Ex/CON/PE/T/124/2017

B.E. CONSTRUCTION ENGINEERING 1ST YEAR 2ND SEMESTER,2017

THERMODYNAMICS AND HEAT POWER

Time: Three Hours **Full Marks:100**

Answer question No. 1 (compulsory) and any four questions from the rest

Answer to all parts of a question must be together

Assume any data, if not furnished, consistent with the problem. Use of relevant steam tables and charts are permitted.

1.(a) Define (i) control volume; (ii) intensive property; (iii) dryness fraction; (iv) TER [8]

(b) State the purpose of reheating a simple Rankine cycle. [2]

(c) What do you understand by "increase of entropy principle"? [2]

(d) Define heat and work. [4]

(e) It is desired to have a comfortable 20°C inside a room on a hot summer day having an outside temperature of 40°C. What will be the power consumption if a 2 TON air-conditioner is running on the room? [1 TON = 3.5 kW] [4]

2.(a) Show that the efficiency of an irreversible heat engine is always less than the efficiency of a reversible one operating between the same two reservoirs. [10]

(b) Briefly mention how the combustion process is initiated in the cylinder of a SI and CI engine. What are the corresponding ideal cycles used for these two reciprocating engines? What is mean effective pressure in a reciprocating engine? [4+2+4]

3.(a) Write six difference between a 2-stroke and a 4-stroke engine. [6]

(b) An ideal Otto cycle has a compression ratio of 8. At the beginning of the compression process, air is at 100 kPa and 17°C, and 800 kJ/kg of heat is transferred to air during the constant-volume heat-addition process. Accounting for the variation of specific heats of air with temperature, determine (*i*) the maximum temperature and pressure that occur during the cycle, (*ii*) the net work output, (*iii*) the thermal efficiency, and (*iv*) the mean effective pressure for the cycle. [14]

4.(a) Deduce the expression for cycle efficiency in terms of pressure ratio for a gas turbine power plant, operating on an ideal Brayton cycle. [8]

(b) A gas-turbine power plant operating on an ideal Brayton cycle has a pressure ratio of 8. The gas temperature is 300 K at the compressor inlet and 1300 K at the turbine inlet. Assuming a compressor efficiency of 80 % and a turbine efficiency of 85 % and utilizing the air-standard assumptions, determine (*i*) the back work ratio, and (*ii*) the thermal efficiency. [12]

5. Consider a steam power plant operating on the ideal reheat Rankine cycle. Steam enters the high-pressure turbine at 15 MPa and 600°C and is condensed in the condenser at a pressure of 10 kPa. The reheat pressure is 4 MPa. If the moisture content of the steam at the exit of the low-pressure turbine is

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not to exceed 10.4 percent, Determine, the thermal efficiency of the cycle. Assume the steam is reheated to the inlet temperature of the high-pressure turbine. [20]

6.(a) A 50-kg block of iron casting at 500 K is thrown into a large lake that is at a temperature of 285 K. The iron block eventually reaches thermal equilibrium with the lake water. Assuming an average specific heat of 0.45 kJ/kg·K for the iron, determine (i) the entropy change of the iron block, (ii) the entropy change of the lake water, and (iii) the entropy generated during this process. [6]

(b) Two system maintained at constant pressure are initially at temperature T_1 and T_2, T_1 being higher than T_2. Show that the maximum work obtainable from these two finite bodies, is:

$$W = C_p\left[\sqrt{T_1} - \sqrt{T_2}\right]^2$$ [8]

(c) Ten grams of water at 20°C is converted into ice at –10°C at constant atmospheric pressure. Assuming the specific heat of liquid water to remain constant at 4.2 J/g-K and that of ice to be half of this value, and taking the latent heat of fusion of ice at 0°C to be 335 J/g, calculate the total entropy change of the system. [6]

7.(a) A household refrigerator that has a power input of 450 W and a COP of 1.5 is to cool 5 large watermelons, 10 kg each, to 8°C. If the watermelons are initially at 28°C, determine how long it will take for the refrigerator to cool them. The watermelons can be treated as water whose specific heat is 4.2 kJ/kg·°C. [6]

(b) State the Kelvin-Planck and Clausius statement of 2nd law? What is the difference between a refrigerator and a heat pump? [6]

(c) A heat engine operating between two reservoirs at 1000 K and 300 K is used to drive a heat pump which extracts heat from the reservoir at 300 K at a rate twice that at which the engine rejects heat to it. What is the temperature of the reservoir to which the heat pump rejects heat? What is the rate of heat rejection from the heat pump if the rate of heat supply to the engine is 50 kW? [8]

8.(a) A turbine operates under steady flow conditions, receiving steam at the following state: Pressure 1.2 MPa, temperature 188°C, enthalpy 2785 kJ/kg, velocity 33.3 m/s and elevation 3 m. The steam leaves the turbine at the following state: Pressure 20 kPa, enthalpy 2512 kJ/kg, velocity 100 m/s, and elevation 0 m. Heat is lost to the surroundings at the rate of 0.29 kJ/s. If the rate of steam flow through the turbine is 0.42 kg/s, what is the power output of the turbine in kW? [8]

(b) Derive the energy balance equation for a steady flow system with a single stream. What is the difference between a closed and open system? [6+2]

(c) Derive the expression for work done in an adiabatic process with ideal gas as the working medium. [4]