

**B.E. DEGREE EXAMINATIONS: APRIL/MAY 2011**

Sixth Semester

**AERONAUTICAL ENGINEERING**

U07ARE04: Heat Transfer

(Use of Heat & Mass Transfer Data Book is permitted)

**Time: Three Hours**

**Maximum Marks: 100**

**Answer ALL Questions:-**

**PART A (10 x 1 = 20 Marks)**

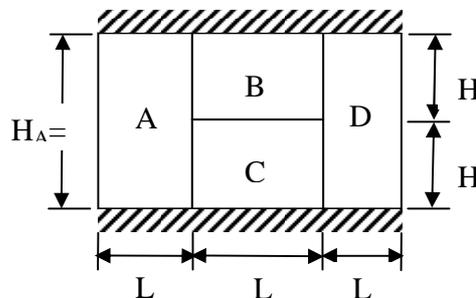
1. The variation of temperature is linear across a
  - a) Cylindrical wall
  - b) Plane wall
  - c) Composite wall
  - d) Fin
2. Lumped heat analysis for transient heat transfer is valid, when
  - a)  $Bi > 1$
  - b)  $Bi = 1$
  - c)  $hL_c/k_s \ll 1$
  - d) Momentum
3. Nusselt number in free convection is a function of
  - a) Gr and Pr
  - b) Re and Pr
  - c) Bi and Fo
  - d) Bi and Re
4. For a flow over a flat plate, transition from laminar to turbulent occurs, approximately at
  - a)  $5 \times 10^5$
  - b) 2500
  - c) 10000
  - d) 5000
5. The emission from a surface at  $40^\circ\text{C}$  is proportional to
  - a)  $64 \times 10^4$
  - b)  $256 \times 10^4$
  - c)  $96 \times 10^8$
  - d) 98000
6. The radiation shape factor for surfaces exchanging heat with non-absorbing medium depends on
  - a) Temperature and geometry
  - b) Temperature and emissivity
  - c) Emissivity and geometry
  - d) Geometry and orientation
7. Fouling factor  $R_f$ , of a heat exchanger is defined as
  - a)  $R_f = \frac{1}{U_{dirty}}$
  - b)  $R_f = \frac{1}{U_{dirty}} - \frac{1}{U_{clean}}$
  - c)  $R_f = \frac{1}{U_{dirty}} + \frac{1}{U_{clean}}$
  - d)  $R_f = \frac{1}{U_{dirty}}$
8. The limiting outlet temperature of a cold fluid in a counter flow heat exchanger is
  - a)  $T_{h,inlet}$
  - b)  $> T_{h,exit}$
  - c) Both (a) and (b)
  - d)  $T_{h,inlet}/2$
9. Recovery factor is defined as
  - a)  $r = \frac{T_{aw} - T_\infty}{T_0 - T_\infty}$
  - b)  $r = \frac{T_0 - T_\infty}{T_{aw} - T_\infty}$
  - c)  $r = T_{aw}/T_\infty$
  - d)  $r = T_0/T_{aw}$
10. Heat transfer assumes significance in a flow with free stream temperature same as wall temperature when,
  - a)  $M=1$
  - b)  $M \gg 1$
  - c)  $Re > 10^5$
  - d)  $Re > 2300$

**PART B (10 x 2 = 20 Marks)**

11. What is significance of critical radius of insulation?
12. Define fin efficiency and fin effectiveness.
13. Elucidate the difference between Biot and Nusselt numbers.
14. What is meant by a developed flow?
15. What is Wien's displacement law?
16. How does radiation heat transfer differ from other modes of heat transfer?
17. How are heat exchangers classified?
18. Differentiate LMTD and  $\epsilon$ -NTU methods of heat exchanger analysis.
19. What is meant by ablation?
20. What is the use of reference temperature in High-speed flows?

**PART C (5 x 14 = 70 Marks)**

21. a) (i) Depict the variation of temperature across a plane wall, whose thermal conductivity is (a) a constant, (b) directly proportional to temperature and (c) inversely proportional to temperature. (6)
- (a) Thermal conductivity is constant
  - (b) Thermal conductivity is directly proportional to temperature
  - (c) Thermal conductivity is inversely proportional to temperature
- (ii) A composite wall having unit length normal to the plane of the paper is insulated at the top and bottom as shown in Figure 1. It is composed of four different materials A, B, C and D. The dimensions are  $H_A=H_D=3\text{m}$ ,  $H_B=H_C=1.5\text{m}$ ,  $L_1=L_3=0.05\text{m}$ ,  $L_2=0.1\text{m}$ . The values of thermal conductivities are  $k_A=k_D=50\text{W/mK}$ ,  $k_B=10\text{W/mK}$  and  $k_C=1\text{W/mK}$ . The fluid temperatures and heat transfer coefficients are  $T_1=200^\circ\text{C}$ ,



$h_1=50\text{W/m}^2\text{K}$  and  $T_2=25^\circ\text{C}$  and  $h_2=10\text{W/mK}$ . Assuming one-dimensional conduction,

(a) sketch the thermal circuit of the system and (b) determine the heat transfer rate through the wall. (8)

(OR)

b) (i) What are the assumptions made in obtaining the governing equations for 1-d fin heat transfer:  $\frac{d^2\theta}{dx^2} - m^2\theta = 0$  (3)

(ii) A 70 cm long steel cylinder of 0.35 m diameter, initially at 20°C is placed in a furnace, where  $T=1050^\circ\text{C}$ . Determine the temperatures at the centre and on the surface of the cylinder after an hour. Assume  $h=232.5 \text{ W/m}^2\text{K}$ ,  $k=34.9\text{W/mK}$ ,  $c_p=0.7 \text{ kJ/kgK}$  and  $\rho=7800\text{kg/m}^3$ . (11)

22. a) (i) Sketch the velocity and temperature profile in the boundary layer for free convection over a vertical plate, wherein the plate is at a higher temperature than that of air. (3)

(ii) Consider a 0.6-m  $\times$  0.6-m thin square plate in a room at 30°C. One side of the plate is maintained at a temperature of 90°C, while the other side is insulated. Determine the rate of heat transfer from the plate by natural convection if the plate is (a) vertical and (b) horizontal with hot surface facing up.

(OR)

b) (i) Sketch qualitatively, the hydrodynamic and thermal boundary layers for cases of  $Pr < 1$ ,  $Pr = 1$  and  $Pr > 1$ . (6)

(ii) Briefly describe the classification of convective heat transfer. (4)

(iii) List the correlations of Nusselt numbers used for laminar and turbulent convective flows and the conditions in which they are valid. (4)

23. a) (i) Prove Kirchoff's law of radiation. (4)

(ii) The temperature of the filament of an incandescent light bulb is 2500 K. Assuming the filament to be a blackbody, determine the fraction of the radiant energy emitted by the filament that falls in the visible range. Also, determine the wavelength at which the emission of radiation from the filament peaks. (10)

(OR)

b) (i) Obtain the shape factors associated with an enclosure formed by two concentric spheres of radii  $r_1$  and  $r_o$ . (7)

(ii) A furnace is shaped like a long equilateral triangular duct. The width of each side is 1m. The base surface has an emissivity of 0.7 and is maintained at a uniform temperature of 600 K. The heated left-side surface closely approximates a blackbody at 1000 K. The right-side surface is well insulated. Determine the rate at which heat must be supplied to the heated side externally per unit length of the duct in order to maintain these operating conditions. (7)

24. a) A counter flow double pipe heat exchanger is to heat water from 20°C to 80°C at a rate of 1.2 kg/s. The heating is to be accomplished by geothermal water available at 160°C at a mass flow rate of 2 kg/s. the inner tube is thin-walled and has a diameter of 1.5 cm. If the overall heat transfer coefficient of the heat exchanger is 640W/m<sup>2</sup>C, determine the length of the heat exchanger required to achieve the desired heating.

**(OR)**

b) Cold water enters a counter flow heat exchanger at 10°C at a rate of 8 kg/s, where it is heated by a hot water stream that enters the heat exchanger at 70°C at a rate of 2 kg/s. Assuming the specific heat of water to remain constant at 4.18 kJ/kg°C, determine the maximum heat transfer rate and the outlet temperatures of the cold and hot water streams for this limiting case.

25. a) (i) Discuss the reasons for high temperature in a high-speed flow, even when the ambient air is at sub-zero temperature. (5)

(ii) What are the heat transfer issues in a gas turbine combustion chamber? Discuss with appropriate diagrams, the means to alleviate these. (9)

**(OR)**

b) (i) Explain briefly any two methods of cooling of rocket thrust chambers. (8)

(ii) Discuss briefly the aerodynamic heating and thermal protection system for re-entry vehicles. (6)

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