BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
FIRST SEMESTER, 2022 – 2023, DATE: 14/02/2023
COMPREHENSIVE EXAMINATION (CLOSED BOOK)

BITS F111 THERMODYNAMICS   Time: 180 min.   Max. Marks: 120

ID Number	**Name**	**Invigilator Sign**

- It consists of Conceptual questions in Part-A, and subjective questions in Part-B
- Answer Conceptual questions (Part-A) in question paper itself in the space provided.
- Answer PART-B questions in the main answer book.
- Underline the final answers and assume suitable data wherever necessary

Marks: A   B   C   D   E   Total =   Sign

Recheck Request:

A) A compressor receives air at 100 kPa, 300 K, and delivers at 500 kPa, 460 K. The mass flow rate of the air is 0.4 kg/s. 25 kJ/kg of heat is rejected out from the compressor during the process. Assuming the changes in kinetic and potential energies are negligibly small, determine the power input to the compressor (kW). [6M]

B) Two Carnot engines operate in series between two reservoirs maintained at 500 °C (T_1) and 100 °C (T_3), respectively. The heat rejected by the first engine is input into the second engine. If the efficiency of the first engine is 25% higher than that of the efficiency of the second engine, calculate the intermediate temperature in °C (T_2). [6M]

C) A design engineer has developed a refrigeration unit that maintains the cold space at -20 °C while operating in a 30 °C room. A COP of 6 is claimed. Evaluate the claim based on your calculations. Justify. [6M]

D) One kg of air expands in a reversible isothermal process such that the volume doubles. Determine the change in entropy of the air and entropy generation during the process. [6M]

E) An evacuated 150 L tank is connected to a line flowing air (constant specific heat) at room temperature, 25 °C, and 8 MPa pressure. The valve is opened, allowing air to flow into the tank until the pressure inside is 6 MPa. At this point, the valve is closed. This filling process occurs rapidly and is essentially adiabatic. The tank is then placed in storage, where it eventually returns to room temperature. What is the final pressure? [6M]

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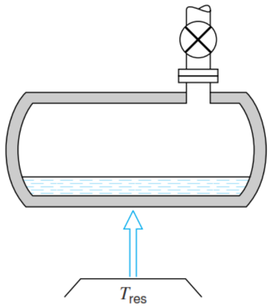
Answer PART-B questions in the main answer book.

PART –B

Q.1. A well-insulated, shell-and-tube heat exchanger is used to heat water in the tubes from 20 °C (state 1) to 70 °C (state 2) at a rate of 4.5 kg/s. Heat is supplied by hot oil (C_p = 2.30 kJ/kg-°C) that enters the shell side at 170 °C (state 3) at a rate of 10 kg/s. Disregarding any heat loss from the heat exchanger and assuming ambient at 25 °C, determine *a*) the exit temperature of the oil (state 4, °C), *b*) the rate of entropy generation in the heat exchanger (kW/K), and *c*) irreversibility rate in the heat exchanger (kW). [20 M]

Q.2 A 500 L tank containing water at 175 kPa and having a quality of 12%. When heat is transferred to water from a reservoir at 400 ˚C, the safety valve opens at a pressure of 1.3 MPa, and saturated vapor flows out. If a total 0.64 kg mass of water flowed out, maintaining 1.3 MPa inside, determine a) the final quality inside the tank, b) total heat transfer, and c) entropy generation during the process. [23 M]

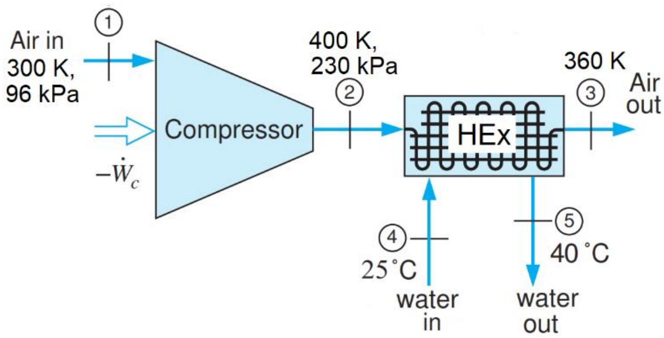


Q.3 A constant pressure piston-cylinder arrangement has 2 kg methane at 100 kPa and 125 K. Now it is heated to 200 K from a heat source at 350 °C. If the ambient temperature is 25 °C, determine a) the heat transfers to the methane (kJ), b) the total entropy generation (kJ/K), c) irreversibility during process (kJ), and d) reversible work (kJ). [22M]

Q.4 Air (ideal gas) flows through the compressor and heat exchanger, as shown in Fig. below. A separate liquid water stream also flows through the heat exchanger. The volumetric flow rate of air into the compressor is 26.91 m³/min. The pressure and temperature data corresponding to various states are indicated in the figure under steady-state operating conditions. The changes in kinetic and potential energies and heat transfer to the surroundings can be neglected. Evaluate:

a. The mass flow rate of the cooling water (kg/s)
b. The compressor power input (kW)
c. The rate of entropy production for the compressor (kW/K)
d. The rate of entropy production for the heat exchanger (kW/K)

[25M]



****** **Best luck** ******

P.T.O.