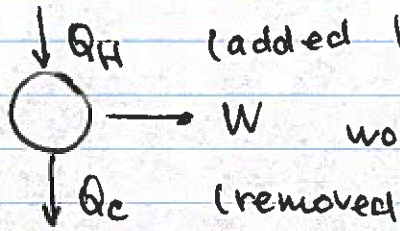
More uses of a thermal engine

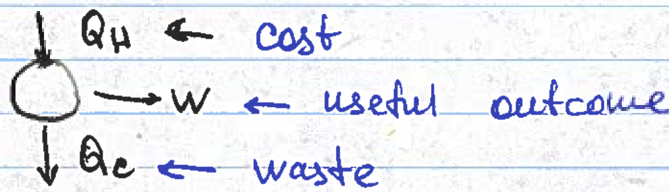
A typical thermodinamic cycle



$$e = \frac{\text{useful outcom}}{\text{cost}}$$

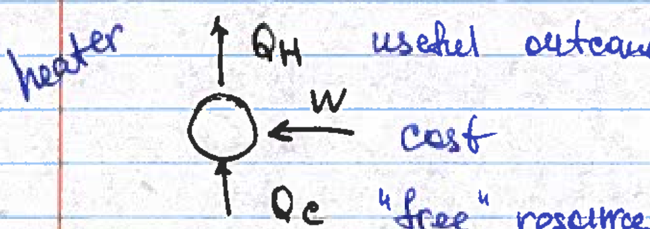
One can use this cycle for different purpose, and what is cost and what is a usefull output depends on what we want.

Heat engine : useful output – mechanical work



$$e = \frac{W}{Q_H} = 1 - \frac{|Q_c|}{Q_H}$$

If we run this backward, it is either a heater or a refrigerator

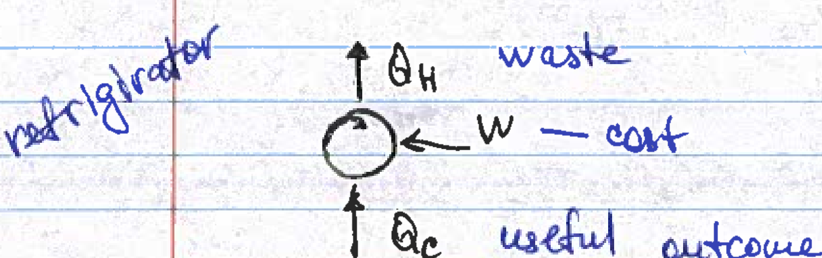


Coefficient of Perfomance

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

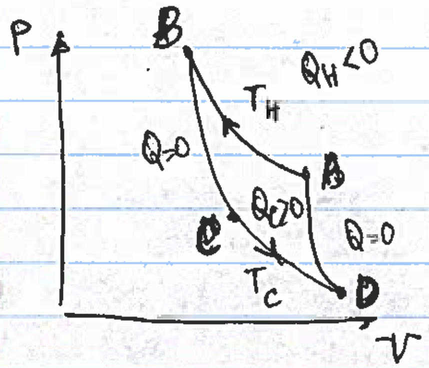
First law of thermodynamics

$$-W = Q_c - |Q_H|$$



$$COP = \frac{Q_c}{W} = \frac{Q_c}{|Q_H| - Q_c}$$

What if we use a Carno cycle as a heat pump?



AB: gas does negative work (a positive work done on the gas) heat flows out

$$Q_H = nRT_H \ln \frac{V_B}{V_A} < 0 \qquad |Q_H| = nRT_H \ln \frac{V_A}{V_B}$$

BC: adiabatic, temperature drops, $Q = 0$

CD: gas expands and does positive work, heat is extracted from the cold reservoir

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

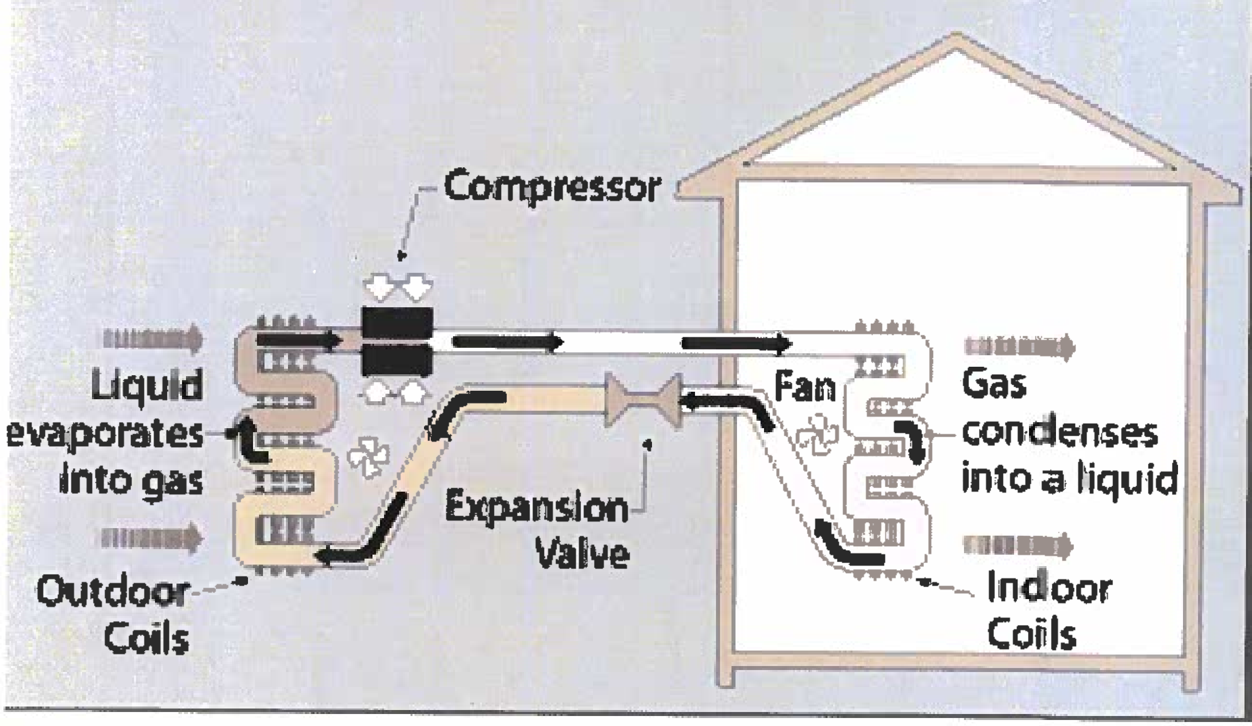
$$COP = \frac{|Q_H|}{|Q_H| - Q_C} = \frac{T_H}{T_H - T_C} > 1$$

Interesting to not COP drops if T_C gets lower (that is why heat pump are less efficient when it is ~~cold~~ too cold outside)

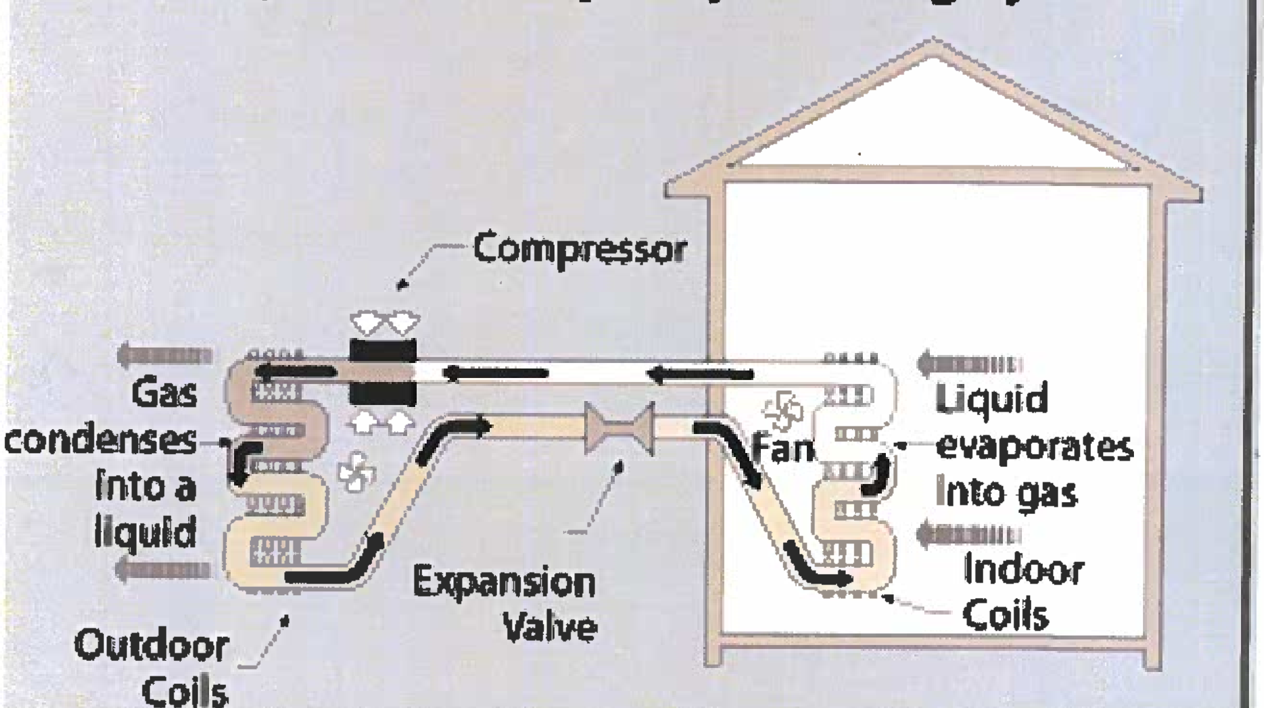
If we do the same for a fridge

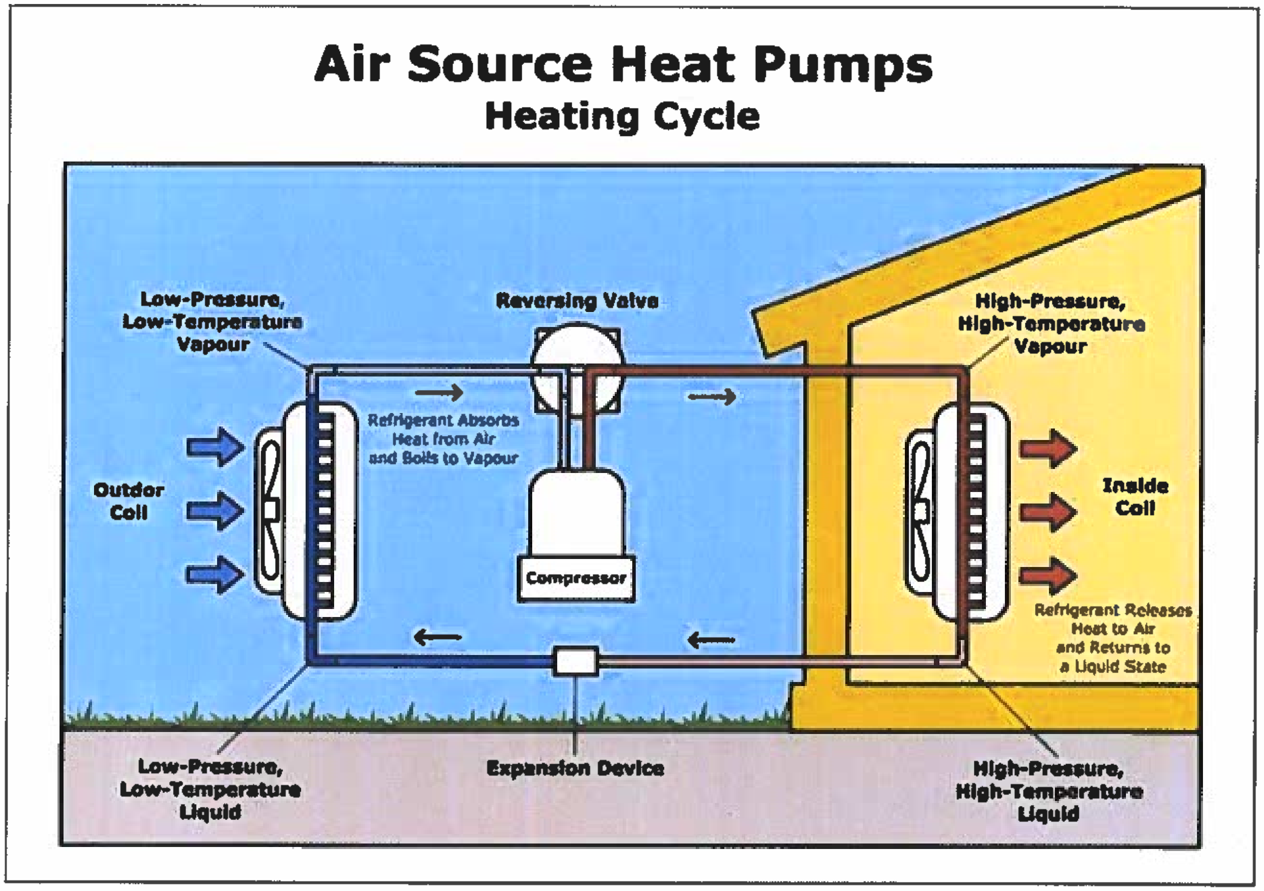
$$COP = \frac{T_C}{T_H - T_C}$$

A split-system heat pump heating cycle

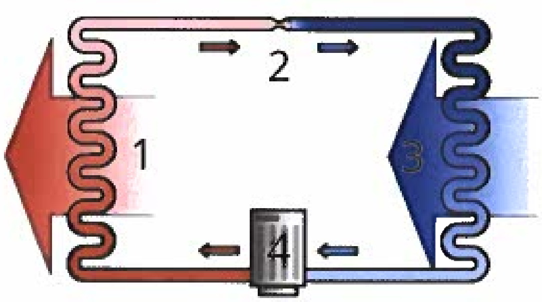


A split-system heat pump cooling cycle

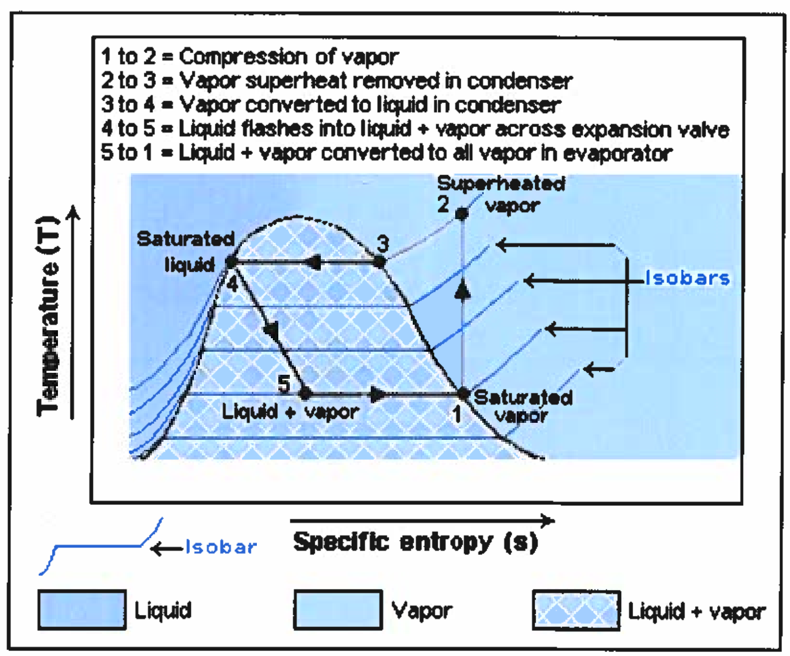




Air Source Heat Pumps
Heating Cycle
Low-Pressure, Low-Temperature Vapour
Reversing Valve
High-Pressure, High-Temperature Vapour
Refrigerant Absorbs Heat from Air and Boils to Vapour
Outdoor Coil
Compressor
Inside Coil
Refrigerant Releases Heat to Air and Returns to a Liquid State
Low-Pressure, Low-Temperature Liquid
Expansion Device
High-Pressure, High-Temperature Liquid



2
1
3
4



1 to 2 = Compression of vapor
2 to 3 = Vapor superheat removed in condenser
3 to 4 = Vapor converted to liquid in condenser
4 to 5 = Liquid flashes into liquid + vapor across expansion valve
5 to 1 = Liquid + vapor converted to all vapor in evaporator
Superheated vapor
Saturated liquid
Isobars
Liquid + vapor
Saturated vapor
Temperature (T)
Isobar
Specific entropy (s)
Liquid
Vapor
Liquid + vapor