Ex/CON/PE/T/124/2018

B.E. CONSTRUCTION ENGINEERING 1ST YEAR 2ND SEMESTER,2018

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.

1.(a) Define a Quasi-static process. What is the difference between a path and a point function? 4

(b) What is the difference between intensive and extensive properties? Give examples. 4

(c) Define COP. Show that for same source and sink a heat engine has higher COP than a refrigerator. 4

(d) What is the difference between a refrigerator and a heat pump? Establish the relation: $COP_{HP} = COP_R + 1$. 4

(e) A refrigerator plant for a food store operates as a reversed carnot heat engine cycle. The store is to be maintained at a temperature of -5°C and the heat transfer from the store to the cycle is at a rate of 5 kW. If heat is transferred from the cycle to the atmosphere at a temperature of 25°C; calculate the power required to drive the plant. 4

2.(a) Show that the violation of Kelvin-Planck statement leads to the violation of Clausius statement. 10

(b) Prove that the efficiency of a reversible heat engine operating between two given temperatures is the maximum. Mention the Carnot principles. 10

3.(a) Write the expression for cycle efficiency, in terms of compression ratio, for an Otto cycle and show the processes on p-V planes. 10

(b) A blower handles 1 kg/s of air at 20°C and consumes a power of 15 kW. The inlet and outlet velocities of air 100 m/s and 150 m/s respectively. Find the exit air temperature, assuming adiabatic conditions. 10

4.(a) Which is a more effective way of increasing the efficiency of a Carnot engine – to increase source temperature (T_1), keeping sink temperature (T_2) constant or to decrease T_2, keeping T_1 constant? 10

(b) A reversible heat engine takes heat from a reservoir at 840°C and rejects heat to a reservoir at 60°C. The heat engine drives a reversible heat pump which takes heat from a reservoir at 5°C and delivers heat to a reservoir at 60°C. The reversible heat engine also drives another machine that absorbs 30 kW. If the heat pump extracts 17 kJ/s from the 5°C, determine:

(i) the rate of heat supply from 840°C source

(ii) the rate of heat rejection to 60°C sink. 10

5.(a) Water is heated at a constant pressure of 0.7 MPa. The boiling point is 164.97°C. The initial temperature of water is 0°C. The latent heat of evaporation is 2066.3 kJ/kg. Find the increase of entropy of water, if the final state is steam. 6

(b) Two bodies each of equal mass m and heat capacity c, are of temperatures T_1 and T_2 ($T_1>T_2$) respectively. The first body is used as a source of reversible engine and the second body as the sink. Show that the maximum work obtainable from such an arrangement is:

$$W_{max} = mc[(\sqrt{T_1} - \sqrt{T_2})]^2$$ 8

(c) A 30-kg iron block and a 40-kg copper block, both initially at 80°C, are dropped into a large lake at 15°C.Thermal equilibrium is established after a while as a result of heat transfer between the blocks and the lake water. Determine the total entropy change for this process. 6

6.(a) Using an engine of 30 % thermal efficiency to drive a refrigerator having a COP of 5, what is the heat input into the engine for 1 MJ removed from the cold body by the refrigerator? If this system is used as a heat pump, how many MJ of heat would be available for heating, for each MJ of heat input to the engine? 8

(b) State the Clausius statement. What is a PMM-II? 4

(c) Two Carnot engines A and B are connected in series between two thermal reservoirs maintained at 1000 K and 100 K respectively. Engine A receives 1680 kJ of heat from the high-temperature reservoir and rejects heat to the Carnot engine B. Engine B takes in heat rejected by engine A and rejects heat to the low-temperature reservoir. If engines A and B have equal thermal efficiencies, determine:

(i) The temperature at which heat is rejected by engine A;

(ii) The heat rejected by engine B;

(iii) The work done during the process by engines, A and B respectively. 8

7.(a) Air flows steadily at the rate of 0.4 kg/s through an air compressor, entering at 6 m/s with a pressure of 1 bar and a specific volume of 0.85 m^3/kg, and leaving at 4.5 m/s with a pressure of 6.9 bar and a specific volume of 0.16 m^3/kg. The internal energy of the air leaving is 88 kJ/kg greater than that of the air entering. Cooling water in a jacket surrounding the cylinder absorbs heat from the air at the rate of 59 W. Calculate the power required to drive the compressor and the inlet and outlet cross-sectional areas. 12

(b) From the definition of First law of thermodynamics derive the expression for heat interaction during an adiabatic process, with ideal gas as the working medium. 6

(c) Highlight two difference between a CI and SI engine. 2