Phys 114
Seminar 2

W1

Warmup Problems

W1) Entropy of an ideal gas G+T 2.24

(a) Use Eq. (2.133) to derive $TV^{\gamma-1} = \text{const}$ which is Eq. (2.44), for a quasistatic, adiabatic process.

for monatomic ideal gas

$$\Delta S = 0 = \frac{3}{2} Nk \ln \frac{T_2}{T_1} + Nk \ln \frac{V_2}{V_1} \;;$$

$$\text{so} \quad \frac{0}{Nk} = \cancel{Nk} \ln\left[\left(\frac{T_2}{T_1}\right)^{3/2}\left(\frac{V_2}{V_1}\right)\right]$$

$$\therefore \quad e^0 = 1 = \left(\frac{T_2}{T_1}\right)^{3/2}\left(\frac{V_2}{V_1}\right)$$

$$\Rightarrow \quad T_1^{3/2} V_1 = T_2^{3/2} V_2$$

$$\Rightarrow \quad T_1 V_1^{2/3} = T_2 V_2^{2/3} = T_j V_j^{\gamma-1}$$

where $\gamma = 5/3$

(b) Start with N particles at V_1 & T. Then, gas is allowed to expand freely to V_2. A free expansion. $\Delta S = ?$

Here, T does not change! so

$$\Delta S = \tfrac{3}{2} Nk \ln \cancel{\frac{T}{T}} + Nk \ln \frac{V_2}{V_1}$$

0

(c) What is $\Delta S(T, P)$?

subin here..

We use $V = NkT/P$ in $\Delta S = \tfrac{3}{2} Nk \ln \frac{T_2}{T_1} + Nk \ln \frac{V_2}{V_1}$

$$\Rightarrow \Delta S = \tfrac{5}{2} Nk \ln \frac{T_2}{T_1} - Nk \ln \frac{P_2}{P_1}$$

W2

2) B+B 13.1

A heat pump has efficiency > 100%. Does this violate the laws of thermo?

No. Though we might be concerned at the word "efficiency", we note that for a heat pump, it is $\eta = \frac{Q_h}{W}$, which is the heat exhausted to the hot reservoir, divided by the work done. For example, for a carnot heat pump, $\eta_c = \frac{T_h}{T_h - T_l} > 100\%$

In words, we can easily turn work into heat with perfect efficiency ... and via the mechanism of a heat pump, use work to do even better than this ... and move some heat against the "natural" direction, so that $W + Q_l = Q_h$ ... with Q_l leaving the cold reservoir, and Q_h being deposited in the hot one ... and

$$\eta = \frac{Q_h}{Q_h - Q_l} > 100\%$$