Name : .....

Roll No : .....

Invigilator's Signature : .....

# CS/B.Tech/(AUE-N)/SEM-5/AUE-502/2013-14

## 2013

## 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) For free convection Nusselt number is function of
   a) Prandtl & Grashoff Number
   b) Prandtl & Reynolds Number
   c) Reynolds & Eckert number
   d) Reynolds & Grashoff number.

ii) For phase change LMTD of counter flow heat exchanger is
   a) More than LMTD of parallel flow heat exchanger
   b) Equal to LMTD of parallel flow heat exchanger
   c) Less than LMTD of parallel flow heat exchanger
   d) May be more or than LMTD of parallel flow heat exchanger.









iii) Fins are provided on heat transferring surface
   a) to increase temperature gradient
   b) to increase heat transfer coefficient
   c) to increase heat transfer area
   d) level of turbulence.

iv) A good absorber of thermal radiation is also a good emitter. It is called
   a) Wien's law b) Plank's law
   c) Stefan's law d) Kirchhoff's law.

v) The thickness of thermal and hydrodynamic boundary layers are equal if ( Pr = Prandtl Number, Nu = Nusselt Number )
   a) Pr = 1 b) Pr > 1
   c) Pr < 1 d) Pr = Nu.

vi) Which of the following statements is incorrect ?
   a) Black surfaces are better absorberst than white ones
   b) Black surfaces are better radiators than white ones
   c) Rough surfaces are better radiators than smooth surfaces
   d) Highly polished mirror like surfaces are very good radiators.

vii) The dimensionless parameter ( b g r $^2$ D t ) / m $^3$ is referred to as

a) Stanton number b) Schmidt number

c) Grashoff number d) Peelet number.

viii) A perfect black body is the one which

a) is coated with lamp black

b) absorbs almost all the radiation

c) absorbs all incident radiation

d) reflects all incident radiation.

ix) The critical radius of insulation for a spherical shell is equal to

a) h/k b) 2h/k

c) k/h d) 2k/h.

x) The internal thermal resistance of a solid can be ignored if the Biot number is less than

a) 1.0 b) 0.5

c) 0.1 d) Fourier number.









## GROUP – B

### ( Short Answer Type Questions )

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

2. Define thermal diffusivity and explain its significance ? Derive critical radius of insulation in case of cylinder. 2 + 3

3. Show that, the shape factor between two surfaces $A_1$ and $A_2$ of infinite length in one direction is equal to,

$$F_{12} = \frac{[\,(\text{Sum of crossed string}) - (\text{Sum of uncrossed string})\,]}{[\,2 \times (\text{Length of Surface 1})\,]}$$ 5

4. Find out the Reynolds number using Buckingham's $\pi$ Theorem. 5

5. Define various terms : Reynolds number, Prandtl number, Nusselt number, Stanton number, Grashoff number. 5

6. In a counter flow heat exchanger, if $\Delta T_{inlet} = \Delta T_{outlet}$, show that LMTD = $\Delta T_{inlet} = \Delta T_{outlet}$. 5

## GROUP – C

### ( Long Answer Type Questions )

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

7. a) Show that total heat transfer from a finned wall is given by $Q = h\,\theta_0\,\{A - (1 - \eta_f) A_f\}$ where A = total area of fin and unfined surface, $A_f$ = area of the finned surface, $\eta_f$ = fin efficiency and $\theta_0 = T_b - T_\infty$. 7

b) A reactor wall 320 mm thick is made up of inner layer of fire brick ( $k_{fb} = 0.84$ W/m°C ) covered with a layer of insulation ( ( $k_{ins} = 0.16$ W/m°C ). The reactor operates at a temperature of 1325°C and the ambient temperature is 25°C.

i) Determine the thickness of firebrick and insulation which gives minimum heat loss.

ii) Calculate the heat loss presuming that the insulating material has a maximum temperature of 1200°C. 8

8. a) What is natural convection ?

b) A heated vertical plate maintained at a uniform temperature $T_w$ , placed in a stagnant air ( $u_a = 0$ ) possessing a constant temperature $T_a$ ( $T_a < T_w$ ) 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 co-efficient of thermal expansion β is reciprocal to the absolute temperature T. ( Assume the boundary-layer flow is steady and laminar. ).

$2 + \{(2 + 2) + 9\}$







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9. a) For a two dimensional flow of an incompressible, constant property fluid, derive the Navier-Stokes equation.

b) For Couette flow with zero pressure gradient, determine the velocity and temperature distribution between the two plate. ( Assume, the velocity of the moving plate is U and L is the normal distance between the two plates. ) $[7 + (4 + 4)]$

10. a) Show that for parallel flow heat exchanger

$$\varepsilon = \frac{1 - \exp[-NTU(1 + R)]}{1 + R}, \quad R = \frac{C_{min}}{C_{max}}$$ with $C_{min}$, $C_{max}$ having their usual meanings. 8

b) In a certain double pipe heat exchanger hot water flows at a rate of 5000 kg/h and gets cooled from 95°C to 65°C. At the same type 50000 kg/h of cooling water at 30°C enters the heat exchanger. The flow condition are such that overall heat transfer coefficient remains constant at 2270 W/m$^2$ K. Determine the heat transfer area required and the effectiveness, assuming two streams are in parallel flow. Assume for both the streams $C_p = 4.2$ kJ/kg K. 7

11. a) 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 the 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.

b) 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 temperature at the interface of the material of the furnace wall is 500°C. The thermal conductivity of the refractory and insulating material are 2 and 0.2 W/mK respectively. The combined coefficient of heat transfer by convection and radiation between the gases and inside refractory surface is 200 $W/m^2K$ and between outside surface and atmosphere is 40 $W/m^2K$. Find

i) The required thickness of eah 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 $kW/m^2$.

7 + 8