NATIONAL EXAMINATIONS - December 2002

98-BS-10, Thermodynamics

3 Hours Duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit, with the answer paper, a clear statement of any assumptions made.

2. Any one of the approved Casio or Sharp calculator models is permitted. This is a "Closed-Book" examination with one 8.5x11 inch sheet of notes (both sides) allowed.

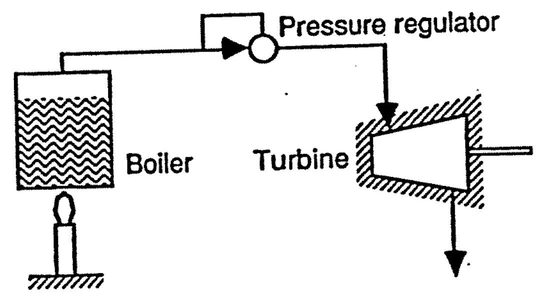
3. Property tables and charts are provided where necessary.

4. The **two** questions from part "A" plus **four** questions from part "B" (a total of **six** questions) constitutes a complete paper. Unless clearly indicated otherwise by you, only the first two questions from part "A" and the first four questions from part "B" that you answered will be marked.

5. The mark associated with each question is specified.

PART A. DO ONLY TWO OF QUESTIONS 1, 2, or 3
(Each question is worth **20 marks**)

1. A steam power plant is proposed as shown in the figure below. The boiler has a volume of 1 [m^3] and initially contains 90% liquid and 10% vapor <u>by volume</u> at 0.10135 [MPa]. To initiate the process, the burner is turned on. When the pressure inside the boiler reaches 1 [MPa], the pressure regulating valve opens and saturated vapor at this pressure leaves the boiler. The valve then maintains the boiler pressure at 1 [MPa]. Saturated vapor at a pressure of 0.10135 [MPa] leaves the turbine and is discharged to the surroundings. When the liquid in the boiler is depleted, the burner shuts off automatically. Determine:
   (a) The heat transfer in [MJ] and the work in [MJ] for one charge of the system.
   (b) The thermal efficiency of the power plant.

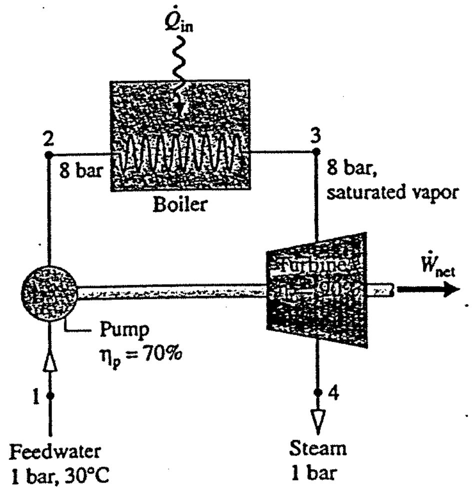


2. In a food processing plant, a cooling tower is used to remove waste heat. Cooling water enters the tower at 40 [°C] at a mass flow rate of 110 [kg/s] and is removed, after cooling, at 25 [°C]. Atmospheric air enters the tower at 20 [°C] and 70% relative humidity and leaves saturated at 35 [°C]. In the area where the plant is located, the atmospheric pressure is 96 [kPa]. Do <u>not</u> use the psychrometric chart for your solution. Neglecting the power input to the fan, determine:
   (a) the volume flow rate of air into the cooling tower, and
   (b) the mass flow rate of makeup water required.

3. An R134a compression refrigeration machine operates at a rated capacity of 28 [kJ/s] with pressures in the evaporator and condenser of 243 [kPa] and 666 [kPa], respectively. Dry, saturated vapor enters the compressor and vapor leaves the compressor at 35 [°C]. Heat removed from the refrigerant being compressed amounts to 2.4 [kJ/kg]. Liquid enters the valve at 20 [°C]. Determine the power input and the irreversibility rate.

PART B. DO ONLY FOUR OF QUESTIONS 4, 5, 6, 7 or 8
(Each question is worth **15 marks**)

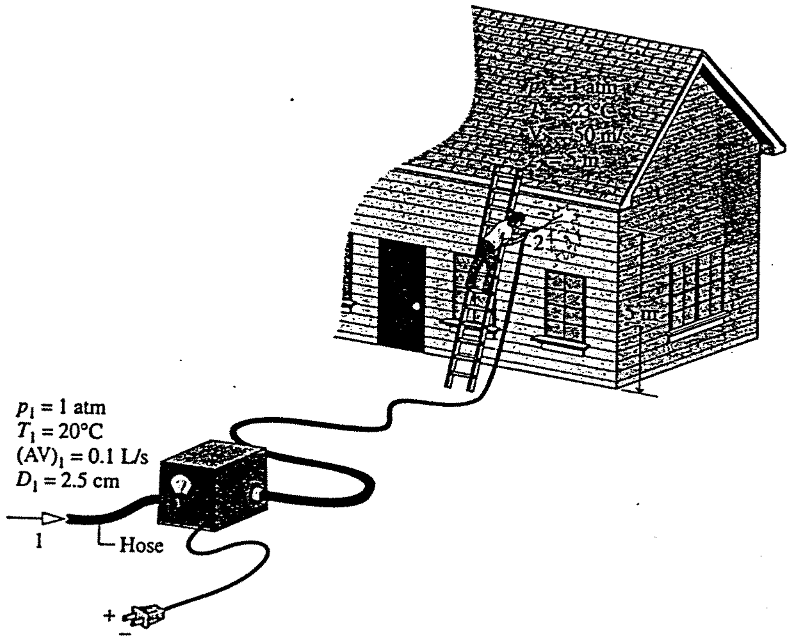
4. The figure below shows a basic open power system comprised of a pump, a boiler and a turbine all operating at steady state. Operating conditions are indicated in the figure (note that 1 bar = 100 [kPa]). The isentropic efficiencies of the pump and turbine are 70% and 90%, respectively. As in most power systems, the turbine provides power to operate the pump and the system yields a net output of W_{net}. For adiabatic operation of the pump and turbine, and ignoring potential and kinetic energy effects, determine (per unit mass of steam flow):
   (a) the work required by the pump
   (b) the heat transfer to the boiler
   (c) the work developed by the turbine
   (d) the thermal efficiency of the system



5. An adiabatic compressor operates at steady state with Refrigerant 134a as the working fluid. The refrigerant enters the compressor at 0.2 [MPa], 0 [°C] with a mass flow rate of 0.1 [kg/s]. The areas of the inlet and exit pipes are 0.0008 [m^2] and 0.0001 [m^2], respectively. At the exit, the pressure is 1.0 [MPa], 50 [°C]. Determine the inlet and outlet velocities of the refrigerant and the power input to the compressor in [kW].

6. A four cylinder spark-ignition engine has a compression ratio of 8 and each cylinder has a maximum volume of 0.6 [L]. At the beginning of the compression process, the air is at 98 [kPa] and 17 [°C], and the maximum temperature in the cycle is 1800[K]. Assuming the engine to operate on the ideal Otto cycle and assuming variable specific heats for air, determine:
   a. the amount of heat supplied per cylinder
   b. the thermal efficiency
   c. the number of revolutions per minute required for a power output of 60 [kW].

7. A power washer is being used to clean the siding of a house. Water enters the washer at 20 [°C], 101.35 [kPa] with a volumetric flowrate of 0.1 [L/s] through a 2.5 [cm] diameter hose. A jet of water exits at 23 [°C], 101.35 [kPa], with a velocity of 50 [m/s] at an elevation of 5 [m]. At steady state, the magnitude of the heat transfer rate *from* the power washer unit *to* the surroundings is 10% of the power input. The water can be considered incompressible with ρ= 1000 [kg/m^3], Cp= 4.18 [kJ/kg K]. Determine the power input to the power washer motor.



8. Two insulated tanks are connected by a valve. One tank initially contains 0.5 [kg] of air at 80 [°C], 100 [kPa], and the other tank contains 1.0 [kg] of air at 50 [°C], 200 [kPa]. The valve is opened and the two quantities of air mix until thermodynamic equilibrium is achieved. Employing the ideal gas model for air, determine:
   (a) The final temperature
   (b) The final pressure
   (c) The amount of entropy generated