

**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  $0.1 \text{ m}^2$  of surface. The layers of materials consists of 10 cm thick brick with hot surface at  $200^\circ\text{C}$ , 1 cm thick timber with cold surface at  $10^\circ\text{C}$ . These two layers are interposed by a third layer of insulating material 25 cm thick. The conductivities of the materials are :

$$K(\text{Brick}) = 0.93 \text{ W/mK}, K(\text{Insulation}) = 0.12 \text{ W/mK}$$

$$K(\text{Wood}) = 0.175 \text{ W/mK}, K(\text{Aluminium}) = 204 \text{ W/mK}$$

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  $0.076 \text{ ohm/km}$  and the thermal conductivity of copper is  $380 \text{ W/mK}$ . The surrounding temperature is  $35^\circ\text{C}$ . The combined convection and radiation coefficient for heat transfer from the wire surface to the surrounding is  $14 \text{ W/m}^2\text{K}$ . Calculate :

(1) The surface temperature of the transmission line.

(2) The heat generated per unit volume.

(3) The maximum temperature in the line.

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

The properties are : density  $\rho = 7850 \text{ kg/m}^3$

Specific heat  $C_p = 480 \text{ J/kgK}$

Conductivity  $k = 40 \text{ W/mK}$  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 200°C and the fin is exposed to a convection environment at 15°C with convection coefficient 25 W/m<sup>2</sup>°C. Each fin has cross-sectional area of 2.5 cm<sup>2</sup>, perimeter 5 cm and is made of a material having thermal conductivity 250 W/m°C.

Neglect the heat loss from the tip of the fin.

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- (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 181.1°C. 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 120°C. The heat transfer co-efficient between steam and steam well is 420 kW/m<sup>2</sup>K 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  $Re = \frac{\rho VL}{\mu}$  and

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

All above symbols have their usual meanings.

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- (b) In a gas turbine system, hot gases at 1000°C flow at 75 m/s past the surface of a combustion chamber which is at a uniform temperature of 300°C. 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

$$R_{e_{cr}} = 5 \times 10^5.$$

Take the following properties of gas :

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

$$K = 0.0744 \text{ W/mK}, \text{ and } Pr = 0.625. \quad 7$$

**OR**

6. (a) Write short notes on the following :
- Velocity boundary layer and thermal boundary layer formation.
  - Significance of Reynolds number and Nusselt number. 6

- (b) Water entering at 10°C is heated to 40°C 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<sup>2</sup> over the surface. Determine :

- Reynolds number
- Heat transfer coefficient
- Length of pipe needed for a 30°C 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 15°C. If the duct is uninsulated and exposed to air at 25°C, calculate the heat gained by the duct per meter length assuming it to be horizontal.

Use the following properties of air :

$$C_p = 1005 \text{ J/kgK}, \nu = 15 \times 10^{-6} \text{ m}^2/\text{s}$$

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

- (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  $5 \times 5$  square array. Calculate the rate of condensation per meter length of the array, if its surface temperature is maintained at  $40^\circ\text{C}$ .

Use properties of Freon-12 as :

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

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

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9. (a) Calculate the following for an industrial furnace in the form of a black body and emitting radiation at  $2500^\circ\text{C}$  :
- (i) Monochromatic emissive power at  $1.2 \mu\text{m}$  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 :

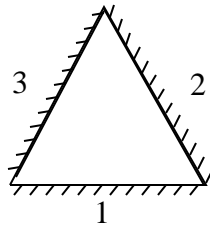
- (i) Emissivity
- (ii) Intensity of radiation
- (iii) Black body and gray body
- (iv) Lambert's cosine law. 6

**OR**

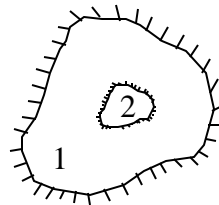
10. (a) State and explain properties of shape factor. 4
- (b) Calculate the shape factor for the configuration shown in the figure given below :
- (i) Long tube with cross-section of an equilateral triangle.
- (ii) Black body inside a black surface.

(iii) Diagonal partitions within a long square duct.

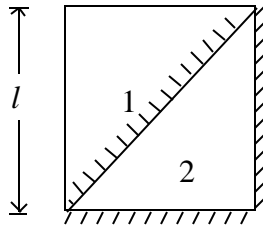
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(i)



(ii)



(iii)

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

$$\epsilon = \frac{1 - \exp[-NTU(1-C)]}{1 - C \cdot \exp[-NTU(1-C)]}$$

where  $\epsilon$  = Effectiveness of Heat Exchanger

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

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

**OR**

12. In an oil cooler, oil enters at 160°C. If water entering at 35°C flows parallel to oil, the exit temperatures of oil and water are 90°C 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