

Air Conditioners

Question

If you open the door of a refrigerator and let it operate for a while, the average temperature in the room will

1. become colder
2. become hotter
3. stay the same

Heat Machines

- Air conditioners
 - use work to transfer heat from cold to hot
 - heat pumps
- Automobiles
 - use flow of heat from hot to cold to do work
 - heat engines

Thermodynamics

- Rules governing movement of thermal energy
- Relationships between
 - thermal energy and mechanical work
 - disordered energy and ordered energy
- Codified in the four laws of thermodynamics

0th Law

Law about Thermal Equilibrium

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

1st Law

Law about Conservation of Energy

“Change in internal energy equals heat in minus work out”

where:

- Internal energy: thermal + stored energies
- Heat in: heat transferred into the object
- Work out: outside work done by the object

Order versus Disorder

- It is easy to convert ordered energy into thermal (disordered) energy
- It is hard to converting thermal energy into ordered energy
- Statistically, order → disorder is one-way

Entropy

- Entropy is a measure of an object's disorder
 - Includes thermal disorder and structural disorder
- Disorder of isolated system never decreases
- Entropy can move or be transferred

2nd Law

Law about Disorder (Entropy)

“Entropy of a thermally isolated system never decreases”

3rd Law

Law about Entropy and Temperature

“An object's entropy approaches zero as its temperature approaches absolute zero”

More on the 2nd Law

- According to the 2nd Law:
 - Entropy of thermally isolated system can't decrease
 - But entropy can be redistributed within system
 - Part can become hotter while part becomes colder!

Natural heat flow

- Heat naturally flows from hot to cold
 - Remove heat from hot object—entropy decreases
 - Add heat to cold object—entropy increases
- Entropy of combined system increases
- A joule of thermal energy is more disordering to a cold object than to a hot object

Unnatural heat flow

- Can heat naturally flow from cold to hot? NO!
 - Removing heat from cold object decreases entropy
 - Adding heat to hot object increases entropy
 - More entropy removed than added
 - Energy is conserved, but total entropy decreases
- To avoid violating 2nd law, need more entropy
- Ordered energy must become disordered

Air conditioner

- Moves heat against its natural flow
 - Heat flows from cold room air to hot outside air
 - Converts ordered energy into disordered energy
 - Doesn't decrease the world's total entropy!
- Uses fluid to transfer heat – working fluid
 - Working fluid absorbs heat from cool room air
 - Working fluid releases heat to warm outside air

Air conditioner

- Evaporator – located in room air
 - transfers heat from room air to fluid
- Condenser – located in outside air
 - transfers heat from fluid to outside air
- Compressor – located in outside air
 - does work on fluid and creates entropy

Evaporator 1

- Heat exchanger made from long metal pipe
- Fluid approaches evaporator
 - as a high pressure liquid near room temperature
- A constriction reduces the fluid's pressure
- Fluid enters evaporator
 - as a low pressure liquid near room temperature

Evaporator 2

- Working fluid evaporates in the evaporator
 - Breaking bonds takes energy – thermal energy
 - Fluid becomes colder gas
 - Heat flows from room air into fluid
- Fluid leaves evaporator
 - as a low pressure gas near room temperature
- Heat has left the room!

Compressor

- Working fluid enters compressor
 - as a low pressure gas near room temperature
- Compressor does work on fluid
 - Pushes gas inward as the gas moves inward
 - Gas temperature rises (first law)
 - Ordered energy becomes disordered energy
- Fluid leaves compressor
 - as hot, high pressure gas

Condenser 1

- Heat exchanger made from long metal pipe
- Fluid enters condenser
 - as a hot, high pressure gas
 - heat flows from fluid to outside air

Condenser 2

- Working Fluid condenses in the condenser
 - forming bonds releases energy – thermal energy
 - Fluid becomes hotter liquid
 - More heat flows from fluid into outside air
- Fluid leaves condenser
 - as high pressure liquid near room temperature
- Heat has reached the outside air!

Air conditioner Summary

- Evaporator – located in room air
 - transfers heat from room air to fluid
- Compressor – located in outside air
 - does work on fluid, so fluid gets hotter
- Condenser – located in outside air
 - transfers heat from fluid to outside air,
 - including thermal energy extracted from inside air
 - and thermal energy added by compressor

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