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10ME63

Sixth Semester B.E. Degree Examination, Feb./Mar. 2022
Heat and Mass Transfer

Time: 3 hrs. Max. Marks:100

Note: ***1. Answer any FIVE full questions, selecting at least TWO full questions from each part.***
2. Use of heat transfer data hand book and steam table is permitted.

PART – A

1 a. Write down the one dimensional, heat conduction equation in Cartesian, cylindrical and spherical co-ordinate systems. **(06 Marks)**

b. Explain the three types of boundary conditions used in conduction heat transfer with examples. **(08 Marks)**

c. A spherical vessel of 0.5m outside diameter is insulated with 0.2m thickness of insulation of thermal conductivity 0.04W/m°C. The surface temperature of the vessel is -195°C and outside air is at 10°C. Determine:
i) Heat flow
ii) Heat flow per m^2 based on inside and outside area
iii) Temperature gradients at the inner and outside surface. **(06 Marks)**

2 a. Obtain an expression for temperature distribution and heat flow through a rectangular fin, when the end of fin is insulated. **(12 Marks)**

b. A rod of 10mm diameter and 80mm length with thermal conductivity 16W/m°C protrudes from a surface at 160°C. The rod is exposed to air at 30°C with a convection coefficient of $25W/m^2°C$. How does the heat flow from this rod set affected if the same material volume is used for two fins of the same length? Assume short fin with end insulated. **(08 Marks)**

3 a. What are Biot and Fourier number? Explain their significance. **(04 Marks)**

b. What do you mean by lumped system analysis? Explain clearly. **(04 Marks)**

c. A metallic sphere of radius 10mm is initially at a uniform temperature of 400°C. It is heat treated by first cooling it in air ($h = 10W/m^2K$) at 20°C unfil its central temperature reaches 335°C. It is then quenched in a water bath at 20°C with $h = 6000W/m^2K$ until the centre of the sphere cools from 335°C to 50°C. Compute the time required for cooling in air and water for the following physical properties of the sphere.
$\rho = 3000kg/m^3$, $C = 1000J/kgK$, $K = 20W/mK$, $\alpha = 6.66 \times 10^{-6}\ m^2/s$. Also calculate the surface temperature at the end of cooling in water. **(12 Marks)**

4 a. Explain the mechanism of convective heat transfer. **(04 Marks)**

b. Explain the following:
i) Velocity boundary layer
ii) Thermal boundary layer **(08 Marks)**

c. Calculate the coefficient of heat transfer by free convection between a horizontal wire and air at 25°C. The surface of the wire is at 95°C and its diameter is 2.5mm. Also find the maximum admissible current intensity if the resistance of the wire is 6 ohm/m.
The properties of air at film temperature are:
$P_r = 0.696$, $K = 28.96 \times 10^{-3} W/mK$, $\nu = 18.97 \times 10^{-6}\ m^2/s$ **(08 Marks)**

PART – B

5 a. Using dimensional analysis, obtain fundamental relation between dimensionless parameters in forced convection. **(10 Marks)**

b. Air at 30°C is flowing across a tube with a velocity of 25m/s. The tube could be either a square with a side of 5cm or a circular cylinder of diameter 5cm. Compare the heat transfer coefficient in each case if the tube surface temperature is 124°C.
The properties of air at firm temperature are:
$\nu = 20.92 \times 10^{-6}\ m^2/s$, $K = 3 \times 10^{-2} W/mK$, $P_r = 0.7$. **(10 Marks)**

6 a. Derive an expression for LMTD for counter flow heat exchanger state the assumptions made. **(10 Marks)**

b. A counterflow concentric tube heat exchanger is used to cool engine oil (C = 2130J/kgK) from 160°C to 60°C with water, available at 25°C as the cooling medium. The flow rate of cooling water through the inner tube of 0.5m diameter is 2kg/s while the flow rate of oil through the outer annulus O.D = 0.7m is also 2kg/s. If the value of the overall heat transfer coefficient is $250W/m^2K$, how long must the heat exchanger be to meet its cooling requirement? **(10 Marks)**

7 a. Clearly explain the regimes of pool boiling with a neat sketch. **(06 Marks)**

b. Define: i) Mass concentration ii) Molar concentration. **(04 Marks)**

c. A vertical flat plate in the form of fin 600mm in height and is exposed to steam at atmospheric pressure. If surface of the plate is maintained at 60°C, calculate the following:
i) The film thickness at the trailing edge of the film
ii) The overall heat transfer coefficient
iii) The heat transfer rate
iv) The condensate mass flow rate
Assume laminar flow conditions and unit width of the plate. **(10 Marks)**

8 a. With reference to thermal radiation, explain the following terms:
i) Black body and gray body
ii) Specular and diffuse surface
iii) Radiocity and irradiation. **(06 Marks)**

b. A pipe carrying steam runs in a large room and exposed to air at 30˚C. The pipe surface temperature is 200˚C. Diameter of the pipe is 20 cm. If the total heat loss per metre length of the pipe is 1.9193 kW/m, determine the emissivity to the pipe surface. **(08 Marks)**

c. A thermos flask has a double walled bottle and the space between the walls is evacuated so as to reduce the heat flow. The bottle surfaces are silver plated and the emissivity of each surface is 0.025. If the contents of the bottle are at 375K, find the rate of heat loss from the thermos flask bottle to the ambient air at 300K. What thickness of cork (K = 0.03W/m°) would be required if the same insulating effect is to be achieved by the use of cork. **(06 Marks)**

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