VIT
Vellore Institute of Technology

Final Assessment Test – November 2019

Course: MEE2038 - Thermal and Heat Transfer

Class NBR(s): 1128

Slot: C1+TC1+V2

Time: Three Hours

Max. Marks: 100

KEEPING MOBILE PHONE/SMART WATCH, EVEN IN 'OFF' POSITION, IS EXAM MALPRACTICE

General Instructions:

i) Use of Steam tables, Refrigeration tables, Psychrometric chart and Heat & Mass Transfer data book are permitted

ii) Missing data if any, may be reasonably assumed

Answer any TEN Questions
(10 X 10 = 100 Marks)

1.a) A three-stage reciprocating air-compressor delivers 5.2 m^3 of free air per minute at the rated inlet condition of 1.03 bar and 20 °C. The suction pressure and temperature are 1 bar and 30 °C respectively. The air is cooled to 30 °C after each stage of compression. The delivery pressure of the compressor is 150 bar when it is rotating at 300 rpm. Assume the clearance volume of all three cylinders is 5% of respective stroke volumes. If the index of compression and expansion in all the three stages is 1.35, find the power required to run the compressor. [5]

b) The capacity of a saturation vapour compression refrigeration cycle with R-12 as refrigerant is 10 tonns. This refrigeration unit is operating between -6 °C and 36 °C. For this unit, find the mass flow rate of refrigerant. If the compressor employed in this used is single cylinder and single-acting which is running at 300 rpm, then find its cylinder diameter. Assume the ratio between stroke length and cylinder diameter as 1.2 and volumetric efficiency as 0.9. [5]

2. An office is to be air-conditioned for 50 members when the outdoor conditions are 30 °C dry bulb temperature and 75 % relative humidity. If the quantity of air supplied is 0.4 m^3/min/person, find the following:

i) Capacity of cooling coil in tonnes of refrigeration
ii) Capacity of heating coil in kW
iii) Amount of water vapour removed per hour

Assume that required air inlet conditions are 20 °C dry bulb temperature and 60 % relative humidity. Air is conditioned first by cooling and dehumidifying and then by heating

iv) If the heating coil surface temperature is 20 °C, find the by-pass factor of the heating coil.

3.a) Determine the thermal conductivity of asbestos powder packed in between two concentric copper pipes of 25 mm inner diameter and 36 mm outer diameter. The inner pipe has a heating coil which has a rated power of 120 W/m. Assume negligible thermal contact resistance between the heating coil and inner surface of the pipe. The average temperature of inner and outer pipes are measured to be 42.4 °C and 27.9 °C respectively [5]

b) A copper wire of 40 mm diameter carries a current of 250 A and has an electrical resistance of $0.25\times 10^{-4}\Omega cm$ per unit length. The surface temperature of copper wire is 250 °C and the ambient air temperature is 10 °C. If the thermal conductivity of the copper wire is 175 W/m-K, calculate maximum temperature and heat transfer co-efficient between wire surface and ambient air [5]

4. Alloy steel ball of 12 mm diameter heated to 800 °C is quenched in a bath at 100 °C. Consider the following material properties for the ball:

- Thermal conductivity = 57 W/m-K
- Density = 7860 kg/m^3
- Specific heat capacity = 450 J/kg-K

The convective heat transfer coefficient between the fluid in the quenching bath and steel ball is 41.7 W/m^2-K. For this heat treatment process, determine (i) temperature of the ball after 10 seconds (ii) Time taken for the steel ball to cool to 400 °C

5. Consider the cylinder wall of an IC engine as a plane wall. The initial temperature of the wall before combustion process is 25 °C. It is given that the temperature of the combustion mixture is 800 °C. Assume the convective heat transfer coefficient between the combustion mixture and wall to be 20 W/m^2-K. For design consideration, the maximum allowable temperature for the wall is 400 °C. To meet the design criteria, determine the permissible time of exposure to the combustion mixture. Consider the following thermo-physical properties for cylinder wall

- Thermal conductivity = 57 W/m-K
- Thermal diffusivity = 1.66×10^{-5} m^2/s

6. Air flows over a flat plate at a velocity of 3 m/s and at temperature 15 °C. The plate is maintained at 85 °C. If the length of the plate is 100 cm long along the flow of air, find the heat lost by the plate per unit width.

7. A vertical plate of 0.75 m height is at 170 °C and is exposed to air at a temperature of 105 °C and 1 bar atmospheric pressure. Calculate mean heat transfer coefficient and rate of heat transfer per unit width of the plate

8. In a double pipe heat exchanger, hot fluid with a specific heat of 2300 J/kg-K at 380 °C and leaves at 300 °C. Cold fluid enters at 25 °C and leaves at 210 °C. Calculate the heat exchanger area required for counter flow and what would be the percentage increase in area if the fluid flows were parallel.
Take overall heat transfer coefficient to be 750 W/m^2-K and mass flow rate hot water to be 1 kg/s.

9. Derive the expression for pressure ratio for maximum discharge from steam nozzle, starting from steady flow energy equation.
Also, find the numerical value of critical pressure ratio for dry saturated and superheated steam from the derived expression.

10. Steam at a pressure of 10.5 bar and 0.95 dry is expanded through a convergent divergent nozzle. The pressure of the steam leaving the nozzle is 0.85 bar. Find the velocity of steam at throat for maximum discharge. Take index of expansion, n = 1.135.
Also, find the throat area at the exit and the steam discharge if the throat area is 1.2 cm^2. Assume the flow is isentropic and there are no friction losses.

11. Ten thin brass fins of 1 mm thick, 5 cm wide and length 7 cm are placed axially on an engine cylinder at equidistance of 1 cm. The temperature of the fluid surrounding the fin is 27 °C with a convective heat transfer coefficient of 15 W/m^2-K. Consider the thermal conductivity of the fin as 100 W/m-K and the base temperature of the fin as 760 °C. Calculate the total heat transfer from the engine cylinder. Assume negligible heat transfer from the fin tip.

12. Discuss in detail the role of following in automobiles
    i) Extended surfaces
    ii) Heat exchangers

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