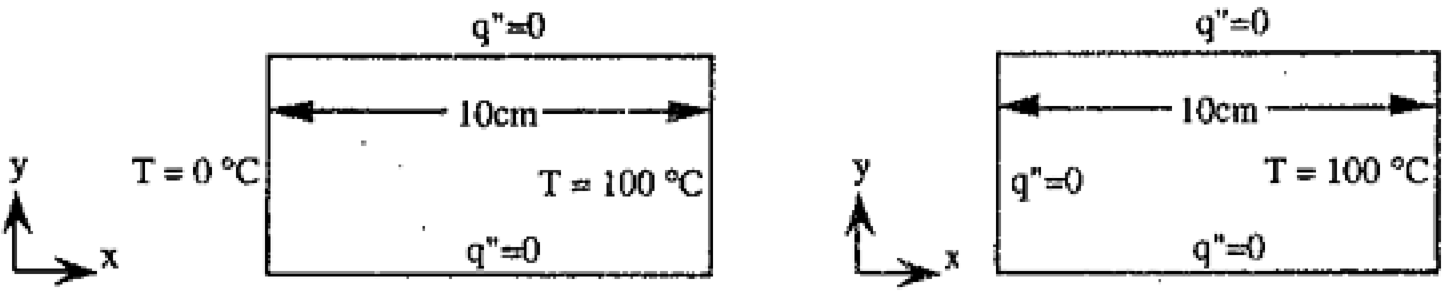
1. According to the boundary conditions specified in Fig. 1, the temperature fields in these two cases are in steady state. Draw the isotherms or write down the solution. (No calculation required) (10%)



(a) (b) Fig. 1

2. (a) Consider a layer of insulation which is installed around a circular pipe (see Fig. 2). The outer radius of the pipe is r_i and the outer radius of the insulation is r_o. Prove that the critical radius of insulation is $r_o = k / h$ and it has maximum heat loss. (15%) Hint: Critical radius of insulation here means that when $r_o = k / h$, it has maximum or minimum heat loss.

(b) A pipe (12-cm-diameter) need insulating by using asbestos [k = 0.17 W/m°C]. The pipe will be exposed to room air at 20 °C with h = 3.0 W/m^2. What will you do to avoid the critical thickness of insulation? (5%)

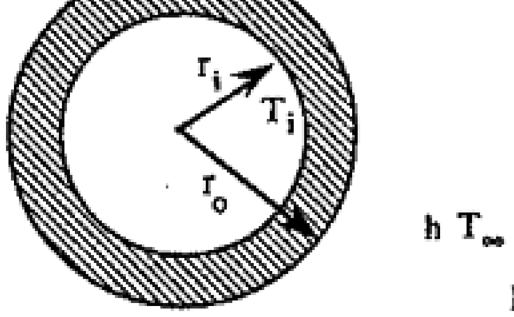


Fig. 2

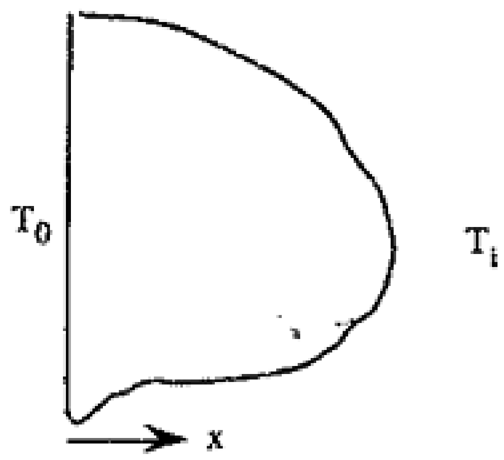


Fig. 3

3. Consider the semi-infinite solid shown in Fig. 3 maintained at some initial temperature T_i. The surface temperature is suddenly lowered and maintain at a temperature T_0. Derive an expression of the temperature distribution for this transient problem. (15%)

Hint: (1) $\eta = a\, x^b t^c$, (2) $erf(\eta) = \dfrac{2}{\sqrt{\pi}} \int_0^{\eta} e^{-u^2} du$

4. A steady uniform flow, U_∞, passes over a flat plate. The fluid, whose Pr is larger than one, is at uniform temperature T_∞ and the plate has a uniform temperature, T_w, starting at $x = x_0$.

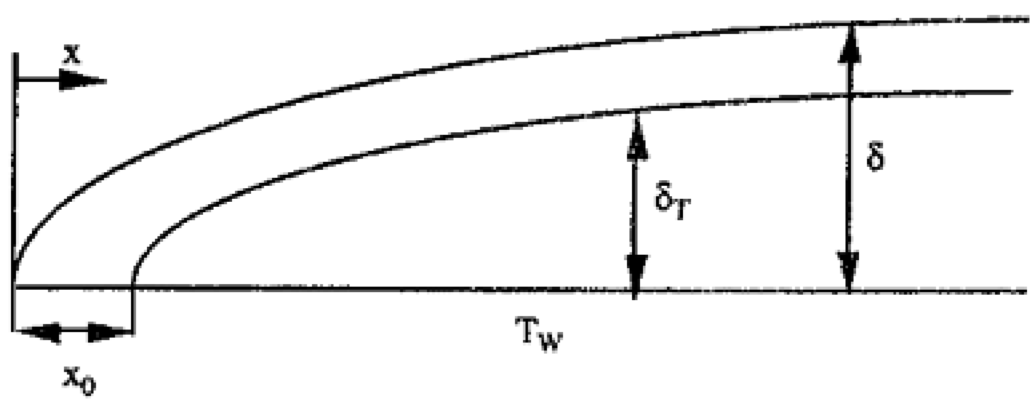


Fig. 4

(1) Prove that the integral equation of momentum is $\dfrac{d}{dx}\left[\int_0^{\delta} \rho u (U_\infty - u) dy\right] = \mu \dfrac{\partial u}{\partial y}\Big|_{y=0}$ (10%)

(2) Prove the integral equation of energy is $\frac{d}{dx}\int_0^{\delta_T} u(T_\infty - T)dy = \alpha \frac{\partial T}{\partial y}\Big|_{y=0}$ (10%)

(3) Assuming the velocity distribution as $\frac{u}{U_\infty} = C_1 + C_2\frac{y}{\delta}$, derive the expression of δ/x. (10%)

(4) Assuming the velocity distribution as $\frac{T-T_w}{T_\infty - T_w} = C_3 + C_4\frac{y}{\delta_T}$, derive the expression of δ_T/x. (10%)

5. Answer the following questions. (15%)

(1) To choose a heat-insulated material, which property will you use , thermal conductivity or thermal diffusivity? Why?

(2) What's the difference between Bi and Nu?

(3) What's physical meaning of Pr? How is it related to momentum and thermal boundary layer thicknesses?