USN | | | | | | | | | | |

06ME65

Sixth Semester B.E. Degree Examination, June/July 2013
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 heat transfer data hand book/ steam tables/charts is permitted.***

PART – A

1 a. What are the different types of boundary conditions? Explain them with suitable sketches for one dimensional heat conduction. **(06 Marks)**

b. Consider a solid cylinder of radius r = b in which energy is generated at a constant rate of g_0 W/m^3, while the boundary surface at r = b is maintained at a constant temperature T_2. Develop an expression for the one-dimensional, radial, steady state temperature distribution T(r) and the heat flux q(r). **(06 Marks)**

c. A steel tube is covered with a layer of insulation made of asbestos material. This tube is used for the flow of hot gases. The following data is given: ID of steel tube = 75 mm, OD of steel tube = 100 mm, Thickness of asbestos layer = 30 mm, Temperature of hot gases = 350°C, Temperature of outside ambient air = 40°C, K for steel = 50 W/m-K, K of asbestos layer = 0.15 W/m-K, Convective heat transfer coefficients for hot gases and ambient air are 300 and 20 W/m^2-K respectively. Calculate : i) Overall heat transfer coefficient based on outside surface area ii) Heat loss per metre length of pipe and iii) Temperature drop across the asbestos. **(08 Marks)**

2 a. What is the critical thickness of insulation? Derive an expression for critical thickness of insulation for a sphere. **(05 Marks)**

b. Obtain an expression for temperature distribution and heat flow through a rectangular fin, when the end of fin is insulated. **(10 Marks)**

c. The temperature of the air stream in a tube is measured with the help of a thermometer placed into a protective well filled with oil. The thermometer well is made of a steel tube (K = 55.8 W/m-K), 120 mm long and 1.5 mm thick. The heat transfer coefficient between the flowing air and the protective well is 23.3 W/m^2-K and the temperature recorded by the thermometer is 84°C. Estimate the error in the measurement if the temperature at the base of the well is 40°C. **(05 Marks)**

3 a. Derive an expression for temperature distribution in a lumped system. Also derive equations for instantaneous rate of heat flow and to energy transfer for the given time. **(12 Marks)**

b. A person is found dead at 5 PM in a room which is at 20°C. The temperature of body is measured to be 25°C when found and the heat transfer coefficient is estimated to be 8 W/m^2-K. Modeling the body as a short cylinder of 30 cm diameter and 1.7 m long, estimate the time of death of that person. Use the lumped system of analysis and assume the following properties: K = 0.617 W/m-K, S = 996 kg/m^3, C_p = 4187 J/kg-K, Temperature of the body before died = 37°C. **(05 Marks)**

c. One surface of a thick Nickel steel (K = 19 W/m-K, $\alpha = 0.52\times10^{-5}$ m^2/s) slab, which is initially at 30°C, is suddenly raised to a temperature of 530°C. By treating this as a one-dimensional transient conduction problem in a semi-infinite medium, determine the temperature at a depth of 50 mm after a time of 50 seconds. **(03 Marks)**

4 a. With sketches, explain the velocity boundary layer and thermal boundary layer thickness for a flow over the flat plate. **(04 Marks)**

b. An approximate expression for the velocity profile for laminar boundary layer flow along a flat plate is given by,

$$\frac{u}{u_\infty} = \sin\left[\frac{\pi}{2}\frac{y}{\delta}\right]$$

where the boundary layer thickness δ is given by,

$$\frac{\delta}{x} = 4.80 R_{ex}^{-\frac{1}{2}}$$

i) Develop an expression for the local drag coefficient.

ii) Develop an expression for the average drag coefficient over a distance L from the leading edge of the plate. **(08 Marks)**

c. Calculate the rate of heat loss from the top and bottom of a flat 1 m square horizontal restaurant grill heated to 227°C and kept in an stagnant ambient air at 27°C. **(08 Marks)**

PART – B

5 a. Using Buckingham's π-theorem, obtain the relationship between various non-dimensional numbers for forced convection heat transfer. **(10 Marks)**

b. A nuclear reactor uses a heat exchanger consisting of 5 cm ID constant heat flux tube, 3.5 kg/s mass flow rate of a liquid metal at 200°C is passed through the tube having wall temperature of 230°C. Find the length of the tube required for a 10°C rise in temperature of the fluid. Use the following properties of the fluid : $\rho = 7.7 \times 10^3$ kg/m^3, $\upsilon = 8 \times 10^{-8}$ m^2/s, C_p = 130 J/kg-K, K = 12 W/m-K. Average Nusselt number is given by $N_u = 4.82 + 0.0185\,(R_eP_r)^{0.827}$. **(10 Marks)**

6 a. Derive an expression for the LMTD of a parallel flow heat exchanger. **(08 Marks)**

b. Define effectiveness and NTU of a heat exchanger. Give their equations. **(04 Marks)**

c. A tubular heat exchanger consists of 200 tubes each 20 mm outer diameter and 5 m length. Hot fluid flows inside the tube and cold fluid flow over it, but in opposite direction to that of hot fluid. The overall heat transfer coefficient based on OD is 320 W/m^2-K. Determine the outlet temperatures of both fluids and total heat transfer using the data given below:

T_{hi} = 120°C, T_{ci} = 20°C, $\dot{m}_h = 20$ kg/s, $\dot{m}_C = 5$ kg/s, $C_{ph} = 2000$ J/kg-K, $C_{pC} = 4000$ J/kg-K. **(08 Marks)**

7 a. With a neat sketch, discuss the different regimes of pool boiling. **(06 Marks)**

b. Distinguish between Film condensation and dropwise condensation. **(04 Marks)**

c. Determine the average heat transfer coefficient and the total condensation rate for air-free saturated steam at 65°C condenses on the outersurface of a 2.5 cm OD, 3 m long vertical tube maintained at a uniform temperature of 35°C by the flow of cooling water through the tube. If the tube is made horizontal, what will be the above values? Comment on results. **(10 Marks)**

8 a. State and prove the Kirchoff's law of radiation. **(04 Marks)**

b. With usual notations, prove that the emissive power of a diffuse surface is π times its intensity. **(08 Marks)**

c. Two large parallel plates of equal areas are at temperature of 150°C and 40°C, while their emissivities are 0.6 and 0.7 respectively. If a radiation shield of emissivity 0.04 is inserted in between the plates, estimate the percentage reduction in heat exchange by radiation. **(08 Marks)**

* * * * *