CLOSED BOOK EXAM. You may reference one or two 8-1/2"X11" sheets of prepared notes in addition to your tables of thermodynamic properties. No other materials are allowed for reference.

1) (20%) 2.0 kg of water at $T_1 = 30\,^\circ C$ is contained in a sealed, rigid container with a total volume of 0.5 m$^3$. The water is heated until the final temperature is $T_2 = 600\,^\circ C$.
   a) What is the final pressure in the tank (MPa)?
   b) What is the heat transfer for this process (kJ)?
   c) What is the work done in this process (kJ)?
   d) If the heat is added from a source at 700 C, what is the entropy production for this process (kJ/K)?

2) (20%) 3 kg of AIR at $P_1 = 200\,kPa$ and 27 C is contained in a piston and cylinder device. The air is heated until the final temperature is $T_2 = 827\,^\circ C$. During the process, the pressure in the cylinder remains constant. Assume constant specific heats at the average temperature of the process.
   a) What is the heat transfer for this process (kJ)?
   b) What is the work done in this process (kJ)?
   c) What is the change in entropy of the air for this process (kJ/K)?

3) (20%) A refrigerator is in a room where the temperature is 20 C. The temperature inside the refrigerator is maintained at 5 C.
   a) What is the maximum possible C.O.P for this refrigerator?
   b) If the refrigerator removes 5,000 J/s of heat from the cold space, what is the minimum required power input (kW)
   c) If the actual cycle is a CARNOT cycle using R-134a, and the refrigerant changes phase from SAT VAP to SAT LIQ during the heat rejection process, sketch the cycle on a $T$-$s$ diagram in relation to the two-phase region
   d) For the cycle in c) and the cooling requirement in b) find the required mass flow rate of refrigerant.
4) (40%) A simple steam power cycle is shown in the schematic below. Steam enters the turbine at 1000°C and 9 MPa (state 1) and exhausts to the condenser at 10 kPa (state 2). The isentropic efficiency of the adiabatic turbine is 88%. The condenser is at constant pressure, and SATURATED LIQUID at 10 kPa enters the adiabatic pump (state 3). The pump has an isentropic efficiency of 70%, and the pressure entering the boiler is again 9 MPa (state 4). Neglect all kinetic and potential energies.

a) What is the output of the turbine (kJ/kg)?

b) What is the heat rejected in the condenser (kJ/kg)?

c) What is the required pump input (kJ/kg)?

d) What is the heat added in the boiler (kJ/kg)?

e) If the net work output of the cycle is to be 10 MW, what is the required mass flow rate through the system (kg/s)?

f) What is the thermal efficiency of this cycle?