(1) Compressible Flow (15%)

For low-speed flow the stagnation pressure (P_0) can be computed from Bernoulli's incompressible equation $P_0 = P + \rho V^2/2$ (P : static pressure; ρ : density; V: velocity). For high-speed perfect-gas flow, the following equation ($\gamma = c_P/c_v$; Ma : Mach number)

$$\frac{P_0}{P} = \left[1 + \frac{1}{2}(\gamma - 1)Ma^2\right]^{\gamma/(\gamma-1)}$$

should be used. Verify that the above equation can be expanded into a series as follows (5%):

$$P_0 = P + \frac{1}{2}\rho V^2\left(1 + \frac{1}{4}Ma^2 + \frac{2-\gamma}{24}Ma^4 + \cdots\right)$$

Suppose that a pitot tube measures the difference P_0- P in subsonic flow ($\gamma = 1.4$) and that the velocity is computed from the approximation $V^2 = 2(P_0 - P)/\rho_0$. At what Mach number will this calculation be in error by 2 percent? (10%) The relationship between ρ_0 and ρ can be determined readily according to an isentropic process.

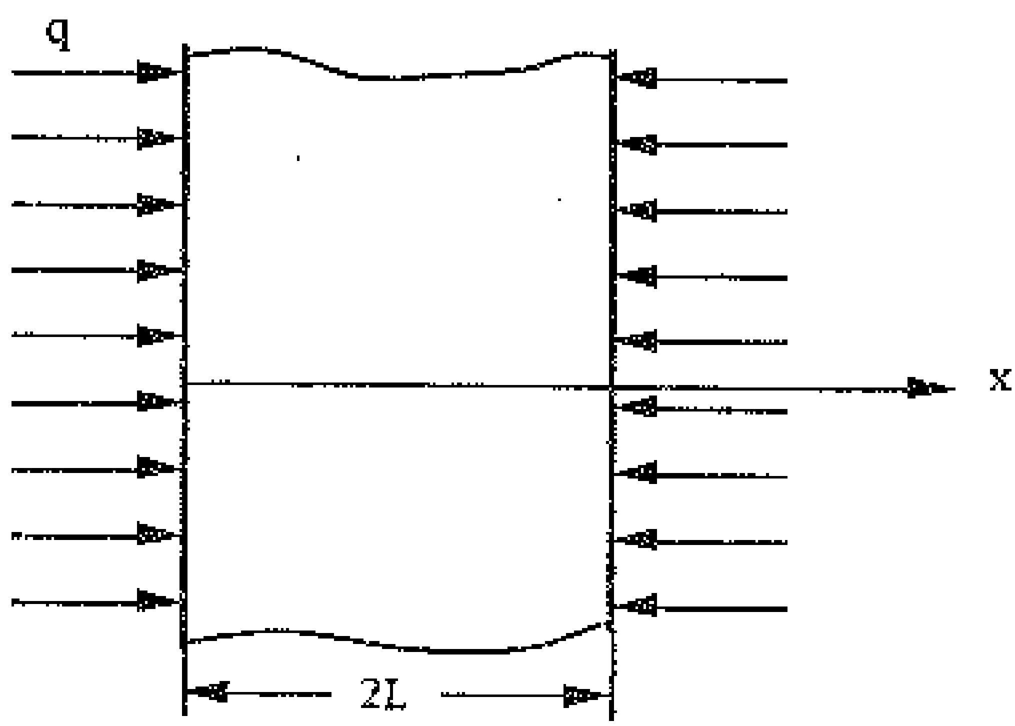
國立清華大學命題紙

八十四學年度 動力機械研究 所 甲 組碩士班研究生入學考試

科目 熱流學(II) 科號 1801 共 3 頁第 2 頁 *請在試卷【答案卷】內作答

(2) Heat Conduction (20%)

The constant heat flux (q) is applied to the both surfaces of a flat plate of thickness 2L. The initial temperature of the plate is T_∞.



Please give the formulation of the problem (10%) and find the unsteady temperature of the plate (10%).

(3) Radiation (15%)

Explain the greenhouse effect (15%).

(4) Potential Flow

Please explain the physical meanings of each term on the right hand side of the equation for stream function

$$\psi = U_\infty r \sin\theta - \frac{\lambda \sin\theta}{r} - K \ln r + \text{const}$$

If we choose $\lambda = U_\infty a^2$ and let const=K ln a, then the stream function becomes

$$\frac{\psi}{U_\infty a} = \sin\theta \left(\frac{r}{a} - \frac{1}{\frac{r}{a}}\right) - \left(\frac{K}{U_\infty a}\right) \ln \frac{r}{a}$$

Please draw the stream lines if the value of $\frac{K}{U_\infty a}$ is

(a) 0 (b) 1.0 (c) 2.0 (d) 3.0. (20%)

(5) Forced and Natural Convection

(a) Let x be the longitudinal distance from the leading edge. The critical Reynolds number based on x, $Re_c = Ux_c/\nu = 5\times10^5$ marking the laminar-turbulent transition. For a uniform air flow over a plane wall, what will be the range of the critical length x_c for the transition if U = 2-10 m/s. (6%)

(b) Similarly, the critical Grashof number $Gr_c = g\beta\,\Delta T\, x_c^3/\nu^2 = 10^9$ indicates the laminar-turbulent transition for a natural convection air flow near a heated vertical plate with a temperature difference ΔT from the ambient temperature. Please give the range of the critical length x_c for the transition if ΔT= 20-100 K. (6%)

(ν=0.15 cm^2/s, α=0.21 cm^2/s, and $g\beta/\nu\alpha$ = 107 cm^{-3} K^{-1})

(6) Internal Convection

Starting with continuity, momentum and energy equations, please prove that the value of Nusselt number is Nu=48/11 for a hydrodynamically and thermally fully developed flow in a uniformly heated long circular pipe. (18%)