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15ME63

**Sixth Semester B.E. Degree Examination, Feb./Mar. 2022**  
**Heat Transfer**

Time: 3 hrs.

Max. Marks: 80

- Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.  
2. Use of Heat Transfer Data Handbook is permitted.*

**Module-1**

- 1 a. Derive the 3-D general heat conduction equation in Cartesian coordinates. (08 Marks)  
b. The temperatures on the two surfaces of a 25 mm thick steel plate, ( $k = 48 \text{ W/mK}$ ) having a uniform volumetric heat generation of  $30 \times 10^6 \text{ W/m}^3$ , are  $180^\circ\text{C}$  and  $120^\circ\text{C}$ . Neglecting the end effects, determine:  
(i) Temperature distribution across the plate.  
(ii) Value and position of maximum temperature  
(iii) Flow of heat from each surface of the plate. (08 Marks)

**OR**

- 2 a. What do you mean by boundary conditions of 3 kinds? (03 Marks)  
b. Define the terms:  
(i) Thermal conductivity (ii) Thermal diffusivity  
(iii) Convective heat transfer coefficient (iv) Stefan Boltzman's law (04 Marks)  
c. An exterior wall of a house may be approximated by a 0.1 m layer of common brick ( $k = 0.7 \text{ W/mK}$ ) followed by a 0.04 m layer of gypsum plaster ( $K = 0.48 \text{ W/mK}$ ). What thickness of loosely packed rock wool insulation ( $K = 0.65 \text{ W/mK}$ ) should be added to reduce the heat loss through the wall by 80%? (09 Marks)

**Module-2**

- 3 a. What are the significances of critical thickness of insulation? Derive an expression for the same in case of a sphere. (05 Marks)  
b. Define the terms Fin efficiency and Fin effectiveness. (03 Marks)  
c. A 60 mm thick large steel plate ( $k = 42.6 \text{ W/m}^\circ\text{C}$ ,  $\alpha = 0.043 \text{ m}^2/\text{h}$ ), initially at  $440^\circ\text{C}$  is suddenly exposed on both sides to an environment with convective heat transfer coefficient  $235 \text{ W/m}^2\text{C}$  and temperature  $50^\circ\text{C}$ . Determine the centre line temperature and temperature inside the plate 15 mm from the midplane after 4.3 minutes. (08 Marks)

**OR**

- 4 a. What do you mean by lumped system analysis? Derive an expression for the temperature distribution of a solid body when it is suddenly exposed to ambient air using lumped parameter analysis. (08 Marks)  
b. The aluminium square fins ( $0.5 \text{ mm} \times 0.5 \text{ mm}$ ) of 10 mm length are provided on a surface of semiconductor electronic device to carry 1W of energy generated by the device. The temperature at the surface of the device should not exceed  $80^\circ\text{C}$  when surrounding temperature is  $40^\circ\text{C}$ . Neglecting the heat loss from the end of fins, find the number of fins required to carry out the above operation. Take,  $k_{Al} = 200 \text{ W/mK}$ ,  $h = 15 \text{ W/m}^2\text{K}$ . (08 Marks)

**Module-3**

- 5 a. Derive an expression for finite difference formulation for one dimensional, steady state heat conduction in Cartesian coordinates using energy balance approach. Take prescribed temperatures at the boundaries. (08 Marks)
- b. Assuming the sun (diameter =  $1.4 \times 10^9$  m) as a black body having a surface temperature of 5750 K and at a mean distance of  $15 \times 10^{10}$  m from the earth (diameter =  $12.8 \times 10^6$  m) estimate the following:
- Total energy emitted by the sun.
  - The emission received per  $m^2$  just outside the atmosphere of the earth.
  - The total energy received by the earth if no radiation is blocked by the atmosphere of earth.
  - The energy received by a  $1.6 \text{ m} \times 1.6 \text{ m}$  solar collector whose normal is inclined at  $50^\circ$  to the sun. The energy loss through the atmosphere is 42 percent and diffuse radiation is 22 percent of direct radiation. (08 Marks)

**OR**

- 6 a. Define the following:
- Black body
  - Kirchoff's law
  - Shape factor
  - Spectral emissive power (04 Marks)
- b. Derive an expression for radiation heat exchange in two-zone enclosure. (04 Marks)
- c. Calculate the net radiant heat exchange per  $m^2$  area for 2 large parallel plates at temperatures of  $427^\circ\text{C}$  and  $27^\circ\text{C}$  respectively.  $\epsilon$  (hot plate) = 0.9 and  $\epsilon$  (cold plate) = 0.6. If a polished aluminium shield is placed between them, find the percentage reduction in the heat transfer.  $\epsilon$  (shield) = 0.4. (08 Marks)

**Module-4**

- 7 a. With sketches show the different regions of velocity and thermal boundary layer of forced convection over a flat plate. (08 Marks)
- b. In a straight tube of 60 mm diameter, water is flowing at a velocity of 12 m/s. The tube surface temperature is maintained at  $70^\circ\text{C}$  and the flowing water is heated from the inlet temperature of  $15^\circ\text{C}$  to an outlet temperature of  $45^\circ\text{C}$ . Taking the physical properties of water at its mean bulk temperature, calculate the following:
- Heat transfer coefficient from the tube surface to water.
  - Heat transferred.
  - Length of the tube. (08 Marks)

**OR**

- 8 a. Assuming that a man can be represented by a cylinder 350 mm diameter and 1.65 m high with a surface temperature of  $28^\circ\text{C}$ . Calculate the heat he would lose while standing in a 30 km/h wind at  $12^\circ\text{C}$ . (08 Marks)
- b. A nuclear reactor with its core constructed of parallel vertical plates 2.2 m high and 1.4 m wide has been designed on free convection heating of liquid bismuth. The maximum temperature of the plate surface is limited to  $960^\circ\text{C}$  while the lowest available temperature is  $340^\circ\text{C}$ . Calculate the maximum possible heat dissipation from both sides of each plate. Take the thermophysical properties of bismuth as,  $\rho = 10000 \text{ kg/m}^3$ ,  $\mu = 3.12 \text{ kg/mh}$ ,  $c_p = 150.7 \text{ J/kgK}$ ,  $k = 13.02 \text{ W/mK}$ . (08 Marks)

Module-5

- 9 a. Derive an expression for LMTD for counter flow in a heat exchanger with proper assumptions. (08 Marks)
- b. Water at atmospheric pressure is to be boiled in polished copper pan. The diameter of the pan is 350 mm and is kept at 115°C. Calculate the following:
- (i) Burner power
  - (ii) Rate of evaporation in kg/h
  - (iii) Critical heat flux
- (08 Marks)

OR

- 10 a. Explain the terms:
- (i) Filmwise and dropwise condensation (04 Marks)
  - (ii) Nucleate pool boiling (04 Marks)
- b. With a sketch show different boiling regimes. (04 Marks)
- c. It is required to design a shell and tube heat exchanger for heating 2.4 kg/s of water from 20°C to 90°C by hot engine oil ( $C_p = 2.4 \text{ kJ/kgK}$ ) flowing through the shell of the heat exchanger. The oil makes a single pass entering at 145°C and leaving at 90°C with an average heat transfer coefficient of 380 W/m<sup>2</sup>K. The water flows through 12 thin walled tubes of 25 mm diameter with each tube making 8 passes through the shell. The heat transfer coefficient on the water side is 2900 W/m<sup>2</sup>K. Calculate the length of the tube required for the heat exchanger to accomplish the required heating. (08 Marks)

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