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

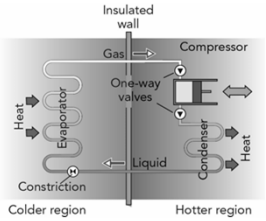
Fluid condenses in condenser

- 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