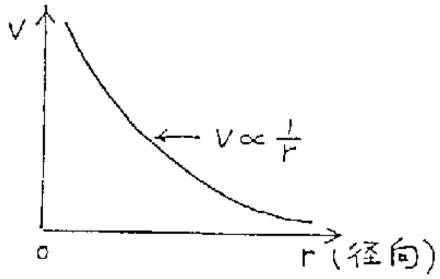
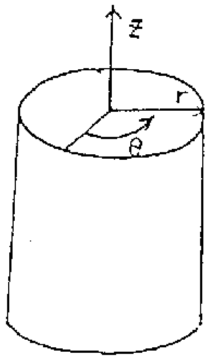
1. Potential Flow (20%)

在一盛水的圓桶中，將一根木棒插入圓桶中心開始攪動，直到圓桶中的切向(tangential)速度V（此爲惟一不爲零的速度）沿著徑向(radial)的分佈如圖所示，是與徑向成反比（除掉靠近桶壁及桶中心外）。請將水視爲非黏性不可壓縮流。試問

(1) 依據這個速度的分佈，你如何稱呼這個流場

(2) 說明靜壓(static pressure)及全壓(total pressure)在整個水面的分佈特性（沿徑向及切線方向），須附上合理之解釋





θ: 切線方向
r: 徑向

2. Fundamental Concepts (20 %)

(a) Draw the typical flow patterns for flow past a circular cylinder at $Re_c = 1$, $Re_c = 30$, and $Re_c = 2{,}000$, where $Re_c = \rho U D_1/\mu$ and D_1 the diameter of the circular cylinder. (score: 6 points)

(b) Draw the flow pattern for flow past a streamlined strut at $Re_s = 20{,}000$, where $Re_s = \rho U D_2/\mu$. (score: 2 points)

(c) Is the drag force of (a) at $Re_c = 2{,}000$ (greater than, less than, or equal to) that of (b) at $Re_s = 20{,}000$? Choose only one answer. (score: 2 points)

(d) Briefly explain your result at (c) based on the width of the wake. (score: 5 points)

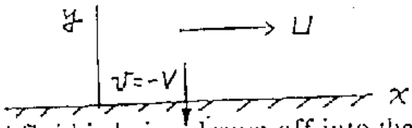
(e) Briefly define the boundary layer thickness (δ), the displacement thickness (δ*), and the momentum thickness (Θ). Also compare their order. (score: 5 points)

3. (20%)

(a) Based on the Reynolds' experiment, illustrate the three types of the pipe flow, and describe their characteristics. (5%)
(b) Draw and depict the development of the boundary layer and the velocity profiles in the entrance region, developing region, and fully-developed region in a pipe system. (10%)
(c) Based on the shear stress distribution, describe the structure of turbulent flow in fully-developed region in a pipe. (5%)

4. Boundary-Layer (20 %)

Consider a flat surface over which a steady uniform flow exists as sketched as follows.



Assume the surface is porous and fluid is being drawn off into the porous surface such that the normal component of velocity at the surface is V. If the pressure is constant and the velocity in the x-direction is a function of y only.

(a) Write down the governing equations including a continuity equation and momentum equations in the x and y directions.
(Hint: v, the velocity in the y-direction, is not zero). (score: 4 points)

(b) Write down the boundary conditions (u(x,0), v(x,0), etc.). (score: 4 points)

(c) Integrating the continuity equation to show v(x,y) is actually a constant. (score: 2 points)

(d) Momentum equations can be reduced to a single equation, write it out. (score: 3 points)

(e) Use the above momentum equation to find u(y).
(Hint: integrate the momentum equation and use the boundary conditions) (score: 5 points)

(f) If $u = U(1 - e^{-2})$, then what is the thickness of the layer which is affected by viscosity?
(Hint: $y = \delta = ?$) (score: 2 points)

5. (20%)

1) Consider the energy equation for the adiabatic flow of a perfect gas, $c_pT + V^2/2 =$ constant. In terms of the stagnation temperature T_0, c_p and $k=c_p/c_v$, determine

(a) The velocity and temperature at a position where M = 1.

(b) The highest veocity theoretically attainable in this flow. (10%)

2) Consider the supersonic flow over a wedge. Consider the three possible states: weak oblique, strong oblique and detached shocks. For each state

(a) Sketch the shock pattern, streamlines, and indicate regions of subsonic and supersonic flow.

(b) Discuss the variation in entropy, stagnation enthalpy and vorticity along a typical streamline in each of the flows.

(c) Discuss the variation in entropy, stagnation enthalpy and vorticity between two neighboring streamlines in each of the flows.

(d) Indicate the state which has the highest, second highest and smallest values of entropy on the body streamline. Explain your answer. (10%)