CBCS SCHEME

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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 W/mK) having a uniform volumetric heat generation of 30×10^6 W/m^3, are 180°C and 120°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 W/mK) followed by a 0.04 m layer of gypsum plaster (K = 0.48 W/mK). What thickness of loosely packed rock wool insulation (K = 0.65 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 W/m°C, α = 0.043 m^2/h), initially at 440°C is suddenly exposed on both sides to an environment with convective heat transfer coefficient 235 W/m^2°C and temperature 50°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 mm × 0.5 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°C when surrounding temperature is 40°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 W/mK, h = 15 W/m^{2}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 = 1.4×10^9 m) as a black body having a surface temperature of 5750 K and at a mean distance of 15×10^{10} m from the earth (diameter = 12.8×10^6 m) estimate the following:
   (i) Total energy emitted by the sun.
   (ii) The emission received per m^2 just outside the atmosphere of the earth.
   (iii) The total energy received by the earth of no radiation is blocked by the atmosphere of earth.
   (iv) The energy received by a 1.6 m × 1.6 m solar collector whose normal is inclined at 50° 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:
   (i) Black body (ii) Kirchoff's law
   (iii) Shape factor (iv) 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°C and 27°C respectively. $\in$ (hot plate) = 0.9 and $\in$ (cold plate) = 0.6. If a polished aluminium shield is placed between them, find the percentage reduction in the heat transfer. $\in$ (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 plats. **(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°C and the flowing water is heated from the inlet temperature of 15°C to an outlet temperature of 45°C. Taking the physical properties of water at its mean bulk temperature, calculate the following:
   (i) Heat transfer coefficient from the tube surface to water.
   (ii) Heat transferred.
   (iii) 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°C. Calculate the heat he would loose while standing in a 30 km/h wind at 12°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 bismith. The maximum temperature of the plate surface is limited to 960°C while the lowest available temperature is 340°C. Calculate the maximum possible heat dissipation from both sides of each plate. Take the thermophysical properties of bismith as, ρ = 10000 kg/m^3, μ = 3.12 kg/mh, c_p = 150.7 J/kgK, k = 13.02 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
   (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 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^{2}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^{2}K. Calculate the length of the tube required for the heat exchanger to accomplish the required heating. **(08 Marks)**

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