MULTIPLE CHOICE SECTION, PROBLEMS 1-4 [2 POINTS EACH]
Please select one answer for each question.

(1) The main purpose of a throttle devise for a real substance is to provide conversion between

a) potential energy (pe) and internal energy (u)
b) internal energy (u) and flow energy (pv)
c) kinetic energy(ke) and flow energy (pv)
d) kinetic energy (ke) and internal energy (u).

(2) Steam exits a subsonic diffuser at a

a) higher pressure and lower velocity than the inlet
b) higher pressure and higher velocity than the inlet
c) lower pressure and lower velocity than the inlet
d) lower pressure and higher velocity than the inlet

(3) An ideal gas undergoes a **constant temperature** compression process from pressure, P_1 to pressure, P_2 in a closed system. During this process the specific volume change is $\Delta v = v_1 - v_2$. Given $R = c_p - c_v$, the amount of heat transfer and work per unit mass of the gas are respectively,

a) $q=0$, $w=RT \ln(P_2/P_1)$
b) $q=\Delta v\,(P_2-P_1)$, $w=0$
c) $q=\Delta v\,(P_2-P_1)$, $w=\Delta v\,(P_2-P_1)$
d) $q=RT \ln(P_2/P_1)$, $w=RT \ln(P_2/P_1)$

(4) One kg of an ideal gas initially at 300K is contained in (i) 1 m^3 **rigid** tank at 200kPa or (ii) 2 m^3 **rigid** tank at 100kPa. Heat is transferred to the tank and the final pressure is 400 kPa. If the specific heat is constant, which statement is true

a) More heat is needed for (i)
b) More heat is needed for (ii)
c) The same heat is needed for (i) and (ii)
d) Insufficient information is provided.

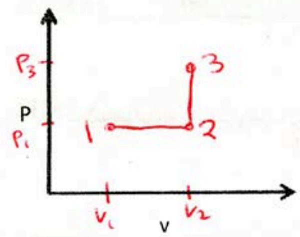
Please do not write in this table.

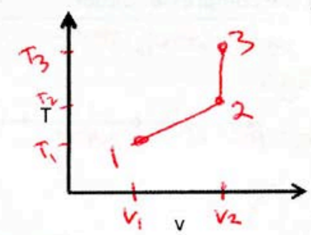
1-4	
5	
6	
Total	

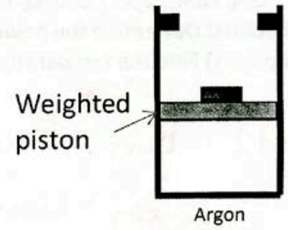
(5) [10 points] A weighted piston-cylinder device has a set of stops on the top as sketched. The device contains initially 1 kg of argon at 100 kPa and 300K (State 1). Heat is transferred to the device. When the stops are reached by the piston, the volume inside the cylinder is twice of its initial value (double) and the pressure is 100 kPa (State 2). Additional heat is added to the device until the final pressure reaches 200 kPa (State 3). Specific heats of argon are: c_p=0.50 kJ/kg-K, c_v= 0.3 kJ/kg-K.

(2 points for each question)

a) Sketch the process on a pressure-specific volume (P-*v*) diagram labeling all states.
b) Sketch the process on a temperature-specific volume (T-*v*) diagram labeling all states.
c) Determine the amount of work done by the argon.
d) Determine the argon temperature at the final state.
e) Determine the amount of heat transfer.







c) Boundary work is done between states (1) - (2)

Isobaric process: $W_b = P\Delta V$

Ideal Gas: $PV = mRT$

$V_1 = \frac{mRT_1}{P_1}$

$R = c_p - c_v = 0.2\ kJ/kgK$

$V_1 = \frac{(1\ kg)(0.2\ kJ/kgK)(300K)}{100\ kPa}$

$V_1 = 0.6 m^3$

$V_2 = 2V_1 = 1.2 m^3$

$W_b = (100 kPa)(1.2 - 0.6)m^3$

$W_b = 60\ kJ$

d) $T_3 = \frac{P_3 V_3}{Rm}$

$V_3 = V_2$

$T_3 = \frac{(200 kPa)(1.2 m^3)}{(0.2 kJ/kgK)(1 kg)}$

$T_3 = 1200K$

e) Process (1)-(2): Isobaric

$(Q_{in} + W_{in}) - (Q_{out} + W_{out}) = \Delta U + \Delta KE + \Delta PE$

$Q_{in} - W_{bout} = \Delta U$

$Q_{in} = \Delta U + W_{bout} = \Delta H$

$Q_{in} = mc_p\Delta T$

$T_2 = \frac{P_2 V_2}{mR} = 600K$

$Q_{in} = (1 kg)(0.5 kJ/kgK)(600-300)K$

$Q_{in} = 150\ kJ$

Process (2)-(3): Isochoric

$(Q_{in} + W_{in}) - (Q_{out} + W_{out}) = \Delta U + \Delta KE + \Delta PE$

$Q_{in} = \Delta U = m\Delta u = mc_v\Delta T$

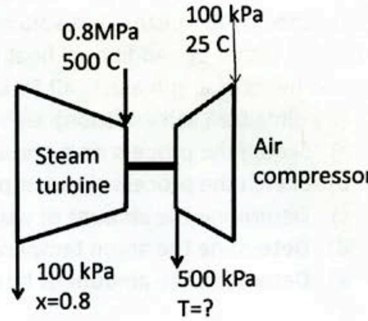
$Q_{in} = (1 kg)(0.3 kJ/kgK)(1200-600)K$

$Q_{in} = 180\ kJ$

$Q_{in,total} = (150 + 180) kJ$

$Q_{in,total} = 330\ kJ$

6) [12 points] An adiabatic steam turbine is used to power an air compressor as sketched. The steam enters the turbine at 0.8 MPa and 500°C at a rate of 0.2 kg/s and exits at 100 kPa and a quality of 0.8. Air enters the compressor at 100 kPa and 25°C with a rate of 10 kg/s and exits at 500 kPa. The compressor losses heat to the surrounding at a rate of 1 kW. Changes in potential and kinetic energies are negligible in both turbine and compressor. Air can be modeled as an ideal gas with constant values of specific heats: c_p=1.00 kJ/kg-K and c_v= 0.72 kJ/kg-K.



a) (6 points) Determine the power generated by the turbine.

b) (6 points) Find the temperature of the air at the compressor outlet.

Turbine

a) $\dot{E}_{in} - \dot{E}_{out} = \Delta \dot{E}_{sys} \rightarrow 0$ steady state

$\dot{Q}_{in} + \dot{W}_{in} + \sum_{in} \dot{m}(h + ke + pe) = \dot{Q}_{out} + \dot{W}_{out} + \sum_{out} \dot{m}(h + ke + pe)$

$\dot{W}_{out} = \dot{m}(h_{in} - h_{out})$

$h_{in} \Rightarrow$ water, $P = 0.8$ MPa, $T = 500C \Rightarrow 3481.3$ KJ/kg

$h_{out} \Rightarrow$ water, $P = 100$ KPa, $x = 0.8$

$h_f = 417.51$ KJ/kg

$h_{fg} = 2257.5$ KJ/kg

$h_{out} = h_f + x h_{fg}$

$h_{out} = 417.51 + 0.8(2257.5) = 2223.51$ KJ/kg

$\dot{W}_{out} = 0.2$ kg/s $(3481.3 - 2223.51)$ KJ/kg

$\dot{W}_{out} = 251.6$ kW

b) Compressor : $\dot{W}_{out,turbine} = \dot{W}_{in,compressor}$

$\dot{Q}_{in} + \dot{W}_{in} + \dot{m}h_{in} = \dot{Q}_{out} + \dot{W}_{out} + \dot{m}h_{out}$

$\dot{W}_{in} - \dot{Q}_{out} = \dot{m}(h_{out} - h_{in})$

Ideal gas: $\Delta h = c_p \Delta T$

$\dot{W}_{in} - \dot{Q}_{out} = \dot{m} c_p (T_{out} - T_{in})$

$251.6\,kW - 1\,kW = 10\,kg/s\,(1\,KJ/kgK)(T_{out} - 298.15K)$

$T_{out} = 323.2K =$ **50.1C**