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P.E.S. College of Engineering, Mandya - 571 401

(An Autonomous Institution affiliated to VTU, Belgaum)

Sixth Semester, B.E. - Mechanical Engineering

Semester End Examination; June/July - 2015

Heat and Mass Transfer

Time: 3 hrs *Max. Marks: 100*

***Note**: i) Answer any **FIVE** full questions, selecting at least **TWO** full questions from each **part**.*
ii) Use of Design data handbook is permitted.
iii) Any missing data required may be suitably assumed.

PART - A

1. a. Develop an expression for three dimensional heat conduction equations in Cartesian coordinate system and hence deduce Laplace equation. 8

b. A small thin metal plate of area A m^2 is kept insulated on one side and exposed to the sun on the other side. The plate absorbs solar energy at a rate of 500 W/m^2 and dissipates it by convection into the ambient air at 300 K with a convection heat transfer coefficient of 20 W/m^2K and by radiation into surrounding area which may be assumed to be black body at 280 K. The emissivity of the surface is 0.9. Determine the equilibrium temperature of the plate. 6

c. Consider the case of a rectangular region $0 \leq x \leq L$, $0 \leq y \leq W$ is maintained at the following conditions.
The boundary at y = 0 is at a uniform temperature of T_0 and the boundary at $y = w$ is dissipating heat by convection into a medium at a temperature T_∞. The boundary surfaces at $x = 0$ and $x = L$ are insulated. Write the mathematical formulation of the steady state heat conduction problem. 6

2 a. Develop expressions for temperature distribution and heat dissipation under one dimensional steady state heat conduction for the following system. 14
i) Hollow cylinder ii) Fin insulated at tip.

b. A steam boiler furnace is made of a layer of fireclay 12.5 cm thick and a layer of red brick 50 cm thick. If the wall temperature inside the boiler furnace is 1100ºC and that on the outside wall is 50ºC, determine the amount of heat loss per square meter of the furnace wall. 6
Take $K_{Fireclay} = 0.533$ W/m K and $K_{redbrick} = 0.7$ W/m K.

3 a. What is humped capacity? what are the assumptions for lumped capacity analysis? 4

b. What are Heisler charts? Explain their significance in solving transient conduction problems. 6

c. An alluminium plate K = 160 W/m K, ρ = 2790 kg/m^3, $C_p = 0.38$ kJ/kgK and thickness 3 cm, at a uniform temperature of 225ºC is suddenly immersed in a well stirred fluid maintained at a constant temperature of 25ºC. The heat transfer coefficient between the plate and the fluid is 300 W/m^2K. Determine the time required for the centre of the plate to reach 50ºC. 10

Contd…2

4 a. The exact expression for local Nusselt number for laminar flow along a flat plate is given by

$$N_{Ux} = \frac{h_x x}{K} = 0.332 P_r^{1/3} R_{ex}^{1/2}$$

Shot that the average heat transfer coefficient $\bar{h}$ over the length L of the plate is twice the value of local heat transfer coefficient. 8

b. A tube of 10 cm outer diameter and 3 m long is maintained at a uniform temperature of 100ºC. It is exposed to ambient air at a uniform temperature of 20ºC. Determine the rate of heat transfer from the surface of the tube to ambient air when. 12

i) Tube is vertical ii) Tube is Horizontal.

PART - B

5 a. Explain the physical significance of 9

i) Reynold's number ii) Prandtl number iii) Nusselt number

b. Air at 20º C flows past a 800 mm long plate at a velocity of 45 m/s.

If the surface of the plate is maintained at 300º C. Determine,

i) The heat transferred from the entire plate length to air taking into consideration both laminar and turbulent portions of the boundary layer. 11

ii) The percentage error if the boundary layer is assumed to be turbulent from the leading edge of the plate, Assume unit width of the plate and critical Reynolds number of 5 x 10^5.

6. a. Derive an expression for LMTD for a parallel flow heat exchanger. 10

b. The following data refers to a water to water heat exchanger,

$$\dot{M}_C = 200\ kg/\min \quad \dot{M}_h = 100\ kg/\min$$
$$T_{Ci} = 35°C, \quad T_{CO} = 55°C, \quad T_{hO} = 95°C,$$
$$U = 1400\ W/m^2K$$

10

Velocity of cold water = 0.4 m/s.

Calculate the number of tubes for counter flow heat exchanger assuming length of the tubes is 2 m, density and specific heat of hot water and cold water are same in the given temperature range.

7 a. Discuss the difference between condensation and boiling. 5

b. State and explain Fick's law of diffusion. 5

c. A vertical square plate 30 cm x 30 cm is exposed to steam at atmospheric pressure. The plate temperature is 98ºC. Calculate the heat transfer and the mass of steam condensed per hour. 10

8 a. Define; i) Emissive power ii) Grey bodies. 4

b. State and prove Kirchhoff's law of radiation. 6

c. Two large parallel plates with ε = 0.5 each, are maintained at different temperatures and are exchanging neat by radiation. Two equally large radium shields with surface emissivity 0.05 are introduced in parallel to the plates. Find the percentage reduction in net radiative heat transfer. 10

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