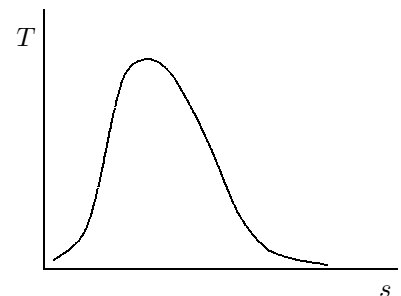


DO NOT WRITE ON THE BLUE TABLES. RETURN THE BLUE TABLES WITH YOUR EXAM. DO NOT STAPLE THE EXAM SHEETS TOGETHER. Put your answers on the same sheet as the question, Use many digits in your computation. You must give the units of your answers. You must write clearly. Encircle the right answer number in 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.*

- (5%) Your air conditioning is set to an inside temperature of  $25^{\circ}\text{C}$  and it is  $40^{\circ}\text{C}$  outside. The A/C is removing heat at a rate of  $4\text{kW}$  from your house. It will be using at least \_\_\_\_\_ kW of electricity.
- (5%) One of the following heat engines is fine, one does not satisfy the first law, and one does not satisfy the second law. Which is the one that does not satisfy the second law?
  - $W = 0, Q_H = 0, Q_L = 0$
  - $W = 1, Q_H = 0, Q_L = 0$
  - $W = 1, Q_H = 1, Q_L = 0$
- (5%) What is the work done when air is compressed reversibly at constant temperature from  $300\text{ K}$  and  $100\text{ kPa}$  to  $200\text{ kPa}$ ? Ignoring kinetic and potential energy changes the work will be \_\_\_\_\_ kJ/kg
- (5%) If you add  $500\text{ kJ}$  of heat to  $4\text{ kg}$  of marble at  $27^{\circ}\text{C}$ , you raise its temperature by \_\_\_\_\_  $^{\circ}\text{C}$  and its entropy by \_\_\_\_\_ kJ/K.
- (5%) A heat engine with a thermal efficiency of  $0.1$  will require \_\_\_\_\_ kW of heat for each kW of power produced.
- (5%) Liquid water is reversibly compressed at room temperature from  $100\text{ kPa}$  to  $500\text{ kPa}$  at a rate of  $2\text{ L/s}$ . The required power will be \_\_\_\_\_ kW. Ignore kinetic and potential energy changes.
- (5%) *Neatly* draw the  $T - s$  diagram for the reversible cycle described below. Label each state and label the lowest and highest temperatures and entropies on the axes.

- 1-2 isobaric heating from saturated liquid to somewhere in the middle of the superheated region;
- 2-3 reversible adiabatic pressure reduction to saturated vapor;
- 3-4 isothermal heat removal;
- 4-1 isentropic process,



8. (33%) A piston cylinder device contains 4 kg of water at 100°C and 50 kPa. Heat is now removed from the water in a reversible way while maintaining the same temperature until the water turns into saturated liquid.
- (a) Neatly construct the initial phase in the  $Ts$ -diagram, marking all lines and points used to do it with their values.
  - (b) Show the process in the  $Ts$ -diagram as a fat line, marking start as 1 and end as 2.
  - (c) Find the heat removed from the substance.
  - (d) Find the work done by the substance during the process.

You must show the derivations and reasoning completely and correctly for full credit. You must give units for your answers. Most accurate procedure only unless stated otherwise.

9. (32%) Helium is to be compressed from 100 kPa and 27°C to 300 kPa pressure at a rate of 10 g/s by a very well insulated compressor. All kinetic and potential energy can be neglected.
- (a) Compute the exit temperature and work required assuming that the process in the compressor is reversible.
  - (b) After the compressor is actually installed and turned on, it turns out that it requires 10 kW of power to run it. What is the performance parameter called that is not quite perfect? What is its value?

You must show the derivations and reasoning completely and correctly for full credit. You must give units for your answers. Most accurate procedure only unless stated otherwise.