Code: 9A03505

1

B.Tech IV Year II Semester (R09) Regular Examinations, March/April 2013

HEAT TRANSFER

(Aeronautical Engineering)

Time: 3 hours Max. Marks: 70

Answer any FIVE questions.
All questions carry equal marks.

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1 (a) Distinguish between conduction, convection and radiation modes of heat transfer.
(b) A solar pane, 1 m $\times$ 1.25 m receives solar radiation 1500 watts, calculate surface temperature of the pane if the ambient temperature is 25℃ and the convective heat transfer coefficient of the air film over the surface of pane is 12.5 W/m^2-deg.

2 (a) Draw the temperature gradient through a plane wall when the thermal conductivity:
(i) Remains constant with increase in temperature.
(ii) Increases with increase in temperature.
(iii) Decreases with increase in temperature.
(b) The door of a cold storage plant is made from two 6 mm thick glass sheets separated by a uniform air gap of 2 mm. The temperature of the air inside the room is -20^0 and the ambient air temperature is 30℃. Assuming the heat transfer coefficient between glass and air to be 23.26 W/m^{2}K, determine the rate of heat leaking in to the room per unit area of the door. Neglect convection effects in the air gap.

3 (a) What is lumped capacity? What are the assumptions for lumped capacity analysis?
(b) Calculate the temperature in a plane 200 mm from the surface of a very thick wall and also the heat flowing per unit area of this plane 10 hours after the surface temperature of the wall changes form 25℃ to 800℃ and remains constant thereafter. Also find the total heat energy taken up by the wall in 10 hours. Assume for wall material, k = 0.8 W/mK and α = 0.003 m^2/h.

4 Prove the Navier stokes equations for a steady, two-dimensional flow of an incompressible, constant property fluid, list the assumptions made in this equation. Give the physical significance of various terms in this equation.

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5 (a) Discuss the problem of combined free and forced convection.

(b) Air enters a rectangular duct measuring 0.3 m with a velocity of 8.5 m/s and a temperature of 40℃. The flowing air has a thermal conductivity 0.028 W/m.K, kinematic viscosity 16.95×10^{-6} m^2/s and from the empirical correlations the Nusselt number has been approximated to be 425. Work out the equivalent diameter of the flow passage, the Reynolds number and the convective heat film coefficient.

6 Give the boiling correlations for the following:

(a) Nucleate pool boiling.

(b) Peak heat flux in nucleate pool boiling.

(c) Stable film pool boiling.

7 (a) Derive the relationship between effectiveness and number of transfer units for a parallel flow heat exchanger.

(b) Determine the heat transfer area required for a heat exchanger constructed from a 2 cm OD tube to cool 26,000 kg/hr of an alcohol solution (C_p = 3.81 kJ/kg.K) from 90^0 to 50℃, using H_2O which enters at 20℃ and leaves at 40℃ and for the following arrangements:
(i) Parallel flow.
(ii) Counter current shell and tube heat exchanger, alcohol in shell and water through the tubes. (Assume correction factor for LMTD = 0.95). Assume that the overall heat transfer coefficient based on the outer tube area is 830 kJ/hr.m^2 K.

8 (a) Calculate the shape factor F_{12} between a small area A_1 and a circular segment of a spherical surface of radius R (area A_2). Area A_1 is located symmetrically at the centre of the sphere and the segment subtends an angle 2α at A_1.

(b) Explain about the electrical analogy in radiation networks for four gray surfaces with a neat diagram.

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1 Write the mathematical formulation of one dimensional, steady state heat conduction for a hollow sphere in the region $a \le r \le b$, when heat is supplied at a rate of q_0 (W/m^2) from the boundary surface at r = a and dissipated by convection from the boundary surface at r = b in to a medium at zero temperature with a heat transfer coefficient h.

2 (a) The outside and inside surface temperatures of a 20 cm outer diameter and 18 cm inner diameter pipe (k = 40 W/m K) are 400℃ and 460℃ respectively. Calculate the reduction in heat loss if a 5cm layer of insulation (k = 0.06 W/m K) is put on the pipe. Assume that the inner and outer surface temperature of insulation is 390℃ and 140℃. What is the inside surface temperature of this pipe in this case?

(b) Explain the following:
(i) Log mean area as applied to hollow cylinder.
(ii) Geometric mean area as applied to hollow sphere.

3 (a) What are Biot and Fourier numbers? Explain their physical significance.

(b) A stainless steel rod of outer diameter 1cm originally at a temperature of 320℃ is suddenly immersed in a liquid at 120℃ for which the convective heat transfer coefficient is 100 W/m^2 K. Determine the time required for the rod to reach a temperature of 200℃.

4 Prove the energy equation. List the assumptions made in this equation.

$$\rho c_p (V.\nabla T) = k\nabla^2 T$$

5 Explain the fluid flow along a flat plate:
(i) Velocity distribution in hydrodynamic boundary layer.
(ii) Temperature distribution in thermal boundary layer.
(iii) Variation of local heat transfer coefficient along the flow.

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6 (a) Water is boiled at a rate of 30 kg/h in a copper pan, 30 cm in diameter, at atmospheric pressure. Estimate the temperature of the bottom surface to the pan assuming nucleate boiling conditions.

(b) Draw the pool boiling curve for water and explain critical heat flux and film boiling.

7 (a) Hot oil (C_p = 5.2 kJ/kg. k) with a capacity rate of 2800 Kg/min flows through a double pipe heat exchanger. It enters at 380℃ and leaves at 300℃. Cold oil (C_p = 4.8 kJ/kg. k) enters at 30℃ and leaves at 200℃. If the overall heat transfer coefficient is 1000 W/m^2K, determine the heat transfer area required for:

(i) Parallel flow and

(ii) Counter flow.

(b) Define overall heat transfer coefficient and write an expression for it by accounting fouling resistances at the inner and outer tube surfaces in shell and tube heat exchanger.

8 (a) Briefly explain about the radiation shields.

(b) The net radiation from the surface of two parallel plates maintained at temperatures T_1 and T_2 is to be reduced by 79 times. Calculate the number of screens to be placed between the surfaces to achieve this reduction in heat exchange, assuming the emissivity of the screen as 0.005 and that of the surface as 0.8.

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1. Heat is flowing through an annular pipe of inside radius r_0 and outside radius r_1. The thermal conductivity varies linearly with temperature from k_0 at T_0 to k_1 at T_1. Develop an expression for heat flow through the pipe. Simplify if the expression assuming that r_1-r_0 is very small. Interpret the result physically.

2. (a) An exterior wall of a house 0.1 m layer of common brick (k = 0.7 w/m^{0}c) followed by 0.038 m layer of gypsum plaster (k = 0.48 w/m^{0}c). What thickness of loosely packed rock-wool insulation (k = 0.0675 w/m^{0}c) should be added to reduce the heat loss (gain) through the wall by 80%?
   (b) Differentiate between conduction and conductance. What are their units?

3. (a) What is meant by transient heat conduction?
   (b) The temperature distribution across a large concrete slab 50 mm thick heated from one side as measured by thermocouple approximates to the following relation:
   $T = 60 - 50x + 12x^2 + 20x^3 - 15x^4$, where T is in ℃ and x is in metres. Consider an area of 5 m^2, compute
   (i) The heat entering and leaving the slab in unit time.
   (ii) The heat energy stored in unit time.
   (iii) The rate of temperature change at both sides of the slab.
   (iv) The point where the rate of heating or cooling is maximum.

4. State the Buckingham's π theorem. Explain the various parameters used in forced convection. Using dimensional analysis obtain an expression for Nusselt number in terms of Reynolds and Prandtl numbers.

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5 (a) Describe the equations used for calculating heat transfer for flow over cylinders and sphere.

(b) Air at 30℃ is flowing across a tube with a velocity of 25 m/s. The tube could be either a square with a side of 5 cm or a circular cylinder of diameter 5 cm. Compare the rate of heat transfer in each case if the tube surface temperature is 12℃.

6 (a) What are the assumptions made in Nusselt's analysis of film condensation?

(b) Dry saturated steam at a pressure of 2.45 bar condenses on the surface of a vertical tube of height 1 m. The tube surface temperature is kept at 117℃. Estimate the thickness of the condensate film and the local heat transfer coefficient at a distance of 0.2 m from the upper end of the tube.

7 (a) Discuss the various factors which have an effect on heat transfer capacity of an evaporator and on its economics.

(b) How are heat exchangers classified and sketch the temperature distribution in fluids in condensers and evaporators?

8 (a) Calculate the heat flux due to radiation between black discs arranged parallel and opposite to each other. The two discs are maintained at T_1 = 500℃ and T_2 = 200℃. The two discs are of the same size, d_1 and d_2 = 20 cm and they are placed 40 cm apart.

(b) Explain the Plank's law.

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HEAT TRANSFER

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1 Consider the case of transient heat conduction through a solid cylinder of radius R initially at a temperature T_0. The heat generated inside at a rate $\dot{q}$ (W/m^3) from the outer surface by convection into a medium at temperature T∞ with a heat transfer coefficient h. Write the mathematical formulation.

2 (a) Compute the efficiency of a plate fin of length L = 1.5 cm and thickness 2.0 mm for the following two cases.
(i) Fin material is steel (k = 40 W/m K) and h = 510 W/m^2 K.
(ii) Fin material is aluminium (k = 210 W/m K) and the heat transfer coefficient is 285 W/m^2 K.
(b) Explain the importance of insulated tip solution for the fins used in practice.

3 (a) What is a semi-infinite body? Define the error function and explain its significance in a semi-infinite body in transient state.
(b) A slab of aluminium 10 cm thick is originally at a temperature of 500℃. It is suddenly immersed in a liquid in a liquid at 100℃ resulting in a heat transfer coefficient of 1200 W/m^2 K. Determine the temperature at the centerline and the surface 1 minute after the immersion. Also calculate the total thermal energy removed per unit area of the slab during this period. The properties of aluminium for the given conditions are $\alpha = 8.4 \times 10^{-5}$ m^2/s, k = 215 W/m K, ρ = 2700 kg/m^2, c = 0.9 kJ/kg K.

4 State and prove the continuity equation in terms of axisymmetric cylindrical polar coordinates for incompressible flows as follows and list the assumptions made in this equation.

$$\frac{\partial v_r}{\partial r} + \frac{v_r}{r} + \frac{\partial v_z}{\partial z} = 0$$

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5 Water at 25℃ flows through a tube of 50 mm diameter. Determine the flow rate that will result in a Reynolds number of 1600. The tube is provided with a nichrome heating element on its surface and receives a constant heat flux of 800 W/m length of the tube. Determine the average heat transfer coefficient between the water and the tube wall, assuming fully developed conditions. Also determine the length of the tube for the bulk temperature of water to rise from 25℃ to 50℃.

6 Nucleate boiling of saturated water at 4.825 MPa is being conducted by means of a submerged brass heater producing a heat flux of 2050 kW/m^2. Estimate the surface temperature of the heater.

Thermal properties of water

ρ = 968 kg/m^3

k = 0.58 W/m ℃

C_p = 4180 J/kg ℃

$\mu = 1.14 \times 10^{-6}$ $N.sec/m^2$

7 (a) In a double pipe, counter flow, heat exchanger 10,000 kg/h of oil having a specific heat of 2095 J/kg.K is cooled from 80℃ to 50℃ by 8000 kg/h of water entering at 25℃. Determine the heat exchanger area for an overall heat transfer coefficient of 300 W/m^2.K. Take C_p for water as 4180 J/kg.K.

(b) Discuss the advantages of NTU method over the LMTD method in heat exchanger design.

8 (a) A black body is kept at a temperature of 1000 K. Determine the fraction of thermal radiation emitted by the surface in the wavelength band 1.0 to 6.0.

(b) Estimate the rate of solar radiation on a plate normal to the sun rays. Assume the sun to be a black body at a temperature of 5527 ℃. The diameter of the sun is 1.39×10^6 km and its distance from the earth is 1.5×10^8 km.

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