Chapter 12: Thermodynamics

Heat Reservoir: a system with unlimited heat capacity—so the addition or removal of heat causes no change in temp.
0^{th} Law: all objects at the same temp. are at thermal equilibrium.
1^{st} Law: conservation of energy. $\mathbf{\Delta Q = \Delta U + W}$ ΔQ: (+ or -) heat *added* to or *removed* from the system
ΔU: change in internal energy of the system W: (+ or -) work done *by* the system or *on* the system
- *Work Done By A Gas*: $\mathbf{W = P\Delta V}$ P: pressure of gas ΔV: change in volume of gas
  - If $\Delta V > 0$: gas expands, W is positive If $\Delta V < 0$: gas compresses, W is negative
  - The work done by a system is equal to the area under the process curve on a P-V diagram.

1. Isothermal Process: (constant temp. and constant internal temp.) Heat is turned completely to work.
   $\Delta T = 0$, $\Delta U = 0$ → $\mathbf{Q = W}$ $\mathbf{W_{isothermal} = nRT \ln(V_2/V_1)}$
2. Isobaric Process: (constant pressure) $\mathbf{Q = \Delta U + P\Delta V}$ $\mathbf{W_{isobaric} = P(V_2 - V_1) = P\Delta V}$
3. Isometric (Isochoric) Process: (constant volume) No work is done. $\Delta V = 0$, $W = 0$ → $\mathbf{Q = \Delta U}$
4. Adiabatic Process: (no heat enters or leaves the system) $Q = 0$ → $W = -\Delta U$
   $\mathbf{W_{adiabatic} = (P_1V_1 - P_2V_2) / (\gamma - 1)}$ where… $\gamma = c_p/c_v$ (the ratio of specific heats)
   - *Monatomic Gases*: $\gamma = 1.67$ *Diatomic Gases*: $\gamma = 1.40$

Process	***Characteristic***	***Result***	***1st Law of Thermodynamics***
Isothermal	T = constant	$\Delta U = 0$	Q = W
Isobaric	P = constant	$W = P\Delta V$	$Q = \Delta U + P\Delta V$
Isometric	V = constant	W = 0	$Q = \Delta U$
Adiabatic	Q = 0		$\Delta U = -W$

2^{nd} Law: heat won't flow *spontaneously* from a cold object to a hot object (but it will from a hot object to a cold one); nothing is 100% efficient (work output is always less than energy input); entropy in the universe will always increase.
$\mathbf{\Delta S = (Q/T)}$ ΔS: change in entropy (J/K) Q: heat added or removed (J) T: temp. (K)
- +Q = Heat is absorbed - Q = Heat is released. $\Delta S \geq 0$

Heat Engine: devices that convert heat energy into work (transfer heat from hot to cold). $\mathbf{W_{net} = Q_h - Q_c}$
Thermal Efficiency: **E = (work done / heat input)** or $\mathbf{E = (W_{net}/Q_h) = ((Q_h - Q_c)/Q_h) = 1 - (Q_c/Q_h)}$
Thermal Pump: does work to transfer heat from cold reservoirs to hot. (Ex: refrigerator, heat pumps, air conditioners)
Coefficient Of Performance (COP): *Fridge or Air Conditioner* → $\mathbf{COP_{ref} = (Q_c/W_{in}) = (Q_c /(Q_h - Q_c))}$
Heat Pump → $\mathbf{COP_{hp} = (Q_h/W_{in}) = (Q_h/(Q_h - Q_c))}$
- COP_{ref} = heat removed from cold reservoir. vs. COP_{hp} = heat delivered to hot reservoir.
- PV Diagram: Cycle is clockwise = Heat Engine = $-W_{net}$ vs. Counterclockwise = Ref = $+W_{net}$

Carnot Cycle: Isothermal expansion → Adiabatic expansion → Isothermal compression → Adiabatic compression
- *Heat Added*: $Q_h = T_h\Delta S$ vs. *Heat Exhausted*: $Q_c = T_c\Delta S$ → $\mathbf{W_{net} = Q_h - Q_c = (T_h - T_c)(\Delta S)}$

Carnot Efficiency: $\mathbf{E_C = 1 - (T_c/T_h)}$
3^{rd} Law: it's impossible to reach absolute zero in a finite number of thermal processes.