編號： 87 系所：機械工程學系甲組 科目：流體力學

本試題是否可以使用計算機： ☑可使用 ， □不可使用 （請命題老師勾選）

Problem 1 (30%)

(A) Please write down the Bernoulli equation and describe the basic assumptions used in its derivation. (5%)

(B) Based on the Bernoulli equation, what kind of instrument is used to measure local fluid speed? Please explain its principle and show the basic equation for determining fluid speed. How can we use this instrument to determine the flow direction? (10%)

(C) Based on the Bernoulli equation, what kinds of instrument can be used to measure fluid flow rates in pipes? Please show two examples, explain their principle, and write down the basic equation for determining fluid flow rates in pipes. In real applications, this basic equation derived from Bernoulli equation needs modification to obtain an accurate flow rate. What is the reason for such a modification? (10%)

(D) Express the Bernoulli equation to have the units of length in each of the terms. Use this expression to describe the energy line and the hydraulic line. (5%)

Problem 2 (20%)

(A) Express the material derivative (or substantial derivative) operator. Please use this operator to explain the relationship between Eulerian and Lagrangian concepts, and give some physical examples to further explain unsteady effects and convective effects in flows. (10%)

(B) Write down the general form of the Reynolds transport theorem. Please describe its physical interpretation and its relationship (similarities and dissimilarities) to the material derivative. (10%)

（背面仍有題目,請繼續作答）

Problem 3 (15 %)

Suppose that a large amount of energy E is suddenly released in air (a point explosion). Experimental evidence suggests that the radius R of the high-pressure blast wave depends on time t, as well as the energy E and the density of the ambient air ρ.

(a) Using Pi theorem, find the equation for R as a function of t, ρ, and E.

(b) Show that the speed of the wave front $V \sim R^{-3/2}$.

(c) If the pressure rise Δp across the blast wave also is known to depend only on t, ρ, and E, show that $\Delta p \sim R^{-3}$.

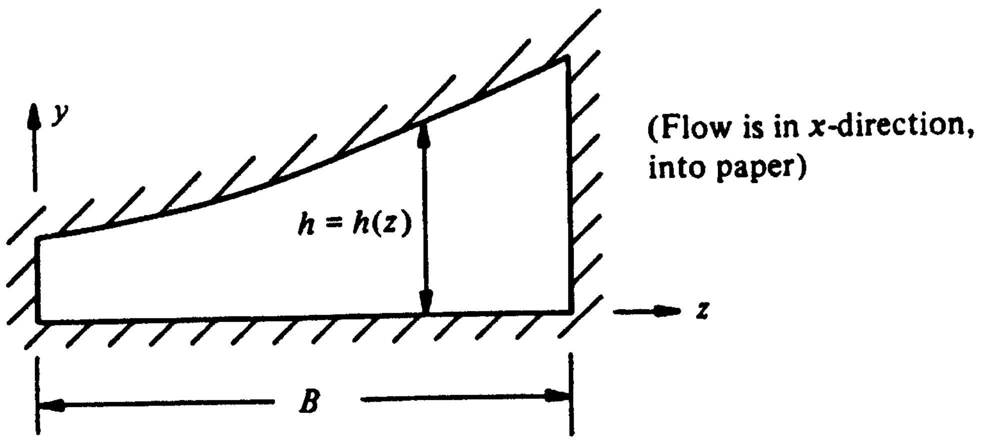
Problem 4 (20 %)

(a) Show that the mean velocity V for incompressible laminar flow between two parallel plates separated by a small distance h due to a pressure gradient $\Delta p/l$ is

$$V = \frac{\Delta p h^2}{12\mu l}.$$

To earn full credits, clearly explain your assumptions and derivations.

(b) Consider now the flow in a channel for which h is not constant but varies with z, the distance transverse to the flow (see the sketch below). The flow is in the x-direction. If the channel width B in the z-direction is large compared with $h = h(z)$, then $\partial^2 u/\partial z^2$ may be neglected compared with $\partial^2 u/\partial y^2$. Also neglect the effects of the vertical sides. Write an integral expression for the discharge (i.e., volumetric flowrate) Q as a function of Δp, μ, l, h, and B, assuming that $B \gg h$.



(c) Finally, consider an eccentric plunger of radius R working in a cylinder with mean radial clearance h_0 and eccentricity ϵh_0 (see the sketch on the next page). The variable radial clearance is then $h \approx h_0[1 + \epsilon \cos(z/R)]$, assuming $\epsilon \ll 1$. Letting Q_ϵ represent the leakage flow in a direction normal to the paper past the eccentric plunger, *due to pressure only*, and Q_0 represent the same leakage with the plunger centered, derive an expression for Q_ϵ/Q_0 as a function of ϵ only.

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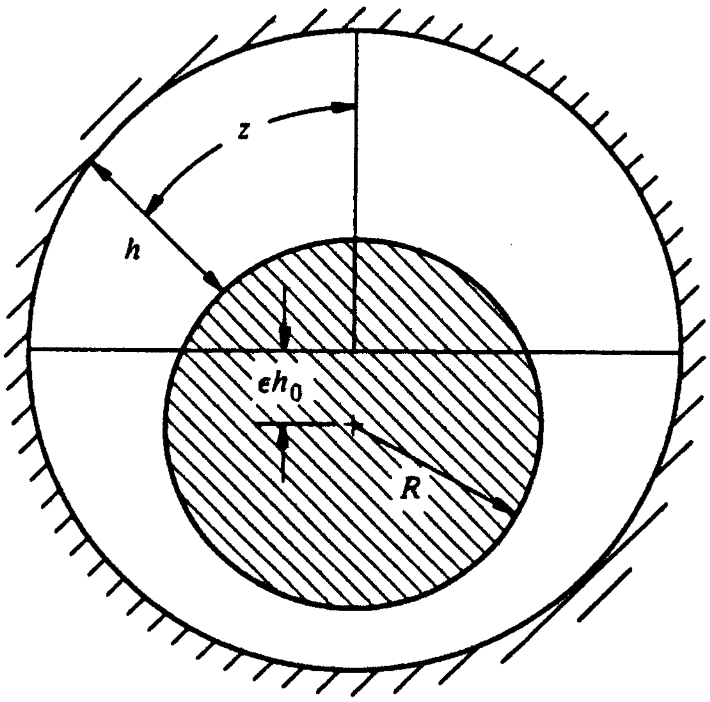

Problem 5 (15 %)

A laminar boundary layer forms on a *porous* flat surface that removes fluid from the main flow at a constant velocity v_0 (i.e., $v = -v_0$ at $y = 0$), as shown below. Using the approximate integral method and assuming that $u/U_0 = f(y/\delta)$ only (with $f = 1$ for $y > \delta$), show that

$$c_f = \frac{2\tau_w}{\rho U_0^2} = 2a\frac{d\delta}{dx} + 2\frac{v_0}{U_0},$$

where

$$a = \int_0^1 (f - f^2) d(y/\delta).$$