EXAM II

HEAT TRANSFER

June 3, 2014

I. Explain the following terms: (15%)

(1) Prandtl number

(2) Laminer sublayer

(3) Bulk fluid temperature

(4) Natural convection

(5) Similarity conditions

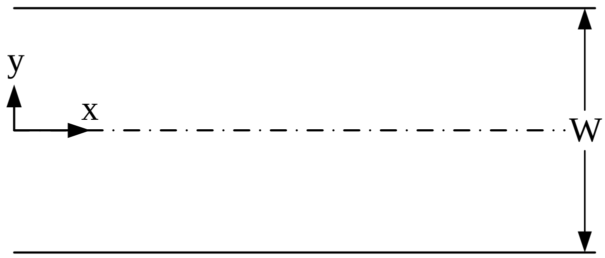
II. 簡答題: (33%)

1. In what conditions is there no convection heat transfer?
2. What's relationship between Prandtl number and boundary layer thickness?
3. For a thermal flow in a tube, why is the bulk fluid temperature used instead of the average temperature?
4. In a convection-heat-transfer problem, in what condition can the effect of free convection be neglected?
5. For a thermal flow in a tube does $\partial T/\partial z = 0$ mean "fully-developed" for the temperature field? Why? or why not?
6. If the fluid is melted material, which boundary layer thickness is larger, the momentum or thermal boundary layer thickness? Why?
7. Is the boundary layer theory useful for a flow field of low Reynolds number? Why? or Why not?
8. What problem will be created when the viscous term is neglected in the momentum equation?
9. How do people judge whether natural convection is important in a convection problem?
10. In natural convection, the density is changed with temperature. This would make the problem of natural convection very difficult to solve. How do Boussineq propose to make the problem easier?
11. For a uniform flow of liquid metal passing a flat plate, it can be assumed that $u = U_\infty$. Why?

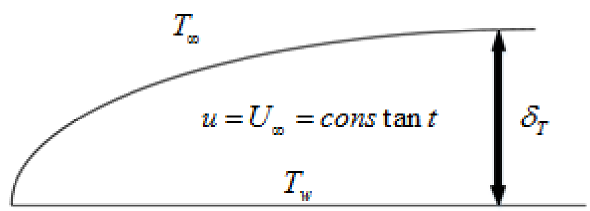
III. Consider the heat transfer in a parallel plate duct with constant wall heat flux.

(a) Prove $\frac{\partial T}{\partial z} = \frac{\partial T_w}{\partial z} = \frac{\partial T_m}{\partial z} = \text{constant}$, where T_m is the bulk fluid temperature and T_w is the wall temperature.(7%)

(b) Derive the expression of Nu for the case of constant wall heat flux in the fully-developed region if it is assumed that $u = U_\infty$ and $v = 0$ (10%)



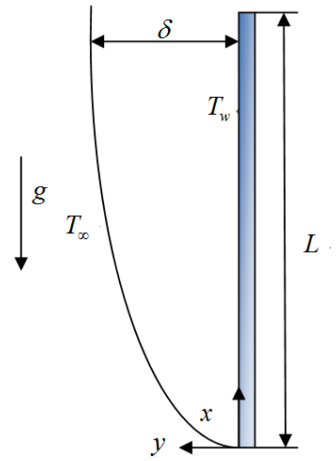
IV. A steady uniform flow, whose velocity is U_∞, passes over a flat plate. The fluid is at uniform temperature T_∞ and the temperature of the plate is T_w. Assume that $u = U_\infty = \text{constant}$ and $v = 0$.



Derive the integral equation of energy.

$$\frac{d}{dx}\int_0^{\delta_t} U_\infty (T_\infty - T)\, dy = \alpha \left.\frac{\partial T}{\partial y}\right)_w \quad (12\%)$$

V. A vertical plate with a uniform temperature T_w in an environment at temperature T_∞. Assume Pr = 1.



(a) In the boundary layer, what are the two forces, which determine the velocity prefile in the layer? How do these two forces determine the velocity profile? (6%)

(b) Derive the momentum equation in the boundary layer,

$$\rho\left(u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right)=\rho\beta g\left(T-T_\infty\right)+\mu\frac{\partial^2 u}{\partial y^2},$$

From the equation,

$$\rho\left(u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right)=-\frac{dp}{dx}-\rho g+\mu\frac{\partial^2 u}{\partial y^2}\quad(8\%)$$

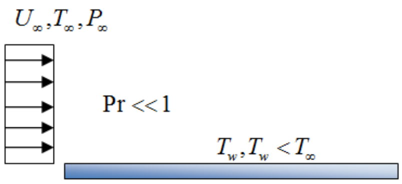
Hint: $\beta=\frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_p$

(c) Derive the floolwing dimensionless equation,

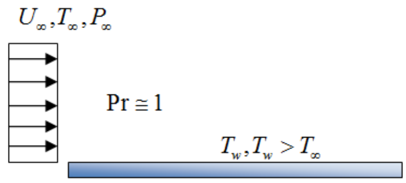
$$u^*\frac{\partial u^*}{\partial x^*}+v^*\frac{\partial u^*}{\partial y^*}=\theta+\frac{1}{\sqrt{Gr}}\left(\frac{L^2}{\delta^2}\right)\frac{\partial^2 u^*}{\partial y^{*2}}\ (9\%)$$

VI. 根據下列流動狀況來手繪流體邊界層、熱邊界層以及溫度、速度分布圖。(20%)

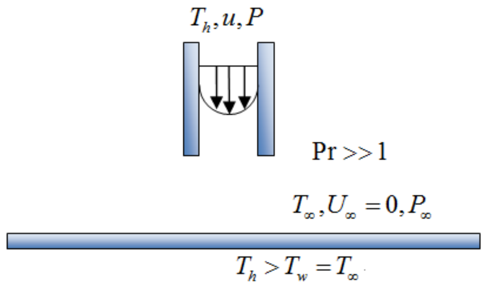
(a)



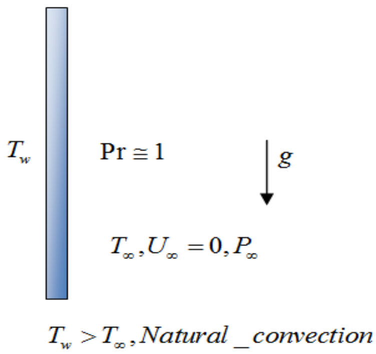
(b)



(c)



(d)



(e)