Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.TECH/AUE(N)/SEM-5/AUE-502/2012-13

2012

HEAT TRANSFER

Time Allotted : 3 Hours *Full Marks* : 70

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

GROUP – A

(Multiple Choice Type Questions)

1. Choose the correct alternatives for the following : $10 \times 1 = 10$

   i) Up to the critical radius of insulation

      a) added insulation will increase heat loss

      b) added insulation will decrease heat loss

      c) convection heat loss will be less than conduction heat flux

      d) heat flux will decrease.

   ii) According to reciprocity theorem

      a) $A_1F_{12} = A_2F_{21}$ b) $A_2F_{12} = A_1F_{21}$

      c) $A_1F_{21} = A_2F_{12}$ d) all of these.

iii) The ratio of heat flow Q_1/Q_2 from two walls of same thickness having thermal conductivity $K_1 = 2K_2$ for the same temperature difference will be

a) 1·0 b) 2·0

c) 0·5 d) 4·0.

iv) Addition of fin to the surface increases the heat transfer if $\sqrt{\frac{hA}{K_P}}$ is

a) equal to one

b) greater than one

c) less than one

d) greater than one but less than two.

v) For gases Prandtl Number is

a) near unity b) between 5 and 50

c) between 60 and 100 d) between 150 and 300.

vi) In free convection, motion of the fluid is caused

a) by the weight of the fluid element

b) by the hydrostatic force on the element

c) by the buoyancy force arising from density of fluid with the temperature

d) none of these.

vii) A surface for which emissivity is constant at all temperatures and throughout the entire range of wavelength is called

a) opaque b) gray

c) specular d) diathermanous.

viii) For flow over a flat plat $\Pr > 1$, the thermal boundary layer for laminar forced convection

a) is thinner than the hydrodynamic boundary layer

b) has a thickness equal to zero

c) is of same thickness as hydrodynamic boundary layer

d) is thicker than the hydrodynamic boundary layer.

ix) Consider two infinitely long black body concentric cylinder with diameter ratio $\frac{D_2}{D_1} = 3$. The shape factor for the outer cylinder with itself will be

a) 0 b) $\frac{1}{3}$

c) $\frac{2}{3}$ d) 1.

x) For steady heat flow, constant thermal conductivity and in absence of heat generation the temperature distribution for plane wall is

a) parabolic b) hyperbolic

c) cubic d) linear.

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following $3 \times 5 = 15$

2. What is critical thickness of insulation ? Derive critical radius of insulation in case of sphere. 1 + 4

3. Define and explain the *two* of the following : $2 \times 2\frac{1}{2}$

a) Reynolds number

b) Eckert number

c) Weber number.

4. What is the significance of Biot number of Fourier number ?

5. A plane wall (thermal conductivity = 10·2 W/m °C) for 100 mm thickness and area 3 m^2 has steady surface temperature of 170°C and 100°C. Determine

i) the rate of heat flow across the plane wall

ii) the temperature gradient in the flow direction.

6. Show from energy balance consideration that the radiation heat transfer from a plane composite surface area A_4 and made up of plane surface areas A_2 and A_3 to a plane surface area A_1 is given by $A_4F_{41} = A_3F_{31} + A_2F_{21}$ and $F_{14} = F_{12} + F_{13}$.

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. 3 × 15 = 45

7. a) Derive the general heat conduction equation in Cartesian coordinates. Under what condition does this get reduce to Poisson equation, Laplace equation and Fourier equation ?

b) The inner surface $r = a$ and the outer surface at $r = b$ of a cylinder (length of cylinder = L) are maintained at uniform temperature T_1 and T_2 respectively. The thermal conductivity K of the solid is constant.

i) Develop an expression for the 1-dimensional, steady state temperature distribution T (r) in the cylinder

ii) Develop an expression for the radial heat flow rate Q through the cylinder

iii) Develop an expression for the thermal resistance of the cylinder. (6 + 3) + 6

8. a) Using lumped parameter analysis method derive the following relation with usual notations :

$$\frac{t - t_a}{t_1 - t_a} = e^{-Bi \times Fo}$$

b) An egg with mean diameter of 40 mm and initially at 20°C is placed in a boiling water pan for 4 minutes and found to be boiled to the consumer taste. For how long should a similar egg for same consumer be boiled when taken from a refrigerator at 5°C ? Take the following properties for egg :

k = 10W/m°C, ρ = 1200 kg/m^3, c = 2 kJ/kg°C and h (heat transfer coefficient) = 100 W/m°C. Use lump theory. 7 + 8

9. a) What is Couette flow ? Deduce an expression for temperature distribution when the upper and lower plates are different.

b) Given $Nu_x = \frac{h(x)x}{k} = 0 \cdot 332 \,\mathrm{Pr}^{\frac{1}{3}} \,\mathrm{Re}_x^{\frac{1}{2}}$

Develop a relation average $h(x)$ for $0 \le x \le L$

Atmospheric air at T_∞ = 400 K with a velocity u_∞ = 1·5 m/s flows over a flat plate L = 2 cm long maintained at a uniform temperature T_w = 300 K.

Calculate average $h(x)$ that is h_m for $0 \le x \le L$.

Calculate the heat transfer rate for width w = 0·5 m.

Thermodynamic properties of air at 350 K

ρ (kg/m^3)	C_p (kJ/kgK)	$\mu \times 10^7$ (Ns/m^2)	$\nu \times 10^6$ (m^2/s)	$k \times 10^3$ (W/mK)	$\alpha \times 10^6$ (m^2/s)	P_r
0·9950	1·009	208·2	20·92	30	29·9	0·700

8 + 7

10. a) Show that the emissive power of a black body is π times the intensity of emitted radiation.

    b) By using one radiation shield between two surfaces and if all the three surfaces have the same emissivity, show that the net radiant heat transfer is reducing by 50%.

    c) Consider two large parallel plates one at t_1 = 727°C with emissivity ε_1 = 0·8 and other at t_2 = 227°C with emissivity ε_2 = 0·4. An aluminium radiation shield with an emissivity, ε_3 = 0·05 on both sides is placed between the plates. Calculate the percentage reduction in heat transfer rate between the two plates as a result of the shield. Use $\sigma = 5 \cdot 67 \times 10^{-8}\ W/m^2K^4$.

4 + 4 + 7

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