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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°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 ($k = 0.7 \text{ W/mK}$) 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°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°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°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, $k_{Al} = 200 \text{ W/mK}$, $h = 15 \text{ W/m}^2\text{K}$. (08 Marks)



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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:
- 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° 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°C and 27°C respectively. ϵ (hot plate) = 0.9 and ϵ (cold plate) = 0.6. If a polished aluminium shield is placed between them, find the percentage reduction in the heat transfer. ϵ (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°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:
- 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°C . Calculate the heat he would lose 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 bismuth. 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 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)



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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/m²K. 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/m²K. Calculate the length of the tube required for the heat exchanger to accomplish the required heating. (08 Marks)

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