ENGINEERING & MANAGEMENT EXAMINATIONS, DECEMBER – 2006

HEAT TRANSFER

SEMESTER – 5

Time : 3 Hours] [Full Marks : 70

Group – A

(Multiple Choice Questions)

1. Choose the correct alternatives for the following : 10 × 1 = 10

i) In general, the thermal conductivity of a substance is

a) independent of temperature

b) a strong function of pressure

c) strongly temperature dependent

d) independent of pressure.

ii) The product of overall heat transfer coefficient and surface area (UA) is related to the total thermal resistance R as

a) R^2

b) $R^{0.5}$

c) R

d) R^{-1}.

iii) The heat transfer rate by conduction for a hollow sphere with areas A_1 and A_2 varies as

a) $\sqrt{A_1 A_2}$

b) $A_1 A_2$

c) $\frac{1}{A_1 A_2}$

d) $\frac{1}{\sqrt{A_1 A_2}}$

iv) An increase in convection coefficient over a fin will

a) result in higher effectiveness

b) result in lower effectiveness

c) not affect effectiveness

d) influence only the fin efficiency.

v) The lumped parameter procedure should be applied when

a) the connective heat transfer coefficient is low

b) the thermal conductivity is high

c) the characteristic dimension is small

d) all these are true.

vi) The velocity profile for fully developed laminar flow in a tube is

a) linear

b) exponential

c) hyperbolic

d) parabolic.

vii) For free convection. Nusselt number is a function of

a) Prandtl and Grashof number

b) Reynolds and Grashof number

c) Grashof number only

d) Reynolds and Prandtl number.

viii) The shape factor of a hemispherical body placed on a flat surface with respect to itself is

a) 1·0

b) 0·5

c) 0·25

d) zero.

ix) The total emissive power E of a diffused surface is related to radiation intensity I as, E equal to

a) $\frac{\pi}{4} I$

b) $\pi^2 I$

c) πI

d) $4 \pi I$.

x) For a condenser or evaporator of NTU = 2, the effectiveness is

a) $\frac{1}{2}(1 - e^{-4})$

b) $\frac{2}{3}$

c) $1 - e^{-2}$

d) $\frac{3}{2}$

Group - B

(Short Answer Questions)

Answer any *three* questions. $3 \times 5 = 15$

2. The inside and outside radii of a circular hollow cylinder are r_i and r_o. Corresponding temperatures are t_i and t_o. Prove that the temperature inside the thickness of cylinder, in between inside and outside radius, is

$$T = T_i - \frac{T_i - T_o}{\ln\left(\frac{r_o}{r_i}\right)} \ln\left(\frac{r}{r_i}\right)$$

5

3. Determine analytically the view factor from an elemental surface dA_1 to a circular disc A_2 of radius R which are parallel to each other and positioned at a distance L. 5

4. Explain the physical significance of

a) Grashof number

b) Nusselt number and

c) Prandtl number. 5

5. State and explain Planck distribution law and Wien displacement law. 5

Group - C

(Long Answer Questions)

Answer any *three* questions. $3 \times 15 = 45$

6. a) Derive the one-dimensional, steady-state heat conduction equation with internal heat generation in Cartesian co-ordinate system.

b) What is the physical significance of thermal diffusivity of a metal ?

c) A furnace wall is made of three layers, the fist layer of insulation brick ($k = 0.6$ W/m-K) has a thickness of 120 mm. The face is exposed to gas at 870°C with a convection coefficient of 110 W/m^2-K. The layer is backed by a 100 mm layer of firebrick of conductivity $k = 0.8$ W/m-K. The third layer is the backing plate of conductivity 49 W/m-K has a thickness of 10 mm. The plate is exposed to air at 30°C with a convection coefficient of 15 W/m^2-K. Determine the heat flow per unit area, temperatures at the interfaces and the overall heat transfer coefficient. $6 + 2 + 7 = 15$

7. a) Under what circumstances from the heat transfer point of view, will the use of finned walls be better ?

b) Copper plate fins of rectangular cross-section, 1 mm thick, 10 mm long and thermal conductivity as 380 W/m-K are attached to a plane wall maintained at a temperature of 230°C. The fins dissipate heat by convection into an ambient at 30°C with a heat transfer coefficient of 40 W/m^2-K. Fins are spaced at 8 mm. Assume negligible heat loss from the tip. Calculate

i) Fin efficiency

ii) Area weighted fin efficiency

iii) The total heat transfer per m^2 of plane wall surface

iv) The heat transfer rate from the plane wall if there were no fins attached.

$3 + 12 = 15$

8. a) What are the physical significances of Biot Number and Fourier Number ?

b) What is the condition for the validity of lumped capacitance method for transient heat conduction analysis ?

c) A mild steel sphere of 15 mm in diameter initially at 625°C is exposed to a current of air at 25°C with convection coefficient of 120 W/m^2-K. Calculate

i) Time required to cool the sphere to 100°C

ii) Initial rate of cooling in

iii) Instantaneous heat transfer at the end of one minute after the start of cooling

iv) Total energy transferred during first one minute. $4 + 4 + 7 = 15$

9. a) Distinguish between the following :

i) Black body and Gray body

ii) Irradiation and Radioactivity.

b) Starting from fundamentals, explain the terms 'Space Resistance' and 'Surface Resistance' for radiation heat exchange between two surfaces.

c) A cryogenic fluid flows through a long tube of 20 mm diameter, the outer surface of which is diffused and gray ($\varepsilon_1 = 0.02$) at 77 K. This tube is concentric with a larger tube of 50 mm diameter, the inner surface of which is diffused and gray ($\varepsilon_2 = 0.05$) and at 300 K. The space between the surfaces is evacuated. Calculate the heat gain by cryogenic fluid per unit length of tubes. If thin radiation shield of 35 mm diameter ($\varepsilon_3 = 0.02$) both sides is inserted midway between the inner and outer surfaces, calculate the percentage change in heat gain per unit length of the tube. 4 + 4 + 7 = 15

10. a) Using dimensional analysis, derive an expression for heat transfer coefficient in forced convection in terms of Nusselt number, Reynolds number and Prandtl number.

b) Water at 20°C and 1 atm flows over a flat plate at a speed of 0.5 m/s. The width of the plate is 1 m. The entire plate is entirely heated to a temperature of 60°C. Calculate the heat transferred in the first 40 cm length of the plate using the Reynolds-Colburn analogy. Take the properties of water at 40°C as $\rho = 992.04$ kg/m ^{3}, $\mu = 6.556 \times 10^{-4}$ N-s/m ^{2}, $k_f = 0.6328$ W/m-K, $P_r = 4.334$ and $C_p = 4.174$ kJ/kg-K. 6 + 9 = 15

11. a) Derive the expression of heat transfer rate between the cold and hot fluids in terms of overall heat transfer coefficient, heat exchanger area and LMTD for a parallel flow heat exchanger.

b) What advantage does the effectiveness ε-NTU method has over the LMTD method ?

c) A hot fluid at 200°C enters a heat exchanger at a mass flow rate of 10^4 kg/hr. Its specific heat is 2000 J/kg-K. It is to be cooled by another fluid entering at 25°C with a mass flow rate 2500 kg/hr and specific heat 400 J/kg-K. The overall heat transfer coefficient based on outside area of 20 m ^{2} is 2590 W/m ^{2}-K. Find the exit temperature of the hot fluid when the fluids are in parallel flow. 6 + 3 + 6 = 15