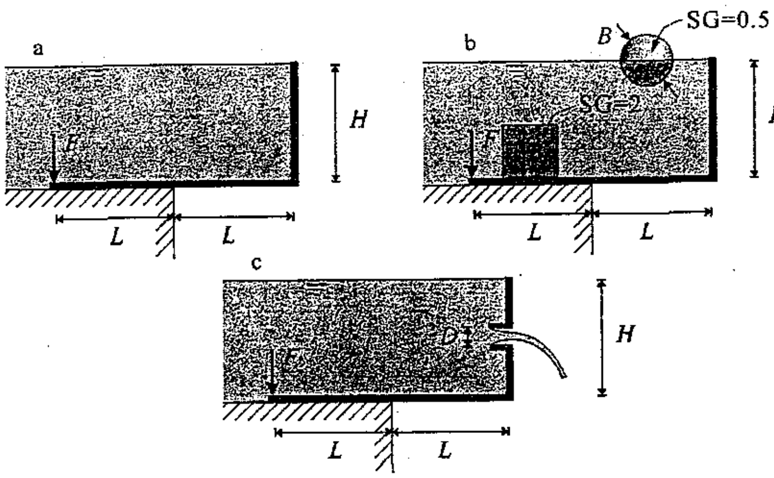


Fig. 1

**Problem 1.** A L-shaped structure retains water at the top of a dam. The width of the structure (normal to the piece of paper) is $W$. A force $F$ is needed to keep the structure from tumbling down. Assume that dimensions $W$, $H$, $L$, $B$ and $D$ are known.

a) Find $F$ when only water at rest is present (see panel a of the figure);

b) Find $F$ when a sphere floats on the water surface and a cube rests on the bottom flange of the L-shaped structure (as shown on panel b of the figure).

c) Find $F$ when water flows out through a Borda orifice of diameter $D$ (as shown on panel c).

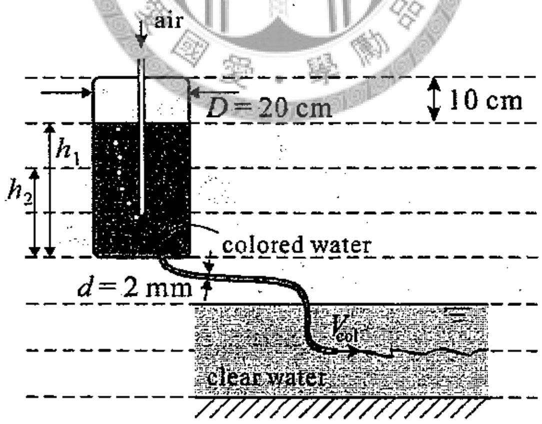


Fig. 2

**Problem 2.** To visualize water motions, colored water is introduced in a channel of clear water using a Mariotte bottle (see figure) of diameter $D$. The colored water inside the bottle is in contact with the atmosphere through a thin tube which lets air enter. Assume inviscid flow.

a) Find the velocity $V_{col}$ of the colored water at the outlet of the pipe (of diameter $d$), when the level of colored water in the bottle is equal to $h_1$.

b) Find $V_{col}$ when the level of colored water in the bottle is equal to $h_2$.

c) Find the time $t$ needed for the colored water level to drop from $h_1$ to $h_2$.

接背面

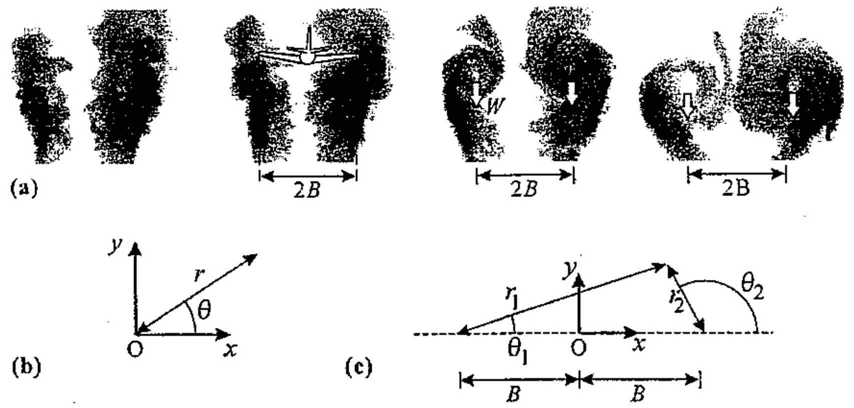


Fig. 3

**Problem 3.** Due to the passage of an airplane, two vortices of equal strength rotating in opposite directions are created, and move down at constant velocity $W$. A steady flow is seen by an observer moving with the two vortices.

a) Using the coordinates of Fig. 3c, formulate the potential $\phi$ of this steady flow.

b) Check that your potential satisfies the Laplace equation $\nabla^2\phi = 0$.

c) Find the streamfunction $\psi$ of this steady flow.

d) Draw the streamlines of this steady flow.

e) Find the maximum air pressure $p_{max}$ and indicate where this pressure occurs.

Hint: the potential for a single vortex is given in polar coordinates by $\phi(r,\theta) = \dfrac{\Gamma}{2\pi}\theta$.

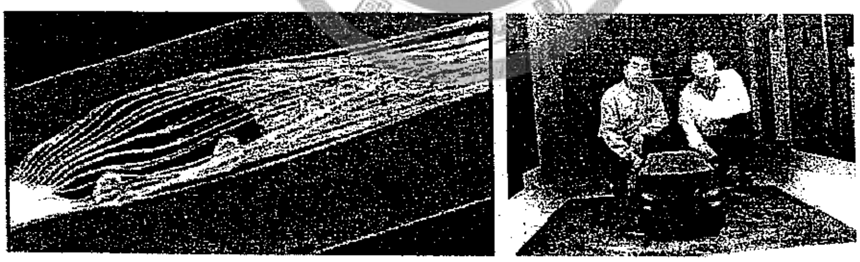

Fig. 4

**Problem 4.** The drag force $F_D$ exerted by air on a car moving at speed $V$ is given by

$$F_D = F(B, H, V, \rho, \mu)$$

where $B$ = width and $H$ = height of the car. Wind tunnel tests using air at atmospheric pressure are conducted with a car model of scale 1:3 (three times smaller than reality).

a) Find a non-dimensional relationship for $F_D$.

b) Find the model air speed $V_m$ corresponding to the real car speed $V = 100$ km/h.

c) At the speed $V_m$ found in b), the measured drag force for the car model is $F_{Dm}$ = 300 N. Find the predicted drag force $F_D$ for the real car at speed $V = 100$ km/h.

接次頁

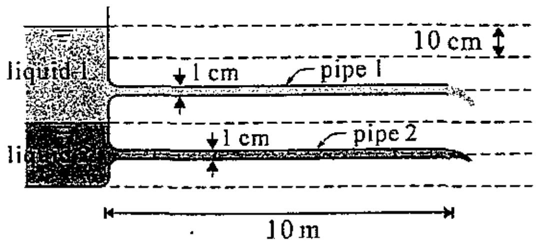


*Fig. 5*

**Problem 5.** Two liquids flow out of the same tank through two pipes as shown on the Figure above. Liquid 1 has density $\rho_1 = 1000$ kg/m$^3$ and kinematic viscosity $\nu_1 = 1\times10^{-6}$ m$^2$/s. Liquid 2 has density $\rho_2 = 2000$ kg/ m$^3$ and kinematic viscosity $\nu_2 = 1\times10^{-3}$ m$^2$/s. Assume that the flow is laminar and that the friction coefficient is

$$f = \frac{64\mu}{\rho V D}.$$

a) Find $Q_1$ = discharge of liquid 1 through pipe 1.
b) Find $Q_2$ = discharge of liquid 2 through pipe 2.
c) Calculate the Reynolds numbers $\mathrm{Re}_1$ and $\mathrm{Re}_2$ in each pipe.
d) Was it correct to assume laminar flow in pipe 1 and in pipe 2 ?
e) Derive the formula above for the laminar friction coefficient $f$.

試題隨卷繳回