DO NOT WRITE ON THE BLUE TABLES. RETURN THE BLUE TABLES WITH YOUR EXAM. DO NOT STAPLE THE EXAM SHEETS TOGETHER. Put your answers on the same sheet as the question, Use at least 5 digits in your computations and answers where possible. You must give the units of your answers. You must write clearly. Encircle the right answer number in multiple choice. To correct, erase the wrong circle as well as you can and encircle the corrected answer number twice. Best possible answer for multiple choice. For questions asking a number, putting the clear correct formula(s) below the question might result in partial credit even if the answer is wrong. *Not following those requirements will result in reduced or no credit.*

1. (3%) You are heating up a pot of tea water. When it starts to boil, a thermometer in the water indicates 95°C. The ambient air pressure is ____________ atm.

2. (3%) In a well-insulated container,
   1. You can change saturated liquid into cooler saturated liquid and saturated vapor into cooler saturated vapor
   2. You can change saturated liquid into cooler saturated liquid and saturated vapor into hotter saturated vapor
   3. You can change saturated liquid into hotter saturated liquid and saturated vapor into cooler saturated vapor
   4. You can change saturated liquid into hotter saturated liquid and saturated vapor into hotter saturated vapor

3. (3%) A piston-cylinder combination contains 3 kg of helium at 27°C and 100 kPa. It is being *compressed* at a rate of 0.7 m^3/s and 20 kW of heat leaks *out*. The rate of temperature increase is ____________ °C/s.

4. (3%) A reversible pump compresses 0.5 kg/s of liquid refrigerant R-134a from 200 kPa to 900 kPa. The power requirement of the pump is ____________ W. (Note units.)

5. (3%) To change the temperature of 2 L of liquid R-134a from -23°C to -8°C requires ____________ kJ of heat and raises its entropy by ____________ kJ/K.

6. (3%) What heat pump is *possible*:
   1. $Q_H = 0$, $Q_L = 1$, $W = 1$
   2. $Q_H = 1$, $Q_L = 0$, $W = 1$
   3. $Q_H = 1$, $Q_L = 1$, $W = 0$

7. (3%) One leg of a mercury manometer is open to the ambient pressure of 100 kPa. The other leg, in which the mercury stands 15 cm lower, is connected to a container holding a noble gas. The pressure in the noble gas is ____________ kPa.

8. (3%) A bucket with 4 kg of water initially at 25°C is used to cool 3 kg of lead initially at 300°C. Ignoring heat conduction with the surroundings, the final temperature of the lead and water in the bucket will be ____________°C.

9. (3%) To compress 7 kg/s of a substance from 100 kPa and 0.6 m^3/kg to 0.2 m^3/kg in a polytropic process with n=1.5 requires ____________ kW of power, ignoring kinetic and potential energy changes.

10. (3%) If a heat engine in a 27°C surroundings takes in 80 kW of heat at 1200 K from its fuel, then the maximum work the engine can produce is ____________ kW and the minimum heat it must dump to the surroundings is ____________ kW.

11. (35%) Water at 200 °C and 800 kPa enters a reversible adiabatic turbine with a velocity of 200 m/s at a rate of 2 kg/s. It exits at 100 kPa with negligible velocity.
    1. Construct the initial phase in a very neat Pv diagram, marking all lines and points used to do it with their values. Do not put more info in the diagram than is needed to construct the phase. State the phase.
    2. Construct the final phase in a very neat Ts diagram in the same way. State the phase. Show the process in the diagram as a fat line.
    3. Find the final temperature, the heat added to the water and the work produced by the turbine.

    You must show the derivations and reasoning completely and correctly for full credit. You must give simplified units for your answers. Most accurate procedure only unless stated otherwise. Use at least 5 significant digits in your computations and answers. Give the source of every number.

12. (35%) An isobaric (*not* adiabatic) piston-cylinder combination contains 3 m^3 of air at 100 kPa and 1400 K. The air is allowed to cool down to the ambient temperature of 20°C.
    1. Figure out the work done on the air and the heat that leaks out of it.
    2. If the heat ends up in the 20°C surroundings, then what is the entropy generated by the process in the complete system?

    You must show the derivations and reasoning completely and correctly for full credit. You must give simplified units for your answers. Most accurate procedure only unless stated otherwise. Use at least 5 significant digits in your computations and answers. Give the source of every number.