Heat Transfer (ME30005), Mid Semester Examination, September 2011, time-2 hours, Full Marks-60

Q1.

Mention whether the following statements are TRUE or FALSE, with precise justifications in favour of your statement (No credit for correct statement with a wrong justification):

(i) An electrical cable should be designed to have an insulation of thickness greater than the critical thickness of insulation.

(ii) Lumped parameter analysis may be used even if Bi is large, for some special cases.

(iii) Given that a large block of Cu (assumed to be semi infinite solid) at 25°C is touched by a person with temperature of the fingers as 35°C. Under these circumstances, the order of magnitude of the depth within the block upto which the heating effect of the finger will be felt at a time t is given by $\sqrt{\alpha t}$, where α is thermal diffusivity of the palm tissue.

(iv) The product of stress tensor and rate of deformation tensor is quantified as viscous dissipation in the energy equation.

(v) Thermal boundary layer equation can be valid even if Reynolds number is small.

10 Marks

Q2.

(a) State the assumptions under which the following expressions/ formulae are valid (symbols have usual meaning):

(i) $$q'' = \frac{kA(T_1 - T_2)}{L}$$

(ii) $$q'' = \sigma\varepsilon\left(T^4 - T_\infty^4\right)$$

(iii) $$-k\left.\frac{\partial T}{\partial y}\right|_{wall} = h\left(T_{wall} - T_\infty\right)$$

(iv) $$\rho c_p \frac{DT}{Dt} = \nabla.(k\nabla T)$$

(v) $$St = \frac{C_f}{2}$$

10 Marks

Q3.

A thin metallic wire of thermal conductivity k, diameter D, and length $2L$ is annealed by passing an electrical current through the wire to induce a uniform volumetric heat generation q'''. The ambient air around the wire is at a temperature T_∞, while the ends of the wire at $x = \pm L$ are also maintained at T_∞. Heat transfer from the wire to the air is characterized by the convection coefficient h. Obtain an expression for the steady-state temperature distribution $T(x)$ along the wire.

14 Marks

Q4.

An infinitely long plate of thickness $2L$, thermal conductivity k, specific heat c, initially at a uniform temperature T_i, is suddenly heated on both surfaces by a convection process (T_∞, h).

(i) Write the governing differential equation for heat conduction. State the assumptions you make.

(ii) Prescribe appropriate boundary conditions and initial conditions.

(iii) If $T = f(x)g(t)$, then show that

$$\int_0^L f_n f_m dx = 0 \qquad \text{if m} \neq \text{m}$$

$$\neq 0 \qquad \text{if m} = \text{n}$$

[8 Marks]

Q5.

Consider a heated flat plate of axial length L and width b. Fluid is forced to flow over the plate with a free stream velocity of U_∞ and temperature of T_∞. In an effort to have an enhanced thermal performance, small holes are drilled in the plate and fluid is injected into the boundary layer through those holes with a uniform velocity v_w. The plate boundary is subjected to a uniform temperature, T_w. All properties of the fluid are taken as constants.

(a) Derive the momentum integral equation and energy integral equation corresponding to the above situation.

(b) Assuming a non-dimensional velocity profile of the form: $\dfrac{u}{U_\infty} = \dfrac{y}{\delta}$, derive an ordinary differential equation depicting the growth of the hydrodynamic boundary layer (δ) as a function of x. Solve that equation in δ for the special case in the limit $v_w \to 0$.

(c) Assuming a non-dimensional temperature profile in the thermal boundary layer of the same form as that of the non-dimensional velocity profile in the hydrodynamic boundary layer, derive an expression for the growth of the thermal boundary layer as a function of x, assuming the momentum diffusivity of fluid to be negligible as compared to its thermal diffusivity. Hence, derive an expression for the local Nusselt number, for the special case in the limit $v_w \to 0$.

[18 marks]