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%) In an adiabatic container, you can [increase] / decrease (circle one) the pressure of saturated liquid and increase / [decrease] (circle one) the pressure of saturated vapor.

2. (3%) To remove 70 W of heat from your cryogenic experiment at -200°C in a 20°C laboratory requires at least ___210.53___ W of electricity.

3. (3%) You have reached the top of one of Colorado's 14,000 ft mountains, where the air pressure is 0.6 bar. Water for your hot soup will boil at about ___86___ °C.

4. (3%) If the air pressure at 14,000 ft is 0.6 bar, and the air pressure at sea level is 100 kPa, then the average air density in between is ___0.95593___ kg/m^3.

5. (3%) If argon in a rigid container changes temperature from 200°C to 20°C, then its entropy increases by -0.14936 kJ/kg K.

6. (3%) A piston-cylinder combination contains 7 kg of argon gas at 200 kPa. If 0.2 kW of heat leaks *into* the argon from the surroundings, then if you want to *reduce* its temperature at a rate of 0.3°C/s, you must *increase* its volume at a rate of 0.004276 m^3/s.

7. (3%) To decrease the temperature of helium from 200°C to 20°C in a reversible adiabatic process, you must decrease its pressure from 100 kPa to 30.226 kPa.

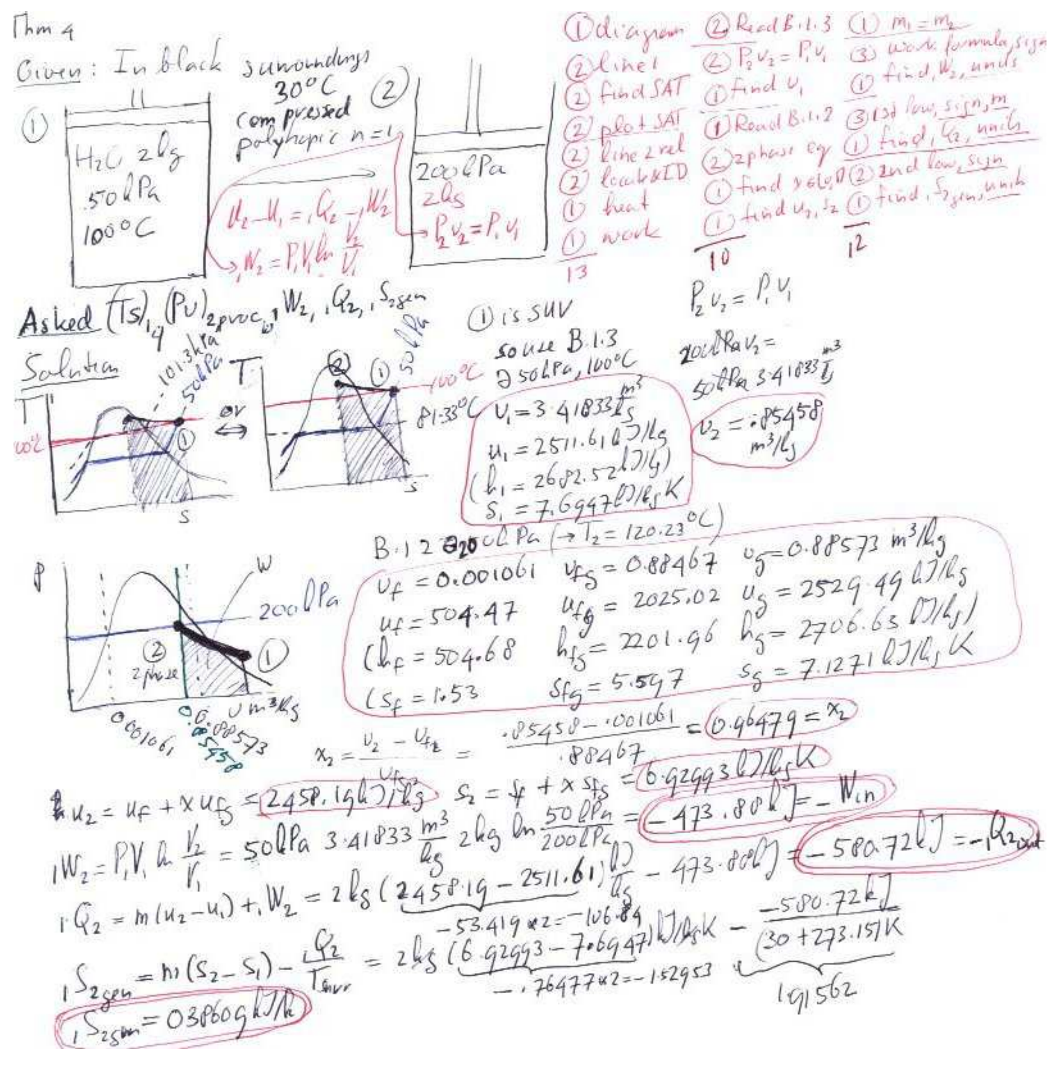
8. (3%) A 2 kW reversible pump can compress 3 kg/s of liquid ammonia from 100 kPa to 502.67 kPa.

9. (3%) If 2 kg of liquid benzene cools down from 80°C to the ambient temperature of 20°C, it releases 206.4 kJ of heat and its entropy changes by -0.64056 kJ/K.

10. (3%) 2 kg/s of superheated steam at 3,000 kPa and 250°C enters a turbine at a speed of 150 m/s. The required entrance pipe diameter must be 34.615 mm (note units).

11. (35%) A piston cylinder combination contains 2 kg of water that is initially at 50 kPa and 100°C. Then the water is compressed to 200 kPa in a process that can be taken to be polytropic with $n = 1$.
    1. Construct the initial phase in a very neat Ts 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 Pv diagram in the same way. State the phase. Show the process in *both* diagrams as a fat line. Also show and identify the heat and work graphically in the diagrams.
    3. Find the work required to compress the water, the heat that leaks out into the 30°C surroundings, and the entropy generated 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.*



12. (35%) A well-insulated compressor takes in 2 kg/s of 200 m/s nitrogen at 100 kPa and 850 K. The nitrogen exits the compressor at 300 kPa with negligible velocity.
    1. First assume that the compressor is reversible. Under that assumption, find (1) the final temperature, (2) the final specific volume, and (3) the power required to run the compressor.
    2. If you assumed room temperature specific heats, what would the appropriate work formula be, and what would it have given for the power?
    3. Now the true compressor is *not* reversible. Instead, it has been measured that the true final temperature is 1200 K. Using that information, (1) compute the *true* power required to run the compressor, and (2) the compressor efficiency.

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.*