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B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2014.

Fourth Semester

Mechanical Engineering

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

(Common to Mechanical and Automation Engineering)

(Regulation 2008/2010)

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

Time : Three hours Maximum : 100 marks

Use of Heat and Mass Transfer Tables permitted.

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. State Fourier's Law of conduction.
2. What is meant by lumped heat capacity analysis?
3. Name four dimensions used for dimensional analysis.
4. Define Grashof Number.
5. What is pool boiling? Give an example for it.
6. What is meant by effectiveness?
7. What are the factors involved in radiation by a body?
8. What is the use of radiation shield?
9. State Fick's law of diffusion
10. List out the various modes of mass transfer.

PART B — ($5 \times 16 = 80$ marks)

11. (a) (i) Derive general heat conduction equation in Cartesian coordinates. (10)

(ii) Compute the heat loss per square meter surface area of a 40 cm thick furnace wall having surface temperatures of 300°C and 50°C if the thermal conductivity k of the wall material is given by $k = 0.005\,T - 5 \times 10^{-6}\,T^2$ where T = temperature in °C. (6)

Or

(b) (i) A furnace wall consists of 200 mm layer of refractory bricks, 6 mm layer of steel plate and a 100 mm layer of insulation bricks. The maximum temperature of the wall is 1150°C on the furnace side and the minimum temperature is 40°C on the outermost side of the wall. An accurate energy balance over the furnace shows that the heat loss from wall is 400 W/m^2. It is known that there is a thin layer of air between the layers of refractory bricks and steel plate. Thermal conductivities for the three layers are 1.52, 45 and 0.138W/m°C respectively. Find

(1) To how many millimeters of insulation brick is the air layer equivalent?

(2) What is the temperature of the outer surface of the steel plate? (8)

(ii) Find out the amount of heat transferred through an iron fin of length 50 mm, width 100 mm and thickness 5 mm. Assume k = 210 kJ/mh°C and h = 42 $kJ/m^2h°C$ for the material of the fin and the temperature at the base of the fin as 80°C . Also determine the temperature at tip of the fin, if atmosphere temperature is 20°C. (8)

12. (a) (i) Explain about velocity boundary layer on a flat plate. (6)

(ii) Assuming that a man can be represented by a cylinder 30 cm in diameter and 1.7 m high with a surface temperature of 30°C, calculate the heat he would lose while standing in a 36 km/h wind at 10°C. (10)

Or

(b) (i) A metal plate 0.609 m high forms the vertical wall of an oven and is at a temperature of 161°C. Within the oven air is at a temperature of 93.0°C and one atmosphere. Assuming that natural convection conditions hold near the plate, estimate the mean heat transfer coefficient and the rate of heat transfer per unit width of the plate. (8)

(ii) A 10 mm diameter spherical steel ball at 260°C is immersed in air at 90°C. Estimate the rate of convective heat loss. (8)

13. (a) A vertical tube of 50 mm outside diameter and 2 m long is exposed to steam at atmospheric pressure. The outer surface of the tube is maintained at a temperature of 84°C by circulating cold water through the tube. Determine the rate of heat transfer and also the condensate mass flow rate. (16)

Or

(b) (i) Explain about Fouling Factors. (4)

(ii) Hot oil with a capacity rate of 2500 W/K flows through a double pipe heat exchanger. It enters at 360 °C and leaves at 300°C. Cold fluid enters at 30°C and leaves at 200°C. If the overall heat transfer coefficient is 800 W/m^2K, determine the heat exchanger area required for (1) Parallel flow and (2) Counter flow. (12)

14. (a) Calculate the following for an industrial furnace in the form of a black body and emitting radiation at 2500°C. (i) Monochromatic emissive power at 1.2 μm length. (ii) Wave length 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. (16)

Or

(b) Two parallel plates of size 1.0 m by 1.0 m spaced 0.5 m apart are located in a very large room, the walls of which are maintained at temperature of 27°C. One plate is maintained at a temperature of 900°C and the other at 400°C. Their emissivities are 0.2 and 0.5 respectively. If the plates exchange heat between themselves and surroundings, find the net heat transfer to each plate and to the room. Consider only the plate surfaces facing each other. (16)

15. (a) (i) Discuss about steady state equimolar counter diffusion. (8)

(ii) Hydrogen gas is maintained at pressures of 2.4 bar and 1 bar on opposite sides of a plastic membrane 0.3 mm thick. The binary diffusion coefficient of hydrogen in the plastic is 8.6×10^{-8} m^2/s and solubility of hydrogen in the membrane is 0.00145 kg mole / m^3-bar. Calculate, under uniform temperature conditions of 24°C the following (1) Molar concentrations of hydrogen at the opposite faces of the membrane, and (2) Molar and mass diffusion flux of hydrogen through the membrane. (8)

Or

(b) (i) Air at 20°C (ρ = 1.205 kg/m^3, υ = 15.06×10^{-6} m^2/s, 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)

(ii) Dry air at 27°C and 1 atm flows over a wet flat plate 50 cm long at a velocity of 50 m/s. calculate the mass transfer coefficient of water vapor in air at the end of the plate. (8)
