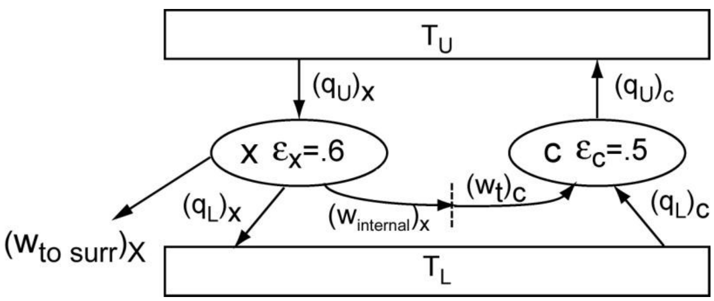
Homework #4
Problems (#22-#24)

22. E&R P5.2 *[same as E&R 2nd ed]*
    the comment about 'subtracting an additional 5%' implies that an additional factor of 95% efficiency must be included in the overall computation

    also *(note [watt] = [J s^{-1}]; 1 watt = 3600 J hr^{-1})*

23. The diagram below, where Carnot engine X and Carnot heat pump C are coupled, is similar to that used in lecture to illustrate that the efficiency of *any* Carnot engine, ε_X, has to be the same as that of an ideal gas Carnot engine, ε_C , when the engines operate between the same two temperatures. The diagram below differs in that now 33% (-20 J) of the total work done by engine X is done on the surroundings, while 67% (-40 J) is input into the Carnot refrigerator C.



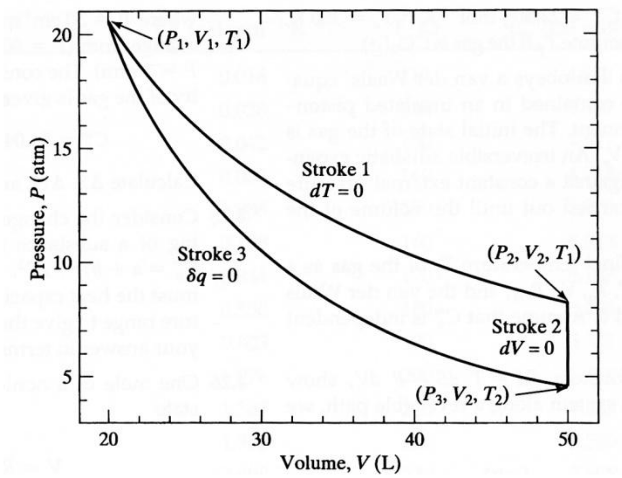
Assume that as indicated ε_x = 0.6 and ε_c=0.5 .

For $(q_U)_x$ = 100J, $(w_{surr})_x$=−20 J, $(w_i)_x$=-−40 J, $(w_t)_c$=+40J, and $(q_U)_c$=−80J

Calculate:

a. $(q_L)_x$
b. $(q_L)_c$
c. $(q_U)_{total} = (q_U)_x + (q_U)_C$
d. $(q_L)_{total} = (q_L)_x + (q_L)_C$
e. $w_{total} = (w_{surr})_x + (w_i)_x + (w_t)_c$
f. Considering the [correct] results for parts c, d, and e, how does the process with coupled Carnot engines X and C having ε_x = 0.6 and ε_c=0.5 violate one of the 'phenomenological' statements of the Second Law of Thermodynamics.

24. (parts A,B,C required); *(Part D, optional problem) *[from Raff 4.12]*
A reversible engine whose uses the three-stroke cycle shown below



:

Stroke 1 is an isothermal expansion at T_1.
Stroke 2 is a constant-volume cooling to T_2.
Stroke 3 is an adiabatic compression that returns the engine to T_1

a. In which stroke is the heat for the engine added? Which stroke produces the change in the surroundings required by the second law?

b. If the 'fluid' in the engine is one mole of an ideal gas, obtain an expression for the total work of the engine (system) done in one cycle. Your expression should be in terms of the volumes, temperatures, and the constant molar heat capacity of the gas $\bar{C}_V$.

c. Show that the efficiency of the engine is:

$$\varepsilon = 1 - \frac{T_1 - T_2}{T_1 \ln\left[\frac{T_1}{T_2}\right]}$$

d.✶ Show that the efficiency of the engine goes to zero as T_2 approaches T_1.