Air Conditioners

Turn off all electronic devices

Observations about Air Conditioners

- They cool the air in a room
- They emit hot air from their outside vents
- They consume lots of electric power
- They are less efficient on hotter days
- Some can be reversed so that they heat room air

5 Questions about Air Conditioners

1. Why doesn't heat flow naturally from cold to hot?
2. Why does an air conditioner need electricity?
3. How does an air conditioner cool room air?
4. What role does the electricity play?
5. How does an air conditioner heat outdoor air?

Question 1

Q: Why doesn't heat flow naturally from cold to hot?
A: Such heat flow would violate the law of entropy

- There are 4 laws of thermodynamics that
  - govern the flow of thermal energy
  - relate disordered (thermal) energy and ordered energy
  - relate heat and work
- We will consider 3 of those laws

Law of Thermal Equilibrium

This law observes that there is a consistency about situations in which heat does not flow:

"If two objects are in thermal equilibrium with a third object, then they are in thermal equilibrium with each other."

Law of Conservation of Energy

This law recognizes that heat is a form of energy:

"The change in the internal energy equals the heat in minus the work out"

where:

- The internal energy is thermal + stored energies
- The heat in is the heat transferred into object
- The work out is the external work done by object

Order versus Disorder

- Converting ordered energy into thermal energy
  - involves events that are likely to occur
  - is easy to accomplish and often happens
- Converting thermal energy into ordered energy
  - involves events that are unlikely to occur
  - is hard to accomplish and effectively never happens
- Statistically, disordered never becomes ordered

Entropy

- Entropy
  - is the measure of a system's disorder
  - includes every type of disorder: energy and structure
- Entropy
  - never decreases in a system that is thermally isolated
  - can be rearranged within a system
  - can be transferred between systems
  - is NOT a conserved quantity!

Law of Entropy

This law observes that entropy guides the time evolution of isolated systems:

"The entropy of a thermally isolated system never decreases"

More on the Law of Entropy

- According to the Law of Entropy:
  - Entropy of thermally isolated system can't decrease
  - but entropy can be rearranged within that system
  - so part of the system can become colder as another part becomes hotter!
  - Entropy is "exported" from cold part to hot part
- Exporting entropy is like throwing out trash!

Natural Heat Flow

- One unit of thermal energy is more disordering to a cold object than to a hot object
- When heat flows from hot object to cold object,
  - hot object's entropy: ↓
  - cold object's entropy: ↑↑
  - so their total entropy: ↑
- Law of Entropy is satisfied

Hypothetical Energy and Entropy

Thermal Energy	Entropy
0	0
1	4
2	7
3	9
4	10

Unnatural Heat Flow

- When heat flows from cold object to hot object,
  - cold object's entropy: ↓↓
  - hot object's entropy: ↑
  - so their total entropy: ↓
- Law of Entropy would be violated,
  - unless we create of additional entropy!
  - unless something ordered becomes disordered!

Question 2

Q: Why does an air conditioner need electricity?

A: Electricity provides the necessary order

- An air conditioner
  - moves heat from cold (room air) to hot (outside air)
  - would cause total entropy of world to decrease
  - were it not for the electric power it consumes!
- It turns electric power into thermal power
  - so the total entropy of world does not decrease

Heat Machines

- Air conditioners are heat pumps
  - use work to transfer heat from cold to hot
- Automobiles are heat engines
  - use flow of heat from hot to cold to do work
- Heat machines are governed by law of entropy

Air Conditioner

- An air conditioner uses a working fluid to
  - absorb heat from cold (room air)
  - release heat to hot (outside air)
- The evaporator (indoors)
  - transfers heat from cold (room air) to working fluid
- The condenser (outdoors)
  - transfers heat from working fluid to hot (outside air)
- The compressor (outdoors)
  - does work on working fluid and produces entropy.

Question 3

Q: How does an air conditioner cool room air?

A: Its evaporator absorbs heat from the room air

- Evaporator is wide indoor pipe
- Working fluid
  - enters evaporator as cool low-pressure liquid
  - absorbs heat from room air and evaporates
  - leaves evaporator as a cool low-pressure gas
- Heat has been removed from the room!

Question 4

Q: What role does the electricity play?

A: It powers the compressor and creates entropy

- Compressor increases gas's pressure and density
- Working fluid
  - enters compressor as a cool low-density gas
  - has work done on it by the compressor
  - leaves compressor as hot high-density gas
- Entropy has been created!

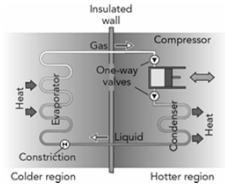
Question 5

Q: How does an air conditioner heat outdoor air?
A: Its condenser releases heat to the outdoor air

- Condenser is narrow outdoor pipe at high pressure
- Working fluid
  - enters condenser as hot high-pressure gas
  - releases heat to outdoor air and condenses
  - leaves condenser as a cool high-pressure liquid
- Heat has been delivered to the outdoors!

Air Conditioner Overview

- Fluid evaporates in evaporator
  - absorbing heat from room air
- Compressor raises pressure
  - evaporation → condensation
- Fluid condenses in condenser
  - releasing heat to outdoor air
- Constriction lowers pressure
  - condensation → evaporation
- and the cycle repeats endlessly…



Summary about Air Conditioners

- They pump heat from cold to hot
- They don't violate thermodynamics
- They convert ordered energy to thermal energy