CLOSED BOOK/CLOSED NOTES. You are allowed to reference a single 8-1/2"x11" prepared sheet of notes in addition to the tables in the appendix of your textbook. No other reference materials are allowed.

1) (30%) A pure substance undergoes a quasi-equilibrium process in a closed system. The substance expands from $P_1 = 1000 \text{ kPa}$ and $\forall_1 = 0.1 \text{ m}^3$ to $\forall_2 = 1.0 \text{ m}^3$. Calculate the work done by the system if
   a) The pressure is constant during the process.
   b) $P \forall^2 = \text{ constant during the process}$.
   c) Pressure varies linearly with $\forall$ during the process and $P_2 = 1900 \text{ kPa}$

2) (50%) 0.500 kg of WATER at 300 kPa is contained in a frictionless piston and cylinder arrangement fitted with stops as shown in the figure. The water is heated until the piston reaches the stops (this is state 2). Additional heat is added until the final pressure is 600 kPa (this is state 3).
   a) What is the work done $W_{1-2}$ (kJ)?
   b) What is the heat transfer $Q_{1-2}$ (kJ)?
   c) What is the work done $W_{2-3}$ (kJ)?
   d) What is the heat transfer $Q_{2-3}$ (kJ)?
   e) Show the entire process on a $P$-$v$ diagram that includes the two-phase region.

3) (20%) AIR at 1 MPa, 750 K and 0.1 m$^3$ expands in a polytropic process with $P\forall^{1.4} = \text{ constant until the volume is 1.0 m}^3$.
   a) What is the final temperature?
   b) Compute the change in enthalpy using a constant value of $c_p$ evaluated at 500 K.
   c) Compute the change in enthalpy using a method that accounts for variations in $c_p$. 