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Paper Code : ME-502

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) A composite slab has two layers of different materials with thermal conductivity k_1 and k_2. If each layer has same thickness, the equivalent thermal conductivity of the slab would be

a) $k_1 \; k_2$

b) $k_1 + k_2$

c) $\dfrac{(k_1 + k_2)}{k_1 k_2}$

d) $\dfrac{k_1 k_2}{(k_1 + k_2)}$.

ii) If the temperature of a hot body is increased by 50%, the amount of radiation emitted by it would increase by nearly

a) 50% b) 100%

c) 200% d) 500%.

iii) LMTD of counterflow heat exchanger as compared to parallel flow heat exchanger for a given heat transfer will be

a) more b) same

c) less d) unpredictable.

iv) Up to critical radius of insulation

a) heat loss decreases with addition of insulation

b) heat loss increases with addition of insulation

c) occurs a decrease in heat flux

d) conduction heat loss is more than convective heat loss.

v) In a counterflow heat exchanger, the hot fluid enters at 100°C and leaves at 60°C. The cold fluid enters at 40°C and leaves at 80°C. It is a balanced heat exchanger with $\dot{m}_h C_h = \dot{m}_c C_c$. The LMTD of the heat exchanger is

a) zero b) indeterminate

c) 40°C d) 20°C.

vi) Two spheres *A* and *B* of same material have radii 1 m and 4 m and temperature 4000 K and 2000 K respectively. Which one of the following statements is correct ? The energy radiated by sphere *A* is

a) greater than that of sphere *B*

b) less than that of sphere *B*

c) equal to that of sphere *B*

d) equal to double that of sphere *B*.

vii) Which one of the following statements is correct ?

a) A gray body is one which absorbs all radiations incident on it

b) At thermal equilibrium, the emissivity and absorption are same

c) The energy absorbed by a body to the total energy falling on it is called emissivity

d) A perfect body is one which is black in colour.

viii) Velocity profile in a fully developed laminar flow is

a) linear b) exponential

c) hyperbolic d) parabolic.

ix) For free convection Nusselt No. is a function of

a) Prandtl & Grashof number

b) Reynolds & Prandtl No.

c) Reynolds & Grashof No.

d) Grashof No. only.

x) 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.

GROUP – B

(Short Answer Type Questions)

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

2. Hot air at a temperature of 65°C is flowing through a steel pipe of 120 mm dia. The pipe is covered with two layers of different insulating materials of thickness 60 mm and 40 mm, and their corresponding thermal conductivities are 0·24 and 0·4 W/m°C. The inside and outside heat transfer coefficients are 60 and 12 W/m°C respectively. The atmosphere is at 20°C. Find the rate of heat loss from 60 m length of pipe ?

3. Derive an expression for temperature distribution from a fin of uniform cross-sectional area and insulated at tip.

4. Define effectiveness and NTU of a heat exchanger. What is the limitation of LMTD method ? How ϵ-NTU method is superior to correction factor-LMTD method ?

5. Define the following non-dimensional numbers and explain their physical significance :

a) Nusselt Number

b) Biot Number.

6. a) i) State Lambert's cosine law.

ii) What is a grey body ?

b) A grey body has an emissivity of 0·35 and is at a temperature of 500 K. If the body is opaque, calculate its reflectivity for a black body radiation coming from a 500 K source. 3 + 2

7. Show that for a plane wall of thickness 2L with uniform heat generation q_g per unit volume, the temperature at mid-plane is given by $T_c = \frac{q_g L^2}{2k} T_s$, where, T_s is the surface temperature on either side.

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. $3 \times 15 = 45$

8. a) Show that for a counterflow heat exchanger, effectiveness can be expressed as,

$$\epsilon = \frac{1 - \exp[-NTU(1-c)]}{1 - c\exp[-NTU(1-c)]}, \text{ where}$$

$$c = \frac{C_{min}}{C_{max}}.$$

b) A heat exchanger is to be designed to cool m_h = 8·7 kg/s an ethyl alcohol solution [C_p = 3840 J/(kg.°C) from T_1 = 75°C to T_2 = 45°C with cooling water [C_p = 4180 J/(kg.°C) entering the tube side at t_1 = 15°C at a rate of m_c = 9·6 kg/s. The overall heat transfer coefficient based on the outer tube surface is U_o = 500 W/(m^2°C). Calculate the heat transfer area for each of the following flow arrangements :

i) Parallel flow

ii) Counterflow. 9 + 6

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

b) Consider a plane composite wall that is composed of two materials whose conductivities are K_1 = 0·1 W/m K and K_2 = 0·04 W/m K and thickness L_1 = 1 cm and L_2 = 2 cm. The contact resistance at the interface between the two materials is known to be 0·3 m^2 K/W. The material 1 adjoins a fluid at 200°C for which h = 10 W/m^{2}K and material 2 adjoins a fluid at 40°C for which h = 20 W/m^{2}K.

i) Find the rate of heat transfer through the composite wall

ii) What is the temperature drop at the interface of two materials ? 5 + 10

10. a) Derive the equation for heat dissipation by a fin with an insulated tip $Q_{fin} = \sqrt{PhkA_c}\,(t_0 - t_a)\tan hml$ by integrating the convective losses along its surface.

b) A steel rod (k = 32 W/m°C), 12 mm in diameter and 60 mm long, with an insulator, is to be used as a spin. It is exposed to surrounding with a temperature of 60°C and a heat transfer coefficient

of 55 $W/m^2°C$. The temperature at the base of fin is 95°C. Determine

i) the fin efficiency

ii) the temperature at the edge of the spin

iii) the heat dissipation. 8 + 7

11. a) What is Reynolds analogy ? Describe the relation between fluid friction and heat transfer.

b) Atmospheric air at 275 K and a free stream velocity of 20 m/s flows over a flat plate 1·5 m long that is maintained at a uniform temperature of 325 K. Calculate the average heat transfer coefficient over the region where the boundary layer is laminar, the average heat transfer coefficient over the entire length of the plate and the total heat transfer rate from the plate to the air over the length 1·5 m and width 1 m. Assume transition occurs at $Re_c = 2 \times 10^5$. 5 + 10

12. a) State and explain Planck Distribution law and Wien's Displacement law.

b) What is radiation shape factor ? Calculate radiation shape factor for a hemispherical surface closed by a plane surface.

c) A black body has an effective temperature of 800 K. Calculate

i) rate of total energy radiation per unit area

ii) intensity of normal radiation.

d) If a black body at 1000 K and a grey body at 1250 K emit the same amount of radiation, determine the emissivity of the grey body.

5 + 5 + 3 + 2