Faculty of Engineering & Technology

Fifth Semester B.E. (Mechanical Engg./Power Engg.) (C.B.S.) Examination

HEAT TRANSFER

Time : Three Hours] [Maximum Marks : 80

INSTRUCTIONS TO CANDIDATES

(1) All questions carry marks as indicated.

(2) Solve **SIX** questions as follows :

Question No. **1** **OR** Question No. **2**

Question No. **3** **OR** Question No. **4**

Question No. **5** **OR** Question No. **6**

Question No. **7** **OR** Question No. **8**

Question No. **9** **OR** Question No. **10**

Question No. **11** **OR** Question No. **12**.

(3) Illustrate the answers with necessary figures/ drawings wherever necessary.

(4) Use of non-programmable calculator is permitted.

(5) Use of Steam tables/Thermodynamic tables for moist air/Psychrometric charts/Heat transfer databook/Mollier's/ Refrigeration charts is permitted.

(6) Assume suitable data wherever necessary.

1. (a) Derive an expression for general heat conduction equation in cylindrical co-ordinates. 7

(b) Obtain an expression for the thermal resistance and overall heat transfer coefficient of the composite sphere storing hot fluid and exposed to cold environment. 7

OR

2. (a) A composite wall has three layers of materials held together by a 3 cm diameter aluminium rivet per 0.1 m^2 of surface. The layers of materials consists of 10 cm thick brick with hot surface at 200ºC, 1 cm thick timber with cold surface at 10ºC. These two layers are interposed by a third layer of insulating material 25 cm thick. The conductivities of the materials are :

K(Brick) = 0.93 W/mK, K(Insulation) = 0.12 W/mK

K(Wood) = 0.175 W/mK, K(Aluminium) = 204 W/mK

Assume one dimensional heat flow, calculate the percentage increase in heat transfer rate due to rivets. 9

(b) Discuss the concept of critical thickness of insulation and derive the expression for critical radius of insulation for a cylinder. 5

3. (a) A 66 kV transmission line carrying a current of 900 ampere is 18 mm in diameter. The electric resistance of the copper conductor is 0.076 ohm/km and the thermal conductivity of copper is 380 W/mK. The surrounding temperature is 35ºC. The combined convection and radiation coefficient for heat transfer from the wire surface to the surrounding is 14 W/m^2K. Calculate :

(1) The surface temperature of the transmission line.

(2) The heat generated per unit volume.

(3) The maximum temperature in the line. 6

(b) During heat treatment, cylindrical pieces of 25 mm diameter, 30 mm height and at 30ºC are placed in a furnace at 750ºC, with convection coefficient of 80 W/m^2K. Calculate the time required to heat the pieces to 600°C. What will be the shortfall in temperature if the pieces are kept only for 285 seconds in the furnace ?

The properties are : density ρ = 7850 kg/m^3

Specific heat C_p = 480 J/kgK

Conductivity k = 40 W/mK 7

OR

4. (a) Which of the following arrangement of pin fins will give higher heat transfer rate from a hot surface ?

6 fins of 10 cm length

12 fins of 6 cm length

The base temperature of the fin is maintained at 200ºC and the fin is exposed to a convection environment at 15ºC with convection coefficient 25 $W/m^2ºC$. Each fin has cross-sectional area of 2.5 cm^2, perimeter 5 cm and is made of a material having thermal conductivity 250 W/mºC.

Neglect the heat loss from the tip of the fin. 6

(b) The temperature of dry saturated steam flowing in a 10 cm diameter steel pipe has been measured in the laboratory by means of thermometric well. The well is of 1.25 cm diameter and 3 mm wall thickness. A reliable pressure gauge fitted to the pipeline reads steam pressure as 10.5 bar. From steam table. Saturation temperature of steam at 10.5 bar is found to be 181.1ºC. What should be

the depth (length) of the well if the limit on maximum error in temperature measurement is 2.5%. The temperature at the pipe wall is 120ºC. The heat transfer co-efficient between steam and steam well is 420 kW/m^2K and thermal conductivity of the wall material is 160 kW/mK. Also draw schematic diagram. 7

5. (a) Show by dimensional analysis that data for forced convection may be correlated by an equation of the form :

$$Nu = f(Re, Pr)$$

Where, Nussult number $Nu = \frac{hL}{K}$

Reynolds number $Re = \frac{?VL}{\mu}$ and

Prandtl number $Pr = \frac{\mu.Cp}{K}$

All above symbols have their usual meanings. 6

(b) In a gas turbine system, hot gases at 1000ºC flow at 75 m/s past the surface of a combustion chamber which is at a uniform temperature of 300ºC. What would be the heat loss from the gases to the combustion chamber which can be idealized as a flat plate measuring 100 cm × 50 cm ? The flow is parallel to the 100 cm side and the transition from the laminar to turbulent conditions is anticipated to be abruptly at a critical Reynolds number of

$R_{e_{cr}} = 5\times10^5$.

Take the following properties of gas :

$\rho = 0.496$ kg/m^3, $\upsilon = 93.5 \times 10^{-6}$ m^2/s

K = 0.0744 W/mK, and Pr = 0.625. 7

OR

6. (a) Write short notes on the following :

(i) Velocity boundary layer and thermal boundary layer formation.

(ii) Significance of Reynolds number and Nussult number. 6

(b) Water entering at 10ºC is heated to 40ºC in a tube of 0.02 m internal diameter at a mass flow rate of 0.01 kg/s. The outside of the tube is covered with an insulated electric heating element that produces a uniform heat flux of 15000 W/m^2 over the surface. Determine :

(i) Reynolds number

(ii) Heat transfer coefficient

(iii) Length of pipe needed for a 30ºC increase in average temperature. 7

7. (a) Air flows through a long rectangular (30 cm × 65 cm width) air conditioning duct and maintains the outer duct surface temperature at 15ºC. If the duct is uninsulated and exposed to air at 25ºC, calculate the heat gained by the duct per meter length assuming it to be horizontal.

Use the following properties of air :

$C_p = 1005$ J/kgK, $\upsilon = 15\times10^{-6}$ m^2/s

$\rho = 1.205$ kg/m^3, K = 0.02593 W/mK. 8

(b) Explain different regimes of pool boiling curve. 5

OR

8. (a) Distinguish between filmwise and dropwise condensation. Also, discuss the effect of non-condensable gases on condensation rate. 6

(b) Saturated Freon-12 vapour condense on outside of a bank of 25 horizontal tubes having outer diameter of 1 cm arranged in 5 × 5 square array. Calculate the rate of condensation per meter length of the array, if its surface temperature is maintained at 40ºC.

Use properties of Freon-12 as :

$\rho = 1218$ kg/m^3, $K_f = 0.0686$ W/mK

$\mu = 0.0248$ kg/ms, $h_{fg} = 1218.12 \times 10^3$ J/kg. 7

9. (a) Calculate the following for an industrial furnace in the form of a black body and emitting radiation at 2500ºC :

(i) Monochromatic emissive power at 1.2 μm length

(ii) Wavelength at which the emission is maximum

(iii) Maximum emissive power.

(iv) Total emissive power and

(v) Total emissive power of the furnace if it is assumed as a real surface with emissivity equal to 0.9. 7

(b) Explain following terms related with radiation :

(i) Emissivity

(ii) Intensity of radiation

(iii) Black body and gray body

(iv) Lambert's cosine law. 6

OR

10. (a) State and explain properties of shape factor. 4

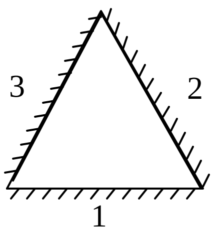
(b) Calculate the shape factor for the configuration shown in the figure given below :

(i) Long tube with cross-section of an equilateral triangle.

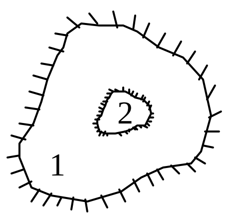
(ii) Black body inside a black surface.

(iii) Diagonal partitions within a long square duct.

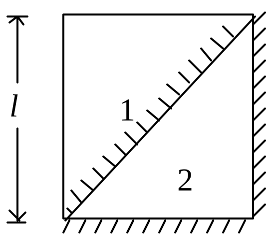
9



(i)



(ii)



(iii)

11. (a) For counter flow heat exchanger show that :

$$\in = \frac{1 - \exp[-NTU(1-C)]}{1 - C.\exp[-NTU(1-C)]}$$

where $\in$ = Effectiveness of Heat Exchanger

$$C = \frac{C_{min}}{C_{max}},\ N = NTU.$$ 7

(b) In a chemical plant 1000 kg/min of the product at 700ºC (Cp = 3.6 kJ/kgK) are to be used to heat 1200 kg/min of the incoming fluid from 100ºC (Cp = 4.2 kJ/kgK). If the installed heat transfer surface area is 42 m^2 and the overall heat transfer coefficient is 1 kW/m^2K. Compare the fluid outlet temperatures with counter flow and parallel flow arrangements. 7

OR

12. In an oil cooler, oil enters at 160ºC. If water entering at 35ºC flows parallel to oil, the exit temperatures of oil and water are 90ºC and 70°C respectively. Determine the exit temperature of oil and water if the two fluids flow in opposite directions. Assume that the flow rates of the two fluids and U_0 remain unaltered. What would be minimum temperatures to which oil could be cooled in parallel flow and counter flow operations ? 14