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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 ($K = 0.78 \text{ W/mC}$), separated by a 10 mm thick stagnant layer of air ($K = 0.026 \text{ W/mC}$), inside temperature of room air is maintained at 20°C with a convective heat transfer coefficient of $10 \text{ W/m}^2\text{C}$. Outside air temperature is -10°C and the convective heat transfer coefficient on the outside is $40 \text{ W/m}^2\text{C}$. 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 ($K = 30 \text{ W/mK}$), 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 $50 \text{ W/m}^2\text{K}$. 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 $K = 0.28(1+0.035T) \text{ W/mK}$. 7
- c. A plane wall of thickness 0.1 m and $K = 25 \text{ W/mK}$, having uniform volumetric heat generation of 0.3 MW/m^3 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 $500 \text{ W/m}^2\text{K}$. 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 ($K = 14.9 \text{ W/mC}$), $\rho = 7900 \text{ kg/m}^3$, $C_p = 477 \text{ J/kgC}$ and $\alpha = 3.95 \times 10^{-6} \text{ m}^2/\text{s}$, 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 $85 \text{ W/m}^2\text{C}$. Determine; 10
- The temperature at the centre of the shaft 25 min after the start of the cooling process.
 - The surface temperature at that time
 - 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. 8
- Hydrodynamic and thermal boundary layer thickness
 - Local and average values of friction coefficient
 - Local and average values of heat transfer coefficient
 - Heat transferred from the first 40cm of the plate for unit width.
- b. A hot square plate $40 \text{ cm} \times 40 \text{ cm}$ at 100°C is exposed to atmospheric air at 20°C . Make calculations for the heat loss from both surfaces of the plate. If; 8
- The plate is kept vertical
 - The plate is kept horizontal
- The following empirical correlations have been suggested :
- $$\text{Nu} = 0.125(\text{Gr.Pr})^{0.33} \text{ for vertical position of the plate}$$
- $$\text{Nu} = 0.72(\text{Gr.Pr})^{0.25} \text{ for upper surface}$$
- $$\text{Nu} = 0.35(\text{Gr.Pr})^{0.25} \text{ for lower surface}$$
- Where the air properties are evaluated at the mean temperature.
- c. Write the significance of; 4
- Grashoff number
 - 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: $\text{Nu}_u = 0.6(\text{Gr.Pr})^{0.25}$, the properties of air at 82°C are: $\gamma = 21.46 \times 10^{-6} \text{ m}^2/\text{s}$, $K = 30.38 \times 10^{-3} \text{ W/mK}$ and $\text{Pr} = 0.699$. 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 $t_1 = 727^\circ\text{C}$ with emissivity $\epsilon_1 = 0.8$ and $t_2 = 227^\circ\text{C}$ with emissivity $\epsilon_2 = 0.4$. An aluminum radiation shield with an emissivity, $\epsilon_s = 0.05$ 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 $1.2 \mu\text{m}$ length | |
| ii) Wavelength at which the emission is maximum | 10 |
| iii) Maximum emissive power | |
| 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 $814 \text{ W/m}^2\text{C}$, calculate the heat transfer area. What would be the increase in area if the fluid flows were parallel? 8

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