Physics D—Chapter 15

Thermodynamics

Thermodynamic Systems

- Thermodynamics
  - Branch that deal with heat and work
  - System
    - Collection of objects that attention is focused on
  - Surroundings or environment
    - All other objects
  - Separated by diathermal or adiabatic walls

Zeroth Law of Thermodynamics

- "Two systems individually in thermal equilibrium with a third system are in thermal equilibrium."
  - Temperature indicates thermal equilibrium
  - No net flow of heat between systems

First Law of Thermodynamics

- Conservation of energy that takes into account
  - Heat
    - + when system gains heat
  - Work
    - + when done by the system—losing energy
  - Internal energy

$$\Delta U = Q - W$$

Sample Problem

- A sample gas lifts a 227 kg object to a height of 8.45 m. The gas had an initial internal energy of 42.0 kJ. If 4.00 kJ of heat is transferred to the gas by heat during the process, what is the final internal energy of the gas?

  •U=27.2kJ

Thermodynamic Processes

- Deal with **internal energy**(U) and transfer of energy by **work**(W) and **heat**(Q)
- Not all processes involve all three quantities

Thermal Processes

- Four common *Quasi-static* thermal processes
  - Means that all processes take place slowly enough that uniform temperatures and pressures exist throughout the system
    - – Isobaric
    - – Isochoric
    - – Isothermal
    - – Adiabatic

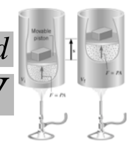
Isobaric

- Process that occurs at a **constant pressure**
  - Expansion
    - + work
    - System does work
  - Compression
    - - work
    - Surrounding does work

$$W = Fd$$

$$W = (PA)d$$

$$W = P\Delta V$$



Sample Problem

- The largest glass-blown bottle is 2 m tall. The pressure used to expand the bottle is 5.1 kPa. If 3600 J of work is done in expanding the bottle, from an initial volume of 0.0 m^3, what is the final volume?

V=0.71 m^3

Isochoric process

- Process that occurs at a constant volume
  - No work is done, but pressure changes
  - Heat transfers energy
  - Internal energy changes

Isothermal

- Process that takes place at a constant temperature
  - Internal energy (thus temperature) remain constant
  - Heat transfers energy
  - Work transfers energy

Adiabatic Process

- Process that occurs with no transfer of heat
  - Heat transfers no energy
  - Work transfers energy
  - Internal energy changes

Second Law of Thermodynamics

- Heat flows spontaneously from a substance of higher temperature to a substance at a lower temperature and does not flow spontaneously in the reverse direction.
  - Cold objects never become colder when left in a warmer environment

Heat Engines

- Any device that uses heat to perform work
  - Heat is supplied from a relatively hot source called the hot reservoir
  - Part of the input heat is used to do work
    - gas mixture in automobile engine expanding
  - Remainder of heat is expelled at a relatively cold temperature to the cold reservoir

$$Q_H = W + Q_C$$

Thermodynamic Efficiency

- Measure of useful energy relative to total energy put in
- Useful energy will do work
- Remainder of energy is lost

$$eff = \frac{W_{net}}{Q_h}$$

Thermodynamic Efficiency

$$eff = \frac{W_{net}}{Q_h}$$

$$eff = \frac{Q_h - Q_c}{Q_h}$$

$$eff = \frac{Q_h}{Q_h} - \frac{Q_c}{Q_h}$$

$$eff = 1 - \frac{Q_c}{Q_h}$$

Sample Problem

- If a gasoline engine has an efficiency of 30 % and loses 920 J of heat to the environment, how much work is done by the engine?

•W=394 J

Carnot's Ideal Engine

•
engine can be ignored
•Thus the heats could be seen as proportional to temperatures on the Kelvin scale
•This allows for a prediction of ideal efficiency

$$eff = 1 - \frac{Q_c}{Q_h}$$

$$eff_{ideal} = 1 - \frac{T_c}{T_h}$$

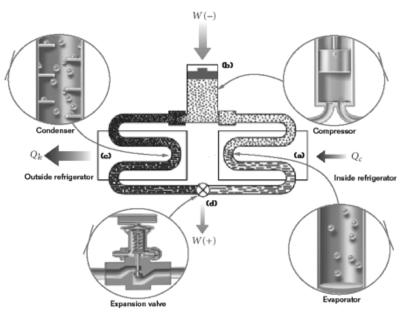
Second Law of Thermodynamics

- No heat engine can ever be 100% efficient, even in theory
- A heat engine must give up some energy to the lower temperature body
  - Some energy will be lost as heat to environment

Refrigeration

- Moves heat from a low temperature to a high temperature
- Requires work to be performed
- Four step cycle

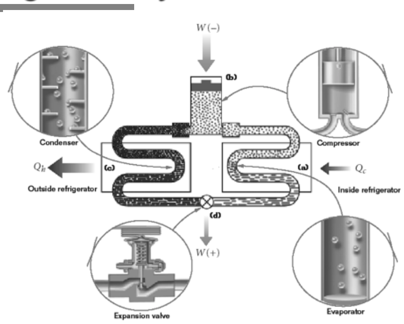
Refrigerator cycle



Step A

- Inside refrigerator
  - Temperature is lower than surrounding
  - Heat transfers to the refrigerant
    - Refrigerant boils
  - No work done

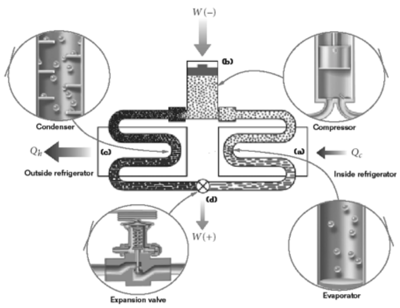
Refrigerator cycle



Step B

- Compressor
  - Does work on the gas
  - Pressure and internal energy (thus temperature) are increased
  - No heat transferred

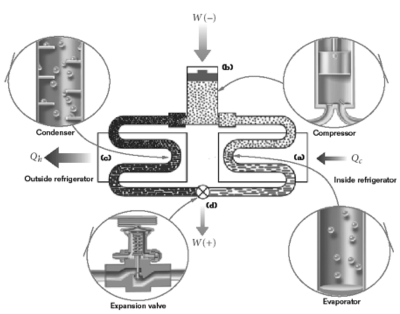
Refrigerator cycle



Step C

- Condenser
  - Temperature is higher than outside air
  - Heat transfers out of refrigerant
    - Refrigerant cools and condenses
  - No work

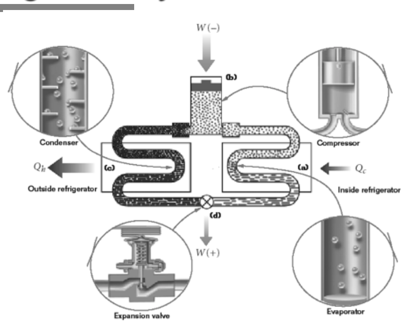
Refrigerator cycle



Step D

- Expansion valve
  - Liquid expands doing work
  - Internal energy decreases
  - No heat transfer

Refrigerator cycle



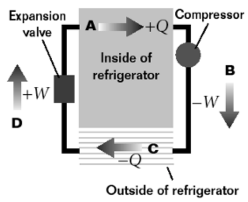
Refrigerator cycle

- Refrigerant now has the same internal energy as when the cycle started

Step	Q	W	ΔU
A	+	0	+
B	0	–	+
C	–	0	–
D	0	+	–

Cyclic Process

- Process where energy is transferred with heat and work, but there is no net change in internal energy



Performance

Refrigerators

$$Coefficient of Performance = \frac{Q_C}{W}$$

Heat Pumps

$$Coefficient of Performance = \frac{Q_H}{W}$$

Entropy

- Measure of a system's disorder
- Systems left alone always move toward a more disordered state
  - Most random state
- Disordered system tends to remain disordered

Higher Entropy = ? Work

- Greater disorder leads to less energy being available for work

$$\Delta S = \frac{Q}{T}$$

2nd Law of Thermodynamics

- The entropy of the universe increases in all processes
- A system's entropy can decrease only if offset by an increase elsewhere

Entropy

- Entropy can be decreased by doing work
- Environment's entropy will increase to offset
- Universe's entropy will increase until at a maximum