

Name :

Roll No. :

Invigilator's Signature :

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2012

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) Unit of thermal diffusivity is

- | | |
|--------------------------|----------------------------|
| a) m/s^2 | b) m^2/s^2 |
| c) m^2/s | d) m^3/s^2 |

ii) Thermal conductivity is highest for

- | | |
|----------|--------|
| a) Cu | b) Ag |
| c) Steel | d) Al. |

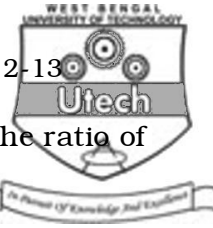
iii) The temperature variation in Lumped heat capacity analysis is

- | | |
|---------------------|---------------------------|
| a) linear with time | b) quadratic with time |
| c) cubic with time | d) exponential with time. |

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- iv) Characteristic length in Biot number is the ratio of
- volume of solid to its surface area
 - surface area to perimeter of the solid
 - perimeter to surface area of solid
 - none of these.
- v) Effectiveness of a fin of uniform cross-section will be high if
- k is less
 - P is less
 - h is less
 - A is large.
- vi) Expression for the critical radius of insulation for sphere is
- $r_c = k/h$
 - $r_c = 2k/h$
 - $r_c = 3k/h$
 - $r_c = 4k/h$.
- vii) For free convection, Nusselt number is a function of
- Prandtl and Grashoff numbers
 - Reynolds and Grashoff numbers
 - Grashoff number only
 - Reynolds and Prandtl numbers.
- viii) Thermal conductivity of pure metal with rise in temperature
- Decreases
 - Increases
 - Remains same
 - None of these.
- ix) LMTD of counter flow heat exchanger as compared to parallel flow heat exchanger for a given heat transfer will be
- More
 - Same
 - Less
 - Unpredictable.

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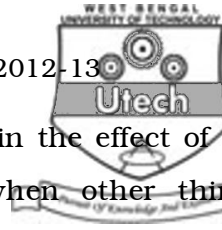


- x) The velocity profile for fully developed laminar flow in a tube is
- | | |
|---------------|----------------|
| a) Linear | b) Exponential |
| c) Hyperbolic | d) Parabolic. |

GROUP – B**(Short Answer Type Questions)**Answer any *three* of the following. $3 \times 5 = 15$

2. Derive one dimensional heat conduction equation in Cartesian co-ordinates.
3. (i) Define efficiency and effectiveness of a fin and show expressions for these for an infinitely long fin. How effectiveness of a fin can be increased ?
- (ii) What is thermal resistance of a fin ? Write down expression for thermal resistance of an infinitely long fin. $3 + 2$
4. a) Define solid angle and explain Lambert's cosine law. Explain a perfect grey body.
- b) A grey body has an emissivity of 0.35 and is at a temperature of 550 K. If the body is opaque, calculate its reflectivity for a black body radiation coming from a 550 K source. $3 + 2$

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5. In forced convection through a pipe explain the effect of the following on heat transfer coefficient, when other things remain unchanged :

- (i) The fluid velocity is doubled
- (ii) The diameter of the pipe is doubled
- (iii) The thermal conductivity is doubled.

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6. Sketch the boundary layer development of a flow over a flat plate and explain the significance of the boundary layer.

GROUP – C

(Long Answer Type Questions)

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

7. a) What is the physical significance of thermal diffusivity of a metal ?
- b) Consider a plane composite wall that is composed of two materials whose conductivities are $K_1 = 0.1 \text{ W/m K}$ and $K_2 = 0.04 \text{ W/m K}$ and thickness $L_1 = 1 \text{ cm}$ and $L_2 = 2 \text{ cm}$. The contact resistance at the interface between the two materials is known to be $0.3 \text{ m}^2\text{K/W}$. The material 1 adjoins a fluid at 200°C for which $h = 10 \text{ W/m}^2\text{K}$ and material 2 adjoins a fluid at 40°C for which $h = 20 \text{ W/m}^2\text{K}$.

Find :

- (i) The rate of heat transfer through the composite wall
- (ii) What is the temperature drop at the interface of two materials ?

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- c) A plane wall is made by fire clay brick. The wall thickness $L = 300$ mm, the temperature of wall surface $T_1 = 1550^\circ\text{C}$ and $T_2 = 50^\circ\text{C}$. Thermal conductivity of brick $K = 0.96 (1 + 0.0008T)$ W/m $^\circ\text{C}$. Calculate and represent graphically the temperature distribution through wall. 2 + 6 + 7

8. a) Derive the expression of rate of heat transfer between the cold and hot fluids in terms of overall heat transfer coefficient, heat exchanger area and LMDT for a parallel flow heat transfer.
- b) What advantage does the effectiveness of NTU method have over the LMDT method ?
- c) Hot oil with capacity rate of 2500 W/K flows through a double pipe heat exchanger. It enters at 360°C and leaves at 300°C . Cold fluid enters at 30°C and leaves at 200°C . If the overall heat transfer coefficient is $800 \text{ W/m}^2\text{K}$, determine the heat exchanger area required for
- (i) parallel flow
- (ii) counter flow. 6 + 3 + 6

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9. a) Using a linear velocity profile $\frac{u}{u_{\infty}} = \frac{y}{\delta}$

For flow over flat plate, obtain an expression for boundary layer thickness as a function of x .

- b) Air at 20°C and at atmospheric pressure flows over a flat plate at a velocity of 1.8 m/sec. If the length of the plate is 2.2 m and is maintained at 100°C, Calculate using exact method (Blasius solution)

- (i) thickness of hydrodynamic boundary layer
- (ii) average heat transfer coefficient
- (iii) heat transfer rate from the plate.

Take properties of air as : $\rho = 1.06 \text{ kg/m}^3$,
 $K = 0.02894 \text{ W/m.K}$, $\nu = 18.97 \times 10^{-6} \text{ m}^2/\text{s}$.
 $C_p = 1.005 \text{ kJ/kg}$, $P_r = 0.696$. 7 + 8

10. 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 unfinned surface, A_f = area of the finned surface. η_f = fin efficiency and $\theta_0 = T_0 - T_{\infty}$. 7

- b) One end of a long rod is inserted into a furnace while the other projects into ambient air. Under steady state the temperature of the rod is measured at two points 75 mm apart and found to be 125°C and 88.5°C, respectively, while the ambient temperature is 20°C. If the rod is 25 mm in diameter and h is 23.36 W/m²K find the thermal conductivity of the rod material. 8

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11. a) State and prove the Kirchhoff's law of radiation.
- b) Two parallel, infinite gray surfaces are maintained at temperatures of 127°C and 227°C respectively. If the temperature of the hot surface is increased to 327°C by what factor is the net radiation exchange per unit area increased ? Assume the emissivities of cooler and hotter surfaces to be 0.9 and 0.7 respectively. 7 + 8
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