Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

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10MTP21

Second Semester M.Tech. Degree Examination, June/July 2013
Advanced Heat Transfer

Time: 3 hrs. Max. Marks:100

Note: ***1. Answer any FIVE full questions.***
2. Use of heat-transfer data handbook, steam tables are permitted.

1 a. Consider a solid sphere of radius R where energy is generated at a constant rate of q_6 W/m^3, when the boundary surface at r = R is exposed to convective heat transfer with a heat transfer coefficient h W/m^2 K at a temperature of T_∞. Write down an expression for one dimensional steady state temperature distribution T(r) and the heat flux q(r) explaining each term of the equation. **(10 Marks)**

b. Show that the steady state temperature distribution T and the radial heat flow rate Q in a hallow sphere in a region $a \le r \le b$ when the boundary surfaces at r = a and r = b are kept at a uniform temperature T_a and T_b respectively may be written as:

$$T = \frac{1}{(b-a)}\left[aT_a\left(\frac{b}{r}-1\right) + bT_b\left(1-\frac{a}{r}\right)\right] \quad \text{and} \quad Q = \frac{(T_a - T_b)4\pi kab}{(b-a)}.$$ **(10 Marks)**

2 a. One end of a long rod is inserted into a furnace while the other end 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 the convective heat transfer coefficient is 23.36 W/m^2 K, find the thermal conductivity of the rod material. **(10 Marks)**

b. Solve the two dimensional steady state heat conduction equation with heat generation, $\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = -10(x^2 + y^2 + 10)$, for a square plate for which all the four sides x = 0, y = 0, x = 3 and y = 3 are maintained at a temperature u = 0. Assume grid size along both x and y direction as $\Delta x = \Delta y = 1$ and use the numerical procedure of Gauss Siedel iteration for solution of linear equation system. **(10 Marks)**

3 a. State the following laws as applied to Thermal Radiation:
i) Stefan Boltzmann law ii) Planck's Distribution law
iii) Wien's Displacement law iv) Kirchoff's law. **(08 Marks)**

b. Show that the radiation shape factor for a small area dA_1 to a circular disc A_2 of diameter D which are parallel to each other with a normal distance L between them is given by

$$F_{dA_1-A_2} = \frac{D^2}{4L^2 + D^2}$$ **(06 Marks)**

c. Two very large parallel plates with emissivities 0.3 and 0.8 exchange heat. Find the percentage reduction in heat transfer when a polished aluminium radiation shield with emissivity of 0.4 is placed between the plates. **(06 Marks)**

4 a. What do you mean by hydrodynamic and thermal boundary layers? How does the ratio between hydrodynamic and thermal boundary layer thickness vary with Prandtl number? **(10 Marks)**

b. Air at 20°C is flowing along a heated flat plate at 134°C at a velocity of 3 m/sec. The plate is 2 m long and 1.5 cm wide. Calculate
   i) the thickness of hydrodynamic boundary layer and the skin-friction coefficient at 40 cm from the leading edge of the plate.
   ii) the local heat transfer coefficient at $x = 0.4$ m. Kinetic viscosity of the air at mean temperature of 77°C is 20.92×10^{-6} m^2/sec. **(10 Marks)**

5 a. Using dimensional analysis, obtain a relationship between the Nusselt number, Reynolds number and Prandtl number for forced convection heat transfer. **(10 Marks)**

b. A metal plate 0.609 m high forms the vertical wall of an oven and is at a temperature of 171°C. Within the over air is at a temperature of 93.4°C and atmospheric pressure. Assume that natural convection conditions hold good near the plate for the present case, The Nusselt number may be expressed as $N_u = 0.548\ (Gr.\ Pr.)^{0.25}$. Find the mean heat transfer coefficient and the heat taken by air per second per meter width. Air properties at mean temperature of 132.2°C. $K = 33.2\times10^{-6}$ kW/m K; $\mu = 0.232\times10^{-4}$ kg/m.sec ; $C_p = 1.005$ kJ/kg K.
Assume air as an ideal gas with R = 0.287 kJ/kg-K. **(10 Marks)**

6 a. Differentiate between free convection and forced convection. **(08 Marks)**

b. Explain significance of (i) Re No. (ii) Nusselt No. **(04 Marks)**

c. For natural convection heat transfer from a horizontal circular cylinder, the following correlation may be used for Rayleigh number (Ra_D) in the range of 10^5 and 10^{12}

$$\overline{Nu_D} = \left[0.60 + \frac{0.387Ra_D^{1/6}}{\left[1 + (0.559/Pr)^{9/16}\right]^{8/27}}\right]^2$$

Determine the rate of heat ton per metre length from a 0.1 m outer diameter steam pipe placed horizontally in ambient air at 30°C. The pipe has an outside wall temperature of 170°C and an emissivity of 0.9. **(08 Marks)**

7 a. Explain the different regimes of pool boiling with the help of appropriate boiling curve. **(10 Marks)**

b. Explain film condensation and dropwise condensation. **(04 Marks)**

c. Saturated steam at 120°C condenses on a 2 cm OD vertical tube which is 20 cm long. The tube wall is maintained at a temperature of 119°C. Calculate the average heat transfer coefficient. The fluid properties may be assumed as:
   Saturation pressure $P_{sat} = 1.985$ bar, Density, $\rho = 943$ kg/m^3
   Latent heat of condensation, $h_{fg} = 2202.2$ kJ/kg , $k_{water} = 0.686$ W/m K.
   $\mu = 271\times10^{-6}$ kg/(m-s) **(06 Marks)**

8 a. Obtain an expression for the effectiveness of a parallel flow heat exchanger in terms of NTU and the heat capacity ratio R. **(10 Marks)**

b. A heat exchanger is required to cool 55,000 kg/hr of alcohol from 66°C to 40°C using 40,000 kg/hr of water entering at 5°C. Calculate (i) exit temperature of water and (ii) surface area required for parallel flow and counter flow heat exchangers.
   $U = 580$ W/m^2 K, C_p(Alcohol) = 3760 J/Kg K and C_p(Water) = 4180 J/kg K. **(10 Marks)**

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