- A woodstove is a heat exchanger—releases heat but not smoke into the room
- Its consumption of the room's oxygen can be minimized
- It is unlikely to set fire to objects in the room

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 heat transfer mechanisms transfer heat from hot to cold

Conduction and Woodstoves

In conduction, heat flows but atoms remain in place

In an electrical insulator (e.g., ceramics and organic materials),

- adjacent atoms jiggle one another
- atoms do work and exchange energies
- on average, heat flows gradually from hotter regions to cold regions

In an electrical conductor (e.g., metals),

- mobile electrons carry thermal energy long distances
- on average, heat flows quickly from hotter regions to cold regions

In a woodstove, conduction moves heat through stove's walls

Convection and Woodstoves

In convection, heat flows with a fluid's atoms and molecules

- 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 from a hot object
- Cooled fluid descends from a cold object
- Natural convection circulates hot air around the room

Radiation and Woodstoves

In radiation, heat flows from a surface via electromagnetic waves

- Electromagnetic waves include radio waves, microwaves, light, …
- You can see some thermal radiation with your eyes

The range of electromagnetic waves depends on surface temperature

- A cold surface emits radio wave, microwaves, infrared light
- A hot surface emits infrared, visible, and ultraviolet light

The higher the temperature, the more thermal radiation emitted

The blacker the surface, the more thermal radiation emitted

- A black emits and absorbs radiation perfectly
- A white, shiny, or transparent surface neither emits nor absorbs it

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

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

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