Code No: 136CA **R16**

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

B. Tech III Year II Semester Examinations, December - 2019

HEAT TRANSFER

(Mechanical Engineering)

Time: 3 Hours **Max. Marks: 75**

Note: This question paper contains two parts A and B.
Part A is compulsory which carries 25 marks. Answer all questions in Part A. Part B consists of 5 Units. Answer any one full question from each unit. Each question carries 10 marks and may have a, b, c as sub questions.

PART - A

(25 Marks)

1.a) What are the physical mechanisms associated with heat transfer by conduction, convection and radiation? [2]

b) The filament of an incandescent lamp of 100 W rating has a total surface area of $50 mm^2$. If the surrounding is at 30^0C and 80% of the power is converted to heat and radiated, determine the temperature of the filament. [3]

c) Define sensitivity (or) time constant of a thermocouple. [2]

d) Explain importance of insulated tip solution for the fins used in practice. [3]

e) Explain the development of velocity boundary layer for flow over a flat plate. [2]

f) Explain the concept of Bulk mean temperature and film temperature. Indicate where it is used. [3]

g) What is physical interpretation of the Grashof number and Rayleigh number? [2]

h) Compare arithmetic mean and log mean temperature differences. [3]

i) Define shape factor, irradiation and emissivity. [2]

j) Write a note on Nucleate and film boiling. [3]

PART - B

(50 Marks)

2.a) Show that the rate of heat conduction through a hollow cylinder is given by

$$Q_k = -k\,A_{ln}\,\frac{T_2-T_1}{x_m} \quad ;where\ A_{ln} = \frac{A_2-A_1}{\ln\frac{A_2}{A_1}}$$

A_1, A_2 are being the areas of inside and outside surfaces of the cylinder and x_w is wall thickness.

b) A furnace wall is of three layers, first layer of insulation brick of 12 cm thickness of conductivity 0.6 W/m K. The face is exposed to gases at 870 ^0C with a convection coefficient of 110 W/m^2 K. This layer is backed by a 10 cm layer of firebrick of conductivity 0.8 W/m K. There is a contact resistance between the layers of $2.6 \times 10^{-4}\ m^2\ {}^0C/W$. The third layer is the plate backing of 10 mm thickness of conductivity 49 W/m K. The contact resistance between the second and third layers is $1.5 \times 10^{-4}\ m^2\ {}^0C/W$. The plate is exposed to air at 30 ^0C with a convection coefficient of 15 W/m^2 K. Determine the heat flow, the surface temperatures and the overall heat transfer coefficient. [5+5]

OR

3.a) Derive general heat conduction equation in spherical coordinates and state the assumption made.

b) A spherical vessel containing hot fluid at 160 ^{0}C (in a chemical process) is of 0.4 m outer diameter and is made of Titanium of 25 mm thickness. The thermal conductivity is 20 W/m K. The vessel is insulated with two layers of 5 cm thick insulations of thermal conductivities 0.06 and 0.12 W/m K. There is a contact resistance of 6×10^{-4} and 5×10^{-4} m^2 ^{0}C/W between the metal and first insulation and between the insulating layers. The outside is exposed to surrounding at 30 ^{0}C with a convection coefficient of 15 W/m^2 K. Determine the rate of heat loss, the interface temperatures and the overall heat transfer coefficient based on the metal surface area. [5+5]

4.a) Derive an expression for heat dissipation in a straight rectangular fin.

b) Thermometer well is made of 1 mm thick material of thermal conductivity 55 W/m K and the inner diameter is 8 mm. The convection coefficient on the surfaces is 50 W/m^{2}K. The wall temperature is 120 ^{0}C. The thermometer placed in contact with well bottom reads 380 ^{0}C. Determine the fluid temperature and the error as a percentage of true temperature in ^{0}C. Discuss the possible methods to reduce the error. The length of the well is 6 cm. [5+5]

OR

5.a) Steady cylinder 0.2 m is diameter of 3 m long, initially at 500 ^{0}C is suddenly immersed in a fluid at 40 ^{0}C. The convective heat transfer coefficient between the cylinder surface and fluid is 200 W/m^2 K. Assuming K = 40 W/m-K, α=1.0 × 10^{-5} m ^{2}/s for the steel cylinder. Calculate after 20 minutes i) The center temperature ii) the surface temperature and iii) the heat transfer to the water during the initial 20 minutes.

b) Consider a plane wall of thickness L whose thermal conductivity varies linearly in a specified temperature range as $k(T) = k_0(1 + \beta T)$ where k_0 and β are constants. The wall surface at x =0 is maintained at a constant temperature of T_1 while the surface at $x = L$ is maintained at T_2. Assuming steady one-dimensional heat transfer, obtain a relation for (*i*) the heat transfer rate through the wall and (*ii*) the temperature distribution $T(x)$ in the wall. [5+5]

6.a) Explain the Reynolds Colburn analogy for laminar flow over a flat plate.

b) Air at atmospheric pressure and 200 ^{0}C flows over a flat plate with a velocity of 5 m/s. The plate is 15 mm wide and is maintained at 120 ^{0}C. Calculate the thickness of velocity and thermal boundary layers and local heat transfer coefficient at a distance of 0.5 m from the leading edge. Assuming that the flow is on one side of the plate, calculate the heat transfer rate. Given: ρ = 0.815 kg/m^3, k = 0.0364 W/m K, $\mu = 2.45 \times 10^{-5}$ kg/ms and Pr = 0.7. [5+5]

OR

7.a) A plate 40 cm square has a uniform heat generation rate of 8 kW/m^2. Water at 20 ^{0}C flows over it with a velocity of 1.2 m/s. Determine the value of convection coefficient at the trailing edge and also the temperature at this location.

b) Using dimensional analysis, derive an expression for heat transfer coefficient in forced convection in terms of Nusselt number, Reynolds number and Prandtl numbers? [5+5]

8.a) Liquid mercury at 20 ^{0}C enters a metal tube of 20 mm internal diameter at the rate of 1 kg/s and is heated to 30 ^{0}C. The tube wall subjected to uniform heat flux is at an average temperature of 40 ^{0}C. Determine the length of the tube. Given for the mercury: $\rho = 13560$ kg/m^3, k = 8.7 W/m K, $\mu = 1.5 \times 10^{-3}$ kg/ms, Pr = 0.025, Cp = 139 J/kg K.

b) Derive the expression for the effectiveness of a parallel flow heat exchanger. [5+5]

OR

9.a) A vertical surface 4 m high and 1.8 m wide is subjected to uniform heat flux of 1000 W/m^2. The surface is insulated from the other side. All of the incident heat is rejected by free convection to the surrounding air at 20 ^{0}C. What average temperature will the plate attain?

b) Air at atmospheric pressure and 20 ^{0}C flows across a long cylinder of 50 mm diameter at a velocity of 40 m/s. The cylinder surface temperature is maintained at 100 ^{0}C. Calculate the heat transfer rate per unit length of the cylinder. [5+5]

10.a) What is radiation shield? Show that presence of n number of radiation shields reduce the radiation heat transfer by a factor of (n+1).

b) Discuss forced-flow boiling in a horizontal tube. Support the answer with suitable sketch. [5+5]

OR

11.a) Draw the boiling curve and identify the burnout point on the curve. Explain how burnout is caused. Why is the burnout point avoided in the design of boilers?

b) Two very large parallel plates are maintained at uniform temperatures of T_1 =1000 K and T_2 = 800 K and have emissivity of $\varepsilon_1 = \varepsilon_2$ =0.2, respectively. It is desired to reduce the net rate of radiation heat transfer between the two plates to one-fifth by placing thin aluminium sheets with an emissivity's of 0.15 on both sides between the plates. Determine the number of sheets that need to be inserted. [5+5]

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