Homework Solutions 4 (Schroeder Chapter 4)

1

(a) The work done *by* the gas on the outside world is $-W$. So the W for the heat engine is the area enclosed by the rectangle,

$$W = (P_2 - P_1)(V_2 - V_1) = 2P_1V_1$$

Steps A and B require heat going into the gas; these give Q_h. For each step, use $Q = C_V \Delta T$ or $Q = C_P \Delta T$ as appropriate.

$$Q_h = \frac{5}{2}V_1(P_2 - P_1) + \frac{7}{2}P_2(V_2 - V_1) = \frac{33}{2}P_1V_1$$

So

$$e = \frac{W}{Q_h} = \frac{4}{33} = 12\%$$

(b) The lowest temperature, T_c, is at the bottom left of the rectangle; T_h is at the upper right. You can see that since $PV = NkT$, $T_h = 6T_c$. Therefore

$$e_{\max} = 1 - \frac{1}{6} = 83\%$$

16 If you use all the work from the imagined HE to drive a Carnot R, you will find that this is equivalent to heat flowing from the cold reservoir to the hot reservoir, with no work being done. Heat cannot spontaneously flow from cold to hot.

For the HE,

$$e > 1 - \frac{T_c}{T_h} \quad \Rightarrow \quad \frac{Q_{c1}}{Q_{h1}} < \frac{T_c}{T_h}$$

Since for the Carnot R,

$$\frac{Q_{c2}}{Q_{h2}} = \frac{T_c}{T_h}$$

And since the work output of 1 is the input to 2, $W = Q_{h1} - Q_{c1} = Q_{h2} - Q_{c2}$. All this means that $Q_{h1} < Q_{h2}$ and $Q_{c1} < Q_{c2}$. The combined machine needs no work (that's all internal), and it moves heat $Q_{c2} - Q_{c1} = Q_{h2} - Q_{h1}$ from cold to hot. This is impossible.