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B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2016.

Fourth/Fifth Semester

Mechanical Engineering

ME 2251/ME 41/ME 1251/080120015/10122 ME 502 — HEAT AND MASS TRANSFER

(Common to Mechanical and Automation Engineering)

(Regulations 2008/2010)

(Common to PTME 2251/10122 ME 502 – Heat and Mass Transfer for Sixth Semester B.E. (Part-Time) Mechanical Engineering – Regulations 2009/2010)

Time : Three hours   Maximum : 100 marks

(Use of Heat and Mass Transfer Tables Permitted)

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Write three dimension general heat conduction differential equation and reduce the same to Laplace Equation by stating the conditions.

2. What is critical radius of insulation and write the importance this term?

3. In a process, water at 30°C flows over a plate maintained at 10°C with a free stream velocity of 0.3 m/s. Determine the hydrodynamic boundary layer thickness and thermal boundary layer thickness.

4. What is the need of identification of a new dimensionless Grashof Number in the case free convection?

5. Name the types of condensation and give one example for each type.

6. Why counter flow heat exchanger is more effective than parallel flow heat exchanger?

7. Distinguish between a black body and gray body.

8. Emissivities of two large parallel plates maintained at 800°C and 300°C are 0.3 and 0.5 respectively. Find the net radiation heat exchange per square metre for these plates.

9. State Fick's law of diffusion.

10. Write Reynolds analogy.

PART B — (5 × 16 = 80 marks)

11. (a) (i) A pipe carrying steam at 230°C has an internal diameter of 12 cm and the pipe thickness is 7.5 mm. The conductivity of the pipe material is 49 W/mK. The convective heat transfer coefficient on the inside is 85 W/m^2K. The pipe is insulated by two layers of insulation one of 5 cm thickness of conductivity 0.15 W/mK and over it another 5 cm thickness of conductivity 0.48 W/mK. The outside is exposed to air at 35°C with a convection coefficient of 18 W/m^2K. Determine the heat loss for 5 m length. Also determine the interface temperatures and the overall heat transfer coefficient based on inside and outside areas. (10)

(ii) A current of 200 A is passed through a stainless-steel wire [k =19 W/m°C) of 3 mm in diameter. The resistivity of the steel may be taken as 70 $\mu\,\Omega$ cm, and the length of the wire is 1 m. The wire is submerged in a liquid at 110°C and experiences a convection heat-transfer coefficient of 4 kW/m^2 °C. Calculate the center temperature of the wire. (6)

Or

(b) (i) A long aluminum cylinder 5.0 cm in diameter and initially at 200°C is suddenly exposed to a convection environment at 70°C and h = 525 W/m^2 °C. Calculate the temperature at a radius of 1.25 cm and the heat lost per unit length 1 mm after the cylinder is exposed to the environment. (10)

(ii) A long rod 12 mm square section made of low carbon steel protrudes into air at 35°C from a furnace wall at 200°C. The convective heat transfer coefficient is estimated at 22W/m^2K. The conductivity of the material is 51.9 W/mK. Determine the location from the wall at which the temperature will be 60°C. Also calculate the temperature at 80 mm from base. (6)

12. (a) Air at 20°C and at 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 56°C. calculate the following quantities at x = 280 mm :

(i) Boundary layer thickness

(ii) Local friction coefficient

(iii) Average friction coefficient

(iv) Shearing stress due to friction

(v) Local convective heat transfer coefficient

(vi) Average convective heat transfer

(vii) Rate of heat transfer by convection

(viii) Total drag on the plate and

(ix) Total mass flow rate through the boundary.

Or

(b) Consider a 0.6-m × 0.6-m thin square plate in a room at 30°C. One side of the plate is maintained at a temperature of 90°C, while the other side is insulated. Determine the rate of heat transfer from the plate by natural convection if the plate is :

(i) Vertical

(ii) Horizontal with hot surface facing up, and

(iii) Horizontal with hot surface facing down.

13. (a) (i) Explain the various boiling regions in detail. (6)

(ii) The bottom of a copper pan, 0.3 m in diameter, is maintained at 118°C by an electric heater. Estimate the power required to boil water in this pan. What is the evaporation rate? Estimate the critical heat flux. (10)

Or

(b) Water at the rate of 0.5 kg/s is forced through a smooth 25 mm ID tube of 15 m length. The inlet water temperature is 10°C and the tube wall is at a constant temperature of 40°C. What is the exit water temperature? Average properties of water are : C_p = 4180 J/kg°C; $\mu = 0.8 \times 10^{-3}$ Pa s; k = 0.57 W/m °C.

14. (a) (i) State and explain Kirchhoff's identity. State the conditions under which it is applicable. (4)

(ii) Two large parallel planes are maintained at 1000 K and 600 K. Determine the heat exchange per unit area.

(1) If surfaces are black

(2) If the hot one has an emissivity of 0.8 and the cooler one 0.5

(3) If a large plate is inserted between these two, the plate having an emissivity of 0.2. (12)

Or

(b) A heater of 1 m diameter is covered by a hemisphere of 4 m diameter. The surface of hemisphere is maintained at 400 K. The emissivity of the surface is 0.8. The heater surface is maintained at 1000 K. The remaining base area is open to surroundings at 300 K. The surrounding may be considered black. The emissivity of healer surface is also 0.8. Determine the heat exchange from heater to the hemisphere and to the surroundings.

15. (a) (i) Obtain expression for steady state equimolar counter diffusion. (8)

(ii) A open pan 20 cm in diameter and 8 cm deep contains water at 25°C and is exposed to dry atmospheric air. If the rate of diffusion of water vapour is 8.54×10^{-4} kg/h, estimate the diffusion coefficient of water in air. (8)

Or

(b) Air at 50°C and 1 atm flow over the surface of a water reservoir at an average velocity of 2.3 m/s. The water surface is 0.65 m long and 0.65 m wide. The water surface temperature is estimated at 30°C. The relative humidity of air is 40%. The density of air is 1.105 kg/m^3 and its viscosity is 1.943×10^{-5} kg/ms. Calculate the amount of water vapour evaporate per hour per square meter of water surface and state the direction of diffusion.