**Q. Code: 395143**

**Reg. No.** | | | | | | | | | | | | | |

# B.E./ B. TECH.DEGREE EXAMINATIONS, MAY 2024

Fifth Semester

## ME18504 – HEAT AND MASS TRANSFER

(Mechanical Engineering)

**(Regulation 2018/2018A)**

**(Use of Heat and Mass transfer data book is permitted)**

**TIME:3 HOURS** **MAX. MARKS: 100**

| COURSE OUTCOMES | STATEMENT | RBT LEVEL |
|---|---|---|
| **CO 1** | Student will illustrate the concepts of heat transfer in steady, transient and infinite solids. | **3** |
| **CO 2** | Students will examine the heat transfer coefficients for Natural and Forced convection. | **3** |
| **CO 3** | Students will apply the concepts of heat transfer in heat exchanger, Boiling and condensation phenomenon. | **3** |
| **CO 4** | Students can determine the radiation in black body, grey body and gases. | **3** |
| **CO 5** | Students will analyze the mass transfer occurring in both diffusion and convection mode. | **3** |

## PART- A(10x2=20Marks)

(Answer all Questions)

| | | CO | RBT LEVEL |
|---|---|---|---|
| **1.** | Write down the three dimensional heat conduction equation in Cartesian co-ordinate system. | **1** | **1** |
| **2.** | Explain the necessity of using the fin (Extended surface). | **1** | **2** |
| **3.** | Define Nusselt number and explain its significance. | **2** | **1** |
| **4.** | What is critical Reynolds number for flow over a flat plate? | **2** | **2** |
| **5.** | Explain fouling factor in the heat exchanger. | **3** | **1** |
| **6.** | Explain the term NTU and LMTD. | **3** | **1** |
| **7.** | Explain Stefan Boltzmann law and Kirchhoff law. | **4** | **2** |
| **8.** | What is the purpose of radiation shield? | **4** | **1** |
| **9.** | Define Sherwood number and Schmit number. | **5** | **1** |
| **10.** | State the Fick's Law of diffusion. | **5** | **2** |

## PART- B (5 x 14=70Marks)

| | | | Marks | CO | RBT LEVEL |
|---|---|---|---|---|---|
| **11. (a)** | **(i)** | Consider a 1 m high and 2.2 m wide double plane window consisting of two 5 mm thick layers of glass (k= 0.78W/mK) separated by a 10mm wide stagnant air space (k=0.026 W/mK). Determine the heat transfer through this double plane window and temperature of the | **(7)** | **1** | **3** |

inner surface, when the room is maintained at 20° C while the temperature of the outdoors is -10° C. Take the convective heat transfer coefficient inner and outer surfaces of the window to be $h_1$ = 12 w/$m^2$K and $h_2$ = 42 W/$m^2$K respectively.

| | | | | | |
|---|---|---|---|---|---|
| | **(ii)** | An aluminum fin (k= 200 W/mK) 3 mm thick and 7.5 cm long protrudes from a wall at 300° C. The ambient temperature is 50° C with h = 25 W/$m^2$K. Determine the heat loss from the fin per unit depth of material. | **(7)** | **1** | **3** |

**(OR)**

| | | | | | |
|---|---|---|---|---|---|
| **(b)** | | In a Quench Harding process steel rods (density = 7832 kg/$m^3$, $C_p$ = 434 J/Kg K, k= 63.9 W/m K) are heated in a furnace to 860°C and then cooled in a water bath to an average temperature of 98° C. The water bath has a uniform temperature of 40°C and h = 450 W/$m^2$ K. If the steel rod have a diameter of 70 mm and a length of 3 m. determine (a) the time required to cool steel rod from 860° C to 98° C in the water bath (b) the total amount of heat transferred to water during the quenching the steel rod. | **(14)** | **1** | **3** |

| | | | | | |
|---|---|---|---|---|---|
| **12. (a)** | | Air at 20° C and a pressure of 1 bar is flowing over a flat plate at a velocity of 3 m/s. If the plate is 280 mm wide and at 56° C, Estimate the following quantities at 280 mm (i) boundary layer thickness (ii) local friction coefficient (iii) average friction coefficient (iv) shearing stress due to friction (v) thickness of thermal boundary layer (vi) local friction coefficient (vii) average convective heat transfer coefficient (viii) rate of heat transfer rate by convection (ix) total drag force on the plate. | **(14)** | **2** | **3** |

**(OR)**

| | | | | | |
|---|---|---|---|---|---|
| **(b)** | **(i)** | A 0.3 m glass plate at 77° C is hung vertically in the air at 27° C. Determine the heat transfer rate through natural convection. | **(7)** | **2** | **3** |
| | **(ii)** | A 10 m long section of a 90 mm diameter horizontal hot water pipe passes through a large room whose temperature is 10° C, if the outer surface temperature of the pipe is 80° C. Determine the rate of heat loss from the pipe natural convection. | **(7)** | **2** | **3** |
| **13. (a)** | | Estimate the power required to boil water in a copper pan 0.35 m in diameter. The pan is maintained at 120° C by an electric heater. | **(14)** | **3** | **3** |

**(OR)**

| | | | | | |
|---|---|---|---|---|---|
| **(b)** | **(i)** | A counter flow heat exchanger is to heat air entering at 400° C with a | **(7)** | **3** | **3** |

flow rate of 6 kg/s by the exhaust gas entering at 800° C with a flow rate of 4 kg/s. The overall heat transfer coefficient is 100 W/m$^2$K and the outlet temperature of air is 551.5° C. The specific heat of both air and exhaust gas can be taken as 1100 J/Kg K. Calculate the heat transfer area needed.

| | | | | | |
|---|---|---|---|---|---|
| | **(ii)** | A chemical having specific heat of 3.3 kJ/kg K flowing at the rate of 20,000 kg/hr enters a parallel flow heat exchanger at 120° C. The flow rate of cooling water is 50,000 kg/hr with an inlet temperature of 20° C. The heat transfer area is 10 m$^2$ and the overall heat transfer coefficient is 1050 W/m$^2$ K, Find (i) the effectiveness of the heat exchanger, Take for water, $C_p$ = 4.186 kJ/kg K | **(7)** | **3** | **3** |
| **14. (a)** | | Determine the shape factor between the surfaces 1-4 and 4-1 as shown in Figure 1. | **(14)** | **4** | **3** |

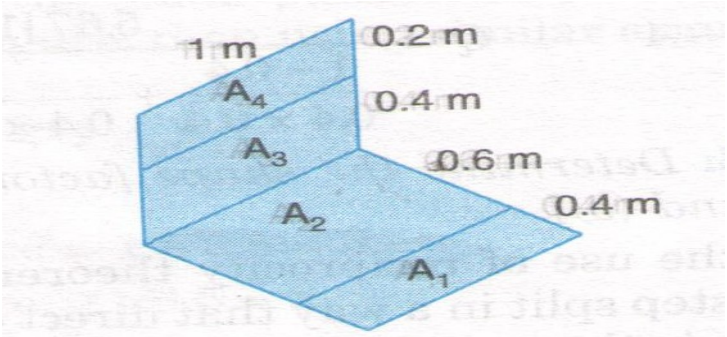


Figure 1

**(OR)**

| | | | | | |
|---|---|---|---|---|---|
| **(b)** | **(i)** | Determine the rate of heat loss by radiation from a steel tube of outside diameter 0.07 m and 3 m long at a temperature of 227° C, if the tube is placed within a square brick conduit 0.3 m side and at 27° C, Take Ɛ (steel) = 0.79 and Ɛ ( brick) = 0.93. | **(7)** | **4** | **3** |
| | **(ii)** | A thin aluminum sheet with an emissivity of 0.1 on both sides is placed between two large parallel plates that are maintained at uniform temperature $T_1$ = 800 K,$T_2$ = 500 K, $Ɛ_1$=0.2, $Ɛ_2$=0.7, determine the net rate of radiation heat transfer between the two plates per unit, surface area of the plates. | **(7)** | **4** | **3** |
| **15. (a)** | **(i)** | Hydrogen gas is maintained at 5 bar and 1 bar on opposite sides of a plastic membrane, which is 0.3 mm thick. The temperature is 25° C | **(7)** | **5** | **2** |

and the binary coefficient of hydrogen in the plastic is 8.7 $x10^{-8}$ $m^2/s$. The solubility of hydrogen in the membrane is 1.5 x $10^{-3}$ kg $mol/m^3$ bar. what is the mass flux of hydrogen by diffusion through the membrane?

| | | | | | |
|---|---|---|---|---|---|
| | **(ii)** | Describe the analogy between heat and mass transfer. | **(7)** | **5** | **3** |
| | | **(OR)** | | | |
| **(b)** | **(i)** | Calculate the mass transfer coefficient of water vapor in air in turbulent flow at 60 m/s at 1 atm, 300 K, over a flat plate. | **(7)** | **5** | **2** |
| | **(ii)** | Air at 25° C and atmospheric pressure, containing small quantities of iodine flows with a velocity of 5 m/s inside a 3 cm inner diameter tube. Determine the mass transfer coefficient from the air stream to the wall surface. Assume $D_{AB}$ (Iodine- air ) = 0.82 $x10^{-5}$ $m^2/s$ | **(7)** | **5** | **3** |

## PART- C (1x 10=10Marks)

(Q.No.16 is compulsory)

| | | Marks | CO | RBT LEVEL |
|---|---|---|---|---|
| **16.** | Steam in the condenser of a power plant is to be condensed at a temperature of 30° C with cooling water nearby lake, which enters the tubes of the condenser at 14° C and leaves at 22° C. the surface area of the tubes is 45 $m^2$ and the overall heat transfer coefficient is 2100 $W/m^2$ K. determine the mass flow rate of the cooling water needed and the rate of condensation of the steam in the condenser. Take specific heat of water = 4.2 kJkg K. | **(10)** | **3** | **3** |

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