1. A homogeneous, 4-ft-wide, 8-ft-long rectangular gate weighing 800 lb is held in place by a horizontal flexible cable as shown in Fig. 1. Water acts against the gate which is hinged at point A. Friction in the hinge is negligible. Determine the tension in the cable. (10%)

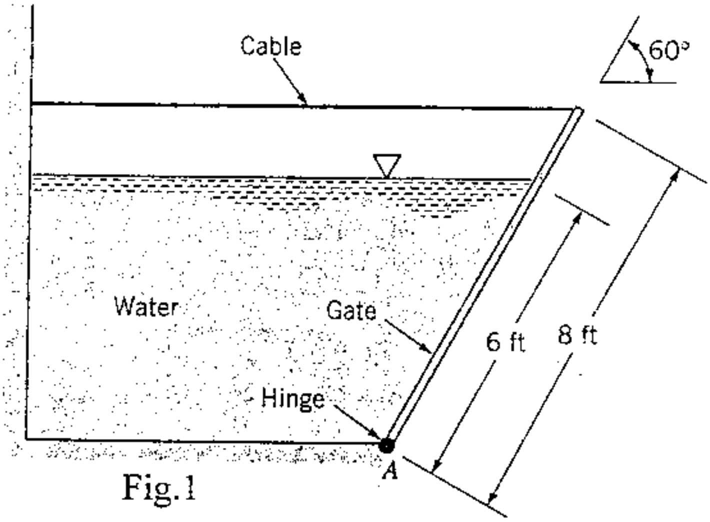

Fig.1

2. Water flows through the pipe contraction shown in Fig. 2. For the given 0.2-m difference in the manometer level, determine the flowrate as a function of the diameter of the small pipe, D. (10%)

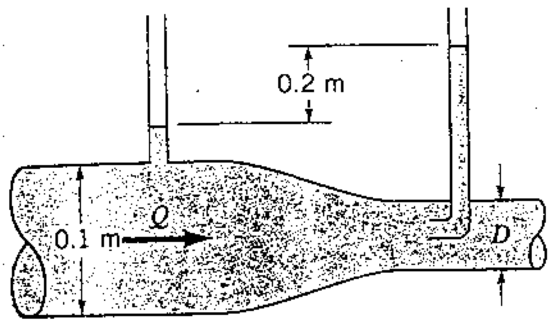

Fig.2

(3)When a fluid flows into a round pipe as shown in Fig.3, viscous effects may cause the velocity profile to change from a uniform profile to change from a uniform profile $(V = V_0\hat{i})$ at the entrance of the pipe to a parabolic profile $\{V = 2V_0[1-(r/R)^2]\hat{i}\}$ at $x = l$. Velocity profiles for various values of x are as indictated in the figure. Use this graph to show that a fluid particle moving along the centerline $(r = 0)$ experiences an acceleration, but a particle close to the edge of the pipe $(r \approx R)$ experiences a deceleration. Does a particle traveling along the line $r = 0.5R$ experience an acceleration or deceleration, or both? Explain.(15%)

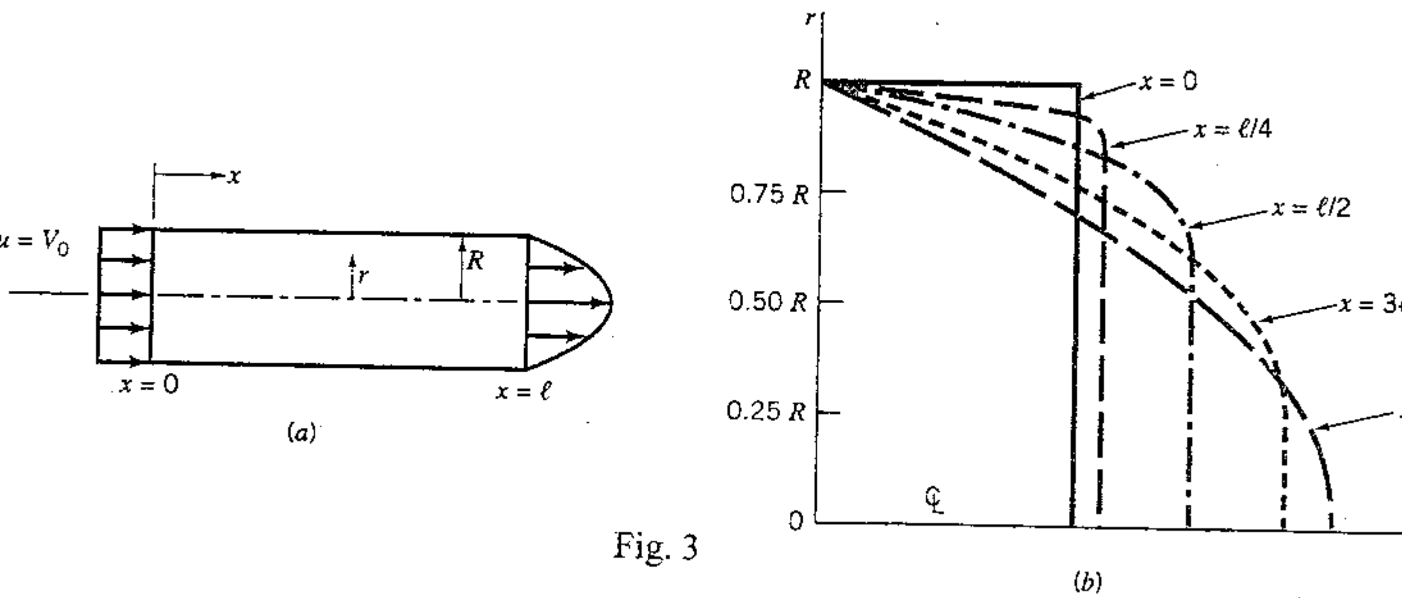

Fig. 3

(4)A hypodermic syringe (Fig. 4)is used to apply a vaccine .If the plunger is moved forward at the steady rate of 20mm/s and if vaccine leaks past. the plunger at 0.1 of the volume flowrate out the needle opening, calculate the average velocity of the needle exit flow. The inside diameters of the syringe and the needle are 20mm and 0.7mm.(15%)

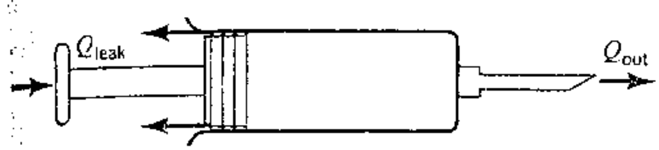

Fig.4

5. [題組] Water's density $\rho = 1{,}000(\text{kg/m}^3)$, dynamic viscosity $\mu = 1.12\times10^{-3}(\text{Ns/m}^2)$.

Fig.5-A 是一艘 16~17 世紀荷蘭船的模型。圖中箭頭所指爲船側之"leeboards"(下風板)。其作用爲側風航行時可防止船的側漂。而 Fig.5-B 則是其外形與五個斷面的形狀。請回答下列與 leeboards 有關之問題。

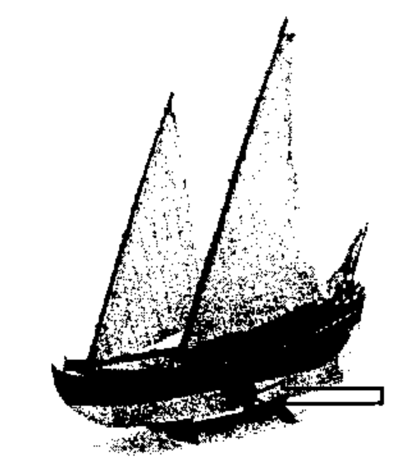

Fig. 5-A

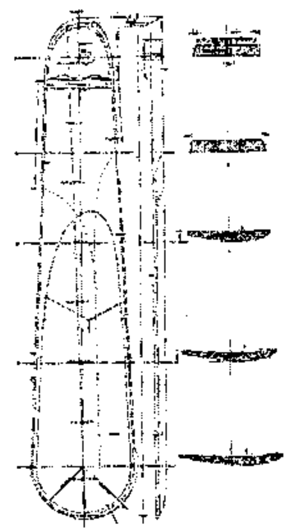

Fig. 5-B

(1) Let a leeboard's average chord length be c, and its length be h. Leeboards are usually fixed. If the ship's speed is U, a leeboard will generate a lift force $\mathscr{L}$ normal to the inflow direction. We know that $\mathscr{L}$ is a function of c, h, U, the fluid density ρ, and fluid viscosity μ.

(a) Let ρ, U, and c as the repeating variables, use dimensional analysis method to determine three PI terms for experiments. (10%)

(b) Explain these PI terms' meanings. (5%)

(2) For study on the lift force, the PI term containing $\mathscr{L}$ can be viewed as a function of the other two PI terms. Usually a model test in a lab has to satisfy similarity requirements (or modeling laws). What are the similarity requirements in a leeboard model experiment? (5%)

(3) In Fig. 5-B, the shape of cross sections can be divided into two groups: i and j belong to the first group and the second group includes k, l, and m.

(a) If the inflow's attack angle is small and same for all of them, which group of the cross section shape can generate more lift? Why? (3%)

(b) To roughly estimate the total lift force, we assume that a leeboard is a rectangular thin smooth plate with uniform cross section k. Its lift coefficient $C_L=2\pi(\alpha+0.023)/(1+2/A)$ where A is aspect ratio and α is attack angle (in radius). Calculate the lift force a leeboard can generate when U=2.51m/s, c=30cm, h=1.5m, and attack angle is +1 degree. (7%)

(4) Now we assume that leeboards are thin, flat, and smooth plates with the dimension and inflow velocity as described in (3)(b). But its attack angle is 0°. If the boundary layer velocity profile is $u/U=(y/\delta)^{1/7}$, the wall shear stress $\tau_w=0.0225\rho U^2(\nu/U\delta)^{1/4}$ where ν is kinematic viscosity. We also know that $\tau_w=\rho U^2(d\theta/dx)$ where θ is boundary layer momentum thickness and x is distance along the flow (chord) direction.

(a) Plot typical velocity profiles of laminar and turbulent boundary layers to compare them. (2%) Is a leeboard's boundar layer laminar or turbulent? Why? (3%)

(b) Derive boudary layer thickness δ as a function of x. (5%)

(c) Derive the wall shear stress τ_w as a function of x (5%)

(d) Obtain the frictional drag force $\mathscr{D}_f$ of a leeboard by integrating $(h\tau_w)$ along x. (5%)