Important dates:

- Monday, November 29, 1:00pm
  Term paper topic due (optional)
- Monday, December 6, 1:00pm
  Term paper due
- Wednesday, December 15, 9:00am - 12:00noon
  Final exam

Machines

- Air conditioners
  - use ordered energy to cause heat to flow against its preferred direction
- Automobiles
  - use thermal energy to do work

Thermodynamics

- Study of the rules governing the movement of thermal energy
- Study of the relationship between thermal energy and mechanical work
- Study of the relationship between disordered energy and ordered energy

0^{th} Law

- Thermal equilibrium

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

1^{st} Law

- Conservation of energy

  Change in internal energy = Heat in - Work out

1^{st} Law

- Internal energy: thermal energy + stored potential energy
- Heat in: heat transferred into the object
- Work out: work done by the object on its surroundings

Order versus Disorder

- Ordered energy can easily be converted into thermal (disordered) energy.
- Converting thermal energy into ordered energy is hard.

Entropy

- Entropy is a measure of an objects disorder.
- Includes thermal disorder and structural disorder.
- Disorder of an isolated system never decreases.
- Can move entropy around.

2nd Law

- Disorder (Entropy)

  Entropy of a thermally isolated system never decreases

3rd Law

- Entropy and Temperature

  An object's entropy approaches zero as its temperature approaches absolute zero.

Entropy

- Entropy of a thermally isolated system never decreases (second law).
- Entropy can be redistributed within the system.
  - One part of a system can become hotter while another 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 doesn't decrease - it increases.
  - A given quantity of heat is more disordering to a cold object than to a hot object.

Unnatural heat flow

- Can heat naturally flow from cold to hot?
  - Remove heat from cold object - entropy decreases.
  - Add heat to hot object - entropy increases, but by less.
- Energy is conserved, but entropy decreases.
  - To keep from violating the 2nd law extra entropy must be added.
  - Conversion of ordered energy into disordered energy is required.

Air conditioner

- Moves heat against its preferred direction.
  - From cold room to hot outside air.
- Uses fluid to transfer heat - working fluid.
  - Fluid absorbs heat from cool room air.
  - Fluid releases heat to warm outside air.

Air conditioner

- Evaporator - inside
  - heat transferred from room to fluid
- Condenser - outside
  - heat transferred to outside air from fluid
- Compressor - outside
  - does work on fluid - adds entropy

Evaporator

- Long metal pipe
- Fluid approaches evaporator as a
  - high pressure liquid
  - near room temperature
- Fluid passes through a constriction
  - pressure drops
  - enters evaporator as a low pressure liquid

Evaporator

- Working fluid enters evaporator as a low pressure liquid
  - begins to evaporate
  - breaking bonds takes energy, thermal energy
  - fluid gets cold
  - heat flows from room into fluid
- Working fluid leaves evaporator as a low pressure gas
- Heat has been removed from the room

Compressor

- Working fluid enters compressor as a low pressure gas
- Compressor does work on fluid, compresses it
  - pushes gas inward as the gas moves inward
  - gas heats up (first law)
  - ordered energy is converted to disordered energy
- Fluid leaves compressor as a hot, high pressure gas

Condenser

- Long metal pipe
- Working fluid enters condenser as a hot, high pressure gas
  - heat flows from fluid to outside air
  - fluid becomes cooler
  - fluid begins to condense
  - forming bonds releases energy, thermal energy
- Working fluid leaves condenser as a high pressure liquid

Air conditioner

- Evaporator - inside
  - heat transferred to fluid
- Compressor - outside
  - does work on fluid
  - heats it up
- Condenser - outside
  - heat transferred to outside air
  - heat includes thermal energy extracted from inside and thermal energy added by compressor