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MANIPAL INSTITUTE OF TECHNOLOGY

III SEMESTER B.TECH (MECHATRONICS ENGINEERING)

END SEMESTER EXAMINATIONS, NOV/DEC 2015

SUBJECT: ENGINEERING THERMODYNAMICS AND HEAT TRANSFER

[MTE 2103]

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** the questions.
- Missing data may be suitably assumed.

1A. A heat engine operates between 2 reservoirs at 800˚C and 20˚C. One half of the work output of the heat engine is used to drive a Carnot refrigerator that removes heat from a cold surrounding at 2˚C and transfers it to a house maintained at 22˚C. If the house is losing heat at a rate of 95000kJ/h, determine the minimum rate of heat supply to the heat engine required to keep the house at 22˚C. **(04)**

1B. A vertical cylinder of cross sectional area $0.25m^2$ fitted with a leak proof piston containing 0.3kg of air. Initially the volume is $0.5m^3$ and temperature is 500˚C. The air is cooled and the piston descends until it hits 2 stops on the inside of the cylinder and the volume of air is then $0.25m^3$. The cooling process is continued until temperature of air becomes 20˚C. Calculate **(04)**

a. Initial pressure of air
b. Temperature of air when the piston hits the stops
c. Pressure of air and force on stops when the temperature is 20˚C

Assume that air is an ideal gas with a gas constant of 0.287 KJ/kgK

1C. For heat transfer purposes, a standing man can be modeled as a 30-cm-diameter, 170-cm-long vertical cylinder with both the top and bottom surfaces insulated and with the side surface at an average temperature of 34°C. For a convection heat transfer coefficient of 15 $W/m^2\,°C$, determine the rate of heat loss from this man by convection in an environment at 20°C. **(02)**

2A. For a steady flow system, the following information is available **(04)**

S. No	Particulars	Inlet Conditions	Exit Conditions
1	Pressure(bar)	10	1
2.	Density(kg/m^3)	2.5	0.85
3.	Diameter(cm)	5	10
4.	Temperature(˚C)	427	27
5.	Elevation(m)	2	1

Working substance rejects heat of 774 MJ/hr. The rate of flow of working substance is 2.15Kg/s and it behaves as an ideal gas for which R=300J/kgK and ratio of specific heats =1.4. Find the power devloped by the turbine in KW.

2B. Derive Heat Diffusion Equation for a steady state condition in Cartesian coordinate system. **(04)**

2C An automobile engine consumes fuel at a rate of 20L/h and delivers 60KW power to the wheels. If the fuel has a heating value of 44000 KJ/kg, and a density of 0.8g/cm^3, determine the efficiency of this engine. **(02)**

3A. Establish the inequality of Clausius. Also show that entropy is a property of the system. **(05)**

3B. A 2-mm-diameter and 10-m-long electric wire is tightly wrapped with a 1-mm-thick plastic cover whose thermal conductivity is k = 0.15 W/m · °C (shown in Fig Q3.B). Electrical measurements indicate that a current of 10 A passes through the wire and there is a voltage drop of 8 V along the wire. If the insulated wire is exposed to a medium at T_∞ = 30°C with a heat transfer coefficient of h = 24 W/m² · °C, determine the temperature at the interface of the wire and the plastic cover in steady operation. Also, determine if doubling the thickness of the plastic cover will increase or decrease this interface temperature. **(03)**

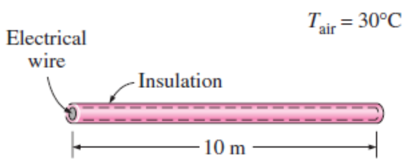

Fig Q3.B

3C. A CPU cabinet as shown in Fig Q3.C contains a graphic processing unit (GPU) and is observed to be the main source of CPU cabinet overheating while gaming. The GPU constantly rejects heat at a rate of 15kJ/h during the **(02)**

game and the metallic cabinet absorbs heat at a rate of 3KJ/h. Assuming that the cabinet is sealed and does not have a cooling fan, calculate the rise in temperature of air within 15 min of start of the game. Also neglect the size of the GPU and presence of other components in the cabinet. Take C_v=0.715kJ/kgK, Room temp=298K, R=287J/kgK and atmospheric pressure as 1 bar.

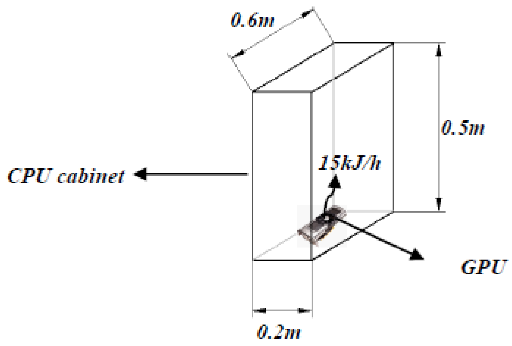

Fig Q3.C

4A. A vapor Compression system communicates thermally with a cold region at 20˚C and a warm region at 45˚C. Saturated vapor enters the compressor at 20˚C and saturated liquid leaves the condenser at 45˚C. The mass flow rate of the refrigerant is 0.008kg/s. Determine: **(04)**

a. Compressor power in KW
b. Dryness fraction after throttling
c. Refrigeration capacity in tons.
d. COP of a Carnot refrigeration cycle operating between warm and cold regions at 45˚C and 20˚C respectively.

Use R12 as the refrigerant.

4B. A thin-walled double-pipe parallel-flow heat exchanger is used to heat a chemical whose specific heat is 1800 J/kg°C with hot water (C_p = 4180 J/kg°C). The chemical enters at 20°C at a rate of 3 kg/s, while the water enters at 110°C at a rate of 2 kg/s. The heat transfer surface area of the heat exchanger is 7 m² and the overall heat transfer coefficient is 1200 W/m² °C. Determine the outlet temperatures of the chemical and the water. Use effectiveness-NTU method. **(04)**

4C. A room of 4 persons has 2 fans each consuming 0.18KW power and three 100 watts lamps. Ventilation air at the rate of 80kg/h enters with an enthalpy of 84kJ/kg and leaves with an enthalpy of 59kJ/kg. If each person puts out **(02)**

heat at the rate of 630kJ/h, determine the rate at which heat is to be removed by a room cooler so that a steady state is maintained in the room.

5A. Consider steady heat transfer between two large parallel plates (shown in Fig Q5.A) at constant temperatures of T_1=300 K and T_2= 200 K that are L=1 cm apart, as shown in figure. Assuming the surfaces to be black (emissivity ε=1), determine the rate of heat transfer between the plates per unit surface area assuming the gap between the plates is (a) filled with atmospheric air, (b) evacuated, (d) filled with superinsulation that has an apparent thermal conductivity of 0.00002 W/m · °C. **(04)**

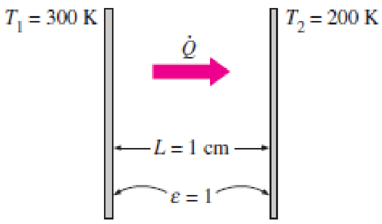

Fig Q5.A

5B. Discuss the considerations taken into account in the selection and design of cooling equipment. **(03)**

5C. Consider Fig Q5.C. The wall of a refrigerator is constructed of fiberglass insulation (k=0.035 W/m °C) sandwiched between two layers of 1-mm-thick sheet metal (k =15.1 W/m °C). The refrigerated space is maintained at 3°C, and the average heat transfer coefficients at the inner and outer surfaces of the wall are 4W/m² °C and 9 W/m² °C, respectively. The kitchen temperature averages 25°C. It is observed that condensation occurs on the outer surfaces of the refrigerator when the temperature of the outer surface drops to 20°C. Determine the minimum thickness of fiber glass insulation that needs to be used in the wall in order to avoid condensation on the outer surfaces. **(03)**

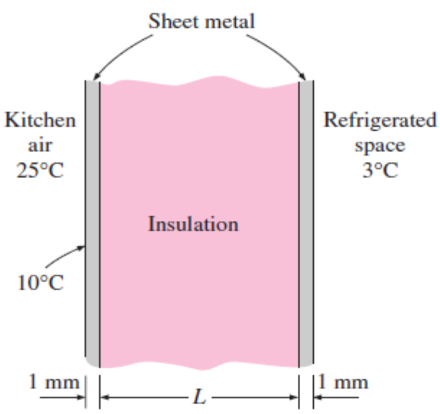

Fig Q5.C