NATIONAL EXAMINATIONS - May 2015

-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 calculator models is permitted. This is a "Closed-Book" examination with one 8.5×11 inch sheet of notes (both sides) allowed.

3. Property tables and charts are provided where necessary.

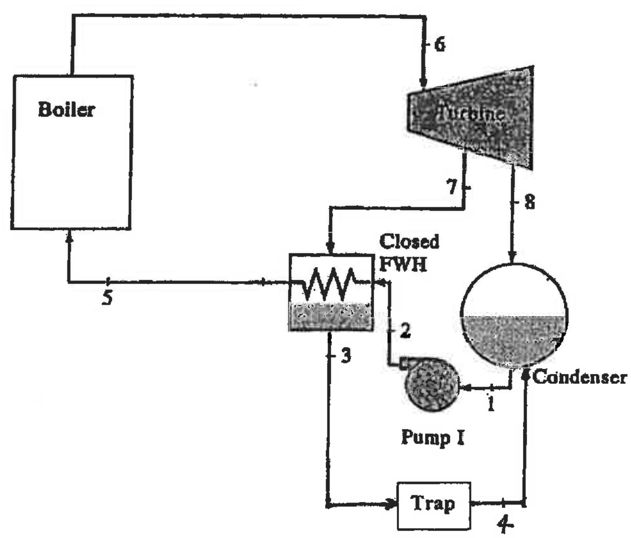
4. The **two** questions from part "A" plus **four** questions from part "B" (a total of **six** questions) constitutes a complete paper. Unless clearly indicated otherwise by you, only the first two questions from part "A" and the first four questions from part "B" that you answered will be marked.

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 power plant operates on a regenerative vapour power cycle with one closed feedwater heater. Steam enters the first turbine stage at 120 bar, 520°C and expands to 10 bar, where some of the steam is extracted and diverted to a closed feedwater heater. Condensate exiting the feedwater heater as saturated liquid at 10 bar passes through a trap into the condenser. The feedwater exits the heater at 120 bar with a temperature of 170°C. The condenser pressure is 0.06 bar. For isentropic processes in each turbine stage and the pump, show the cycle on a T-s diagram with respect to saturation lines and determine

   a) the thermal efficiency of the cycle,
   b) the net power developed, in kW, for a mass flow rate of 10^6 kg/h into the first-stage turbine,
   c) the exergy destruction associated with the heating process in the boiler, in kJ/s, and
   d) the second law efficiency of the cycle assuming a source temperature of 1500 K and a sink temperature of 300 K, and taking T_0 = 300 K.



2. A vapour-compression heat pump with a heating capacity of 500 kJ/min is driven by a power cycle with a thermal efficiency of 25%. For the heat pump, Refrigerant 134a is compressed from saturated vapour at -12°C to the condenser pressure of 1 MPa. The isentropic compressor efficiency is 80%. Liquid enters the expansion valve at 0.96 MPa and 34°C. For the power cycle, 80% of the heat rejected is transferred to the heated space. Determine

   (a) the power input to the heat pump compressor, in kW,
   (b) the coefficient of performance of the heat pump,

(c) the ratio of the total heat delivered to the heated space to the heat input to the power cycle,
(d) the entropy generation rate in the heat pump compressor, in kJ/K·s, and
(e) the rate of exergy destruction in the heat pump compressor, in kJ/s, if T_o = 15°C.

3. A Brayton cycle with regeneration using air as the working fluid has a pressure ratio of 7. The minimum and maximum temperatures in the cycle are 310 and 1150K. The isentropic efficiency is 75% for the compressor and 82% for the turbine, and the effectiveness for the regenerator is 65. Determine

a) the air temperature at the turbine exit,
b) the net work output,
c) the thermal efficiency of the cycle, and
d) the exergy destruction associated with each of the processes of the Brayton cycle, assuming a source temperature of 1800 K and a sink temperature of 310 K.

PART B. DO ONLY FOUR OF QUESTIONS 4, 5, 6, 7, 8 or 9
(Each question is worth **15 marks**)

4. A closed, frictionless, piston-cylinder assembly contains 2 kg of H_2O. Beginning with an initial volume of 0.3 m^3, the H_2O is compressed slowly until the volume has been reduced to 10 percent of the initial volume. During the process, heat transfer from the H_2O occurs at such a rate as to keep the temperature constant at 150°C. Determine the magnitude and direction of the work and of the heat transfer during the process.

5. Air enters a steady-flow turbine. The conditions of the air entering and leaving the turbine are as follows: inlet, 300 kPa and 52°C; exit, 100 kPa and 12°C. The mass flow rate is 10 kg/s. Heat transfer from the turbine to the surroundings and the kinetic and potential energy effects are negligible. Calculate the power developed by the turbine. Determine whether the process in the turbine is reversible? If not, determine the isentropic efficiency of the turbine.

6. Water enters a heat exchanger at a rate of 60 kg/s as a saturated liquid at 70 kPa and leaves at 240°C. The heating of the water is accomplished by heat transfer from a hot stream of air that enters the heat exchanger at 1007°C and leaves at 457°C. Neglect pressure drops of the fluids in the heat exchanger. The heat exchanger is well insulated. Determine (a) the mass flow rate of the hot air and (b) the rate of entropy generation in the heat exchanger.

7. A mixture of 80% N_2, and 20% CO_2 gases (by mole numbers), is compressed isentropically in a compressor. The mixture enters the compressor at 100 kPa and 1000 K and leaves at 500 kPa. Assume constant specific heats at room temperature (300 K). Treat the mixture as an ideal gas. Determine the work input to the compressor per unit mass of the mixture.

8. At the beginning of the compression process of an air-standard Otto cycle, p_1 = 1 bar, T_1 = 290 K, V_1 = 400 cm^3. The maximum temperature in the cycle is 2200 K and the compression ratio is 8. Determine (a) the heat addition, in kJ, (b) the net work, in kJ, (c) the thermal efficiency, and (d) the mean effective pressure, in kPa.

9. A rigid tank initially contains 0.5 kg of steam at 700 kPa and 320°C and is connected through an insulated valve to a steam supply line that supplies steam at a constant condition of 1.5 MPa and 320°C. The valve is opened so that the supply steam flows slowly into the tank until the pressure and temperature inside are 1.0 MPa and 320°C. Determine (a) the final mass of steam in the tank and (b) the heat transfer to or from the steam in the tank during the process.