MAULANA ABUL KALAM AZAD UNIVERSITY OF TECHNOLOGY, WEST BENGAL

AUE-502

HEAT TRANSFER

Time Allotted: 3 Hours | Full Marks: 70

The questions are of equal value.
The figures in the margin indicate full marks.
Candidates are required to give their answers in their own words as far as practicable.
All symbols are of usual significance.

GROUP A
(Multiple Choice Type Questions)

1. Answer *all* questions. 10×1 = 10

(i) The critical radius of insulation for a cylinder is equal to
(A) 2 kh (B) 2 k/h (C) h/2k (D) k/h

(ii) The concept of log mean area (or arithmetic mean area) is normally used in the analysis of
(A) composite plane surface (B) cylindrical surface
(C) spherical surface (D) any plane surface

(iii) The unit of the thermal diffusivity
(A) $m^2/hr°C$ (B) kcal/hr°C (C) m^2/s (D) m/s^2

(iv) Effectiveness of a fin of uniform cross-section will be high if
(A) k is less (B) P is less (C) h is less (D) A is large
the nomenclature have their usual meanings

(v) 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

(vi) The temperature of solid surface is raised from 227°C to 727°C. The emissive power of body will change from E_1 to E_2 such that E_1/E_2 is
(A) 400 (B) 16 (C) 4000 (D) 1600

(vii) Transient conduction means
(A) heat transfer with small temperature difference
(B) variation of temperature with time
(C) heat transfer for a short time
(D) very little heat transfer

(viii) Air enters a counter flow heat exchanger at 70°C and leaves at 40°C, while water enters at 30°C and leaves at 60°C. The LMTD is:
(A) 10°C (B) 20°C (C) 30°C (D) 40°C

(ix) The velocity profile for fully developed laminar flow in a tube is
(A) Linear (B) Exponential (C) Hyperbolic (D) Parabolic

(x) The wavelength for maximum emissive power is given by
(A) Kirchhoff's law (B) Stefan-Boltzmann law
(C) Fourier's law (D) Wien's law

GROUP B
(Short Answer Type Questions)

Answer any *three* questions. 3×5 = 15

2. For a hot solid cylinder of radius r_0 with uniform rate of heat generation q per unit volume conducting heat radially and losing heat from its surface to the ambient (at temperature $T\infty$) by convection with heat transfer coefficient h, prove that

$$\frac{T_0 - T(r)}{T_0 - T_\infty - (qr_0/2h)} = \left(\frac{r}{r_0}\right)^2$$

Where, $T(r)$ = temperature of the cylinder at a distance r from the axis. And T_0 = axis temperature.

3. Derive one dimensional heat conduction equation in Cartesian co-ordinates.

4. A counter flow shell-and-tube heat exchanger is used to heat water at a rate of m = 0.8 kg/s from T_i = 30°C to T_0 = 80°C, with hot oil entering at 120°C and leaving at 85°C. The over wall heat transfer coefficient is U = 125 $W/(m^2°C)$. Calculate the heat transfer area required.

5. For the radiation heat exchange between a plane composite surface area A_4 (made up of plane surface area A_2 and A_3) and a plane surface area A_1, show that

$$A_4 F_{41} = A_3 F_{31} + A_2 F_{21}.$$

6. Derive an expression for "critical insulation radius" of a cylinder.

GROUP C
(Long Answer Type Questions)

Answer any *three* questions. 3×15 = 45

7. (a) What is natural convection? 2+4+9
   (b) A heated vertical plate maintained at a uniform temperature T_w, placed in a stagnant air ($u_\infty = 0$) processing a constant temperature T_∞ ($T_\infty < T_w$) inside a room.
   (i) Draw the temperature and velocity profile in the thermal boundary layer generated due to heat transfer from the plate to the surrounding air.
   (ii) Using the equations of motion, show that the volumetric coefficient of thermal expansion β is reciprocal to the absolute temperature T. (Assume the boundary layer flow is steady and laminar).

8. (a) The inner surface at r = a and the outer surface at r = b of a sphere are maintained at uniform temperature T_1 and T_2 respectively. The thermal conductivity k of the solid is constant. 10
   (i) Develop an expression for the 1-dimensional, steady state temperature distribution $T(r)$ in the sphere.
   (ii) Develop an expression for the radial heat flow rate Q through the sphere.
   (iii) Develop an expression for the thermal resistance of the sphere.
   (b) Pin fins are provided to increase the heat transfer rate from a hot body surface. Find out which of the following arrangements will provide higher heat transfer rate? 5
   (i) 6 fins of 10 cm length.
   (ii) 12 fins of 6 cm length.
   It is given k = 210 W/mK, h = 20 W/m^{2}K, cross-sectional area of fin = 3 cm^2, perimeter of fin = 5 cm, fin base temperature = 240°C and surrounding temperature = 35°C.

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9. (a) Using lumped parameter analysis method derives the following relation. 7

$$\frac{t - t_\infty}{t_i - t_\infty} = e^{-Bi_1 Fo}$$ With usual notations.

   (b) A die cast component has a mass of 1.25 kg and density 7250 kg/m^3 with surface area 0.08 m^2. The component comes out of machine at 350°C and is exposed to air at 25°C with convective heat transfer coefficient 60 W/m^2°C. Make calculation for the followings: 8
   (i) Temperature of the component after 5 minutes
   (ii) Time constant
   (iii) Value of convective heat transfer coefficient up to which lumped parameter analysis is valid.
   (iv) Value of volume/area ratio up to which lumped parameter analysis is valid.
   For the material of component take thermal conductivity = 100 W/m°C and specific heat = 400 J/kgK.

10. (a) What is couette flow? Deduce an expression for temperature distribution when the upper and lower plates are different. 8
   (b) Taking the velocity profile in the turbulent flow over a plane surface as 7

$$u = u_\infty \left(\frac{y}{\delta}\right)^{1/7}$$

   and wall shear stress as $$\tau_w = 0.0228 \rho u^2 . \left(\frac{\nu}{u.\delta}\right)^{1/4}$$

   show that the boundary layer thickness is given by $$\frac{\delta}{x} = \frac{0.376}{(\mathrm{Re}_x)^{1/5}}.$$

11. (a) Show that the emissive power of a black body is π - times the intensity of emitted radiation. 5
   (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%. 4
   (c) Show that for counter flow heat exchanger, the effectiveness is expressed as 6

$$\varepsilon = \frac{1 - \exp[-NTU(1-R)]}{1 - R\exp[-NTU(1-R)]}$$

   R = C_{min}/ C_{max} with C_{min} and C_{max} having their usual meanings.