Turn in this HW on or before Friday at 8pm.

1 Analyze TS rectangle

Consider a monatomic ideal gas that undergoes a 4-step cyclic process. On a T-S diagram, the four steps of the process trace out a rectangle. The cycle proceeds in the clockwise direction around the rectangular path. The four sides of the rectangle correspond to
(A) Constant temperature, T_h
(B) Constant entropy, S_h
(C) Constant temperature, T_l
(D) Constant entropy, S_l

(a) Make a T-S diagram that represents this cyclic process. Label the axes, the four steps (A through D), the direction of each process, and the key values of S and T. The horizontal axis corresponds to which variable? Why?

(b) Does a clockwise path in T-S space correspond to a heat engine or a heat pump?

(c) Create a table, like the one below, and fill in all the values in terms of T_l, T_h, S_l and S_h:

Process	ΔU	Q	W
A			
B			
C			
D			

(d) If this cycle corresponds to a heat engine, find the efficiency in terms of T_h and T_l. Alternatively, if this cycle corresponds to a heat pump, find the coefficient of performance in terms of T_h and T_l.

2 Helmholtz Free Energy of a Van Der Waals Gas

The Helmholtz free energy of a van der Waals (vdW) gas can be written as:

$$F = -NkT\left\{1 + \ln\left[\frac{(V - Nb)T^{\frac{3}{2}}}{N}\right]\right\} - \frac{aN^2}{V}$$

Where a and b are constants.

(a) Derive the equation of state (relationship between p, T, and V) for this Helmholtz free energy.
Hint: The starting equations for this problem include the thermodynamic identity, the definition of Helmholtz free energy, $F = U - TS$, and math identities such as the overlord equation.
Bonus point: Rearrange the vdW equation of state to highlight any similiarites with the ideal gas equation of state ($pV = NkT$). To highlight similarities, group together terms that have dimensions of pressure, group together terms that have dimension of volume, etc.

(b) Using your expression from part (a), sketch or plot $p(V)$ at various fixed temperatures. The volume axis should include Nb up to $6Nb$. Your plot can be dimensionless (i.e. V/Nb on the x axis). Select values of NkT and aN^2 that give curves with different shapes. Can you create a minima in pressure near $V = 2Nb$?