Name : ....

Roll No. : ....

Invigilator's Signature : ....

CS/M.TECH(CHE)/SEM-1/CHE-01/2011-12

2011

ADVANCED 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.

Answer any ***five*** *questions selecting at least* ***one*** *from each Group.*

Symbols bear usual significance if otherwise mentioned.

GROUP – A

1. a) Obtain an analytical expression for temperature distribution in a plane wall uniform reference temperature t_1 and t_2 at x_1 and x_2 respectively and a thermal conductivity varies linearly with temperature $k = k_0(1 + \beta t)$. Discuss the nature of temperature curve for positive and negative values of β. 5

b) An infinite slab of 20 cm thickness and thermal conductivity 20 W/mK separates two fluids having temperature 35°C and 25°C respectively. The heat transfer coefficient on the hot fluid side is 25 W/m^2K and that on the cold fluid side is 50 W/m^2K. If the heat generation rate in the slab is at uniform rate of 6 k W/m^3, set up an expression for the temperature distribution in the slab. Also determine maximum temperature in the slab and its location. 9

2. a) Heat is flowing along a bar of circular cross-section with diameter d between two thermal reservoir A at temperature t_1 and reservoir B at temperature t_2. The bar has a length l. The system will also be subjected to convective heat loss (assume heat transfer coefficient to be h) from the bar to the surrounding at temperature t_a. Work out an expression for the heat loss to surrounding for the system. 8

b) Water pipes are to be buried underground in a wet soil ($\alpha = 2 \cdot 78 \times 10^{-3} \mathrm{m^2/h}$) which is initially at 5°C. The soil surface temperature suddenly drops to –10°C and remains for 12 h. Calculate the minimum depth at which the pipes be laid if the surrounding soil temperature is to remain above 0°C. 6

GROUP – B

3. Derive the differential energy equation for thermal boundary layer during fluid flow past a flat surface. State clearly the assumptions taken to derive the expression. Show from Pohlhausen solution of energy equation for the above-mentioned situation that

$$\frac{\delta_1}{x} = \frac{5 \cdot 0}{\sqrt{\mathrm{Re}_x}} \text{ when } pr = 1$$ 6 + 2 + 6

4. a) A fluid is flowing through a tube of radius R in laminar regime. The maximum velocity of the fluid is held at the centre of the tube to be $V_{\max}$. If heat flux through the tube is constant then determine the steady state temperature distribution equation in the tube cross-section. 8

   b) A hot plate of 3 cm × 5 cm area at 200°C is exposed to still air at 30°C temperature. Determine the heat transfer rate when smaller side is held vertical and when larger side of the plate is held vertical.

   The appropriate correlation for the convection coefficient is $Nu = 0 \cdot 6(Gr \times Pr)^{0 \cdot 25}$ 6

   Use the following thermo-physical property for air :

   $\rho = 0 \cdot 91 \text{ kg/m}^3$; $C_\rho = 1 \cdot 008 \text{ kJ/kg K}$;

   $\mu = 22 \cdot 65 \times 10^{-6}$ Pa-s; k = 0·033 W/mK

GROUP – C

5. a) Why logarithmic mean temperature difference is used to determine overall heat transfer coefficient of heat exchanger ? Why temperature correction factor is required for multi-pass shell-tube heat exchanger ? Discuss the rating and sizing problem of heat exchanger design. 3 + 2 + 4

   b) Derive a relation between the effectiveness and number of transfer unit for a counterflow heat exchanger. 5

6. a) Determine a relation showing how bubble diameter generated during nucleate boiling situation is dependent on the surface tension of the boiling liquid under consideration. 6

   b) Saturated steam at atmospheric pressure condenses on the outer surface of the vertical tube of length 1 m and outer diameter 75 mm. The tube wall is maintained at a uniform surface temperature of 40°C by the flow of cooling water inside the tube. Estimate the steam condensation rate and heat transfer rate to the tube. What water flow will result in a 5°C temperature difference of water between the outlet and inlet of pipe ?

Also calculate the flow Reynolds number to check the assumption of laminar flow conditions.

(Pure water property data given at relevant temperature $\lambda = 2258 \cdot 7$ kJ/kg, $\rho = 977 \cdot 8$ kg/m^3,

k = 2·43 kJ/m-h-°C, $\mu = 4 \cdot 06 \times 10^{-4}$ kg/m-s). 8

GROUP – D

7. a) Using the definition of radiosity and irradiation prove that radiant energy interchange between two gray bodies is given by the relation

$$\frac{A_1 \sigma_b \left(T_1^4 - T_2^4\right)}{\left(1-\varepsilon_1\right)/\varepsilon_1 + 1/F_{12} + \left(1-\varepsilon_2\right)/\varepsilon_2 \times \left(A_1 / A_2\right)}$$

The notations have their usual significance. 7

b) Two diffuse surfaces, a small disk of area A_1, and a large disk of area A_2, are parallel to each other and directly opposed, *i.e.* a line joining their centres is normal to both the surfaces. The large disk has a radius R and is located at a height L from the smaller disk. Obtain an expression of view factor of small disk with respect to large disk. 7

8. a) State Lambert's cosine law of radiation and prove that for a unit surface intensity of normal radiation is $\frac{1}{\pi}$ time the emissive power. 2 + 6

b) A radiation measuring instrument detects all emissions occurring between 0·6 μ and 4·5 μ but is unaffected by frequencies outside the range. What fraction of total emission from a black surface will be detected for emitting surface temperature of 2500 K ? The pertinent data from radiation table is listed below :

$\lambda t\ (\mu K)$	1400	1600	11000	11500
$F_{0-\lambda}$	0·0078	0·0197	0·932	0·94

6

Error Function Table

$$erf\ (\ x\ ) = \frac{2}{\sqrt{\pi}} \int_0^x \ e^{-t^2} \mathrm{d}t$$

x	Hundredths digit of x: 0	1	2	3	4	5	6	7	8	9
0.0	0.00000	0.01128	0.02256	0.03384	0.04511	0.05637	0.06762	0.07886	0.09008	0.10128
0.1	0.11246	0.12362	0.13476	0.14587	0.15695	0.16800	0.17901	0.18999	0.20094	0.21184
0.2	0.22270	0.23352	0.24430	0.25502	0.26570	0.27633	0.28690	0.29742	0.30788	0.31828
0.3	0.32863	0.33891	0.34913	0.35928	0.36936	0.37938	0.38933	0.39921	0.40901	0.41874
0.4	0.42839	0.43797	0.44747	0.45689	0.46623	0.47548	0.48466	0.49375	0.50275	0.51167
0.5	0.52050	0.52924	0.53790	0.54646	0.55494	0.56332	0.57162	0.57982	0.58792	0.59594
0.6	0.60386	0.61168	0.61941	0.62705	0.63459	0.64203	0.64938	0.65663	0.66378	0.67084
0.7	0.67780	0.68467	0.69143	0.69810	0.70468	0.71116	0.71754	0.72382	0.73001	0.73610
0.8	0.74210	0.74800	0.75381	0.75952	0.76514	0.77067	0.77610	0.78144	0.78669	0.79184
0.9	0.79691	0.80188	0.80677	0.81156	0.81627	0.82089	0.82542	0.82987	0.83423	0.83851
1.0	0.84270	0.84681	0.85084	0.85478	0.85865	0.86244	0.86614	0.86977	0.87333	0.87680
1.1	0.88021	0.88353	0.88679	0.88997	0.89308	0.89612	0.89910	0.90200	0.90484	0.90761
1.2	0.91031	0.91296	0.91553	0.91805	0.92051	0.92290	0.92524	0.92751	0.92973	0.93190
1.3	0.93401	0.93606	0.93807	0.94002	0.94191	0.94376	0.94556	0.94731	0.94902	0.95067
1.4	0.95229	0.95385	0.95538	0.95686	0.95830	0.95970	0.96105	0.96237	0.96365	0.96490
1.5	0.96611	0.96728	0.96841	0.96952	0.97059	0.97162	0.97263	0.97360	0.97455	0.97546
1.6	0.97635	0.97721	0.97804	0.97884	0.97962	0.98038	0.98110	0.98181	0.98249	0.98315
1.7	0.98379	0.98441	0.98500	0.98558	0.98613	0.98667	0.98719	0.98769	0.98817	0.98864
1.8	0.98909	0.98952	0.98994	0.99035	0.99074	0.99111	0.99147	0.99182	0.99216	0.99248
1.9	0.99279	0.99309	0.99338	0.99366	0.99392	0.99418	0.99443	0.99466	0.99489	0.99511
2.0	0.99532	0.99552	0.99572	0.99591	0.99609	0.99626	0.99642	0.99658	0.99673	0.99688
2.1	0.99702	0.99715	0.99728	0.99741	0.99753	0.99764	0.99775	0.99785	0.99795	0.99805
2.2	0.99814	0.99822	0.99831	0.99839	0.99846	0.99854	0.99861	0.99867	0.99874	0.99880
2.3	0.99886	0.99891	0.99897	0.99902	0.99906	0.99911	0.99915	0.99920	0.99924	0.99928
2.4	0.99931	0.99935	0.99938	0.99941	0.99944	0.99947	0.99950	0.99952	0.99955	0.99957
2.5	0.99959	0.99961	0.99963	0.99965	0.99967	0.99969	0.99971	0.99972	0.99974	0.99975
2.6	0.99976	0.99978	0.99979	0.99980	0.99981	0.99982	0.99983	0.99984	0.99985	0.99986
2.7	0.99987	0.99987	0.99988	0.99989	0.99989	0.99990	0.99991	0.99991	0.99992	0.99992
2.8	0.99992	0.99993	0.99993	0.99994	0.99994	0.99994	0.99995	0.99995	0.99995	0.99996
2.9	0.99996	0.99996	0.99996	0.99997	0.99997	0.99997	0.99997	0.99997	0.99997	0.99998
3.0	0.99998	0.99998	0.99998	0.99998	0.99998	0.99998	0.99998	0.99999	0.99999	0.99999
3.1	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999	0.99999
3.2	0.99999	0.99999	0.99999	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000

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