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Question Paper Code : Q 2012

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2009.

Sixth Semester

Aeronautical Engineering

AE 1352 — HEAT TRANSFER

(Regulation 2004)

Time : Three hours

Maximum : 100 marks

Heat and mass transfer data book and steam table may be permitted.

Use of standard charts and tables are allowed.

Any missing data can be suitably assumed.

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Distinguish between diffusion and radiation heat transfer.

2. State the condition which must be satisfied to treat the temperature distribution in a fin as one-dimensional.

3. What is the effect of the Prandtl number of a fluid on the relative thicknesses of velocity and temperature boundary layers when the fluid flow is parallel to a flat plate?

4. Discuss what is diffuse surface.

5. What is meant by radiation shape factor?

6. When is NTU method useful in heat exchanger analysis?

7. Why the directions of fluid flows are immaterial when one fluid undergoes phase change?

8. How will you define the characteristic length of a horizontal plate?

9. Brief on ablative cooling.

10. What is meant by radiation blockage effect?

PART B — (5 × 16 = 80 marks)

11. (a) (i) A spherical, thin walled metallic container is used to store liquid nitrogen at – 193°C. The container diameter is 0.5 m and covered with two insulation materials of each 25 mm thick and outer surface is exposed to ambient air at 303 K. The thermal conductivities of first and second layers are 0.044 W/m K and 0.0018 W/m K respectively. If outer heat transfer coefficient is 22 W/m² K and latent heat of vaporization of liquid nitrogen is 2×10^2 kJ/kg K. Determine the rate of vaporization of liquid nitrogen per hour. (8)

(ii) The temperature distribution across a wall 1 m thick at a certain instant of time is given as $T(x) = a + bx + cx^2$.

where T is in degrees Celsius and x is in meters, while a = 950°C, b = 300°C/m, and c = 50°C/m².

A uniform heat generation of 2000 W/m³ is present in the wall of area 15 m² having the properties ρ = 1600 kg/m³, K = 50 W/mK, and Cp = 4.5 kJ/kgK. Determine the rate of heat transfer entering the wall ($x = 0$) and leaving the wall ($x = 1m$). Determine the rate of change of energy storage in the wall. Determine the time rate of temperature change at x = 0,0.25, and 0.5 m. (8)

Or

(b) (i) An iron rod is attached horizontally to a large tank at temperature 200°C. The diameter of rod is 1 cm, length 30cm and thermal conductivity is 65 W/mK. The rod is dissipating heat by convection into the ambient air at 20°C with heat transfer coefficient 15 W/m² K. What is the temperature of the rod at 10cm and 20cm from the tank? Calculate the heat transfer rate from the fin efficient and effectiveness. (8)

(ii) A steel pipeline (1.1 m diameter) has a wall thickness of 38 mm. The pipe is heavily insulated on the outside, and before the initiation of flow, the walls of the pipe are at a uniform temperature of –21°C. With the initiation of flow, hot oil at 60°C is pumped through the pipe, creating a convective condition corresponding to h = 500 W/m² K at the inner surface of the pipe, What are the appropriate Biot and Fourier numbers 8 min after the initiation of flow? At t = 8 min, what is the temperature of the exterior pipe surface covered by the insulation? What is the heat flux to the pipe from the oil at t = 8 min? (8)

12. (a) (i) A 2.5 kW immersion heater is required to heat water to 65°C without the surface temperature of the heater exceeding 90°C. Assuming that this heating surface is a horizontal cylinder and diameter d, find a numerical formula relating these two dimensions. Hence determine the length of heating element required when the diameter is (1) 10mm and (2) 50mm. (8)

(ii) Find the surface temperature of 1 m square vertical metal plate insulated on one side with the other side exposed to a solar radiation flux of 350 W/m². The exposed surface has 100% absorptivity and the incoming radiation is lost by free convection to the ambient air at 27°C. (8)

Or

(b) (i) Find the average heat transfer coefficient and the total heat transfer from a rectangular plate of 0.8 m long in the direction of flow and 1.25 m wide. The plate is maintained at 60°C when placed in nitrogen that has a velocity of 2.5 m/s and a temperature of 20°C. (8)

(ii) Determine the boundary layer thickness at distances of 0.30 and 0.50 m from the leading edge of a 1 m depth flat plate when air at 300 K and 1 bar flows over the plate at a velocity of 300 m/min. Find the mass flow rate which enters the boundary layer between x = 0.3 m and 0.5 m. The viscosity of air at 300 K is 1.85×10^{-5} kg/ms. (8)

13. (a) (i) A jet of liquid metal at 2100°C pours from a crucible. It is 4mm in diameter. A long cylindrical radiation shield 6 cm diameter, surrounds the jet through an angle of 325°, but there is a 30° slit in it. The jet and the shield radiate as black bodies. They sit in a room at 30°C, and the shield has a temperature of 700°C. Calculate the net heat transfer: from the jet to the room through the slit; from the jet to the shield; and from the inside of the shield to the room. (8)

(ii) Refrigerant liquid flows through a tube of 3 cm diameter, which is having outer surface emissivity 0.03 and temperature 80 K. The tube is concentric with a larger tube of 6cm diameter and inner surface is having emissivity of 0.06 and temperature of 350 K. Find the reduction in radiation heat transfer if a thin radiation shield of 45 mm diameter and emissivity of 0.012 on both sides is inserted between the tubes. Assume the space between the surface as vacuum. (8)

Or

(b) (i) A cubical room of side 3 m is heated from the floor by maintaining it at a uniform temperature 350 K. The heat transfer takes place to the ceiling and side walls, which are maintained at 290 K. The floor has an emissivity of 0.9 and the ceiling has an emissivity of 0.6. Determine the heat transfer (1) to the side walls having emissivity of 0.5 (2) to the side walls if they are well insulated and (3) find the radiocities when walls are insulated. (10)

(ii) Determine the emissivity of CO_2 in a gas body of spherical shape of 1.75 m diameter at temperature of 1600 K in the following pressures. The gas consists of 20% of CO_2 and the rest are non-radiating gases. The total pressure of the gas is (1) 1 atm. (2) 4 atm and (3) 0.4 atm. (6)

14. (a) (i) Light lubricating oil (C_{ph} = 2090 J/kg K) is cooled by allowing it to exchange energy with water in a small heat exchanger. The oil enters and leaves the heat exchanger at 375 K and 350 K, respectively, and flows at a rate of 0.5 kg/s. Water at 280 K is available in sufficient quantity to allow 0.201 kg/s to be used for cooling purposes. Determine the required heat transfer area for (1) counter flow, and (2) parallel flow operation. The overall heat transfer coefficient may be taken as 250 W/m²K in both cases. (8)

(ii) The condensation temperature of a vapour in a condenser is 125°C. The inlet and outlet temperatures of cooling water flowing at the rate of 1.1 kg/s through the tubes are 30°C and 65°C respectively. The tube diameter ms 40mm, length is 8 m and 10 in number. Determine the (1) overall heat transfer coefficient (2) number of transfer units (3) effectiveness of the condenser and (4) rate of condensation if latent heat of condensation is 2200 kJ/kg. (8)

Or

(b) (i) Dry saturated steam at 180°C flows in a pipe with a bore of 175 mm with a mean velocity of 7 m/s. The pipe has a wall 7.5 mm thick and is covered with a layer of insulation 45 mm thick. The surrounding atmospheric air is at 20°C. Calculate the heat transfer rate for 1 m length. The Nusselt number is given by $Nu = 0.23 Re^{0.8} Pr^{0.4}$. K for pipe = 50 W/m K and for insulation 0.08 W/m K. The surface heat transfer coefficient for a long horizontal cylinder is $1.32 (\Delta T / D)^{1/4}$ (10)

(ii) A counter flow double pipe heat exchanger is used to heat water from 25°C to 45°C with a hot oil which enters the exchanger at 185°C and leaves at 145°C. The flow rate of water is 3.5 kg/s and overall heat transfer coefficient is 140 W/m² K. Assume the specific heat of oil as 2.1 kJ/kg K. Suppose the water flow rate is reduced to half, what new oil flow rate would be necessary to maintain the same outlet water temperature. (6)

15. (a) (i) Discuss in detail the convective heat transfer in gas turbine combustion chamber. (8)

(ii) Explain about the factors affecting the liquid propellant rocket thrust chamber coolant system. (8)

Or

(b) (i) Explain Radiative heat transfer in rocket nozzles. (8)

(ii) Discuss in detail the effects of aerodynamic heating and heat transfer of a steady supersonic flight. (8)