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(2125)

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B. Tech 6th Semester Examination

Heat Transfer (ME) (OS)

ME-6006

Time : 3 Hours **Max. Marks : 100**

The candidates shall limit their answers precisely within the answer-book (40 pages) issued to them and no supplementary/continuation sheet will be issued.

Note : Attempt five questions in all, selecting one from each section A, B, C and D. All subparts of Section E are compulsory. Assume suitable value of any Missing data. Use of heat transfer data book is allowed. All question carry equal marks.

SECTION - A

1. (a) Write the Fourier rate equation for heat transfer by conduction. Give the physical significance of each term.

(b) A metal piece of length of 60 cm has a cross section corresponding to a sector of a circle of radius 10 cm and included angle 60°C. Its ends are maintained at temperature of 125°C and 25°C, and the thermal conductivity of the material has a linear variation with temperature in degree Celsius.

K = (100 – 0.01t) W/m - deg

Find the heat flow rate through the metallic piece. Presume uni-directional heat conduction, i,e., neglect any variation of temperature in the θ and r-directions. (20)

2. (a) Derive an expression for the temperature distribution and maximum temperature for a plane wall with uniform heat generation.

(b) A furnace wall comprises three layers: 13.5 cm thick inside layer of fire brick, 7.5 cm thick middle layer of insulating brick and 11.5 cm thick outside layer of red brick. The furnace operates at 870°C and it is anticipated that the outside of this composite wall can be maintained at 40°C by the circulation of air. Assuming close bonding of layers at their interfaces, find the rate of heat loss from the furnace and the wall interface temperature. The wall measures 5 m × 2 m and the data on thermal conductivities is:

Fire brick K_1 = 1.2 W/m-deg

Insulating brick K_2 = 0.14 W/m-deg

Red brick K_3 = 0.85 W/m-deg. (20)

SECTION - B

3. (a) From the lumps parameter analysis derive an expression for temperature distribution for solids having negligible thermal resistance.

[P.T.O.]

(b) A 12 mm diameter mild steel sphere (K=42.5 W/mK) is exposed to cooling airflow at 27°C resulting in the convective coefficient h = 114 W/m²K. Determine (i) time required to cool the sphere from 540°C to 95°C (ii) Instantaneous heat transfer rate 2 minutes after the start of cooling and (iii) total energy transferred during the first 2 minutes. The relevant properties of mild steel are:

Density ρ = 7850 kg/m³; specific heat c = 475 J/kg K, and thermal diffusivity α = 0.0043 m²/hr. (20)

4. (a) Prove that for a forced convection the momentum equation is given by: $u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\gamma\frac{\partial^2 u}{\partial y^2}$

(b) Air at 20°C flows over a flat surface maintained at 80°C. The value of local heat transfer coefficient of the local heat flow at a point was measured as 1250W/m². Proceed to calculate temperature gradient at the surface and temperature at a distance of 0.6mm from the surface. Take thermal conductivity of air as 0.028W/M-deg. (20)

SECTION - C

5. (a) Derive an expression for LMTD for a parallel flow heat exchanger.

(b) Exhaust gases (c_p=1.12 kj/kg-deg) flowing through a tubular heat exchanger at the rate of 1200 kg/hr are cooled from 400°C to 120°C. The cooling rate is affected by water (c_p=4.18 kJ/kg K) that enters the system at 10°C at the rate of 1500 kg/hr. If the overall heat transfer coefficient is 500 kJ/m²-hr-deg, what heat exchanger area is required to handle the load for (a) parallel flow and (b) counter flow arrangement? (20)

6. (a) State and prove Kirchoffs law of radiation. What restrictive conditions are inherent in the derivation of Kirchoffs law?

(b) It has been observed that when the sun is overhead the earth's surface on a clear day, the radiation received by the earth's surface is 1 kW/m² and an additional 0.3 kW/m² is absorbed by the earth's atmosphere. Assuming the sun to be a black body, determine the temperature of the sun. Given: dia of sun= 1.39 x 10^9 m; dia of earth = 12.6 × 10^6m; distance between the sun and earth = 1.5 × 10^{11} m. (20)

SECTION - D

7. (a) Explain the pool boiling and different regimes of boiling.

(b) Explain the laminar film condensation on a vertical plate. (20)

8. (a) Define Lambert's cosine law of radiation and prove that the intensity of radiation is always constant at any angle of emission for a diffused surface.

(b) The wall of 4 mm long and 20 mm diameter is held at constant temperature by providing a steam jacket. A viscous fluid enters the tube at 30°C and leaves at 40°C at the rate of 180 kg/hr. Determine the average heat transfer coefficient and the wall temperature.

Use the following correlation

$$Nu = 3.65 + \frac{0.67\frac{d}{l}Re\,Pr}{1+0.04\left(\frac{d}{l}Re\,Pr\right)^{0.67}}$$

And take the following thermo-physical properties: ρ = 850kg/m³; K=0.1396 W/m-deg; c_p = 2000 J/kg K and v = 5.1 x 10^{-6} m²/s. (20)

SECTION - E

9. (i) Which of the following would not increase the rate of heat transferred from a heater pipe?
   (a) Insulating with materials whose thickness is below that of critical thickness is for insulation.
   (b) Blowing air over it. (c) Providing fins
   (d) Putting the heater pipe within another whose thermal conductivity is smaller in number and 2 inches thick.

(ii) The overall coefficient of heat transfer is used in the problem of
   (a) Radiation (b) Conduction (c) Convection (d) Conduction & Convection

(iii) Heat transfer takes place according to
   (a) Zeroth law of thermodynamics (b) first law of thermodynamics
   (c) Second law of thermodynamics (d) Third law of thermodynamics

(iv) A 10 kg solid at 100°C with specific heat 0.8 kJ/kg°C is immersed in 40 kg of 20°C liquid with a specific heat of 4.0 kJ/kg°C. The temperature after a long time if the container is insulated will be
   (a) 30°C (b) 28°C (c) 26°C (d)24°C

(v) Consider the following statement
   1. Under certain conditions, an increase in thickness of insulation may increase the heat loss from a heated pipe.
   2. The heat loss from an insulated pipe reaches a maximum when the outside radius insulation is equal to the ratio of thermal conductivity to the surface coefficient.
   3. Small diameter tubes are invariably insulated.
   4. Economic insulation is based on minimum heat loss from pipe.
   Of these statements
   (a) 1 and 3 are correct (b) 2 and 4 are correct
   (c) 1 and 2 are correct (d) 3 and 4 are correct

(vi) Heat is mainly transferred by conduction convection and radiation in
   (a) Insulated pipes carrying hot water (b) Refrigerator freezer coil
   (c) Boiler furnaces (d) Condensation of steam in condenser

(vii) Which of the following temperature measuring device will have least accuracy?
   (a) Clinical thermometer (b) Alcohol filled thermometer
   (c) Optical pyrometer (d) Nitrogen filled thermometer

(viii) In free convection heat transfer transition from laminar to turbulent flow is governed by the critical value of the
   (a) Reynold's number (b) Grashoff's number (c) Reynolds number, Grashoffs number (d) Grashoffs number, Prandtl number

(ix) Thermal boundary layer is a region where
   (a) Inertia terms are of the same order of magnitude as convection terms
   (b) Convection terms are of the same order of magnitude as dissipation terms

   (c) Convection terms arc of the same order of magnitude as conduction terms
   (d) Dissipation is negligible

(x) A thin plate 2mx2m is hanging free in air. The temperature of the surrounding is 25deg. ºC, Solar radiation is falling on one side of three plate at the rate of 500 W/m^2. The temperature of the plate will remain constant at 300deg. ºC, if the convective heat transfer coefficient (in W.m^2 deg. ºC) is (a) 25 (b) 50 (c) 100 (d) 200

(xi) Thermal boundary layer is a region where
   (a) Inertia terms are of the same order of magnitude as convection terms
   (b) Convection terms are of the same order of magnitude as dissipation terms
   (c) Convection terms are of the same order of magnitude as conduction terms
   (d) Dissipation is negligible.

(xii) The wavelength of the radiation emitted by a body depends upon
   (a) Nature of its surface (b) Area of its surface (c) The temperature of its surface (d) all of the above.

(xiii) Which surface will have least emissivity?
   (a) smooth glass (b) plaster (c) aluminum foil (d) concrete

(xiv) Temperature of the sun can be measured with a
   (a) Mercury thermometer (b) standard thermometer (c) radiation pyrometer (d) none of these

(xv) In a heat exchanger with one fluid evaporating or condensing the surface area required is least in (a) Parallel flow (b) counter flow (c) cross flow (d) same in all above

(xvi) For evaporators and condensers, for the given conditions, the logarithmic mean temperature difference (LMTD) for parallel flow is
   (a) Equal to that of counter flow (b) Greater than that for counterflow (c) Smaller than that for counterflow (d) Very much smaller than that for counterflow

(xvii) For a current wire of 20mm diameter exposed to air (h= 20 W/m^2 K.) maximum heat dissipation occurs when thickness of insulation (k=0.5 W/mK) is
   (a) 20mm (b) 25mm (c) 40mm (d) 10mm

(xviii) For a given heat flow and for the same thickness the temperature drop across the material will be maximum for
   (a) Copper (b) steel (c) glass wool (d) refractory brick

(xix) Heat is transferred from an electric bulb by
   (a) Conduction (b) convection (c) radiation (d) all of these

(xx) The ratio of energy transferred by convection to that by conduction is called
   (a) Stanton number (b) Nusselt number (c) Biot number (d) preclet number

(1×20=20)