



Name :

Roll No. :

Invigilator's Signature :

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2011

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) The temperature distribution at a certain instant of time in a concrete slab during curing is given by $T = 3x^2 + 3x + 16$, where x is in cm and T is in K. The rate of change of temperature with time is given by (assuming thermal diffusivity to be $5 \times 10^{-4} \text{ cm}^2/\text{s}$)

- | | |
|-----------------|------------------|
| a) + 0.0009 k/s | b) 0.0045 k/s |
| c) – 0.0030 k/s | d) – 0.0018 k/s. |

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- ii) For more effective heat transfer, fins should be
- thick and small in number
 - thin and large in number
 - medium size and small in number
 - none of these.
- iii) For a current carrying wire of 20 mm diameter exposed to air ($h = 25 \text{ W/m}^2 \text{ K}$), maximum heat transfer occurs when the thickness of insulation ($K = 0.5 \text{ W/m K}$) is
- 20 mm
 - 10 mm
 - 5 mm
 - 0 mm.
- iv) Fourier number is defined as
- non-dimensional time
 - non-dimensional temperature
 - non-dimensional internal energy
 - non-dimensional heat flux.
- v) For flow of a heat transfer oil ($Pr = 20$) over a flat plate, the thermal boundary layer thickness for laminar forced convection is
- thicker than the hydrodynamic boundary layer
 - equal to that of hydrodynamic boundary layer
 - thinner than the hydrodynamic boundary layer
 - constant along the plate.

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vi) Convective heat transfer coefficient in natural convection is a function of

- a) Re and Pr b) Gr and Bi
c) Re and Bi d) Gr and Pr .

vii) For laminar fully developed flow through a pipe, the local heat transfer coefficient (h_x)

- a) increases with axial distance, x
b) remains constant
c) decreases with axial distance, x
d) first increases with x and then decreases.

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) View factor of the inner surface of a hemispherical shell with respect itself is

- a) 1 b) 0.75
c) 0.5 d) 0.25.

x) The total emissive power of a blackbody surface is related to its radiation intensity I as

- a) $E = 4\pi I$ b) $E = \pi^2 I$
c) $E = 2\pi I$ d) $E = \pi I$.

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**GROUP – B****(Short Answer Type Questions)**Answer any *three* of the following.

3 × 5 = 15

2. Derive the following equation for a small metal casting being quenched in a bath after removing it from a hot surface.

$$T - T_{\infty} = (T_0 - T_{\infty}) \exp(-hAt/\rho CV)$$

where

 T **Error!**

3. For a hot solid cylinder of radius r

Error!

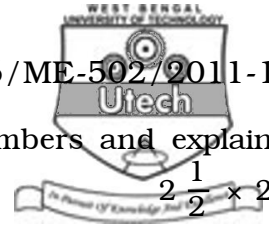
$$\frac{T_0 - T(r)}{T_0 - T_{\infty} - (qr_{0/2h})} = (r/r_0)^2$$

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

and T_0 = axis temperature.

4. Write down the energy equation, for a 2-dimensional incompressible laminar flow, in Cartesian coordinates. Do not neglect the volumetric heat generation and viscous dissipation terms. Explain the physical significance of each term.

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

a) Nusselt Number

b) Biot Number .

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

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

GROUP – C

(Long Answer Type Questions)

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

7. a) A furnace has a composite wall constructed of a refractory material for the inside layer and an insulating material on the outside. The total wall thickness is limited to 60 cm. The mean temperature of the gases within the furnace is 850°C , the external air temperature is 30°C and the temperature at the interface of the two materials of the furnace wall is 500°C .

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The thermal conductivity's of refractory and insulating materials are 2 and 0.2 W/m K respectively. The combined coefficient of heat transfer by convection and radiation between the gases and inside refractory surface is $200 \text{ W/m}^2 \text{ K}$ and between outside surface and atmosphere is $40 \text{ W/m}^2 \text{ K}$. Find

- i) The required thickness of each material.
 - ii) The temperature of the surface exposed to gases and that of the surface exposed to air.
 - iii) The rate of heat loss to atmosphere in kW/m^2 .
- b) The heat transfer coefficient for a gas flowing over a flat plate 3 m long and 0.3 m wide varies with distance from the leading edge according to
- $$h_0(x) = 10x^{-1/4} \text{ W/m}^2 \text{ K}$$
- calculate :
- i) The average heat transfer coefficient.
 - ii) The rate of heat transfer between the plate and the gas if the plate at 170°C and gas is at 30°C .
 - iii) Local heat flux, 2 m from the leading edge. 9 + 6

8. a) Derive the equation for heat dissipation by a fin with an insulated tip. Consider A as the cross-section area, P the perimeter and L the length of the fin, h as the average heat transfer coefficient of the fluid in which the fin is immersed and k as the thermal conductivity of the fin material. The fin base is at a temperature T_0 and the surrounding temperature is T_∞ .

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- b) A stainless steel turbine blade, 6 cm long, 4.65 cm^2 cross-sectional area, 12 cm perimeter ($k = 23.3 \text{ W/m K}$) is exposed to a hot gas at 870°C . The root of the blade is fixed at the base, which is at 500°C . Heat transfer coefficient between the plate and hot gas is $440 \text{ W/m}^2 \text{ K}$. Assuming the tip of the blade to be installed, determine
- the maximum temperature on the blade
 - the rate of heat transfer at the root of the blade.

8 + 7

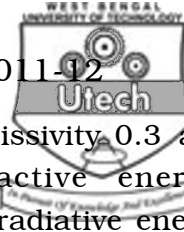
9. Two parallel plates are separated by a distance L , with the intermediate space filled by a liquid of viscosity μ , density ρ , thermal conductivity k and specific heat C

Error!

- Find out the temperature distribution of the liquid as a function of height (above the lower plate) in terms of the fluid properties and U_1 .
- Find out the expression of maximum temperature T_{max} in the liquid if $T_1 > T_0$. Also determine the location at which the maximum temperature occurs.

9 + 6

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10. a) Two very large parallel planes with emissivity 0.3 and 0.8, respectively, exchange radioactive energy. Determine the percentage reduction in radiative energy transfer when a polished aluminum radiation shield ($\epsilon = 0.04$) is placed between them.

b) Lubricating oil at a temperature of 60°C enters a 1 cm diameter tube with a velocity of 3.5 m/s. The tube surface is maintained at 30°C . Calculate the tube length required to cool the oil to 45°C . Assume that the oil has the following properties : $\rho = 865 \text{ kg/m}^3$, $k = 0.14 \text{ W/m K}$, $C_p = 1.78 \text{ KJ/kg K}$ and $\gamma = 9 \times 10^{-6} \text{ m}^2/\text{s}$.

8 + 7

11. a) Show that for counter flow heat exchanger, the effectiveness is expressed as

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

$R = \frac{C_{min}}{C_{max}}$ with C_{min} and C_{max} having their usual meanings.

b) A heat exchanger is to be designed to cool ethyl alcohol ($C_p = 3840 \text{ J/kg K}$) from 75°C to 45°C with cooling water entering at 15°C . The flow rates of ethyl alcohol and water are 8 kg/s and 9.6 kg/s, respectively.

If the overall heat transfer coefficient based on the outer tube surface is $500 \text{ W/m}^2 \text{ K}$, calculate the requisite heat exchanger length for

i) Parallel flow and

ii) Counter flow configurations.

Given, Tube outer dia = 30 mm and No. of tubes = 20.

8 + 7