One gram of nitrogen gas is held in a container at 1 atmosphere of pressure and 300 K. It is heated at constant volume to state 2, where the temperature is 500 K. It is then expanded by polytropic process with $\gamma = 1.4$ to a final pressure of 1 atm at state 3.

a) List the pressure, temperature, and volume of each state.

b) Determine the work in Joules for each process. Specify whether the work is done ON or BY the system.

From the IGL, we can get $V_1$, which is $mRT/P$. $R$ is $8.314/0.028 \text{ J/kg-K}$. Volume is then $8.791 \times 10^{-4} \text{ m}^3$, or just under a liter – which makes sense.

For the first process, the volume is constant, so there’s no work. From the IGL, we recalculate $P$ as $mRT/V_1 = 168,875 \text{ Pa}$, or 1.67 atm.

For the final state, we have $P_3$, and we can get $V_3$ from $PV^{1.4} = \text{constant}$. So we can say that $V_3 = (P_2V_2^{1.4}/P_3)^{(1/1.4)} = 1.266 \times 10^{-3} \text{ m}^3$. Then from the IGL, we get a final temperature of 432 K or 159 °C.

For the second process, we can use the work expression $(P_3V_3-P_2V_2)/(1-\gamma) = 50.45 \text{ Joules}$. A positive value means work done BY the system.