Heat Transfer (ME30005), End Semester Examination, November 2011, time-3 hours, Full Marks-100

Q1.

(a) A 3 mm diameter and 5 m long electric wire is tightly wrapped with a 2 mm thick plastic cover whose thermal conductivity is 0.15 W/m.K. Electrical measurements indicate that a current of 10 A passes through the wire and there is a voltage drop of 8 V along the wire. If the insulated wire is exposed to a medium at $T_\infty = 30^o C$ with a heat transfer coefficient of 12 W/m^2.K, determine the temperature of the interface of the wire and the plastic cover at steady state. Also determine whether doubling the thickness of the plastic cover will increase or decrease this interface temperature.

(b) A metallic sphere of radius R is initially at a temperature T_i and is allowed to be heated by exchange of energy with its surroundings, solely in the mode of radiation. The ambient temperature is T_∞. What will be the time required to elevate the temperature of the sphere to a final value of T_f? Assume blackbody radiation exchange. Also assume that temperature within the sphere is spatially uniform at any instant of time. All temperatures are given in absolute scale.

[10 + 10 = 20 marks]

Q2.

(a) Consider thermally fully developed flow through a circular tube, with constant wall heat flux boundary condition. The velocity profile is both axially and radially uniform. Derive the value of Nusselt number. State the assumptions you make.

(b) Steam condenses along the wall of a cooled vertical flat plate. Because of some interesting interfacial phenomenon at the wall, the no-slip boundary condition is violated and is replaced by the following boundary condition at the wall: $u = l\frac{\partial u}{\partial y}$, where y is the wall-outward normal direction. Derive an expression for the local condensate layer thickness as a function of the pertinent relevant physical parameters, following Nusselt's theoretical considerations. State the assumptions you make.

[15 + 15 = 30 marks]

Q3.

(a)A fluid with viscosity = 0.001 Pa.s, density = 1000 kg/m^3, specific heat at constant pressure = 1 kJ/kg.K, and thermal conductivity = 100 W/m.K, flows over a heated vertical flat plate. The thermal boundary layer thickness is of the order of 1 mm. By executing a scaling (order of magnitude) analysis, determine the order of magnitude of the thickness of an wall-adjacent imaginary layer in which viscous force balances the buoyancy force. State the assumptions you make.

(b)In a counterflow heat exchanger,
$\dot{m}_h = 1kg/s, C_{ph} = 4kJ/kg.K, \dot{m}_c = 2kg/s, C_{pc} = 2kJ/kg.K$.

(i) If the inlet temperature of the hot fluid is $100^{o}C$ and exit temperature of the cold fluid is $60^{o}C$, sketch the temperature profiles of the heat exchanger qualitatively and justify the nature of your plots mathematically. Also, what is the LMTD of the heat exchanger?

(ii) If the inlet temperature of the cold fluid is $20^{o}C$, then, what are the values of number of transfer units and effectiveness of the heat exchanger? Do not use any $\varepsilon - NTU$ relationship formula.

[15 + 13 =28 marks]

Q4.

(a)A surface with area of 2 cm^2 emits radiation as a blackbody at T = 1000 K. If $\dot{Q}_1$ be the rate of radiation emitted into a solid angle subtended by $0 \le \phi \le 2\pi$; and $0 \le \theta \le \pi/6$; and $\dot{Q}_2$ be the radiation emitted into the entire hemispherical space, then obtain $\dot{Q}_1/\dot{Q}_2$.

(b) Two very large parallel plates with emissivities 0.3 and 0.8 exchange radiative energy. Determine the percentage reduction in radiative energy exchange when a plate of emissivity 0.04 is placed in between them.

(c) The surfaces in a cubical space are numbered as follows: top (1), bottom (2), left (3), right (4), front (5), back (6). If the view factor $F_{12} = 0.2$, what is the value of F_{16}? (Hint: use symmetry).

[8 + 8 + 6 = 22 marks]