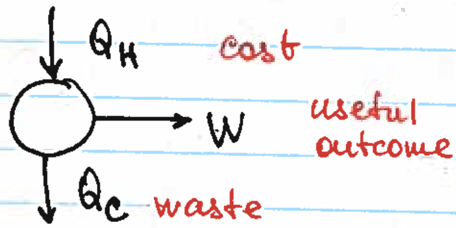
~~[illegible]~~ More uses of a thermal engine

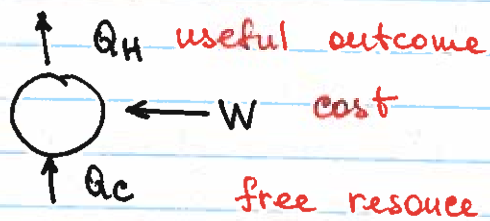
So far we discussed a typical heat engine that converst heat (from a hot reservoir) into useful mechanical work



Engine efficiency

$$e = \frac{\text{useful outcome}}{\text{cost}} = \frac{W}{Q_H} = 1 - \frac{|Q_C|}{Q_H}$$

Heat pump: converts mechanical work into heat



Coefficient of performance

$$COP = \frac{\text{useful outcome}}{\text{cost}} = \frac{|Q_H|}{W}$$

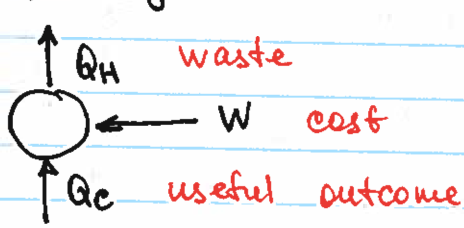
First law of thermodynamics

$$\underbrace{Q_C + W}_{\text{energy in}} = \underbrace{|Q_H|}_{\text{energy out}}$$

$$W = |Q_H| - Q_C$$

$$COP = \frac{|Q_H|}{|Q_H| - Q_C} > 1$$

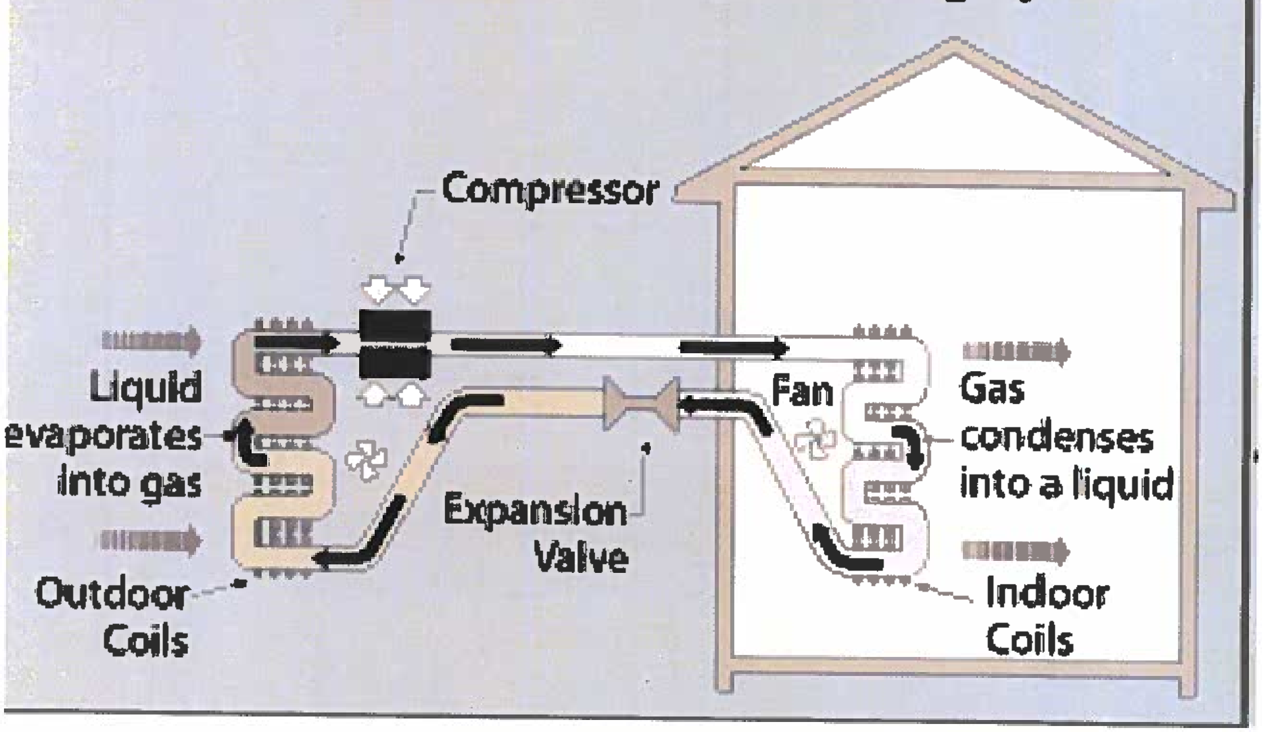
AC/ refrigerator: extracts heat from cold reservoir



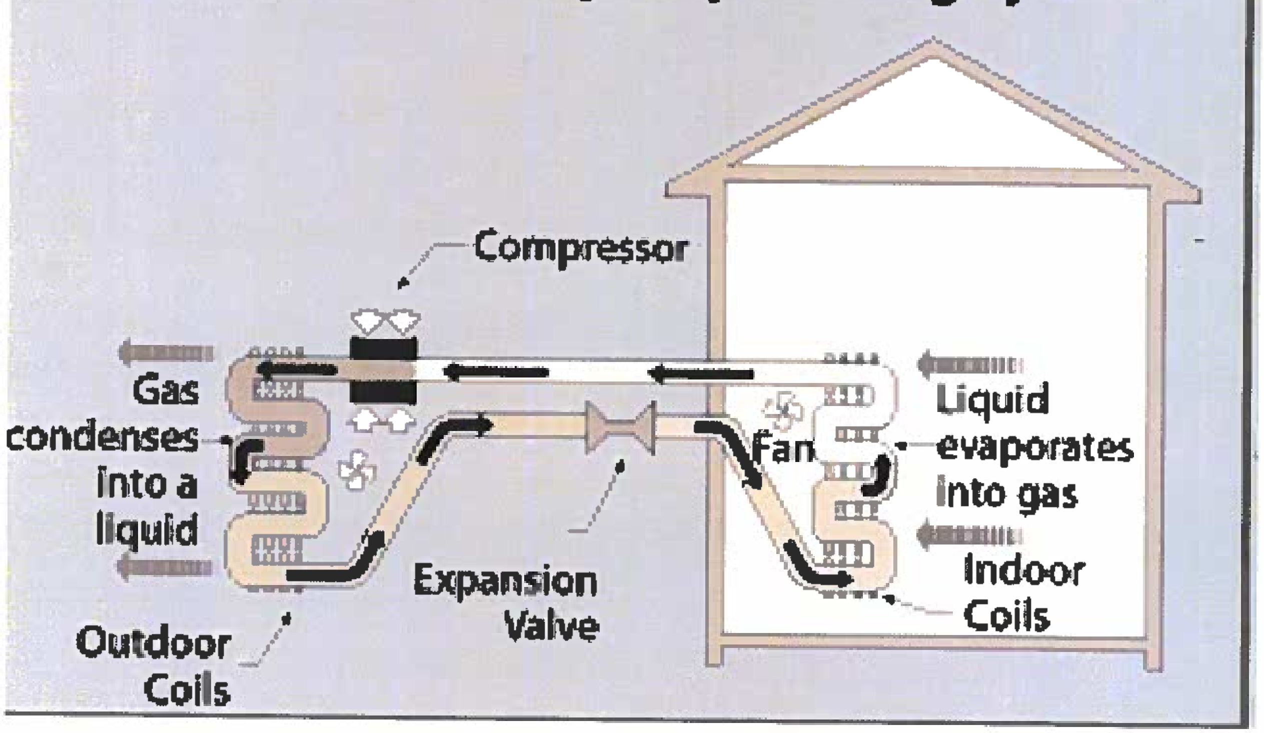
Coefficient of performance

$$COP = \frac{\text{useful outcome}}{\text{cost}} = \frac{Q_C}{W}$$

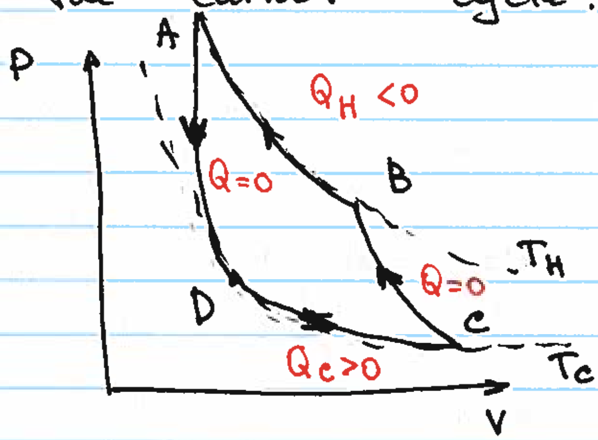
A split-system heat pump heating cycle



A split-system heat pump cooling cycle



What if a heat pump operates on the Carnot cycle?



BA ~~AB~~: Gas does negative work, heat flows from the gas into the room

AD: adiabatic expansion (gas temperature drops)

DC: Gas does positive work, heat flows from the environment into the gas

CB: adiabatic compression (gas temperature increases)

Useful outcome: $Q_H = nRT_H \ln \frac{V_A}{V_B}$ $(Q_H < 0)$

$$Q_C = nRT_C \ln \frac{V_C}{V_D} = nRT_C \ln\left(\frac{V_B}{V_A}\right) > 0$$

$$COP_{\text{heat pump}} = \frac{|Q_H|}{|Q_H| - Q_C} = \frac{T_H}{T_H - T_C}$$

Interestingly, the lower T_C is, the less efficient the heat pump.

We can run the same cycle in reverse to operate as a refrigirator:

AB: gas does positive work, heat is dumped into the (hot) environment

BC: adiabatic expansion (gas temperature drops)

CD: gas does negative work, heat is sucked from the cold reservoir (as desired)

DA: adiabatic compression (gas temperature increases)

$$COP_{\text{refrigerato}} = T_C / T_H - T_C$$