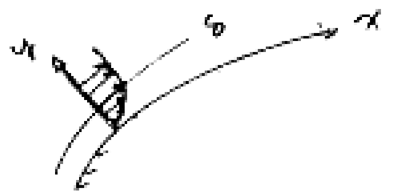
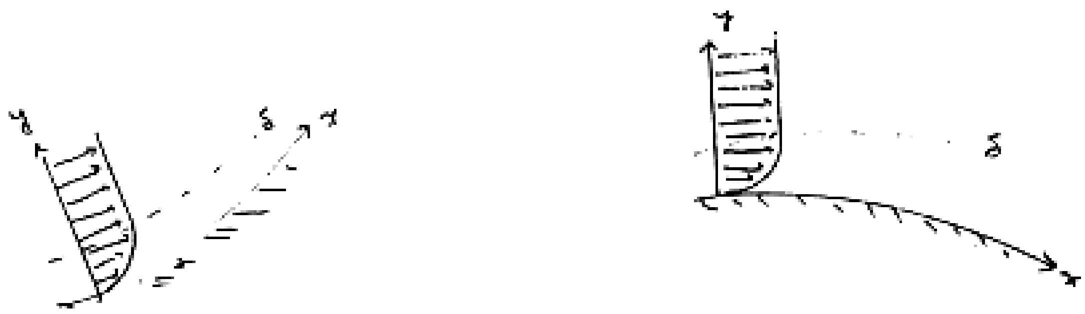
(20%) 1. Brief answer the following questions.

(a) For a boundary layer flow as shown, the pressure variation along y-direction is constant or nearly constant? Why? (5%)



(b) For the following curved surfaces shown in the schematic diagrams, indicate whether or not the boundary layer flow becomes separated flow in the down stream and explain the reason. (10%)



(c) If the laminar boundary layer flow of item (b) becomes turbulent, does the separation point move upstream or down stream? (5%)

(20%) 2. Consider the two-dimensional flow field defined by the following velocity components:

$$u = x(1 + 3t^2),\ v = y$$

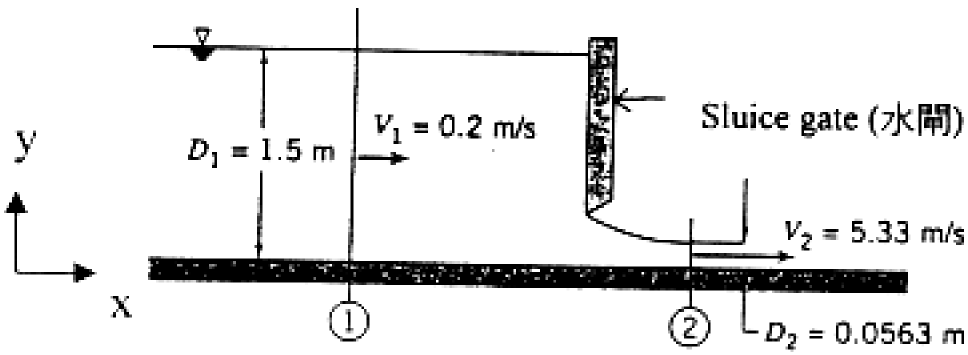
for this flow field, find the equation and draw the line of:

(a) The streamline through the point (1,1) at $t = 0$,

(b) The pathline for a particle released at the point (1,1) at $t = 0$,

(c) The streakline at $t = 0$ which passes through the point (1,1).

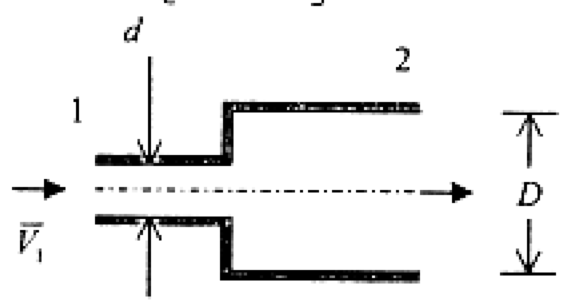
(20%) 3. Water in an open channel flows under a sluice gate as shown in the sketch. The flow is incompressible and uniform at sections ① and ②. Hydrostatic pressure distributions may be assumed at sections ① and ② because the flow streamlines are essentially straight there. Determine the magnitude and direction of the horizontal force per unit width exerted on the gate by the flow.




Hint: (1) neglect friction on channel bottom
(2) assume steady flow
(3) density of water $\rho = 999 \frac{kg}{m^3}$

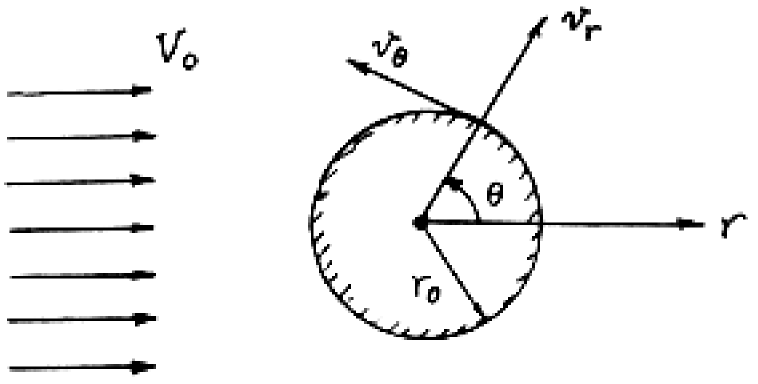
(20%) 4. Consider flow through the sudden expansion shown. If the flow is incompressible and friction is neglected, show that the pressure rise, $\Delta p = p_2 - p_1$, is given by

$$\frac{\Delta p}{\frac{1}{2}\rho \bar{V}_1^2} = 2\left(\frac{d}{D}\right)\left[1-\left(\frac{d}{D}\right)^2\right]$$



(20%) 5. A flow over a two-dimensional circular cylinder shown below is studied based on the assumption that flow is inviscid and irrotational. Hence, the flow can be represented by a velocity potential $\phi$.

$$\psi = V_0 r\left(1+\frac{r_0^2}{r^2}\right)\cos\theta$$




Note that the radius of the circular cylinder is $r_0$, and the freestream velocity $V_0$ is a constant. Find

(a) $v_r$ at $r = r_0$, $v_r$ denotes the velocity along $r$ direction; (5 points)

(b) $v_\theta$ at $r = r_0$, $v_\theta$ denotes the velocity along $\theta$ direction; (5 points)

(c) the drag force due to the presence of the circular cylinder in the flow. (10 points)