the 2nd law of thermodynamics, problem set #2

1) The pV-diagram in fig. 1 shows a cycle of a heat engine that uses 0.250 mole of an ideal gas having $\gamma = 1.40$. The curved part ab of the cycle is an adiabatic process.

a) Find the pressure of the gas at point a. [**2 pts**]
b) How much heat enters this gas per cycle, and where does it happen? [**3 pts**]
c) How much heat leaves this gas in a cycle, and where does it occur? [**3 pts**]
d) How much work does this engine do in a cycle? [**3 pts**]
e) What is the thermal efficiency of the engine? [**2 pts**]

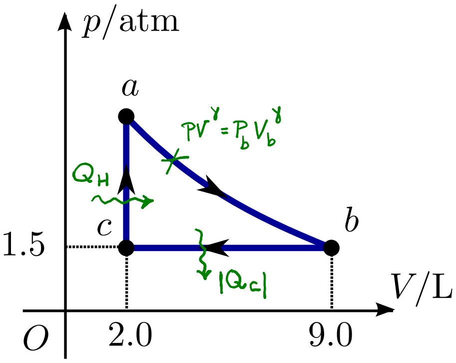


Figure 1: pV-diagram.

a) the process ab is adiabatic so $PV^\gamma = \text{const.}$

$$P_a V_a^\gamma = P_b V_b^\gamma \rightarrow P_a = P_b\left(\frac{V_b}{V_a}\right)^\gamma = 12 \text{ atm.}$$

b) during the process ca heat is entering,

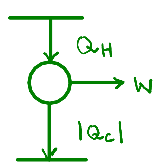
$$Q_H = Q_{ca} = n C_V (T_a - T_c) = \frac{C_V}{R} V_a (P_a - P_c) = 5.5 \text{ kJ}$$

Remember $\gamma = 1.40 = \frac{7/2}{5/2} = \frac{C_P}{C_V} \rightarrow$ diatomic gas (like air, not like He), $C_V = \frac{5}{2}R$, $C_P = C_V + R$.

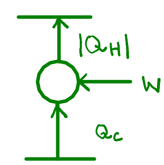
c) during the process bc heat is leaving,

$$Q_c = +Q_{bc} = +n C_p (T_c - T_b) = n C_p (-T_b + T_c) = \frac{C_p}{R} P_b (-V_b + V_c) = -3.7 \text{ kJ}$$

I just learned that in your book's notation Q_c is negative for heat engines, so $Q_c = Q_{bc}$ above & it's negative. What your book does is to put $|Q_c|$ in heat engine diagrams as arrow is showing the sign,



In a refrigrator it's opposite, $Q_H < 0$, $Q_c > 0$



d) $W = Q_H - |Q_c| = 1.8 \text{ kJ}$.

e) $e = \frac{W}{Q_H} = \frac{1.8 \text{ kJ}}{5.5 \text{ kJ}} = 30\%$.