USN

10ME63

Sixth Semester B.E. Degree Examination, Jan./Feb. 2023

Heat and Mass Transfer

Time: 3 hrs. Max. Marks:100

Note: 1. Answer any FIVE full questions, selecting at least TWO questions from each part.
2. Use of HMT data hand book is permitted.

PART – A

1 a. Derive an expression for one dimensional conduction equation without heat generation through cylinders. **(08 Marks)**

b. What are the assumptions made while deriving Fourier's conduction equation? **(04 Marks)**

c. An insulating wall is composed of 15 cm of a material having thermal conductivity of 0.15 W/mK and unknown thickness of cork of thermal conductivity 0.045 W/mK. The inside wall is in contact with a fluid at a temperature of 30°C with a surface heat transfer coefficient of 10 W/m^2K where as outside wall temperature is –5°C. Determine the thickness of the cork required to keep the heat loss to 10 W/m^2. **(08 Marks)**

2 a. Derive an expression for the rate of heat transfer for a plane wall of non-uniform thermal conductivity undergoing one dimensional steady state heat conduction. **(08 Marks)**

b. Briefly explain:
(i) Critical thickness of insulation
(ii) Thermal contact resistance **(04 Marks)**

c. A rod (k = 200 W/mK) 10 mm in diameter and 5 cm long has its one end maintained at 100°C. The surface of the rod is exposed to ambient air at 30°C with convective heat transfer coefficient of 100 W/m^2K. Assuming other end insulated, determine:
(i) Temperature of the rod at 25 mm distance from the end at 100°C.
(ii) Heat dissipation rate from the surface of the rod.
(iii) Effectiveness **(08 Marks)**

3 a. Explain the significances of (i) Biot number (ii) Fourier number **(04 Marks)**

b. Using lumped system analysis, show that $\dfrac{T(t)-T_\infty}{T_o-T_\infty}=e^{-mt}$. **(08 Marks)**

c. A slab of aluminium 10 cm thick is originally at a temperature of 500°C. It is suddenly immersed in a liquid at 100°C, resulting in a heat transfer coefficient of 1200 W/m^2K. Determine the temperature at the centre line and the surface 1 minute after the immersion. Take properties of aluminium as $\alpha = 8.4 \times 10^{-5}$ m^2/s, $\rho = 2700$ kg/m^3, k = 215 W/mK, $C_p = 0.9$ kJ/kgK. **(08 Marks)**

4 a. With the application of dimensional analysis show that for natural convection $Nu = C\, Gr^m\, Pr^n$ where C, m and n are constants. **(10 Marks)**

b. The exact expression for the local drag coefficient C_x for laminar flow over a flat plate is given by $C_x = \dfrac{0.664}{Rex^{1/2}}$. Air at atmospheric pressure and at $T_\infty = 300$ K flows with a velocity $V_\infty = 15$ m/s along the plate. Determine the distance from the leading edge of a plate where transition begins from laminar to turbulent. Calculate the drag force acting per 1m width of the plate over the distance from x = 0 to where the transition starts. **(08 Marks)**

c. With a sketch indicate different zones of thermal boundary layer. **(02 Marks)**

PART – B

5 a. Explain significance of :
(i) Reynold's number (ii) Prandtl number
(iii) Nusselt number (iv) Stanton number **(08 Marks)**

b. Water is heated while flowing through 1.5 cm × 3.5 cm rectangular cross-section tube at a velocity of 1.2 m/s. The entering temperature of water is 40°C and the tube wall is maintained at 100°C. Determine the length of the tube required in order to raise the temperature of water by 40°C. **(07 Marks)**

c. Air at 27°C is flowing at 0.3 m/s across a 100 W electric bulb at 127°C. If the bulb is approximated as a 10 cm dia and 1m high cylinder estimate the heat transfer rate. **(05 Marks)**

6 a. Derive an expression for the effectiveness of a parallel flow heat exchanger using N.T.U. method. **(10 Marks)**

b. A counter flow heat exchanger is employed to cool 0.55 kg/s of oil (C_p = 2.45 kJ/kgK) from 115°C to 40°C by the use of water. The inlet and outlet temperature of cooling water are 15°C and 75°C respectively. The overall heat transfer coefficient is expected to be 1450 W/m^2K. Using NTU method, calculate:
(i) Mass flow rate of water
(ii) Effectiveness of heat exchanger
(iii) Surface area required **(10 Marks)**

7 a. With a neat sketch, explain different regimes of boiling. **(08 Marks)**

b. Define Fick's law of mass transfer. **(02 Marks)**

c. Saturated steam at 80°C condenses as a film on vertical plate at a temperature of 70°C. Calculate the average heat transfer coefficient and the rate of condensation. Assume hfg at 80°C as 2309 kJ/kg and length is 1m. **(10 Marks)**

8 a. Derive an expression for the net heat transfer between 2 black bodies. **(10 Marks)**

b. Consider two large parallel plates one at 1000 K with emissivity 0.8 and other is at 300 K having emissivity 0.6. A radiation shield is placed between them. The shield has emissivity 0.1 on the side facing hot plate and 0.3 on the side facing cold plate. Calculate percentage reduction in radiation heat transfer as a result of radiation shield. **(10 Marks)**

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