I. A circular cylinder of radius R in a uniform cross stream of velocity $U\infty$ with a circulation of strength Γ on it.

(a) Find the potential and stream functions for this flow field. (6%)

(b) Find the complex velocity distribution for this flow field. (6%)

(c) Show that the lift force on cylinder per unit length is $L=\rho U\infty \Gamma$ (8%)

II. An air compressor is used to pressurize an initially evacuated tank. The tank is 1 m in diameter and 2 m long. The supply line is 20 cm in diameter and conveys a flow with velocity 2 m/s . The air compressors' output pressure and temperature are constants at 350 Kpa and 30 °C. The tank temperature is keeping in constant of 20 °C.

(a) Write down the governing equation and the related initial conditions of this problem. (10%)

(b) Calculate the time required for the tank pressure to reach 110 Kpa. (10%)

Note: The gas constant for air is **R=287.05 N • m/Kg • K**

3. (20%)

A cylinder of diameter, D (m), is observed to oscillate with frequency f (cycles/sec) when held in a uniform flow of U (m/s).

(a) Write down the equations of motion. (4%)

(b) Perform a dimensional analysis on the equations of motion. (6%) What are the dimensionless parameters involved in this problem? (4%) Explain their physical meaning.(6%)

4. Consider a two-dimensional flat plate, with chord length c, is flying against a uniform stream U_∞ at an angle of attack α.

(a) By the method of inviscid, incompressible flow theory, one may obtain the results of no lift and no drag exerting on the flat plate. Explain these results and sketch the flow field around the flat plate. (4%)

(b) By the method of inviscid, incompressible flow theory, one may obtain the results of no drag, but there is a lift is exerting on the flat plate. Explain these results and sketch the flow field around the flat plate. (4%)

(c) In problems of (a) and (b) above, which results are close to the practical experiences? Why? (4%)

(d) What is the thin airfoil theory? If using the thin airfoil theory, what is the value of the lift coefficient per unit span , C_l can be obtained? (4%)

5. For a rectangular flat plate wing, with span b and chord length c, is flying in a freestream U_∞ at an angle of attack α. Assume the Circulation Γ along the wing span is elliptic, i.e.,

$$\Gamma = \Gamma_0\sqrt{1-(y/s)^2}$$

where s = b/2, y =spanwise coordinate, and Γ_0 is the circulation at mid-wing section. Determine, in terms of Γ_0, U_∞, b and c, the lift coefficient C_L, the induced angle of attack α_i, and the induced drag coefficient C_{Dv} of this rectangular wing. (14%)

6. Consider a rectangular flat plate wing, with span b and chord length c, is flying against a supersonic freestream U_∞ at an angle of attack α. Assume the supersonic freestream flow is inviscid, and use the Ackeret linearized theory where the pressure coefficient C_p is

$$C_p = 2\ \theta / B$$

where $B = \sqrt{M\infty^2 - 1}$, M_∞ = freetream Mach number, and θ = flow deflection angle.

For the case of $[B(b/c) > 2]$, show the lift coefficient C_L and the wave drag coefficient C_{DW} of this supersonic rectangular wing. (10%)