Problem T2. (Unified Thermodynamics)

Consider the helium tank from the gas-pressurized, bipropellant, 4th-stage rocket engine from homework T1.

Assume the initial conditions at launch in the helium tank are p_i = 100MPa and T_i = 300K.

a) As the vehicle passes into the upper atmosphere at high speed (using stages 1-3) it heats up due to friction from the surrounding atmosphere. Assume the helium tank is rigid. Prior to igniting the 4th stage, the temperature of the helium has risen to 400K. What is the pressure in the tank at this condition?

b) How much work was done during the heating process in part a)?

c) Now assume that the tank is not rigid, but expands quasi-statically a small amount as the pressure is increased such that dp/dv = 1e05 MPa*kg/m^3. If the helium reaches the same final temperature before igniting the 4th stage (400K), what is the final pressure?

d) How much work was done during the heating process in part c)?

e) Sketch processes a) and c) on a p-v diagram. To make the sketch clearer you may want to accentuate the changes in volume with pressure for the second process. Also, include a series of isotherms in the background as a reference.

(LO#4, LO#5)