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MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent institution of MAHE, Manipal)

III SEMESTER B.TECH. (MECHATRONICS ENGINEERING)

END SEMESTER EXAMINATIONS, NOV 2018

SUBJECT: ENGINEERING THERMODYNAMICS AND HEAT TRANSFER

[MTE 2103]

(22/11/2018)

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** the questions.
- Data not provided may be suitably assumed

1A. Calculate enthalpy change for 3 kg of steam to be heated from 300 ºC to 700 ºC. Specific heat of superheated steam at 150 kPa is given as Cp = 2.07 + (T-400) / 1480 kJ/kg. ºC **02**

1B. Air is compressed in a cylinder such that its volume changes from 0.2 m^3 to 0.02 m^3. The pressure and temperature at the beginning of the process is 200 kPa and 50 °C. Evaluate the work and heat transfer if (a) The pressure is constant and (b) Temperature is constant at 50 °C. (c) Sketch both the process on PV diagram separately. Take R= 0.287 kJ/kg °C, C_v = 0.718 kJ/kg °C **04**

1C. Two Carnot engines A and B are connected in series between two thermal reservoirs maintained at 1000 K and 100 K respectively. The engine A receives 1680 kJ heat from high temperature reservoir and rejects heat to the Carnot engine B. The engine B takes in heat rejected by engine A and rejects heat to a low temperature reservoir at 100 K. If engines A and B have equal thermal efficiencies, determine: **04**

i. Heat rejected by engine B

ii. Temperature at which heat is rejected by engine A

iii. Work done by engines A and B respectively.

2A. An ideal vapor-compression refrigeration cycle operates at steady state with Refrigerant 134a as the working fluid. Saturated vapor enters the compressor at 10 °C, and saturated liquid leaves the condenser at 28 °C. The mass flow rate of refrigerant is 5 kg/min. Determine **06**

(i) the compressor power, in kW.

(ii) the refrigerating capacity, in tons.

(iii) the coefficient of performance.

(iv) If in the same question if compressor is not 100 % efficient then what will be the effect on COP and how?

2B. A Carnot engine draws heat from a reservoir at a temperature T_A and rejects heat to another reservoir at temperature T_B. The engine drives a refrigerator which absorbs heat from a reservoir at a temperature T_C and rejects heat to a reservoir at temperature T_B. For T_A=500 K and T_C = 250K, estimate T_B such that the heat taken in by the engine from the reservoir at T_A equals the heat absorbed by the refrigerator from the reservoir at T_C. Also estimate the efficiency of the engine and COP of the refrigerator. **04**

3A Air enters a one-inlet, one-exit control volume at 8 bar, 600 K, and 40 m/s through a flow area of 20 cm^2. At the exit, the pressure is 2 bar, the temperature is 400 K, and the velocity is 350 m/s. The air behaves as an ideal gas. For steady-state operation, determine **04**

(a) the mass flow rate, in kg/s.

(b) the exit flow area, in cm^2.

3B An electric motor drives a centrifugal pump which circulates a hot liquid metal at 480°C (Fig 3B). The motor is coupled to the pump impeller by a horizontal steel shaft (k=32 W/m °C), 25 mm in diameter. If the ambient air temperature is 20°C, temperature of the motor is limited to a maximum value of 55°C and heat transfer coefficient between the steel shaft and ambient air is 14.8 W/m^2°C, estimate the length of shaft should be specified between motor and pump? Consider an insulated tip boundary condition. **04**

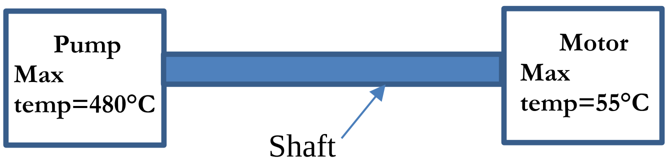

Fig 3B

3C A transistor with a height of 0.4 cm and a diameter of 0.6 cm is mounted on a circuit board as shown in Fig 3C. The transistor is cooled by air flowing over it with an average heat transfer coefficient of 30 W/m² · °C. If the air temperature is 55°C and the transistor case temperature is not to exceed 70°C, determine the amount of power this transistor can dissipate safely. Disregard any heat transfer from the transistor base. **02**

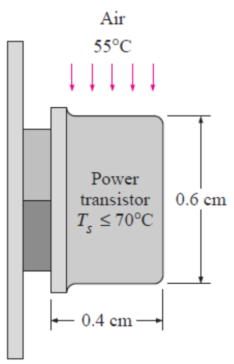

Fig 3C

4A. A 150 mm long steel pipe has an inside diameter of 120 mm and outside diameter of 160 mm. It is insulated at the outside with asbestos. The steam temperature is 150°C and the air temperature is 20°C. Also $h_{steam\ side}$ =100 W/m² °C and $h_{air\ side}$ is 30 W/m² °C. $k_{asbesos}$= 0.8W/m °C and k_{steel}=42 W/m °C. What should be the thickness of asbestos in order to limit the heat loss to 0.15 kw? **05**

4B. Two slabs each 120 mm thick having thermal conductivities of 14.5 W/m°C and 210 W/m°C is shown in Fig Q4B. These are placed in contact, but due to roughness, only 30% of area is in contact and the gap in the remaining area is 0.025 mm thick and is filled with air. If the temperature of the face of the hot surface is at 220°C and outside surface of other slab is 30°C, determine the heat flow through the system and the temperatures at the interface of slab A and air, and slab B and air respectively. **05**

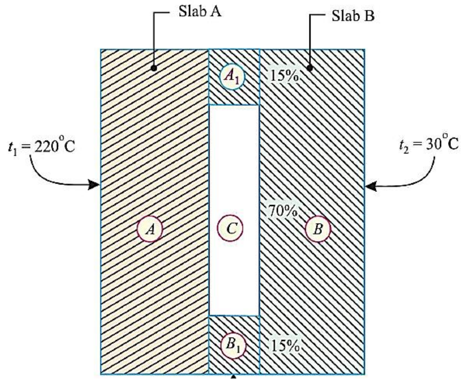

Fig Q4B

5A The flow rates of hot and cold water streams running through a parallel flow heat exchanger are 0.2 kg/s and 0.5 kg/s respectively. The inlet temperatures on the hot and cold sides are 75°C and 20°C respectively. The exit temperature of hot water is 45°C. If the overall heat transfer coefficient is 325 W/m^2 °C, calculate the area of heat exchanger. **04**

5B Consider a spherical container of inner radius r_1=8 cm, outer radius r_2=10 cm, and thermal conductivity k=45 W/m °C, as shown in Fig 5B. The inner and outer surfaces of the container are maintained at constant temperatures of T_1 =200°C and T_2 =80°C, respectively, as a result of some chemical reactions occurring inside. Obtain a general relation for the temperature distribution inside the container shell under steady state conditions. **03**

The governing equation for heat transfer through a sphere is given by

$$\frac{d}{dr}\left(r^2\frac{dt}{dr}\right) = 0$$

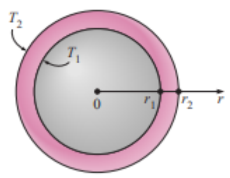

Fig 5B

5C An engineer has designed an electronic cabinet for a particular application. He needs to select an appropriate cooling method for removing the heat from the cabinet. You are asked to explain the methods available to cool the electronic cabinet using different methods you know while addressing their merits and demerits. **03**