Automobiles

Air conditioner

Laws Governing Heat

The four laws of thermodynamics are the rules governing thermal energy flow and establish the relationships between disordered (thermal) energy and ordered energy heat and work.
0th Law of Thermodynamics

The 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 of Thermodynamics

The 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

Converting ordered energy into thermal energy involves events that are likely to occur and is easy to accomplish and often happens.

Converting thermal energy into ordered energy involves events that are unlikely to occur and is hard to accomplish and effectively never happens.

Statistically, ordered always becomes disordered.

Entropy

Entropy is the measure of an object’s disorder. It includes both thermal and structural disorders. An isolated system’s entropy never decreases but entropy can move or be transferred.

2nd Law of Thermodynamics

The law about disorder (entropy): “Entropy of a thermally isolated system never decreases.”

3rd Law of Thermodynamics

The 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

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,
   the hot object’s entropy decreases by a small amount
   and the cold object’s entropy increases by a large amount,
so the overall entropy of the system increases
and total energy is conserved

Laws of motion and thermodynamics satisfied

Unnatural Heat Flow

One unit of thermal energy is more disordering to a cold object than to a hot object.

When heat flows from cold object to hot object,
   the cold object’s entropy decreases by a large amount,
   and the hot object’s entropy increases by a small amount
so the overall entropy of the system decreases
although total energy is conserved

The 2nd law of thermodynamics is violated
   To save 2nd law, we need more entropy!
   Ordered energy must become disordered energy!
**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”

**Air conditioners**

An air conditioner
  - moves heat from cold room air to hot outside air
  - moves heat against its natural flow
  - must convert ordered energy into disordered energy
  - so as not to decrease the world’s total entropy!
  - uses a “working fluid” to transfer heat
    - This fluid absorbs heat from cool room air
    - This fluid releases heat to warm outside air

Evaporator
  - is located in room air
  - transfers heat from room air to working fluid

Condenser
  - is located in outside air
  - transfers heat from working fluid to outside air

Compressor
  - is located in outside air
  - does work on working fluid and produces entropy
The Evaporator

The evaporator is a long, wide metal pipe
pipe is heat exchanger between air and working fluid
The working fluid
arrives as a high pressure, room temperature liquid
but loses pressure passing through a constriction
and enters the evaporator as a low pressure liquid
Loss of pressure destabilizes the liquid phase
The liquid working fluid begins to evaporate!
Fluid absorbs thermal energy while evaporating,
so it transforms into a cold gas
Heat flows from the hot room air to the cold gas
Working fluid leaves the evaporator
as a low density gas near room temperature
and carries away some of the room’s thermal energy
Heat has left the room!

The Compressor

The compressor increases density of a gas
Working fluid
arrives as a low density gas near room temperature,
has work done on it by the compressor,
and experiences a rise in temperature as a result.
Working fluid leaves the compressor
as a hot, high density gas
and carries away electric energy as thermal energy
Ordered energy has become disordered energy!
The Condenser

The condenser is a long, narrow metal pipe
pipe is heat exchanger between air and working fluid
The working fluid
arrives as a hot, high density gas
but begins to lose heat to the cooler outdoor air
Loss of heat destabilizes the gaseous phase
The gaseous working fluid begins to condense!
Fluid releases thermal energy while condensing, so it transforms into a hot liquid
and even more heat flows from fluid into outside air
Working fluid leaves the condenser as high-pressure room-temperature liquid
having released some of the room’s thermal energy
Heat has reached the outside air!

Air Conditioner Overview

Evaporator – located in room air
transfers heat from room air to working fluid

Compressor – located in outside air
does work on fluid, so working fluid gets hotter

Condenser – located in outside air
transfers heat from working fluid to outside air, including thermal energy extracted from inside air and thermal energy added by compressor