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

(An Autonomous Institution affiliated to VTU, Belgaum)

Sixth Semester, B.E. - Mechanical Engineering

Semester End Examination; May / June - 2018

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 hand book permitted. Missing data if any suitable assumed.

UNIT - I

1 a. Derive 3-dimensional general heat conduction equation in cartesian coordinates with suitable assumptions. 8

b. Define fin efficiency and fin effectiveness. 2

c. Determine the steady state heat transfer through a double pane window, 0.8 m high, 1.5 m wide, consisting of two 4 mm thick glass layers (K = 0.78 W/mC), separated by a 10 mm thick stagnant layer of air (K = 0.026 W/mC), inside temperature of room air is maintained at 20°C with a convective heat transfer coefficient of 10 W/m^2C. Outside air temperature is -10°C and the convective heat transfer coefficient on the outside is 40 W/m^2C. Also, determine the overall heat transfer coefficient. 10

2 a. What is thermal diffusivity? Explain its physical significance. 4

b. Derive expression for rate of heat transfer flowing through a long fin. 6

c. A Steel rod (K = 30 W/mK), 10 mm in diameter and 50 mm long with an insulated end is to be used as a fin. It is exposed to surroundings with a temperature of 65°C and a heat transfer coefficient of 50 W/m^3K. The temperature of the base is 98°C. Determine; 10

i) Fin efficiency ii) temperature at the end of the fin iii) Heat dissipation.

UNIT -II

3 a. Derive temperature distribution and rate of heat transfer through a plane slab of variable thermal conductivity under steady state condition. 8

b. A pipe carrying pressurized water is embedded in a 1.2 m thick brick wall, whose surface are held at constant temperature of 200°C and 50°C respectively. It is required to locate the pipe in the wall where temperature should not exceed 125°C. Find how far from the hot surface, the pipe should be embedded? The thermal conductivity of wall material (brick) varies with temperature as K = 0.28(1+0.035T) W/mK. 7

c. A plane wall of thickness 0.1 m and K = 25 W/mK, having uniform volumetric heat generation of 0.3 MW/m3 is insulated on one side and is exposed to a fluid at 92°C. The convective heat transfer coefficient between the wall and the fluid is 500 W/m^2K. Determine; 5

i) Maximum temperature in the wall ii) Temperature at the surface exposed to the fluid.

4 a. Show that the temperature distribution in lumped system is given by $\frac{T-T_\infty}{T_0-T_\infty} = e^{-(Bi)(F_0)}$ 10

b. A long 15 cm diameter cylindrical shaft made of stainless steel (K = 14.9 W/mC), ρ = 7900 kg/m^3, C_ρ = 477 J/kgC and α = 3.95×10^{-6} m^2/s, comes out of an oven at a uniform temperature of 450°C. The shaft is then allowed to cool slowly in a chamber at 150°C with an average heat transfer coefficient of 85 W/m^{2}C. Determine; 10

i) The temperature at the centre of the shaft 25 min after the start of the cooling process.

ii) The surface temperature at that time

iii) The heat transfer per unit length of the shaft during this time period.

UNIT -III

5 a. Engine oil at 30°C is flowing with a velocity of 2 m/s along the length of a flat plate maintained at 90°C. Calculate at a distance of 40 cm from the leading edge.

i) Hydrodynamic and thermal boundary later thickness

ii) Local and average values of friction coefficient 8

iii) Local and average values of heat transfer coefficient

iv) Heat transferred from the first 40cm of the plate for unit width.

b. A hot square plate 40 cm × 40 cm at 100°C is exposed to atmospheric air at 20°C. Make calculations for the heat loss from both surfaces of the plate. If;

i) The plate is kept vertical ii) The plate is kept horizontal

The following empirical correlations have been suggested : 8

Nu = 0.125(Gr.Pr)$^{0.33}$ for vertical position of the plate

Nu = 0.72(Gr.Pr)$^{0.25}$ for upper surface

Nu = 0.35(Gr.Pr)$^{0.25}$ for lower surface

Where the air properties are evaluated at the mean temperature.

c. Write the significance of; 4

i) Grashoff number ii) Nusselt number.

6 a. Estimate the heat transfer rate from a 100 W incandescent bulb at 140°C to an ambient at 24°C. Approximate the bulb at 60 mm diameter sphere. Calculate the percentage of power lost by natural convection. Use the following correlation and air properties: N_u = 0.6(Gr.Pr)$^{0.25}$, the properties of air at 82°C are: γ = 21.46×10^{-6} m^2/s, K = 30.38×10^{-3} W/mK and P_r = 0.699. 6

b. Calculate the rate of heat loss from a human body which may be considered as a vertical cylinder of 30 cm in diameter and 175 cm high, while standing in a 30 km/hr wind at 15°C the surface temperature of the human body is 35°C. 6

c. Show using Buckingham-π theorem of dimensional analysis, that in a natural convection problem, the Nusselt number is a function of Grashoff number and Prandtl number. 8

UNIT - IV

7 a. State and explain;

i) Kirchhoff's law ii) Wein's displacement law 12

iii) Planck's law iv) Lambert cosine law.

b. Consider two large parallel plates at t_1 = 727°C with emissivity ε_1 = 0.8 and t_2 = 227°C with emissivity ε_2 = 0.4. An aluminum radiation shield with an emissivity, ε_s = 0.05 on both sides is placed between the plates. Calculate the percentage reduction in heat transfer rate between the two plates as a result of the shield. 8

8 a. Prove that for a black body enclosed in a hemispherical space, the emissive power of the black body is equal to π times its intensity of radiation. 10

b. Calculate the following for an industrial furnace in the form of a black body and emitting radiation at 2500°C.

i) Monochromatic emissive power at 1.2 μm length

ii) Wavelength at which the emission is maximum

iii) Maximum emissive power 10

iv) Total emissive power

v) Total emissive power of the furnace if it is assumed as a real surface with emissivity equal to 0.9

UNIT - V

9 a. Obtain an expression for the effectiveness of a parallel flow heat exchanger in terms of 'NTU' and the capacity ratio 'C'. 10

b. Explain Fick's first law of diffusion. 6

c. Differentiate between film wise and drop wise condensation. 4

10 a. With the help of a typical experiment boiling curve, explain the different regimes of pool boiling. 8

b. Write a note on fouling factor in heat exchangers. 4

c. A counter flow double pipe heat exchanger using superheated steam is used to heat water at the rate of 10500 kg/h. The steam enters the heat exchanger at 180°C and leaves at 130°C. The inlet and exit temperature of water are 30°C and 80°C respectively. If overall heat transfer coefficient from steam to water is 814 $W/m^{2\circ}C$, calculate the heat transfer area. What would be the increase in area if the fluid flows were parallel? 8

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