Exam Date & Time: 04-May-2024 (02:30 PM - 05:30 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

SIXTH SEMESTER B.TECH END SEMESTER EXAMINATIONS, MAY 2024

HEAT TRANSFER [MME 3251]

Marks: 50 **Duration: 180 mins.**

A

Answer all the questions.

Instructions to Candidates: Answer ALL questions Missing data may be suitably assumed

1) A) The thermal conductivity of a material varies with temperature as $k = k_0(1+AT)$ where A and k_0 are constants. Develop an expression for the temperature distribution in a slab under steady state conditions. (4)

B) Calculate the admissible current intensity for a 2.5 mm diameter copper wire covered with plastic insulation of optimum thickness so as to have positive heat transfer on the condition that the maximum temperature of insulation should not exceed 56°C and the temperature of the surrounding to be 32°C. The thermal conductivity of plastic is 0.014 W/m°C and the electrical resistance of the copper wire is 0.005 Ω/m. Assume the surface heat transfer coefficient to be 10 W/m^2°C. (3)

C) The inner surface of a high temperature reactor will operate at 1623 K. The wall of the reactor will have an overall thickness of 350 mm and is to be made up of an inner layer of firebrick material (k_r = 0.86 W/m K) covered with a layer of insulation (k_i = 0.16 W/m K). This insulating material has a maximum operating temperature of 1473 K. The ambient temperature will be 293 K and it is estimated that the heat transfer coefficient at the exposed surface of the insulation will be 10 W/m^2K. Calculate the thickness of refractory and insulation which gives minimum heat loss and the magnitude of this loss in W/m^2. Also calculate the surface temperature of the insulation. (3)

2) A) Develop an expression for temperature distribution in a solid cylinder with uniform heat generation and convective boundary condition. (5)

B) A copper rod of thermal conductivity 325 W/m°C, 10 mm in diameter spans the distance between 2 parallel plates 150 mm apart. Air flows in the space between the plates providing a heat transfer coefficient of 55 W/m^2°C over the surface of the rod. The surface temperature of the plate exceeds that of the air by 40°C. What is the difference in temperature at the mid span of the rod over that of the air. Also find the heat loss per hour from the surface of the rod. (3)

C) A longitudinal copper fin (k = 390 W/m°C) 800 mm long and 6 mm diameter is exposed to air stream at 21°C. The convective heat transfer coefficient is 20W/m^2°C. If the fin base temperature is 150°C, determine the efficiency and effectiveness of the fin assuming insulated tip condition. (2)

3) A) With usual notations, develop a relationship between Nusselt number, Prandtl number and Reynold's number using Buckingham's pi theorem. (4)

B) A vertical cylinder of diameter 200 mm and height 5 m is maintained at 90 °C in a room at 30 °C . Find heat loss by natural convection. Property of air at mean temperature of 60 °C are given by, (3)

$$\rho = 1.06\, kg/m^3, \quad k = 0.0291 W/m^oC, \quad \beta = 6.2\times 10^{-4} /^o C,$$

$$c_p = 1.005\, kJ/kg^oC, \; \nu = 17.95\times 10^{-6}\, m^2/s$$

Use the correlation $Nu=0.12(Gr.Pr)^{1/3}$.

C) A long annulus *250 mm* inner diameter and *380 mm* outer diameter air is heated by steam at *160 ^{o}C* in the pipe. If the velocity of air in the annulus surrounding the pipe is *6 m/s* and its average temperature is *40 ^{o}C*, calculate the heat transfer coefficient on the air side and the rate of heat transfer. Properties of air at mean temperature *(160 + 40)/2 = 100 ^{o}C* is given as, (3)

$$\alpha = 33.6 \times 10^{-6} m^2/s,\ k = 0.032 W/m^oC,\ \nu = 23.13 \times 10^{-6} m^2/s$$

Use the correlation, $Nu=0.023Re^{0.8}Pr^{0.4}$.

4) A) Develop an expression for the effectiveness of a parallel flow double pipe heat exchanger using the NTU method. (4)

B) A counter-flow heat exchanger is employed to cool 0.55 kg/s (c_p = 2.45 kJ/kg°C) of oil from 115°C to 40°C by the use of water. The inlet and outlet temperatures of cooling water are 15°C and 75°C, respectively. The overall heat transfer coefficient is expected to be 1450 W/m^2°C. Using NTU method, calculate the following:

i. The mass flow rate of water; (3)

ii. The effectiveness of the heat exchanger.

iii. The surface area required.

C) Calculate the effectiveness of the heat exchanger and exit temperature of cold fluid for both parallel and counter flow arrangement by using the following data. Hot oil at 200^{0}C at the mass flow rate of 10000 kg/hr and specific heat of 1900 J/kg K is to be cooled. The flow rate of water is 3000 kg/hr. The inlet temperature of the water is 20^{0}C. The overall heat transfer coefficient is 300 W/m^2 ^{0}C. The total area of the exchanger is 17.5 m^2. (3)

5) A) Using the electrical analogy, determine the rate of heat exchange between two concentric cylindrical grey bodies. (4)

B) Determine the radiation heat loss from each meter of a 200 mm diameter heating pipe, when it is placed centrally in a brick duct of square cross section 300 mm side. Temperature of the pipe surface is *200^{0}C* and the temperature of brick is *20^{0}C.* Emissivity of the pipe surface is 0.8 and emissivity of brick = 0.9. Assume only radiation heat transfer between the pipe and brick duct. (3)

C) Two concentric spheres 200 mm and 300 mm diameters with space between them evacuated are to be used to store liquid air at -153 ^{0}C in a room at 27 ^{0}C. The surface of the sphere is polished with aluminium having emissivity of 0.03. if the latent heat of the liquid air is 0.21x10^6 J/kg, find the rate of evaporation of liquid air. (3)

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