1. Consider the problem of computing the lift force of a wing flapping within air. Let L, U, Φ, f, b, μ and ρ are lift force, flight speed, stroke angle, flapping frequency, semi-span of the wing, viscosity and density of air respectively. We are interested in determining the lift force of a flapping wing. Use the dimensionless analysis to find the relevant dimensionless groups associated with the lift force of a flapping wing. (10%)

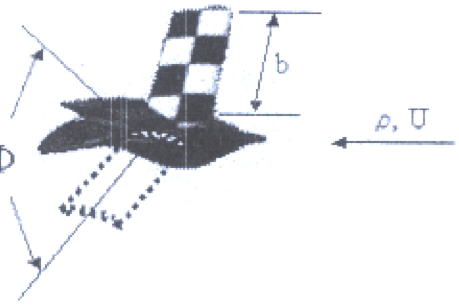

Figure 1

2 Given a velocity potential: $\phi = \frac{1}{3}x^3 + \frac{1}{2}x^2 - xy^2 - \frac{1}{2}y^2$

(i) Show that this field represents a possible incompressible, irrotational flow. (10 %)

(ii) Calculate the circulation Γ about the square enclosed by x=±2 and y=±1, shown in Figure 2. (10%)

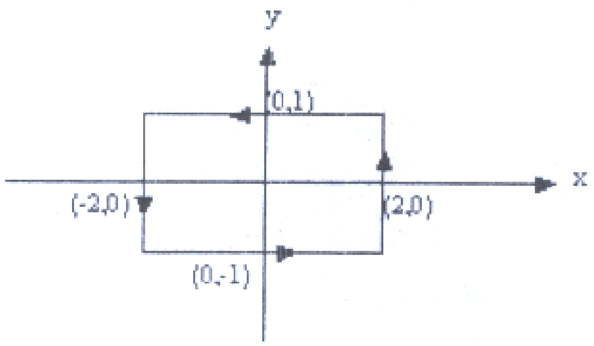

Figure 2

(iii) If the chemical concentration field is described by the expression

$c(x, y, t) = xt + 3xy$. Determine the time rate of change of the concentration of a fluid element as it passes through the point (1,1) at time t=2. (10 %)

(背面仍有題目,請繼續作答)

3 Consider a two-dimensional flow field which is formed by combining two sources of equal strength Λ. The sources are located at (0, -1) and (0, 1), as shown in Figure 3.

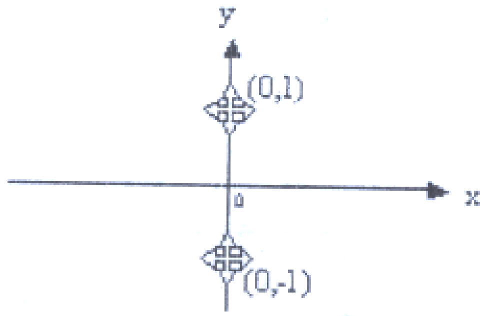

Figure 3

(i) Determine velocity potential ϕ for this combined flow field. (10%)

(ii) Locate the stagnation point in this flow field. (10%)

(iii) Determine the streamline equation passing through the stagnation point in the Cartesian coordinate. (10%)

(iv) Assume the total (or stagnation) pressure in the flow field is P_o and the density of the fluid is ρ, find the static pressure P at the point (1,0). (10%)

For this problem the velocity potential for a source flow located at the origin (0,0) can be formulated as:

$$\phi = \frac{\Lambda}{2\pi}\ln r = \frac{\Lambda}{2\pi}\ln(\sqrt{x^2+y^2})$$

4 The flow field of a cricket ball was visualized by using oil smoke techniques. From the flow visualization results shown in Figure 4, which direction (upward or downward) do you expect the cricket ball will move normal to its flight path? Give the brief reasoning for your answer.

(10%)

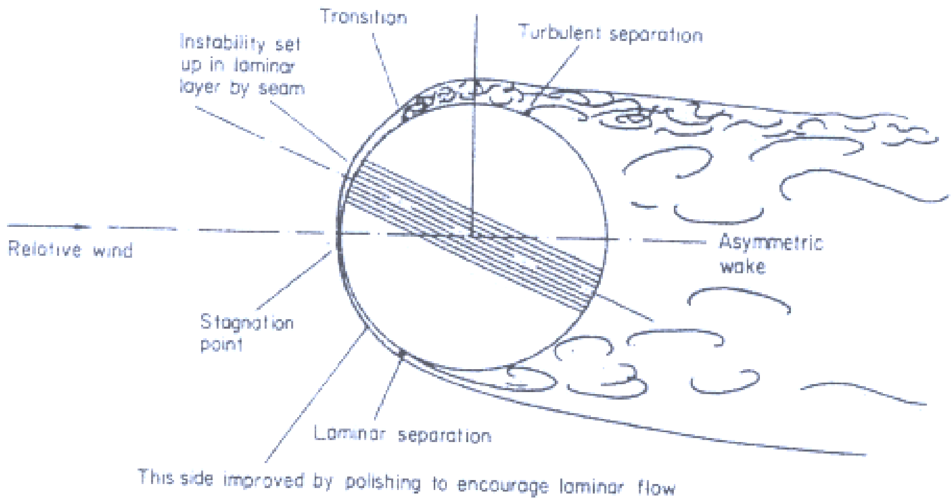

Figure 4

5. A wind stress τ_w (=constant) is exerted on the surface of a two-dimensional horizontal layer of viscous liquid in the x-direction. The liquid is within a container with solid end-walls and bottom as shown in Figure 5. Assume initially that the layer has constant depth H. Argue that a horizontal pressure gradient dp/dx must be setup within the liquid and find out the pressure gradient dp/dx in terms of τ_w and H.

(10%)

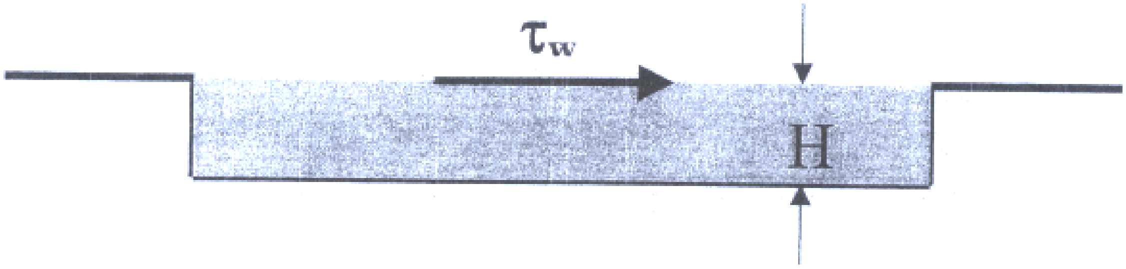

Figure 5