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P.E.S. College of Engineering, Mandya - 571 401

(An Autonomous Institution affiliated to VTU, Belagavi)

Sixth Semester, B.E. - Mechanical Engineering

Semester End Examination; May/June - 2019

Heat and Mass Transfer

Time: 3 hrs *Max. Marks: 100*

Note: *i) Answer FIVE full questions, selecting ONE full question from each unit*
ii) Use of HMT data handbook permitted iii) Missing data if any, suitably assumed.

UNIT - I

1 a. What are the different physical boundary conditions used in the analysis of conduction problems. Explain them with suitable examples. 6

b. Derive an expression for one dimensional steady state temperature distribution in a slab of thickness '*L*' with no heat generation, when the boundary surface at $x = 0$ is kept at a uniform temperature 'T_o' and at $x = L$ dissipates heat by convection with a heat transfer coefficient '*h*' into the ambient air at temperature T_∞. Assume constant thermal conductivity. 10

c. Write the mathematical formulation of one dimensional steady state heat conduction for a hollow sphere with constant thermal conductivity in the region $a \le r \le b$, when heat is supplied to the sphere at the rate of q_0 w/m^2 from the boundary surface at r = a and dissipates heat by convection from the boundary surface at r = b into the medium at zero temperature with a heat transfer coefficient *h*. 4

2 a. Obtain the expression for the critical radius of insulation for the heat transfer through a sphere in terms of thermal conductivity '*k*' and heat transfer co-efficient '*h*'. 8

b. A 3 cm diameter pipe at 120°C is loosing heat by convection at rate of 120 W per meter length. The surrounding temperature is 30°C. It is required to reduce the heat loss to a minimum value by providing insulation. The following insulating materials are available :
Insulation 1: Quantity = 3.15×10^{-3}m^3 per meter length pipe with K_1 = 5 W/mK
Insulation 2: Quantity = 4×10^{-3} m^3 per meter length pipe with K_2 = 1 W/mK
Examine the better insulating layer relative to pipe and determine the percentage change in heat transfer from the arrangement. 12

UNIT - II

3 a. Develop an expression for the steady state temperature distribution in slab of thickness *L*, when the boundary surface at $x = 0$ is kept insulated and boundary surface at x = L is kept at zero temperature. The thermal conductivity of wall '*K*' is constant and within the wall energy is generated at the rate of $g(x) = g_0x^2$ W/m^3. 10

Contd…2

b. A plane wall of thickness 0.1 m and thermal conductivity 25 W/mK having uniform volumetric heat generation of 0.3 mW/m^3 is insulated on one side, while other side is exposed to fluid at 92°C. The convection heat transfer coefficient between plane wall and fluid is 500 W/m^2K. Determine the maximum temperature and location of maximum temperature. 10

4 a. Derive the expression for the temperature distribution in a body at time '*t*' during Newtonian heating or cooling as a function of B and F_0. 6

b. In a quenching process, a copper plate 3 mm thick is heated upto 400°C and then exposed to an ambient at 25°C with the convection coefficient of 28 W/m^2K. Calculate the time required for the plate to reach the temperature of 50°C. 4

Take thermo physical properties as C = 380 J/kg-K, ρ = 8800 kg/m^3, k = 385 W/mK.

c. A 50 mm thick iron plate is initially at 225°C. Its both surfaces are suddenly exposed to an environment at 25°C with convection coefficient of 500 W/m^2K. Calculate;

i) The centre temperature 2 minute after the start of exposure

ii) The temperature at the depth of 10mm from the surface after 2 minute of exposure 10

iii) The energy removed from the plate per square meter during this period. Take, K = 60 W/mK, ρ = 7850 kg/m^3, C = 460 J/kgK, $\alpha = 1.6\times10^{-5}\ m^2/s$

UNIT - III

5 a. With the usual notation, prove that; 6

$$St_m . P_r^{2/3} = \frac{C_m}{2}$$

b. Atmospheric air at T_∞ = 400 k with a velocity u_∞ = 1.5 m/s flows over a flat plate L = 2 m long maintained at a uniform temperature T_w = 300 K. Calculate the average heat transfer coefficient from x = 0 to x = L = 2 m. Calculate the heat transfer rate from air stream to the plate from x = 0 to x = L = 2 m for w = 0.5 m Take $\nu = 0.21\times10^{-4}\ m^2/s$, K = 0.03 W/mK, P_r = 0.697 at mean temperature. 4

c. Air at a temperature of 60°C and a pressure of 1 atm flow over a flat plate at 125 m/s. The plate is at 100°C and 1.5 m long. Calculate;

i) Hydrodynamic boundary layer thickness at the end of the plate

ii) The local skin friction coefficient at the end of the plate

iii) The average skin friction coefficient 10

iv) Drag force per meter width of the plate

v) The local heat transfer coefficient and average heat transfer coefficient

vi) The heat transfer from the plate

6 a. Using Dimensional analysis prove that $N_u = f(G_r, P_r)$ 10

Contd…2

b. Vertical door of a hot oven is 0.5 m high and is maintained at 200°C. It is exposed to atmospheric air. Find; 10

i) Local heat transfer half way up the door ii) Average heat transfer coefficient for entire door

iii) Thickness of free convection boundary layer at the top of the door.

UNIT - IV

7 a. State Wien's Displacement law. Show that $E_{b\lambda}$ will be maximum when λ_{max} T = 2900 μm-K. 8

b. Prove that the total emissive power of a black body $E_b = \sigma T^4$. 6

c. The temperature of a filament of an incandescent light bulb (a black body) is maintained at 2500 k. Calculate the fraction of radiant energy emitted by the filament in the visible spectrum (from 0.4 μm to 0.76 μm). Also calculate the wave length at which the emission from the filament reaches a maximum value. 6

8 a. For the radiation heat exchange between two large parallel gray plates prove that the view factor 10

$$F_{1-2} = \frac{1}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1}$$

b. Emissivities of two large parallel plates maintained at 800ºC and 300ºC are 0.3 and 0.5 respectively. Find; 10

i) Net radiant heat exchange per square meter of the plate

ii) The percentage reduction in heat transfer, when a polished aluminum radiation shield (ε = 0.05) is placed between them

iii) The temperature of the shield

UNIT - V

9 a. Derive an expression for the LMTD of a counter flow heat exchanger. 10

b. A counter flow heat exchanger is used to heat water from 20°C to 80°C at a rate of 1.2 kg/s. The heating is obtained by using geothermal water available to 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. If the overall heat transfers coefficient is 640 W/m^{2}K. Calculate the length of the heat exchanger required to achieve the desired heating by using effectiveness NTU method. Take specific heat of geo thermal water as 4.31 kJ/kg-K and that of ground water as 4.18 kJ/kg-K. 10

10 a. Explain Fick's law of diffusion. 6

b. For a laminar film wise condensation on a vertical plate prove that the local heat transfer co-efficient 10

$$h_x = \left[\frac{g\rho_1 (\rho_L - \rho_V) k_L^3 hfg}{4\mu (T_{sat} - T_s) x} \right]^{1/4}$$

c. Dry saturated steam at a pressure of 2.45 bar condenses on the surface of a vertical tube if height 1m. The tube surface temperature is kept at 117ºC. Estimate the thickness of the condensate film and the local heat transfer coefficient at a distance of 0.2 m from the upper end of the tube. The properties of water at 2.45 bar are : 4

Saturated vapour T_{sat} = 127°C ρ_v = 1.368 kg/m^3 h_{fg} = 2183 kJ/kg

Saturated water; T_f = (117+127)/2 = 122°C

ρ_L = 941.6 kg/m^3 $\mu_L = 227\times10^6$ N-s/m^2 $k_L = 687 \times 10^{-3}$ W/mK

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