NATIONAL EXAMINATIONS - May 2013

04-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 two-stage compression refrigeration system operates with refrigerant 134a between the pressure limits of 1 and 0.14 MPa. The refrigerant leaves the condenser as a saturated liquid and is throttled to a flash chamber operating at 0.5 MPa. The refrigerant leaving the low-pressure compressor at 0.5 MPa is also routed to the flash chamber. The vapor in the flash chamber is then compressed to the condenser pressure by the high-pressure compressor, and the liquid is throttled to the evaporator pressure. The refrigerant leaves the evaporator as saturated vapor and the isentropic efficiency is 90% for both compressors. The mass flow rate through the condenser is 0.25 kg/s. Show the cycle on a T-s diagram with respect to saturation lines and determine

   (a) the mass flow rate through the evaporator, in kg/s,
   (b) the rate of heat removed from the refrigerated space, in kJ/s,
   (c) the coefficient of performance, and
   (d) the exergy destruction in the compressors (Take T_o = 310 K).

2. A Brayton cycle with regeneration using air as the working fluid has a pressure ratio of 10. The minimum and maximum temperatures in the cycle are 300 K and 1200 K. The isentropic efficiencies are 75% and 80% for the compressor and turbine, respectively. The effectiveness of the regenerator is 70%. Assume a source temperature of 1200 K and a sink temperature of 300 K. Take T_o = 300 K. Show the cycle on a T-s diagram. Accounting for the variation of specific heats with temperature, determine

   (a) the rate of heat addition in kJ/kg,
   (b) the net power developed in kJ/kg,
   (c) the thermal efficiency,
   (d) the exergy destruction associated with each of the processes and the total exergy destruction of the cycle, in kJ/kg, and
   (e) the second law efficiency of the cycle.

3. A steam power plant operates on an ideal reheat Rankine cycle. Steam enters the high-pressure turbine at 12.5 MPa and 600°C and leaves at 6 MPa. Steam is then reheated at constant pressure to 600°C before it expands to 25 kPa. Assume a source temperature of 1500 K and a sink temperature of 300 K. Take T_o = 300 K. Show the cycle on a T-s diagram with respect to saturation lines. Determine

   (a) the turbine work output, in kJ/kg,
   (b) the thermal efficiency of the cycle,
   (c) the exergy destruction associated with each of the processes and the total exergy destruction of the cycle, in kJ/kg, and
   (d) the second law efficiency of the cycle.

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

4. An air-standard dual cycle has a compression ratio of 9. At the beginning of the compression, p_1 = 100 kPa and T_1 = 300 K. The heat addition per unit mass of air is 1400 kJ/kg, with two thirds added at constant volume and the rest at constant pressure. If the isentropic compression efficiency is 85% and the isentropic expansion efficiency is 90%, determine

   (a) the net work of the cycle, in kJ/kg
   (b) the thermal efficiency.
   (c) the mean effective pressure, in kPa.

5. A heat pump using refrigerant-134a heats a house by using under-ground water at 8°C as the heat source. The house is losing heat at a rate of 60,000 kJ/h. The refrigerant enters the compressor at 280 kPa and 0°C, and it leaves at 1 MPa and 60°C. The refrigerant exits the condenser at 30°C. Determine

   (a) the power input to the heat pump,
   (b) the rate of heat absorption from the under-ground water, and
   (c) the increase in electric power input if an electric resistance heater is used instead of a heat pump.

6. A mixture of 80% of N_2 and 20% of CO_2 gases (by mole numbers) is compressed isentropically in a compressor. The mixture enters the compressor at 100 kPa and 600 K and leaves at 500 kPa. Treat the mixture as an ideal gas. Determine the work input to the compressor per unit mass of the mixture.

7. A 0.2-m^3 rigid tank initially contains refrigerant-134a at 8°C. At this state, 60 percent of the mass is in the vapor phase, and the rest is in the liquid phase. The tank is connected by a valve to a supply line where refrigerant at 1 MPa and 120°C flows steadily. Now the valve is opened slightly, and the refrigerant is allowed to enter the tank. When the pressure in the tank reaches 800 kPa, the entire refrigerant in the tank exists in the vapor phase only. At this point the valve is closed. Determine

   (a) the final temperature in the tank,
   (b) the mass of refrigerant that has entered the tank, and
   (c) the heat transfer between the system and the surroundings.

8. A rigid tank contains an ideal gas at 40°C which is being stirred by a paddle wheel. The paddle wheel does 200 KJ of work on the ideal gas. It is observed that the temperature of the ideal gas remains constant during this process as a result of heat transfer between the system and the surroundings at 25°C. Determine

(a) the entropy change of the ideal gas and
(b) the entropy change of the surroundings.

9. A turbine operating at steady state receives air at a pressure of p_1 = 3 MPa and a temperature of T_1 = 390 K. Air exits the turbine at a pressure of p_2 = 1MPa. The work developed is measured as 74 kJ/kg. The turbine operates adiabatically and changed in kinetic and potential energy between inlet and exit can be neglected. Using the ideal gas model for air, determine the isentropic efficiency of the turbine.