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06ME65

Sixth Semester B.E. Degree Examination, December 2012
Heat and Mass Transfer

Time: 3 hrs. Max. Marks: 100

Note: 1. *Answer FIVE full questions, selecting at least TWO questions from each part.*
2. *Use of HMT data book is permitted.*

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

PART – A

1 a. Starting from fundamental principles, derive the general, three-dimensional heat conduction equation in Cartesian co-ordinates. **(09 Marks)**

b. A liquid at 100°C flows through a pipe of 40 mm outer and 30 mm inner diameter. The thermal conductivity of pipe material is 0.5 W/mK. The pipe is exposed to air at 40°C. The inner and outer convective heat transfer coefficients are 300 W/m^2K and 5 W/m^2K respectively. Calculate the overall heat transfer coefficient and the heat loss per unit length of pipe. **(08 Marks)**

c. What is the technical need to under take a detailed study of heat transfer, having studied thermodynamics already? **(03 Marks)**

2 a. A tube with an outer diameter of 20 mm is covered with insulation. The thermal conductivity of insulating material is 0.18 W/mK. The outer surface losses heat by convection with a heat transfer coefficient of 12 W/m^2K. Determine the critical thickness of insulation. Also calculate the ratio of heat loss from the tube with critical thickness of insulation to that from the bare tube (without insulation). **(10 Marks)**

b. Derive the one-dimensional fin equation for a fin of uniform cross section. By integrating the fin equation, obtain the expression for the temperature variation in a long fin. **(10 Marks)**

3 a. Consider a solid, with an uniform initial temperature, suddenly immersed in a liquid. Derive the relevant governing differential equation, considering the system as lumped. By solving the differential equation, obtain the expression for the temperature variation with time. **(10 Marks)**

b. A 50 mm thick iron plate (K=60 W/mK, C_p=460 J/kg K, ρ=7800 kg/m^3, $\alpha = 1.6\times10^{-5}\ m^2/s$) is initially at 225°C. Suddenly both surfaces are exposed to a fluid at 25°C, with a heat transfer coefficient of 500 W/m^2K. Calculate the centre and the surface temperatures 2 minutes after the cooling begins using Heisler's charts. **(10 Marks)**

4 a. The velocity profile for boundary layer flow over a flat plate is given by, $\frac{u(x,y)}{u_\infty} = \frac{3}{2}\frac{y}{\delta(x)} - \frac{1}{2}\left\{\frac{y}{\delta(x)}\right\}^3$, where boundary layer thickness $\delta(x) = \sqrt{\frac{280\gamma x}{13u_\infty}}$. Develop an expression for local drag coefficient. Also develop an expression for average drag coefficient for a length of L. **(10 Marks)**

b. Consider a square plate of size 0.6 m in a room with stagnant air at 20°C. One side of plate is maintained at 100°C, while the other side is adiabatic. Determine the heat loss if the plate is, i) vertical and ii) horizontal with hot surface facing up. **(10 Marks)**

PART – B

5 a. Air at 0°C and 20 m/s flows over a flat plate of length 1.5 m, that is maintained at 50°C. Calculate the average heat transfer coefficient over the region where flow is laminar. Find the average heat transfer coefficient and the heat loss for the entire plate per unit width. **(12 Marks)**

b. Air at -20°C and 30 m/s, flows over a sphere of diameter 25 mm, which is maintained at 80°C. Calculate the heat loss from sphere. **(08 Marks)**

6 a. Derive an expression for the logarithmic mean temperature difference (LMTD) for a parallel flow heat exchanger **(12 Marks)**

b. A cross flow heat exchanger, with both fluids unmixed, has an area of 8.4 m^2, is used to heat air (Cp = 1005 J/kgK) with water (Cp = 4180 J/kgK). Air enters at 15°C, at a rate of 2 kg/s, while water enters at 90°C at a rate of 0.25 kg/s. The overall heat transfer coefficient is 250 W/m^2K. Calculate exit temperatures of both fluids and the heat transfer, using effectiveness – NTU method. **(08 Marks)**

7 a. Saturated steam at 65°C condenses on a vertical tube with an outer diameter of 25 mm, which is maintained at 35°C. Determine the length of tube needed, if the condensate flow needed is 6×10^{-3} kg/s. **(10 Marks)**

b. Water at atmospheric pressure and saturation temperature is boiled in a 250 mm diameter, polished stainless steel pan, which is maintained at 116°C. Calculate the heat flux and the evaporation rate. **(10 Marks)**

8 a. State and prove Kirchoff's law of radiation. **(06 Marks)**

b. Two large parallel plates with emissivities 0.5 and 0.8 are maintained at 800 K and 600 K respectively. A radiation shield having an emissivity of 0.1 on one side and 0.05 on the other side is placed in between. Calculate the heat transfer per unit area with and without the radiation shield. **(08 Marks)**

c. Determine the view factors from the base of a cube to each of its five surfaces. **(06 Marks)**

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