Air Conditioners

Question

If you operate a window air conditioner on a table in the middle of a room, the average temperature in the room will

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

Observations About Air Conditioners

- They cool room air on hot days
- They emit hot air from their outside vents
- They consume lots of electric power
- They are less efficient on hotter days
- They can sometimes heat houses, too

Heat Machines

- Air conditioners
  - use work to transfer heat from cold to hot
  - are a type of heat pump
- Automobiles
  - use flow of heat from hot to cold to do work
  - are a type of heat engine

Thermodynamics

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

0^{th} 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 object

Work out: external work done by 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 to disorder is one-way

Entropy

- Entropy is measure of object's disorder
  - Includes both thermal and structural disorders
- Isolated system's disorder never decreases
- But 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 a thermally isolated system can't decrease
  - But entropy can be redistributed within the system
  - Part of the system can become hotter while another part becomes colder!

Natural Heat Flow

- Heat naturally flows from hot to cold
  - Removing heat from a hot object, ↓ entropy
  - Adding heat to a cold object, ↑ entropy
- Entropy of combined system increases
- 1 J of thermal energy is more disordering to a cold object than to a hot object

Unnatural Heat Flow

- Heat can't naturally flow from cold to hot
  - Removing heat from cold object, ↓ entropy
  - Adding heat to hot object, ↑ entropy
  - More entropy removed than added
  - Energy is conserved, but ↓ total entropy
- To save 2nd law, we need more entropy
- Ordered energy must become disordered

Air conditioners, Part 1

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

Air conditioners, Part 2

- 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, Part 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, Part 2

- Working fluid evaporates in the evaporator
  - Breaking bonds uses 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, Part 1

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

Condenser, Part 2

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

Air conditioner Overview

- 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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Summary About Air Conditioners

- They pump heat from cold to hot
- They don't violate thermodynamics
- They consume ordered energy
- They are most efficient for small temperature differences