T.E. (Mechanical) (Semester – I) Examination, 2010
HEAT TRANSFER (New)
(2008 Course)

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) Explain Fourier's Law of heat conduction. 4

b) Explain variation of thermal conductivity in solids and liquids with temperature giving out reasons. 4

c) A steel tube with 5 cm ID and 7 cm OD (k = 28 W/mK), is covered with an insulation covering of thickness 15 mm (k = 0.2 W/m°C). A hot gas at temperature of 400° C with convective heat transfer coefficient of 300 W/m^{2}K flows inside the tube. The outer surface of insulation is exposed to cold air at - 5°C with h = 20 W/m^2 °C. Calculate heat flow rate from the pipe and the interface temperature between steel and insulation. 8

OR

2. a) Derive general heat conduction equation in Cartesian coordinates for 3-dimensional unsteady state heat flow for an-isotropic material with uniform internal heat generation using standard notations. 8

b) A spherical storage of steel of 20 cm ID and 30 cm OD (k = 50 W/mK) stores liquid oxygen, due to which its inside surface temperature is maintained at – 150°C. Outside surface is exposed to ambient air at 20°C with convective heat transfer coefficient of 10 W/m^2K. Determine heat transfer rate. What shall be the percentage decrease in heat transfer rate, if the steel sphere is applied with layer of insulation (k = 0.5 W/m°C) of 25 mm thickness on its outside surface ? 8

Unit – II

3. a) Inner surface of radius $r = r_1$ and the outer surface of radius $r = r_2$ of a hollow cylinder are maintained at uniform temperatures of T_1 and T_2. Thermal conductivity of the cylinder material k is constant. Develop expressions for one dimensional steady state temp. distribution $T_{(r)}$, heat flow rate Q and thermal resistance R. 8

b) A furnace wall is made of layers of fire clay of 100 mm thickness (k = 0.9 W/mK) and red brick of 200 mm thickness (k = 0.6 W/m°C). Space between these two layers of 60 mm width (k = 0.1 W/mK) is filled with normal mud. What should be the thickness of red brick layer, if the furnace wall is to be made without mud layer to keep the heat flow rate same with same temperatures of inside and outside surfaces ? 8

OR

4. a) "While insulating a small diameter electric conductor, aim was to increase the heat transfer rate. However, it was found on measurement that heat transfer rate has in fact decreased." – Justify. 4

b) Derive expression for critical radius of insulation for a sphere using standard notations. 4

c) A metal slab of 2 cm thickness (k = 25 W/mK) generates internal heat energy at a uniform rate of 10^8 W/m^3. One face of this slab is insulated and the other face is maintained at 300° C due to its exposure to a fluid. Determine maximum temperature in the slab and its location. Also, find out total heat flow out (rate) from the slab. 8

Unit – III

5\. a) Starting from boundary conditions, derive the expressions for temp distribution along the length and heat flow rate for a very long fin using standard notations. 9

b) An electric motor 300 mm long dissipating heat at a rate of 350 W is required to be fitted with plate fins radially outwards so that motor surface temperature does not exceed 50°C. Plate fins are 15 mm thick of 50 mm length (height from motor surface) with k = 40 W/m°C. Motor is exposed to atmosphere at 25° C with convective heat transfer coefficient of 20 W/m^2K. Determine number of fins required neglecting convection from tip of fins. Ignore heat convection from unfinned area of motor's outer surface. 9

OR

6\. a) Explain :

i) Biot Number

ii) Fin Efficiency

iii) Fin Effectiveness. 9

b) A solid brass sphere 20 cm diameter initially at a temp of 200° C is suddenly exposed to air stream at – 10° C with a convective heat transfer coefficient of 50 W/m^2K. Find the time required by the sphere to attain temperature of 0°C. If brass sphere is replaced by copper sphere, what percent increase or decrease in time will occur to attain the same temperature of 0°C ? Properties are :

Copper : density = 7,670 kg/m^3; c = 0.372 kJ/kg°C; k = 370 W/mK

Brass : density = 8,552 kg/m^3; c = 0.385 kJ/kg°C; k = 100 W/mK. 9

SECTION – II

Unit – IV

7. a) Explain :

i) Lambert Cosine Law

ii) Solid angle

iii) Shape factor of a body with respect to itself

iv) Emissivity. 8

b) A pipe carrying steam having an outside diameter of 20 cm passes through a large room and is exposed to air at temp of 30°C. Pipe surface temp is 200° C. Find the total heat loss per meter length of pipe both by convection and radiation taking emissivity of the pipe surface as 0.8.

Use the relation : $Nu = 0.53\,(Ra)^{0.25}$ for horizontal pipe

Temp °C	K (W/mK)	V × 10^6 (m^2/s)	Pr
30	0.0267	18.60	0.701
115	0.0330	24.93	0.687
200	0.0393	26.00	0.680

8

OR

8. a) Prove that heat exchange between two grey body eccentrically placed cylinders (one enclosed by the other) is given by :

$$Q = \frac{\sigma . A_1 . \left(T_1^4 - T_2^4\right)}{\frac{1}{\varepsilon_1} + \frac{A_1}{A_2}\left(\frac{1}{\varepsilon_2} - 1\right)}$$

; where T_1 and T_2 are the temps of areas of cylinders A_1 and A_2 facing each other, A_1 enclosed in A_2 and space between them evacuated; ε_1 and ε_2 are the respective emissivities. 8

b) Two large parallel plates (Grey bodies) are maintained at temperatures of 600° C and 300°C having their emissivities of 0.9 and 0.4 respectively. A radiation shield having emissivity of 0.02 is inserted in between them. Calculate :

i) Heat transfer rate without radiation shield

ii) Heat transfer rate with radiation shield

iii) Temperature of shield. 8

Unit – V

9. a) Write short notes :

i) Hydraulic diameter.

ii) Thermal boundary layer for fluid flow over flat plate. 8

b) A circular disc of diameter 25 cm is exposed to air at 293 K. If the disc is maintained at 393 K, estimate the heat transfer rate from it, when;

i) Disc is kept horizontal (Take characteristic length = Area/Perimeter)

ii) Disc is kept vertical.

For air at 70°C, $k = 0.03$ W/mK; $Pr = 0.697$; $v = 2.076 \times 10^{-6}$ m²/s

Use the following correlations :

$Nu = 0.14\ (Ra)^{0.334}$ for surface facing upward

$Nu = 0.27\ (Ra)^{0.25}$ for surface facing downward

$Nu = 0.59\ (Gr.Pr)^{0.25}$ for vertical surface. 8

OR

10. a) Explain the significance of the following :

i) Nusselt Number

ii) Grashoff Number

iii) Prandtl Number

iv) Peclet Number. 8

b) 4800 kg/hr of water is heated from 30°C to 60°C by passing through a square duct of 30 mm × 30 mm. The duct is heated by condensing steam at 100°C on its outer surface. Find the length of the duct required.

Take properties of water : Density = 995 kg/m^3; $\mu = 7.65 \times 10^{-4}$ kg/ms ; C_p = 4.174 kJ/kgK; k = 0.623 W/m°C; Conductivity of duct material = 24 W/mK.

Use : $Nu = 0.023\, Re^{0.8} Pr^{0.4}$ for turbulent flow

$Nu = 4.36$ for laminar flow. 8

Unit – VI

11. a) Explain the following :

i) LMTD

ii) NTU

iii) Heat exchanger effectiveness. 9

b) A chemical (specific heat = 3.2 kJ/kgK) enters a parallel flow heat exchanger at 150°C at a flow rate of 30,000 kg/hr. Cooling water (specific heat = 4187 J/kgK) enters the heat exchanger at 20°C at a flow rate of 1000 kg/min. Heat transfer area of the heat exchanger is 12 m^2. Over all heat transfer coefficient can be taken as 1000 W/m^2K. Find the effectiveness of the heat exchanger and outlet temperatures of both chemical and water. 9

OR

12. a) Explain six regimes of pool boiling curve. 9

b) Name any three convective heat transfer augmentation techniques known to you an explain working principle of any one. 5

c) Explain filmwise and dropwise condensation. 4
