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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 alternative for *any ten* of the following: 1×10=10

(i) On heat transfer surface, fins are provided
 (a) to increase temperature gradient so as to enhance heat transfer.
 (b) to increase turbulence in flow for enhancing heat transfer.
 (c) to increase surface area to promote the rate of heat transfer.
 (d) to decrease the pressure drop of the fluid.

(ii) Two walls of same thickness and cross-sectional area, have thermal conductivities in the ratio 1 : 2. If same temperature difference is maintained across of the two face of both the walls, what is the ratio of heat flow (Q_1/Q_2)?
 (a) 1/2 (b) 1
 (c) 2 (d) 4

(iii) The dimensionless number relevant in transient heat conduction is
 (a) Biot number (b) Grashof number
 (c) Renolds number (d) Weber number

(iv) Two radiating surface $A_1 = 6\ m^2$ and $A_2 = 4\ m^2$ have the shape factor $F_{1-2} = 0{\cdot}1$; the shape factor F_{2-1} will be
 (a) 0·18 (b) 0·15
 (c) 0·12 (d) 0·10

(v) The fin effectiveness can be enhanced by
(a) the choice of a material of high thermal conductivity.
(b) increasing the ratio of peremeter to cross-sectional area of the fin.
(c) the low value of heat transfer coefficient.
(d) All of the above

(vi) Critical radius of insulation for sphere is
(a) k/h
(b) $k/2h$
(c) $2k/j$
(d) $4k/h$

(vii) Radiation shield should have
(a) zero reflectivity
(b) low reflectivity
(c) high reflectivity
(d) None of these

(viii) In forced convection Nusselt number is the function of
(a) Renolds number and Prandtl number
(b) Renolds number and Eckert number
(c) Grashof number and Prandtl number
(d) None of these

(ix) The thermal boundary layer thickness is thicker than momentum boundary layer thickness when Prandtl number is
(a) 0
(b) less than 1
(c) equal to 1
(d) greater than 1

(x) Heat transfer in liquid and gases takes place by
(a) Conduction
(b) Convection
(c) Radiation
(d) Conduction and convection

(xi) Convection heat transfer coefficient depends on
(a) surface geometry.
(b) nature of fluid motion.
(c) properties of the fluid.
(d) All of the above

(xii) Condenser of split type air conditioner is a heat exchanger of
(a) counter flow type.
(b) parallel flow type.
(c) cross flow type.
(d) regeneration type.

Group – B

(Short Answer Type Questions)

Answer *any three* of the following. 5×3=15

2. A pipe is insulated to reduce the heat loss from it. However, measurement indicates that the rate of heat loss has increased instead of decreasing. Can the measurements be right?

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3. Derive the expression of thermal resistance offered by a spherical wall of uniform thermal conductivity during steady state heat conduction without heat generation.

4. For flow over a flat plate the hydrodynamic boundary layer thickness is 0·5 mm. The dynamic viscosity is 25×10^{-6} Pa–s, specific heat is 2·0 kJ/kgK and thermal conductivity is 0·05 W/mK. Calculate the thermal boundary layer thickness.

5. Derive an expression of temperature distribution and rate heat loss for fin with insulated tip.

6. Explain *any two* of the following:
   (a) Radiation view factor
   (b) Radiosity
   (c) Emissivity

7. Show that emissive power of a black body is π-times the intensity of radiation.

Group – C

(Long Answer Type Questions)

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

8. (a) What is critical radius of insulation?
   (b) A fin has 5 mm diameter and 100 mm length. The thermal conductivity of fin material is 400 W/mK. One end of the fin is maintained at 130°C and its remaining surface is exposed to ambient air at 30°C. If the convective heat transfer coefficient is 40 W/m^{2}K, calculate the rate of heat loss from the fin.
   (c) A steam pipe, 10 cm ID and 11 cm OD is covered with an insulating substance (K = 1 W/mK), the steam temperature and ambient temperature are 200°C and 20°C respectively. If convective heat transfer coefficient between the insulation surface and air is 8 W/m^2, find the critical radius of insulation. For this value of r_0, calculate the heat loss per meter of pipe and outer surface temperature. Neglect the resistance of the pipe material. 3+5+7=15

9. (a) What are Biot and Fourier numbers? Explain their physical significance.
   (b) What is Lumped system analysis? In what medium it is more likely applicable — in water or in air?
   (c) A mild steel sphere of 15 mm in diameter initially at 625°C is exposed to a current of air 25°C with convective heat transfer coefficient 120 W/m^{2}K, (Take K = 43 W/mK, c = 474 J/KgK, ρ = 7850 kg/m^3)

   Calculate:
   (i) Time required to cool the sphere to 100°C
   (ii) Initial rate of cooling
   (iii) Instantaneous heat transfer rate at the end of one minute after the start of cooling.

(2+2)+(1+1)+(3×3)=15

10. (a) Show that for parallel flow heat exchanger, the effectiveness is

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

Where R represents the heat capacity ratio of the fluids.

(b) Water (c_p = 4·187 kJ/kg-K) is heated from 40°C to 70°C by an oil having a specific heat of 1·9 kJ/kg-K, entering at 110°C and leaving at 60°C in a counter flow heat exchanger. The mass flow rate of water is 1·4 kg/s. If the overall heat transfer coefficient is 350 W/m^{2}K, calculate the surface area required. 8+7=15

11. (a) Explain the velocity distribution in a hydrodynamic boundary layer for fluid flow along a flat plate.

(b) Air at 27°C and 1 atm pressure flows over a heated plate with a velocity of 2 m/s. The plate is at uniform temperature of 60°C. Calculate the heat transfer rate from first 0·2 m of the plate. Assume the required properties of the air at atmospheric pressure. 7+8=15

12. (a) What is gray body? How does emissivity vary for a gray surface and for a real surface?

(b) For a radiation shield, show that

$$\left(\frac{Q}{A}\right)_{\text{with N shields}} = \frac{1}{N+1}\left(\frac{Q}{A}\right)_{\text{without shields}}$$

(c) Two very large parallel planes with emissivities 0·3 and 0·8 exchange radiative energy. Determine the percentage reduction in radiative energy transfer when a polished aluminium radiation shield with an emissivity of 0·04 is placed between them. (2+2)+6+5=15
