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

Time : 3 Hours   Max. Marks :100

Instructions : *1) Answer 3 questions from Section I and 3 questions from Section II.*
*2) Answers to the **two** Sections should be written in **separate** books.*
*3) **Neat diagrams must be drawn wherever** necessary.*
*4) Black figures to the **right** indicate **full** marks.*
*5) Use of logarithmic tables slide rule, Mollier charts, electronic pocket calculator and steam tables is **allowed**.*
*6) Assume suitable data, **if necessary**.*

SECTION – I

Unit – I

1. a) State and explain Fourier's Law of conduction and Newton's Law of cooling (or heating). 8

b) In a furnace, the temperature of hot gases is 2100°C. Ambient temperature is 40°C. Heat flow by radiation from hot gases to inner surface of the wall is 23 KW/m^2. Convective heat transfer coefficient between hot gases and the inner surface of the wall is 12 W/m^2K. Thermal resistance of the wall is 0.0173 $m^2 K/W$. Heat flow by radiation from external surface of the wall to surroundings is 10 KW/m^2. Temperature of the inside surface of the wall is 900°C. For the external surface of the wall, find surface temperature and convective heat transfer coefficient. 8

OR

2. a) Derive general heat conduction equation in Cartesian coordinates for three dimensional heat flow for unsteady state conditions through anisotropic material having uniform internal heat generation using standard notations. 8

b) A steel tube with 6 cm ID, 8 cm OD and K = 15 W/mK, is covered with an insulation of thickness 2 cm and K = 0.2 W/mK. A hot gas at 300°C with hg = 400 W/m^2K flows inside the tube. The outer surface of the insulation is exposed to cool air at 30°C with ha = 50 W/m^2K. Calculate overall heat transfer coefficient based on outer surface of insulation and the heat flow rate from the tube for 25 m length. 8

Unit – II

3. a) Prove that critical radius of insulation for outer surface of the cylinder is K/h and that for sphere is 2 K/h; where K is conductivity of insulation and h is convective heat transfer coefficient between insulation and surroundings. Use standard notations. 8

b) The insulation boards for air-conditioning purpose are made of three layers, the middle being of packed grass 10 cm thick (K = 0.02 W/mK) and the sides are made of plywood, each of 2 cm thickness (K = 0.12 W/mK). They are glued (bonded) with each other.

i) Determine heat flow rate per m^2 area, if one surface is at 45°C and the other at 20°C. Neglect resistance of the glue (gum).

ii) Instead of glue, if these three boards are bolted by 4 steel boards (k = 40 W/mK) of 1 cm diameter each at the corners per m^2 area of the board, find whether heat flow rate is going to increase or decrease and by what percentage ? 8

OR

4. a) Derive the expression for steady state one dimensional heat flow as

$$q = \frac{K_0(T_1 - T_2)}{L}\left[1 + \frac{a(T_1 + T_2)}{2} + \frac{b(T_1^{\,2} + T_2^{\,2} + T_1T_2)}{3}\right]$$ through the wall of thickness L, if the conductivity of the wall material varies with temperature as $K = K_0(1 + aT + bT^2)$; where a and b are constants. Wall surfaces are maintained at uniform temperatures T_1 and T_2. 8

b) Consider a solid sphere of radius 2 cm, in which internal energy is generated uniformly at a constant rate of 2×10^8 W/m³. Conductivity of the cylinder material is 30 W/mK and its outer surface is maintained at temperature of 100°C. Calculate centre temperature and heat flux at the surface of the sphere. Derive the expressions you use. 8

Unit – III

5. a) A 6 cm diameter steel ball, initially at a uniform temperature of 500°C is suddenly placed in oil at 100°C with h = 10 W/m²K. Calculate the time required for the ball to attain a temperature of 200°C. Steel properties : C_p = 0.46 KJ/kgK; density = 7800 kg/m³; k = 35 W/mK. 8

b) Define fin effectiveness and fin efficiency and derive their standard expressions for adequately long fin (fin with insulated tip) using standard notations starting from standard formula of heat transfer rate from fin. 6

c) Explain the physical significance of Biot number. 4

OR

6. a) A copper rod 1 cm in diameter and 10 cm long protrudes from a wall maintained at 300°C. This rod is exposed to atmosphere at 20°C with h = 15 W/m^2K. Calculate heat loss by the rod and temperature at the end/ tip of the rod assuming it to be short fin. Take K = 370 W/mK for copper. 8

b) Explain as to why error occurs in temperature measurement of a fluid flowing in a conduit by using thermometer in a thermometric well. Drive the expression for the error in temperature measurement using the formula of temperature distribution of pin fin with insulated tip. 6

c) Explain "Time response" of thermocouple. 4

SECTION – II

Unit – IV

7. a) With the help of neat diagrams, explain the development of hydraulic boundry layers in cases of fluid flows through a pipe and over a flat plate. 8

b) The crankcase of an IC engine measuring 80 cm×20 cm may be assumed on flat plate. The engine runs at 90 km/hour and the crankcase is cooled by the air flowing past it at the same speed. Calculate the heat loss from cranksurface to be maintained at 85°C, to the ambient air at 15°C. Properties of air at 50°C : K = 0.02824 W/m°C; $\upsilon = 17.95 \times 10^{-6}\ m^2/s$; Pr = 0.698.
Use following relations:
$Nu = 0.664\ Re^{0.5}\ Pr^{0.334}$ for laminar flow
$Nu = 0.036\ Re^{0.8}\ Pr^{0.334}$ for turbulent flow.
Engine is fitted in the vehicle such that engine length is along the length of vehicle. 8

OR

8. a) Draw neat diagrams to show directions of natural convection fluid flow (development of thermal boundary layers), when :
   i) Plate is kept vertical and surrounding fluid temperature is higher than plate.
   ii) Cylinder is kept horizontal and surrounding fluid temperature is lower than cylinder.
   iii) Plate is horizontal and surrounding fluid temperature is lower than plate.
   iv) Cylinder is vertical and surrounding fluid temperature is lower than cylinder. 8

b) A vertical plate 20 cm high and 10 cm wide is maintained at a temperature of 140°C. Emissivity of the plate on both sides is 0.8. Estimate the total heat flow rate from the plate, if it is suspended in a room at 20°C. Neglect heat flow from thickness of plate and use $Nu = 0.56\ (Gr.Pr.)^{0.25}$. Take air properties as Pr = 0.692; $\upsilon = 21.09 \times 10^{-6}\ m^2/s$; K = 0.03 W/mK; conductivity of metal plate K = 15 W/mK. 8

Unit – V

9. a) Explain the concepts of surface and space resistances. Using these concepts, derive expression for heat exchange (heat transfer rate) between two concentric hollow spheres having another concentric spherical shield in between them by radiation using standard notations. Treat all spheres as gray bodies and space between them evacuated. 8

b) Consider two large parallel plates; one at 727°C with emissivity 0.8 and the other at 227°C with emissivity 0.4. An aluminum radiation shield with an emissivity of 0.05 on both sides is placed parallel between the plates. Calculate percentage reduction in heat transfer rate due to shield. 8

OR

10. a) Explain very briefly :

i) Radiation shield

ii) Wiens Displacement Law

iii) Lambert Cosine Law

iv) Shape factor. 8

b) Cryogenic fluid flows through a tube of 30 mm diameter which is concentric with a tube of 90 mm diameter. Surface emissivites of inner and outer tubes are 0.2 and 0.5 and their temperatures are 100 and 300 K respectively. Find

i) Heat gain rate by the cryogenic fluid per meter length

ii) Percentage reduction in heat gain rate, if a radiation shield of 45 mm diameter having emissivities of 0.1 on inner surface and 0.05 on outer surface is inserted between the two tubes. 8

Unit – VI

11. a) Explain design considerations for heat exchangers. 6

b) A parallel flow heat exchanger is to be designed to cool oil (C_p = 2.1 kJ/kgK; $\dot{m}$ = 20 kg/min) from 70°C to 40°C by using cold water (C_p = 4.2 kJ/kgK; $\dot{m}$ =50 kg/min) available at 30°C. Heat transfer coefficients on water and oil sides are 400 W/m²k and 200 W/m²k respectively. Find the size/ area of heat exchanger, outlet temp. of water and effectiveness. If the above heat exchanger is used with counter flow arrangement, find the exit temps of oil and water and effectiveness. 12

OR

12. a) Saturated steam at 85°C condenses on the outer surface of 225 horizontal tubes of 1.27 cm OD arranged in square arry. Tube surface are maintained at a uniform temperature of 75°C. Calculate the rate of condensation per meter length of the bundel in kg/hr. Properties of water : K = 0.668 W/mK; ρ = 974 kg/m³, $\mu = 0.355\times10^{-3}$ λ (latent heat) = 2309 kJ/kg. 9

b) Write short notes :

i) Critical heatflux (in boiling)

ii) LMTD

iii) Dropwise condensation. 9
