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

Fifth Semester

Mechanical Engineering

ME 6502 — HEAT AND MASS TRANSFER

(Common to Sixth Semester Mechanical and Automation Engineering and Seventh Semester for Mechanical Engineering (Sandwich))

(Regulations 2013)

Time : Three hours | Maximum : 100 marks

(Use of approved heat and mass transfer data book and steam table is permitted)

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. State the Fourier's law of heat conduction. Why is the negative sign used?
2. Under what circumstances from the heat transfer point of view, will the use of finned walls be better?
3. What are the differences between natural and forced convection?
4. What is critical Reynolds number for the flow over the flat plate?
5. Give examples for pool boiling and flow boiling.
6. What are fouling factors?
7. Define monochromatic emissive power.
8. What do you mean by infrared and ultraviolet radiation?
9. State Fick's law of diffusion.
10. Define Schmidt number and state its physical significance.

PART B — (5 × 16 = 80 marks)

11. (a) (i) A body of an electric motor is 360 mm in diameter and 240 mm long. It dissipates 360 W of heat and its surface temperature should not exceed 55°C. Longitudinal fins of 15 mm thickness and 40 mm height are proposed. The heat transfer coefficient is 40 W/m^2K when the ambient temperature 30°C. Determine the number of fins required, if k of the fin material is 40 W/mK. (10)

(ii) Derive an expression for critical radius of insulation for a cylindrical system. (6)

Or

(b) (i) Determine the minimum depth at which one must place a water main below the soil surface to avoid freezing. The soil is initially at a uniform temperature of 20°C. In severe winter condition it is subjected to a temperature of -15°C for a period of 60 days. Use the following properties of the soil : $\rho = 2050\ kg/m^3$, C = 1840 j/kg K and k = 0.52 w/mK. (8)

(ii) A steel pipe with 50 mm OD is covered with two layers of insulation. The inner layer is 7.5 mm thick and has a k = 0.3 w/mK and the top layer is 20 mm thick and k = 0.12 w/mK. The pipe wall is 315°C and the outside air temperature is 25°C. Determine the surface temperature and heat loss per metre length for 10 minutes. Take the convective heat transfer coefficient between air the surface as 16 w/m^2K. (8)

12. (a) (i) Air at a pressure of 8 kN/m^2 and a temperature of 250°C flows over a flat plate 0.3 m wide and 1 m long at a velocity of 8 m/s. If the plate is to be maintained at a temperature of 78°C estimate the rate of heat to be removed continuously from the plate. (8)

(ii) A heated sphere having a diameter of 30 mm is maintained at a temperature of 90°C and is placed in water stream at 20°C. The water flow velocity is 3.5 m/s. Calculate the heat loss from the sphere. (8)

Or

(b) (i) Determine the average heat transfer coefficient over the entire length from a vertical plate of height 2 m to the surrounding air, if it is known that the surface temperature of the plate is 105°C. Assume the ambient temperature is 15°C. (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) Saturated steam at atmospheric pressure condenses on a 2-m-high and 3-m-wide vertical plate that is maintained at 80°C by circulating cooling water through the other side. Determine : (16)

(i) The rate of heat transfer by condensation to the plate and

(ii) The rate at which the condensate drips off the plate at the bottom.

Or

(b) (i) A counter-flow double-pipe heat exchanger is to heat water from 20°C to 80°C at a rate of 1.2 kg/s. The heating is to be accomplished by geothermal water available at 160°C at a mass flow rate of 2 kg/s. The inner tube is thin-walled and has a diameter of 1.5 cm. The overall heat transfer coefficient of the heat exchanger is 640 W/m²K. Using the effectiveness-NTU method determine the length of the heat exchanger required to achieve the desired heating. (10)

(ii) Classify heat exchangers. (6)

14. (a) (i) Charge-Coupled Device (CCD) image sensors, that are common in modern digital cameras, respond differently to light sources with different spectral distributions. The incandescent light may be approximated as a blackbody at the effective surface temperatures of 2800 K. Determine the fraction of radiation emitted within the visible spectrum wavelengths, from 0.40 μm (violet) to 0.76 μm (red), for the incandescent lighting source. (8)

(ii) A thin aluminum sheet with an emissivity of 0.1 on both sides is placed between two very large parallel plates that are maintained at uniform temperatures T_1 = 800 K and T_2 = 500 K and have emissivities $\epsilon_1 = 0.2$ and $\epsilon_2 = 0.7$ and, respectively. Determine the net rate of radiation heat transfer between the two plates per unit surface area of the plates and compare the result to that without the shield. (8)

Or

(b) A cylindrical furnace whose height and diameter are 5 m contains combustion gases at 1200 K and a total pressure of 2 atm. The composition of the combustion gases is determined by volumetric analysis to be 80 percent N_2, 8 percent H_2O, 7 percent O_2, and 5 percent CO_2. Determine the effective emissivity of the combustion gases. (16)

15. (a) (i) A narrow cylindrical vessel contains water at the bottom. It is 5 m deep and has 2.5 m diameter. The water is diffused to dry ambient air over the top of the vessel. The entire arrangement is maintained at 30°C and 1 atm. The diffusion coefficient is 0.24×10^{-14} m²/s. Calculate the rate of diffusion of water into the air. (8)

(ii) O_2 gas at 25°C and a pressure of 2 bar is flowing through a rubber pipe of ID 25 mm and wall thickness 2.5 mm. The diffusivity of O_2 through rubber is $D_{AB} = 0.21 \times 10^{-9}$ m²/s and solubility of O_2 in rubber is 3.12×10^{-3} mol/m³ bar. Find the loss of oxygen by diffusion per metre length of pipe. (8)

Or

(b) (i) Air at 20°C and 1 atm pressure flows with a velocity of 2.5 m/s inside a 12 mm diameter tube. The inside surface of the tube contains a deposit of naphthalene. Determine the average mass transfer coefficient for the transfer of naphthalene from the pipe surface into air. Take $v = 15.7 \times 10^{-6}$ m²/s for air and $D_{AB} = 0.62 \times 10^{-5}$ m²/s. (8)

(ii) An 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 2.37×10^{-7} kg/s estimate the diffusion coefficient of water in air. (8)