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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

B.Tech Degree S6 (S, FE) / S4 (PT) (S, FE) Examination May 2024 (2015 Scheme)

Course Code: ME302

Course Name: Heat and Mass Transfer

Use of heat and mass transfer data book permitted

Max. Marks: 100 Duration: 3 Hours

PART A

Answer any three full questions, each carries 10 marks. Marks

1 a) Define thermal diffusivity. Explain its physical significance. (3)

b) A thick walled stainless steel tube of thermal conductivity K=19 W/m K with 2 cm inner diameter and 4 cm outer diameter is covered with 3 cm layer of asbestos insulation of thermal conductivity 0.1 W/m K. Inside wall temperature is 600°C. The outside surface temperature is 100°C. Calculate the heat loss per meter length of the pipe. (7)

2 a) Define critical radius of insulation? Derive the expression for critical radius of insulation for a cylinder. (5)

b) A 2 mm diameter wire with 0.8 mm thick layer of insulation having thermal conductivity k=0.15 W/m K is used in a certain electric heating application. The insulated surface is exposed to atmosphere with convective heat transfer coefficient of 40 W/m^2 K. What percentage change in heat transfer rate would occur if the critical thickness of insulation is used. Assume the temperature difference between the surface of the wire and surrounding air remains unchanged. (5)

3 a) Explain with a neat sketch the hydrodynamic and thermal boundary layer. Define boundary layer thickness in hydrodynamic and thermal boundary layer. (4)

b) A heat treated steel plate measures 3 x 1 m and is initially at 30°C. It is cooled by blowing air parallel to 1m edge at 9 km/hr. If the air is at 10°C, calculate the convective heat transfer from both sides of the plate. (6)

4 a) Define Nusselt number and Prandtl number. Explain its significance in heat transfer. (4)

b) Using Buckingham pi theorem derive a semi empirical relation for natural convention heat transfer. (6)

PART B

Answer any three full questions, each carries 10 marks.

5 a) Define Biot Number and Fourier number. Explain its significance in transient heat transfer cases. (4)

b) Glass sphere of 2 mm radius and at 500°C is to be cooled by exposing to an air stream at 25°C. Calculate the value of heat transfer coefficient of the medium for the lumped heat capacity analysis to apply. Calculate the minimum time required for cooling to a temperature of 60°C. Assume the following property values, Density of the glass=2250kg/m^3. Specific heat=850 J/kg K, and thermal conductivity of the glass=1.5 W/m K. (6)

6 a) Explain the term Fouling factor? What is the significance of Fouling factor in determining the overall heat transfer coefficient of a heat exchanger. (4)

b) A long carbon steel rod fin of length 40 cm and diameter 10 mm (k = 40 W/m K) is placed in such a way that one of its end is 400°C and the ambient temperature is 30°C. The heat transfer co-efficient is 10 w/m^{2}K. Determine Temperature at the mid length of the fin and heat transfer rate from the fin. (6)

7 a) Explain various regimes of pool boiling process. (5)

b) Water flows at the rate of 65 kg/min through a double pipe counter flow heat exchanger. Water is heated from 50°C to75°C by an oil flowing through the tube. The specific heat of the oil is 1.780 kJ/kg K. The oil enters at 115°C and leaves at 70°C, the overall heat transfer co-efficient is 340 W/m^{2}K. Calculate Heat exchanger area and rate of heat transfer using LMTD method. (5)

8 a) What are the assumptions used in LMTD method of analysis? (4)

b) Hot chemical products (C_p= 2.5 kJ/kg K) at 600° C and at a flow rate of 30 kg/s are used to heat cold chemical products (C_p = 4.2 kJ/kg K) at 200°C and at a flow rate of 20 kg/s in a parallel flow heat exchanger. The total heat transfer is 50 m^2 and the overall heat transfer coefficient may be taken as 1500 W/m^2 K. Calculate the outlet temperatures of the hot and cold chemical products. (6)

PART C

Answer any four full questions, each carries 10 marks.

9 a) State and derive Kirchoff's Law of radiation. (4)

b) The sun emits maximum radiation at λ = 0.52 μm. Assuming the sun to be a black body, calculate the surface temperature of the sun. Also calculate the monochromatic emissive power of the sun's surface. (6)

10 a) Define absorptivity, reflectivity and transmissivity of radiation heat transfer process. (3)

b) Two rectangular surfaces are perpendicular to each other with a common edge of 2 m size. The horizontal plane is 2 m long and vertical plane is 3 m long. Vertical plane is at 1200 K and has an emissivity of 0.4, whereas the horizontal plane is 18°C and has an emissivity of 0.3. Determine the net heat exchange between the planes. (7)

11 a) Define shape factor term used in radiation. Write down any three relations involved in shape factor algebra. (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. Emissivity of the hot plate is 0.9 and that of the cold plate is 0.6. If a polished aluminium shield of emissivity 0.4 is placed between them, find the percentage reduction in the heat transfer. (6)

12 a) Explain the analogy between the heat and mass transfer. (3)

b) 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 8.54×10^{-4} kg/h, estimate the diffusion co-efficient of water in air. Take saturation pressure of water at 25°C as 0.03166 bar. (7)

13 a) Derive an expression for equimolar counter diffusion of gases. (4)

b) A plastic membrane 0.25 mm thick has hydrogen gas maintained at pressures of 2.5 bar and 1 bar on its opposite sides. The binary diffusion coefficient of hydrogen in the plastic is $8.5\text{x}10^{-8}$ m^2/s and the solubility of hydrogen in the membrane is $1.5\text{x}10^{-3}$ kg-mole/m^3 bar. Under uniform temperature conditions of 25°C, Calculate molar and mass diffusion flux of hydrogen through the membrane. (6)

14 a) Define the terms Sherwood number and Lewis number. Explain their significance in mass transfer. (4)

b) Air at 1 atm. and 25^0 C, containing small quantities of iodine flows with a velocity of 5.25 m/s inside a 3 cm diameter tube. Determine the mass transfer coefficient for iodine transfer from the air stream to the weak surface. Assume the following thermo physical properties of air D_{ab}=$0.82\text{x}10^{-5}$ m^2/s and kinematic viscosity $15.5\text{x}10^{-6}$ m^2/s. (6)

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