Reg. No. : | | | | | | | | | | | | |

Question Paper Code : 21849

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2015.

Fourth 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. What do you understand by critical thickness of insulation? Give its expression.

2. What is lumped capacity analysis?

3. Mention the significance of boundary layer.

4. Define Prandtl number and Grashoff number.

5. Differentiate between pool and flow boiling.

6. What do you understand by fouling and heat exchanger effectiveness?

7. Assuming the sun to be a black body emitting radiation with maximum intensity at $\lambda = 0.49\ \mu A$, calculate the surface temperature of the sun.

8. What is irradiation and radiosity?

9. How mass transfer takes through diffusion and convection?

10. What do you mean by equimolar counter diffusion?

PART B — ($5 \times 16 = 80$ marks)

11. (a) (i) A reactor's wall 320 mm thick is made up of an inner layer of fire brick (k = 0.84 W/m°C) covered with a layer of insulation (k = 0.16 W/m°C). The reactor operates at a temperature of 1325°C and the ambient temperature is 25°C. Determine the thickness of the firebrick and insulation which gives minimum heat loss. Calculate the heat loss presuming that the insulating material has a maximum temperature of 1200°C. (8)

(ii) Derive an expression for the heat conduction through a hollow cylinder from the general heat conduction equation. Assume steady state unidirectional heat flow in radial direction and no internal heat generation. (8)

Or

(b) (i) A 25 mm diameter rod of 360 mm length connects two heat sources maintained at 127°C and 227°C respectively. The curved surface of the rod is losing heat to the surrounding air at 27°C. The heat transfer coefficient is 10 W/m^2 °C. Calculate the loss of heat from the rod if it is made of copper (k = 335 W/m°C) and steel (k = 40 W/m°C). (8)

(ii) A thermocouple junction is in the form of 8 mm diameter sphere. The properties of the material are c = 420 J/kg°C; p = 8000 kg/m^3; k = 40 W/m°C and h = 40 W/m°C. The junction is initially at 40°C and inserted in a stream of hot air at 300°C. Find the time constant of the thermocouple. The thermocouple is taken out from the hot air after 10 seconds and kept in still air at 30°C. Assuming the heat transfer coefficient in air of 10 W/m°C, find the temperature attained by the junction 20 seconds after removing from hot air. (8)

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 at 56°C calculate the following at x = 280mm :

(i) Boundary layer thickness

(ii) Local friction coefficient

(iii) Average friction coefficient

(iv) Thickness of the thermal boundary layer

(v) Local convective heat transfer coefficient

(vi) Average convective heat transfer coefficient

(vii) Rate of heat transfer by convection

(viii) Total drag force on the plate. (16)

Or

(b) (i) A cylindrical body of 300 mm diameter and 1.6 m height is maintained at a constant temperature of 36.5°C. The surrounding temperature is 13.5°C. Find the amount of heat generated by the body per hour if c_p = 0.96 kJ/kg°C; ρ = 1.025 kg/m^3; k = 0.0892 W/m°C, v = 15.06×10^{-6} m^2/s and $\beta = 1/298$ K^{-1}. Assume Nu = 0.12 (Gr.Pr)$^{1/3}$. (8)

(ii) A nuclear reactor with its core constructed of parallel vertical plates 2.2 m high and 1.4 m wide has been designed on free convection heating of liquid bismuth. The maximum temperature of the plate surfaces is limited to 960°C while the lowest allowable temperature of bismuth is 340°C. Calculate the maximum possible heat dissipation from both sides of each plate. The properties of bismuth at film temperature are c_p = 150.7 kJ/kg°C; ρ = 10000 kg/m^3; k = 13.02 W/m°C, $\mu = 3.12 \times 10^{-6}$ kg/m h. Assume $Nu = 0.12\,(Gr.Pr)^{1/3}$. (8)

13. (a) (i) Water at atmospheric pressure is to be boiled in a polished copper pan. The diameter of the pan is 350 mm and is kept at 115°C. Calculate the power of the burner, rate of evaporation in kg/h and the critical heat flux. (8)

(ii) A vertical cooling fin approximating a flat plate 40 cm in height is exposed to saturated steam at atmospheric pressure. The fin is maintained at a temperature of 90°C. Estimate the thickness of the film at the bottom of the fin, overall heat transfer coefficient and heat transfer rate after incorporating McAdam's correction. (8)

Or

(b) (i) Explain how heat exchangers are classified? (8)

(ii) A counter flow double pipe heat exchanger using superheated steam is used to heat water at the rate of 10500 kg/h. The steam enters the heat exchanger at 180°C and leaves at 130°C. The inlet and exit temperatures of water are 30°C and 80°C respectively. If U = 814 W/m^2°C, calculate the heat transfer area. What would be the increase in area if the fluid flows were parallel? (8)

14. (a) (i) Calculate the following for an industrial furnace in the form of a black body and emitting radiation at 2500°C :

(1) Monochromatic emissive power at 1.2 μm length

(2) Wavelength at which the emission is maximum

(3) Maximum emissive power

(4) Total emissive power

(5) Total emissive power of the furnace if it is assumed as a real surface with emissivity equal to 0.9. (10)

(ii) Define the following :

(1) Black body

(2) Grey body

(3) Opaque body

(4) White body

(5) Specular reflection

(6) Diffuse reflection. (6)

Or

(b) (i) In the Figure Q. 14 (b) the areas A_1 and A_2 are perpendicular but do not share the common edge. Find the shape factor $F_{1\text{-}2}$ for the arrangement. (12)

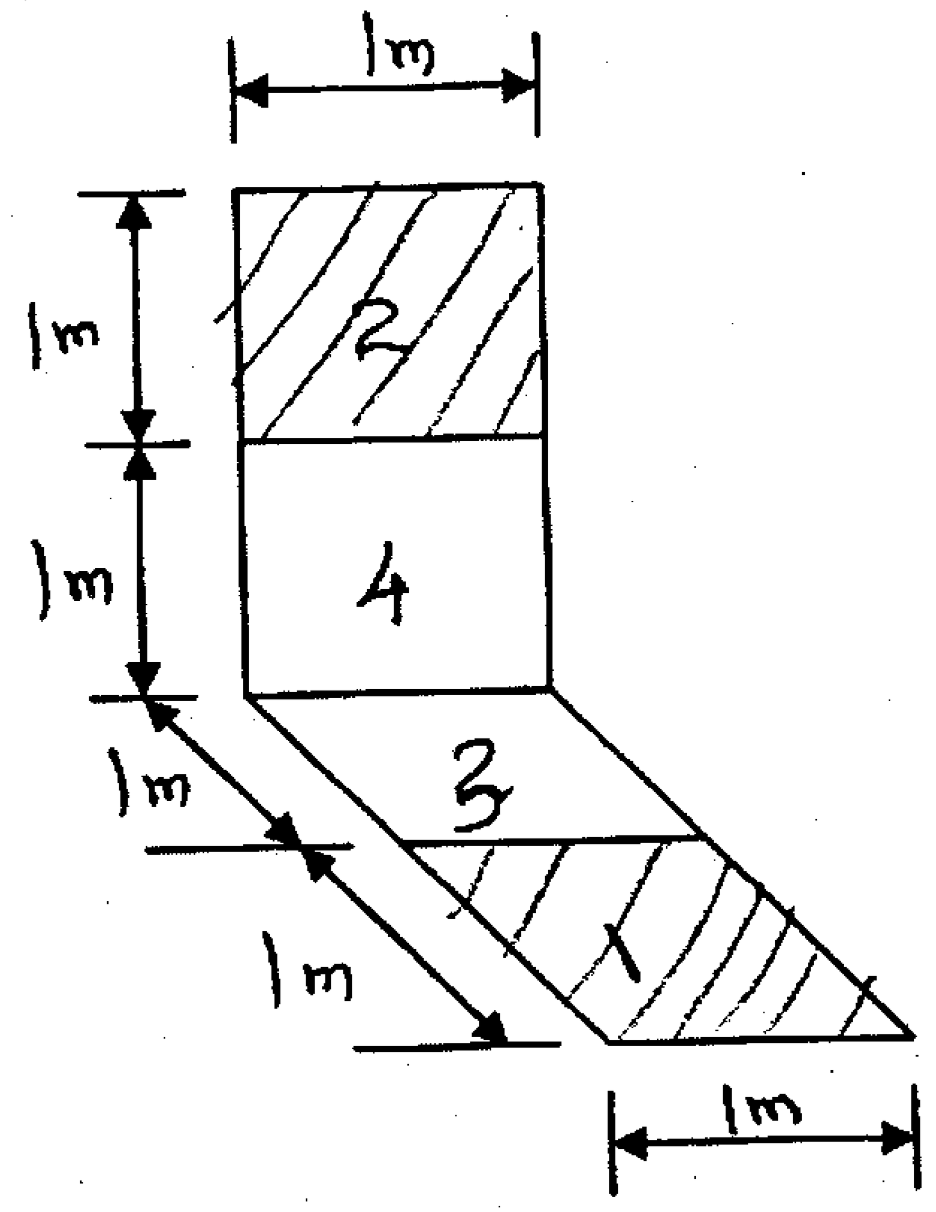

Figure Q. 14 (b)

(ii) Determine the radiant heat exchange in W/m^2 between two large parallel steel plates of emissivities 0.8 and 0.5 held at temperatures of 1000 K and 500 K respectively, if a thin copper plate of emissivity 0.1 is introduced as a radiation shield between the two plates. (4)

15. (a) (i) State Fick's law of diffusion and give its expression. Obtain an expression for the same in terms of partial pressures. (4)

(ii) Derive the general mass transfer equation in Cartesian coordinates. (12)

Or

(b) (i) A vessel contains binary mixture of O_2 and N_2 with partial pressures in the ratio 0.21 and 0.79 at 15°C. The total pressure of the mixture is 1.1 bar. Calculate the following :

(1) Molar concentrations

(2) Mass densities

(3) Mass fractions

(4) Molar fractions of each species. (8)

(ii) Air at 20°C with D = 4.166×10^{-5} m^2/s flows over a tray (length = 320 mm, width = 420 mm) full of water with a velocity of 2.8 m/s. The total pressure of moving air is 1 atm and the partial pressure of water present in the air is 0.0068 bar. If the temperature on the water surface is 15°C, calculate the evaporation rate of water. (8)

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