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Register No.: .... Name: ....

SAINTGITS COLLEGE OF ENGINEERING (AUTONOMOUS)

(AFFILIATED TO APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY, THIRUVANANTHAPURAM)

SIXTH SEMESTER B.TECH DEGREE EXAMINATION (R), MAY 2023
MECHANICAL ENGINEERING
(2020 SCHEME)

Course Code : **20MET302**

Course Name: **Heat and Mass Transfer**

Max. Marks : **100** **Duration: 3 Hours**

Use of Heat and Mass Transfer data book and Steam table are permitted

PART A

(Answer all questions. Each question carries 3 marks)

1. State 3 modes of heat transfer with examples.
2. Define fin effectiveness and discuss the reason for preference of thin and closely packed fins.
3. Discuss the significance of Reynold's number, Prandtl number and Nusselt number.
4. Define boundary layer thickness.
5. Sketch the temperature distribution configuration along length for condenser and evaporator.
6. Give your understanding on the term 'fouling' in heat exchangers. List any 2 common failures in heat exchangers.
7. Prove that for a surface $\alpha + \rho + \tau = 1$ where α, ρ, τ are absorptivity, reflectivity and transmissivity respectively.
8. Differentiate regular and diffuse reflection.
9. Give the analogy between conduction heat transfer and mass diffusion.
10. State Fick's law of diffusion.

PART B

(Answer one full question from each module, each question carries 14 marks)

MODULE I

11. a) Derive the general three dimensional unsteady state heat conduction equation in Cartesian coordinate system. (7)

b) An electric heating application uses wire of 2mm diameter with 0.8mm thick insulation (k = 0.12W/m°C). The heat transfer coefficient (h_0) on the insulated surface is 35W/m^2°C. Determine critical thickness of insulation in this case and the percentage change in heat transfer rate if the critical thickness is used, assuming the temperature difference between the surface of the wire and surrounding air remains unchanged. (7)

OR

12. a) Derive the expression for the temperature distribution of one dimensional steady state heat conduction with internal heat generation for a plane wall with both the walls kept at same temperature. (7)

b) A sphere of 200mm diameter made of cast iron initially at uniform temperature of 400°C is quenched into oil. The oil bath temperature is 40°C and if the temperature of sphere is 100°C after 5 minutes. Find the heat transfer coefficient on the surface of the sphere. Neglect internal thermal resistance. Take C_p (cast iron) = 0.32kJ/kg°C; ρ (cast iron) = 7000kg/m^3. (7)

MODULE II

13. a) Explain hydrodynamic and thermal boundary layer for flow through flat plate with the help of neat sketches. (7)

b) Air stream at 27°C moving at 0.3m/s across 100W incandescent bulb, glowing at 127°C. If the bulb is approximated by a 60mm diameter sphere, estimate the heat transfer rate and percentage of power lost due to convection. (7)

OR

14. a) A vertical plate of 60cm height is at 160°C and is exposed to still air at 100°C. Determine heat transfer rate per metre width. (7)

b) Atmospheric air at 20°C flows over a flat plate with a velocity of 3m/s. The plate has a length of 500mm (in the flow direction) and a width of 300mm. If the plate is maintained at 80°C. Calculate the following quantities at the trailing edge; (7)

(i) hydrodynamic boundary layer thickness
(ii) thermal boundary layer thickness
(iii) local heat transfer coefficient
(iv) rate of heat transfer by convection from plate

MODULE III

15. a) Differentiate pool boiling and forced convection boiling. (4)

b) In an open heart surgery under hypothermic conditions, the patients' blood is cooled before the surgery and re-warmed afterwards. It is proposed that a concentric tube counter flow heat exchanger of length 0.5m is to be used for this purpose, with a thin – walled inner tube having a diameter of 55mm. If water at 60°C and 0.1kg/s is used to heat blood entering the exchanger at 18°C and 0.05kg/s. Determine the temperature of the blood leaving the exchanger and heat flow rate. Take U_0 = 500W/m^{2}K, C_p of blood = 3.5 kJ/kgK and C_p of water = 4.183 kJ/kgK. (10)

OR

16. a) 'Drop-wise condensation is better than film wise condensation'. Comment with valid reason. Discuss the methods to achieve drop wise condensation? (4)

b) In a shell and tube counter flow heat exchanger water flows through a copper tube 20mm internal diameter and 23mm outer diameter, while oil flows through the shell. Water enters at 20°C and comes out at 30°C, while oil enters at 75°C and comes out at 60°C. The water and oil side film coefficients are 4500 and 1250W/m^2°C respectively. The thermal conductivity of tube wall is 335W/m°C. The fouling factors on the water side and oil side may be taken to be 0.0004 and 0.001 respectively. If the length of the tube is 2.4m. Calculate overall heat transfer coefficient and heat transfer rate. (10)

MODULE IV

17. a) The sun emits maximum radiation at λ = 0.52μm. Assuming the sun to be black body, calculate the surface temperature of the sun. Also, determine the monochromatic emissive power of the sun's surface. (4)

b) Two long concentric cylinders having diameters of 300mm and 400mm are at 600°C and 400°C respectively. Their respective emissivities are 0.6 and 0.5. Determine heat radiated for the following cases (i) L = 0.5m (ii) L = ∞ (10)

OR

18. a) Define the term View factor. A hemispherical surface 1 lies over a horizontal plane surface 2 such that the convex portion of the hemisphere is facing the sky. Sketch and determine the value of the geometrical shape factor F_{1-2}. (4)

b) Calculate the net radiant heat exchange per m^{2}area for two large parallel plates at temperatures of 427°C and 27°C respectively. Emissivity values of two plates are ε (hot plate) = 0.9 and ε (cold plate) = 0.6. If a polished aluminium shield (ε = 0.4) is placed between them, find the percentage reduction in heat transfer. (10)

MODULE V

19. a) Explain the phenomenon of equimolar counter diffusion. Sketch the distribution of partial pressures across distance in equimolar counter diffusion of a binary gas mixture. (4)

b) Dry air at 27°C and atmospheric pressure flows over a wet flat plate 50cm long at a velocity of 50m/s. Calculate the mass transfer coefficient of water vapour in air at the end of the plate. Take D = 0.26 x 10^{-4} m^2/s. (10)

OR

20. a) A steel rectangular container having walls 16mm thick is used to store gaseous hydrogen at elevated pressure. The molar concentrations of hydrogen in the steel at the inside and outside surfaces are 1.2kgmole/m^3 and zero respectively. Assuming the diffusion coefficient for hydrogen in steel as 0.248 x 10^{-12} m^2/s. Calculate the molar diffusion flux for hydrogen through the steel. (4)

b) A well is 40m deep and 9m in diameter is exposed to atmosphere at 25°C. The air at the top has a relative humidity of 50%. Calculate the rate of diffusion of water vapour through the wall. (10)
Take mass diffusivity = 2.5 x 10^{-5} m^2/s; molecular weight of water = 18 kg/kg mol; partial pressure of water vapour at 25°C = 3.169kPa.

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