T.E. (Mechanical) (Semester – I) Examination, 2010
HEAT TRANSFER (Common with Mech. S/W for Semester – II)
(2003 Course)

Time : 3 Hours Marks : 100

Instructions : 1) *Answer **any three** questions from **each** Section.*
2) *Answers to the **two** Sections should be written in **separate** books.*
3) ***Neat** diagrams must be drawn **wherever** necessary.*
4) *Use of logarithmic tables, slide rule, Mollier charts, electronic pocket calculator and steam table is **allowed**.*
5) *Assume suitable data, **if necessary**.*

SECTION – I

1. a) Describe the mechanism of heat conduction. Define thermal conductivity and discuss factors affecting it. Differentiate between isotropic and anisotropic materials giving one example of each. 8

b) Air at 20°C blows over a 50 cm × 75 cm hot plate maintained at 250°C. The film heat transfer coefficient is 50 W/m^{2}K. 300 W is being lost from the plate surface by radiation. Calculate heat transfer rate and other side plate temperature. Thermal conductivity of plate material is 43 W/mK and the plate is 2 cm thick. 8

OR

2. a) Write three dimensional heat conduction equation in Cartesian coordinate for anisotropic material for unsteady state condition, and reduction to Fourier equation, Laplace equation and Poisson's equation. 6

b) A square plate heater (size 15 cm × 15 cm) is inserted between two slabs, slab A is 2 cm thick (k = 50 W/mK) and slab B is 1 cm thick (k = 0.2 W/mK). The outside heat transfer coefficient on both sides of A and B are 200 and 50 W/m^{2}K respectively. The temperature (temp) of surrounding air is 25°C. If the rating of heater is 1 kW, find :

i) maximum temperature in the system

ii) outer surface temperature of the two slabs

iii) draw equivalent electrical circuit of the system. 10

3. A cylindrical fuel element of nuclear reactor generates heat according to law $q_g(r) = q_o[1 - (r/R)^2]$, where R is outer radius of fuel element and q_o is the heat generation rate at centre in W/m^3.

   i) Assuming one dimensional steady state heat flow, develop a relation for temperature drop from the centre to surface of the fuel element.

   ii) Find the expression for heat flow at the surface.

   iii) If the heat generated at centre is 1.6×10^8 W/m^3 and outside radius of fuel element is 1 cm and thermal conductivity is 10 W/mK, find temperature drop from centre to surface.

   iv) If the heat reaching the surface is dissipated to a cooling medium at 50°C having heat transfer coefficient of 10000 W/m^2K, find the surface temperature of fuel element. **16**

OR

4. a) What is the purpose of insulation ? Explain significance of critical radius of insulation. Derive an expression for critical radius of insulation for cylinder using standard notations. **7**

   b) Write short notes on the following :

      i) Economic thickness of insulation

      ii) Variation of thermal conductivity with temp in solids, liquids and gases

      iii) Thermal contact resistance. **9**

5. a) Define time constant for a system. What do you understand by response time of a temperature measuring instrument ? What is the relation between time constant and time for getting response with 95% accuracy ? **8**

   b) Thin fins of brass (k = 119.4 W/mK) are welded longitudinally on a 5 cm brass cylinder which stands vertically and is surrounded by air at 35°C with h = 17 W/m^2K. If 12 uniformly spaced fins are used, each 0.76 mm thick and extending 1.27 cm radially outward from the cylinder, find heat transfer rate from finned cylinder when its surface is maintained at 140°C. **10**

OR

6. a) Derive the formula for rate of heat transfer, efficiency and effectiveness for a fin with negligible heat dissipation from tip. **10**

b) Two identical balls of pure iron and copper having diameter of 6 cm and at initial temperature of 500°C are being cooled in oil having temperature of 100°C and heat transfer coefficient of 10 W/m^2K. It is desired that both balls should reach a temperature of 150°C at the same time. Which ball should be put in the oil first ? After how much time, other ball should be put in oil ? Justify the answer and formula used. Use following properties :

Iron – Density = 7897 kg/m^3, K = 73 W/mK, Cp = 0.452 kJ/kgK

Copper – Density = 8954 kg/m^3, k = 386 W/mK, Cp = 0.383 kJ/kgK. 8

SECTION – II

7. a) A pipe carrying steam runs in a large room and is expressed to air at a temperature of 30°C. The pipe surface temperature is 200°C. The pipe diameter is 20 cm. If the total heat loss from the pipe per meter length is 1.9193 kW/m, determine the pipe surface emissivity.

Use correlation $Nu = 0.53 (Gr\ Pr)^{1/4}$

and properties of air at 115°C : $k_f = 0.03306\ W/m^2K$, $\upsilon = 24.93 \times 10^{-6}\ m^2/s$

Pr = 0.687. 8

b) Differentiate between internal flow and external flow. 4

c) Explain the term convective heat transfer coefficient and its relation with thermal boundary layer thickness. 4

OR

8. a) Air at 20°C is flowing along a heated plate at 134°C with a velocity of 3 m/sec. The plate is 2 m long. Heat transferred from first 40 cm from the leading edge is 1.45 kW.

Determine width of the plate. Properties of air at 77°C are :

Density = 0.998 kg/m^3, kinematic viscosity = $20.76 \times 10^{-6}\ m^2/s$, Cp = 1.009 kJ/kg K, k = 0.03 W/mK. Use following correlation. 8

$Nu_x = 0.332\ Re^{0.5}\ Pr^{0.33}$

b) Explain physical significance of the following dimensionless numbers :

Re, Nu, Pr, Gr 8

9. a) Derive expression of Stefan Boltzmann Law from Planck's distribution law. 6

b) Determine i) the wavelength at which the spectral emissive power of a tungsten filament at 1400 K is maximum, ii) the spectral emissive power at that wavelength iii) the spectral emissive power at 5 μm. Assume black body radiation function as 0.8081. 6

c) Define the term irradiation and radiosity. Establish a relationship between them. 4

OR

10. a) Derive an expression for a rate of radiation exchange, when a radiation shield is inserted between two large parallel plates. 8

b) Define radiation view factor. Write expressions of view factor relations. Calculate the view factor between two opposite sides of a hollow cube, if view factor between two adjacent sides of it is 0.2. 8

11. a) Draw the temperature profiles of hot and cold fluids in following types of heat exchangers :

i) Condenser

ii) Boiler

iii) Cross-flow (both fluids unmixed) heat exchanger

iv) Very long length parallel flow heat exchanger

v) Counter flow heat exchanger for fluids with same capacity rate. 10

b) A double pipe heat exchanger is made of stainless steel (k = 15 W/mK) with inner diameter of inner tube = 1.5 cm and outer diameter of inner tube = 1.9 cm. The inner diameter of outer pipe = 3.2 cm.

$h_i = 800 \ W/m^2K$ and $h_0 = 1200 \ W/m^2K$

Fouling factor on inner tube surface = $0.0004 \ m^2 \ K/W$

Fouling factor on outer tube surface = $0.0001 \ m^2 \ K/W$

Determine :

i) Thermal resistance of the heat exchanger per unit length.

ii) Percentage of thermal resistance due to fouling as compared to the total thermal resistance.

iii) Overall heat transfer coefficient based on inner surface area of inner tube. 8

OR

12. a) Derive the expression for average heat transfer coefficient for laminar film condensation on a vertical plate. 10

b) Discuss pool boiling curve. What is the significance of critical heat flux in design of evaporators ? 8