Heat transfer

Supervised Practical Work no3
Forced and free convection

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Exercise 1: Flat plate in parallel flow

Air at atmospheric pressure and ambient temperature ($20°C$) is in parallel flow over the top surface of a flat plate that is heated to a uniform temperature of $40°C$. The plate have a length of $0.2\,m$ (in the flow direction) and a width of $0.1\,m$. The free stream velocity of the air is $v_\infty = 10\,ms^{-1}$. For gases and liquids with $0.6 < Pr < 50$ the local Nussel number can be expressed as

$$\text{for} \quad Re < 5\times10^5 \quad \text{(laminar flow)}, \qquad Nu_x = 0.332 Re_x^{1/2} Pr^{1/3} \tag{1}$$

$$\text{for} \quad 5\times10^5 < Re < 10^7 \quad \text{(turbulent flow)}, \qquad Nu_x = 0.0296 Re_x^{4/5} Pr^{1/3} \tag{2}$$

$$\tag{3}$$

For the air, the heat capacity at constant pressure, the thermal conductivity and the dynamic viscosity are respectively $c_p = 1005\,Jkg^{-1}K^{-1}$, $k = 24\times10^{-3}\,Wm^{-1}K^{-1}$ and $\mu = 18.5\times10^{-6}\,Pa.s$.

1. Calculate the global Reynolds number and deduced the flow regime.
2. Express the local heat transfer coefficient $h(x)$.
3. What is the rate of the heat transfer from the plate to the air?
4. If the free stream velocity of the air is double, what is the rate of heat transfer?
5. Same question when the free stream velocity is multiply by 10 what is the rate of heat transfer?

Exercise 2: Glass screen situated in fireplace opening

A glass-door firescreen (figure 1), used to reduce exfiltration of room air through a chimney, has a height of $0.71\,m$ and a width of $1.02\,m$ and reaches a temperature of $232°C$. If the room temperature is $23°C$, estimate the convection heat rate from the fireplace to the room. For the air let us consider the heat conduction $k = 33.8\times10^{-3}\,Wm^{-1}K^{-1}$, the kinematic viscosity $\nu = 26.4\times10^{-6}\,m^2s^{-1}$, the thermal diffusivity $a = 38.3\times10^{-6}\,m^2s^{-1}$ and thermal expansion $\alpha = 0.0025\,K^{-1}$.

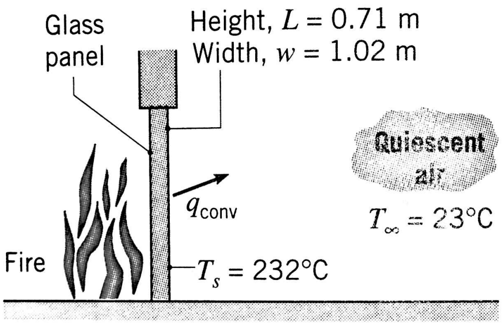

Figure 1: Schematic view of the firescreen

For a vertical plate, the correlation proposed by Churchill and Chu could be used in this case:

$$Nu_L = \left(0.825 + \frac{0.387 Ra_L^{1/6}}{(1 + [0.492/Pr]^{9/16})^{8/27}}\right)^2 \tag{4}$$

This correlation is valid when the turbulent flow is obtained for Rayleigh number higher than 10^9.

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