

III B.Tech II Semester Supplementary Examinations, Apr/May 2008
HEAT TRANSFER

(Common to Mechanical Engineering and Automobile Engineering)

Time: 3 hours

Max Marks: 80

Answer any FIVE Questions
All Questions carry equal marks

1. (a) Distinguish between conduction, convection and radiation modes of heat transfer.
(b) A solar pane, $1 \text{ m} \times 1.25 \text{ m}$ receives solar radiation 1500 watts, Calculate surface temperature of the pane if the ambient temperature is 25°C and the convective heat transfer coefficient of the air film over the surface of pane is $12.5 \text{ W/m}^2\text{-deg}$. [8+8]
2. A composite slab consists of 250 mm fire clay brick ($k=1.09 \text{ W/mK}$) inside, 100 mm fired earth brick (0.26 W/mK) and outer layer of common brick (0.6 W/mK) of thickness 50 mm. If inside surface is at 1200°C and outside surface is at 100°C , find:
 - (a) heat flux,
 - (b) the temperature of the junctions and
 - (c) the temperature at 200 mm from the outer surface of the wall. [16]
3. A wall of thickness 100 mm is insulated on one side and other side is exposed to 0°C . Determine the wall temperature insulated surface if the internal heat generation in the wall is at the rate of 10^6 W/m^3 . Take $k = 40 \text{ W/mK}$. [16]
4. The water in a tank at 20°C is heated by passing the steam through a horizontal pipe of 50 cm long and 5 cm in diameter. If the pipe surface temperature is maintained at 80°C , find heat loss from the pipe per hour. If the pipe is kept vertical, then also find out heat loss from the pipe per hour. [16]
5. (a) Air at 20°C and 1 atmosphere flows over a flat plate at 35 m/s. The plate is 75 cm long and is maintained at 60°C . Calculate the heat transfer from the plate per unit width of the plate. Also calculate the turbulent boundary layer thickness at the end of the plate assuming it to develop from the leading edge of the plate.
(b) Distinguish between bulk mean temperature and film temperature. [12+4]
6. (a) A heated polished copper plate is immersed in a pool of water boiling at atmospheric pressure. If the surface of the copper plate is maintained at a temperature of 125°C , find the surface heat flux and the evaporation rate per unit area of the plate.

- (b) A 10mm dia, 1m long copper tube with a scored surface is to be used to boil water adjacent to the external surface at atm pr, Calculate the surface temperature of the tube so that it operates at half the maximum heat flux. Find also the heat dissipation rate and the evaporation rate of water. [8+8]
7. (a) Distinguish between a black body and grey body.
(b) Prove that intensity of radiation is given by $I_b = E_b/\Pi$
(c) State and explain Kirchoff's identity? What are the condition's under which it is applicable. [4+6+6]
8. (a) Derive an expression for effectiveness of a parallel flow heat exchanger using NTU method.
(b) A hot gas at the rate of 16.2 Kg/Sec at 648 °C ($C_p = 3.52$ KJ/Kg-k) is used to heat 20.2 kg /sec of the incoming fluid at 100 °C ($C_p = 4.2$ KJ/Kg K) in a heat exchanger. If the overall heat transfer Coefficient is 0.92 KW/ m^2 -K for an effective area of 43.8 m^2 , find the fluid outlet temperatures for counter flow and parallel flow arrangements. [8+8]

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1. (a) One side of a plane wall is maintained at 100°C , while the other side is exposed to a convection environment having $T_{\infty}=10^{\circ}\text{C}$ and $h=11\text{ W/m}^2\text{ K}$. The wall has $k=1.6\text{ W/m K}$ and is 40 cm thick. Calculate the heat transfer rate through the wall.
(b) A 6 mm steel plate having a thermal conductivity of 43 W/m K is exposed to a radiant heat flux of 4.9 kW/m^2 in a vacuum space where the convection heat transfer is negligible. Assuming that the surface temperature of the steel exposed to the radiant energy is maintained at 40°C , What will be the other surface temperature if all the radiant energy striking the plate is transferred through the plate by conduction? [16]
2. A composite slab consists of 250 mm fire clay brick ($k=1.09\text{ W/mK}$) inside, 100 mm fired earth brick (0.26 W/mK) and outer layer of common brick (0.6 W/mK) of thickness 50 mm . If inside surface is at 1200°C and outside surface is at 100°C , find:
(a) heat flux,
(b) the temperature of the junctions and
(c) the temperature at 200 mm from the outer surface of the wall. [16]
3. A wall of thickness 100 mm is insulated on one side and other side is exposed to 0°C . Determine the wall temperature insulated surface if the internal heat generation in the wall is at the rate of 10^6 W/m^3 . Take $k=40\text{ W/mK}$. [16]
4. (a) A flat electrical heater of $0.4\text{ m} \times 0.4\text{ m}$ size is placed vertically in still air at 20°C . The heat generated is 1200 W/m^2 . Determine the value of convective heat transfer co-efficient and the average plate temperature.
(b) Explain Grashoff number significance in natural convective heat transfer. [10+4]
5. (a) A thin 80 cm long and 8 cm wide horizontal plate is maintained at a temperature of 130°C in a large tank full of water at 70°C . Estimate the rate of heat input into the plate necessary to maintain the temperature of 130°C .
(b) Differentiate velocity and thermal Boundary layers by a neat diagram. [8+8]
6. (a) A heated polished copper plate is immersed in a pool of water boiling at atmospheric pressure. If the surface of the copper plate is maintained at a temperature of 125°C , find the surface heat flux and the evaporation rate per unit area of the plate.

- (b) A 10mm dia, 1m long copper tube with a scored surface is to be used to boil water adjacent to the external surface at atm pr, Calculate the surface temperature of the tube so that it operates at half the maximum heat flux. Find also the heat dissipation rate and the evaporation rate of water. [8+8]
7. (a) State and prove reciprocity theorem as applied to radiation shape factors.
(b) Two concentric cylinders having diameters of 10 cm and 20 cm have a length of 20 cm. Calculate the shape factor between the open ends of the cylinders. [4+12]
8. A drying plant needs hot air at 135°C . This is obtained by passing 2.45 Kg/Sec of atmospheric air at 1 bar pressure and 27°C over tubes through which hot glycerin is circulated. The tubes have 20mm diameter, 1.5mm thickness, With a thermal conductivity of the material of the tube 50 W/m-K. The hot glycerin enters at 210°C and leaves at 305°C . Assuming counter flow, Find:
- (a) overall heat transfer coefficient
(b) total heating surface and
(c) number of tubes and number of passes for heater length of 3.22m, At average temperature ,the properties for air; $C_p = 1005 \text{ J/kg-K}$; $R = 287 \text{ J/kg-K}$ and convective heat transfer coefficient from air to metal $h = 170 \text{ W/m}^2\text{-K}$ for hot glycerin, $C_p = 1885 \text{ J/kg-K}$; $k = 0.13 \text{ W/m-K}$; $m = 2.0 \times 10^{-3} \text{ Kg/m-s}$ and flow rate = 496 kg/sec-m^2 and the heat transfer coefficient for glycerin to metal is governed by the relation $hd/K = 0.023(Re)^{0.8} Pr^{0.4}$. [16]

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1. (a) The surface of steel plate measuring 0.9m long $\times$ 0.6m wide $\times$ 0.025m thick is maintained at a uniform temperature of 300 $^{\circ}\text{C}$, and the plate loses 250 watt by radiation. If air at 15 $^{\circ}\text{C}$ temperature and 20 $\text{w}/\text{m}^2\text{-deg}$ convective heat transfer coefficient blows over the plate, calculate the temperature on inside surface of the plate. Take thermal conductivity of plate as 45 $\text{w}/\text{m-deg}$.
(b) Derive expressions for temperature distribution during steady state heat conduction in a solid sphere with internal heat generation. [8+8]
2. A composite slab consists of 250 mm fire clay brick ($k=1.09 \text{ W}/\text{mK}$) inside, 100 mm fired earth brick (0.26 W/mK) and outer layer of common brick (0.6 W/mK) of thickness 50 mm. If inside surface is at 1200 $^{\circ}\text{C}$ and outside surface is at 100 $^{\circ}\text{C}$, find:
(a) heat flux,
(b) the temperature of the junctions and
(c) the temperature at 200 mm from the outer surface of the wall. [16]
3. A wall of thickness 100 mm is insulated on one side and other side is exposed to 0 $^{\circ}\text{C}$. Determine the wall temperature insulated surface if the internal heat generation in the wall is at the rate of $10^6 \text{ W}/\text{m}^3$. Take $k = 40 \text{ W}/\text{mK}$. [16]
4. (a) A flat electrical heater of 0.4 m $\times$ 0.4 m size is placed vertically in still air at 20 $^{\circ}\text{C}$. The heat generated is 1200 w/m^2 . Determine the value of convective heat transfer co-efficient and the average plate temperature.
(b) Explain Grashoff number significance in natural convective heat transfer. [10+4]
5. What do you understand by the hydrodynamics and thermal boundary layers. Illustrate with reference to flow over a flat heated plate. [16]
6. (a) Assuming laminar film condensation, calculate the ratio of the heat transfer to a vertical tube to that for a horizontal tube of same diameter, D and length H. Briefly comment on the implications of this in the condenser design.
(b) A vertical plate 0.4m wide and 1.2m high is maintained at 60 $^{\circ}\text{C}$ and exposed to saturated steam at 1 bar. Calculate the heat transfer and the total mass of steam condensed per hour. [10+6]
7. (a) Define irradiation and radiosity.
(b) What does radiation shape factor mean?

- (c) Two parallel black plates 0.5 by 1.0 m are separated by 0.5m distance. One plate is at 1100 °C and the other at 600 °C. What is the net radiant heat exchange between the two plates?
- (d) Calculate the shape factor for a hemispherical surface closed by a plane surface. [4+2+6+4]
8. (a) Derive an expression for logarithmic mean temperature difference for the case of counter flow exchanger.
- (b) A liquid chemical flows through a thin walled copper tube of 12 mm diameter at the rate of 0.5 kg/sec water flows in opposite direction at the rate 0.37 kg/sec through the annular space formed by this tube and a tube diameter of 20 mm. The liquid chemical enters and leaves at 100 °C and 60 °C, while water enters at 10 °C. Find the length of tube required. Also find the length of tube required if the water flows in the same direction as liquid chemical. The properties of water and liquid chemical are: [8+8]

PROPERTIES 27 °C	LIQUID CHEMICAL AT 80 °C	WATER AT
ρ , Kg/ m^3	1078	995
μ , Kg/m- Sec^2	3200×10^{-6}	853×10^{-6}
C_p , J/Kg-K	2050	4180
K , W/mK	0.261	0.614

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 - (a) heat flux,
 - (b) the temperature of the junctions and
 - (c) the temperature at 200 mm from the outer surface of the wall. [16]
3. Derive the general equation for the temperature distribution along a fin? State different boundary conditions and derive the equations for heat flow for:
 - (a) fin with insulated end and
 - (b) long fin. [16]
4. (a) A flat electrical heater of $0.4 \text{ m} \times 0.4 \text{ m}$ size is placed vertically in still air at 20°C . The heat generated is 1200 W/m^2 . Determine the value of convective heat transfer co-efficient and the average plate temperature.
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(b) Differentiate velocity and thermal Boundary layers by a neat diagram. [8+8]
6. (a) Estimate peak heat flux and minimum heat flux for water boiling at atm pressure.
(b) In pool boiling on a horizontal surface with water at atmospheric pressure the heat flow is 50 kW/m^2 . Make calculations for surface temperature required. How does this value compare if the boiling occurs on a vertical flat plate? Use

the following correlations.

$$\begin{aligned} \text{Nu} &= 0.16 (GrPr)^{0.33} \text{ for boiling on horizontal plate} \\ &= 0.16 (GrPr)^{0.25} \text{ for boiling on vertical plate.} \end{aligned} \quad [6+10]$$

7. (a) Derive a general expression for interchange factor for radiation between two non-black parallel surfaces of same area.
- (b) Two opposed, parallel infinite planes are maintained at 400°C and 460°C respectively. Calculate the net radiant heat flux between these planes if one has an emissivity of 0.6 and the other an emissivity of 0.4. [10+6]
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- (b) A liquid chemical flows through a thin walled copper tube of 12 mm diameter at the rate of 0.5 kg/sec water flows in opposite direction at the rate 0.37 kg/sec through the annular space formed by this tube and a tube diameter of 20 mm. The liquid chemical enters and leaves at 100°C and 60°C , while water enters at 10°C . Find the length of tube required. Also find the length of tube required if the water flows in the same direction as liquid chemical. The properties of water and liquid chemical are: [8+8]

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