1. (25 %) Consider a steady axial laminar flow in the annular space between two concentric cylinders with inner radius b and outer radius a. Assume there is no slip at the surface and the velocity $u = u(r)$ only.

(a) State the governing equation and boundary conditions. (5%)

(b) Based on (a), find the solution of u (6%).

(c) Based on (b), sketch the velocity profile (4%),

(d) Calculate the volume flow rate Q (5%).

(e) Determine the position r' at which the velocity attains its maximum (5%).

2. (25 %) Consider an axisymmetric potential flow about the x axis, as shown in the figure.

(a) State the continuity equation for incompressible flow in terms of the velocity components v_r and v_θ (4%).

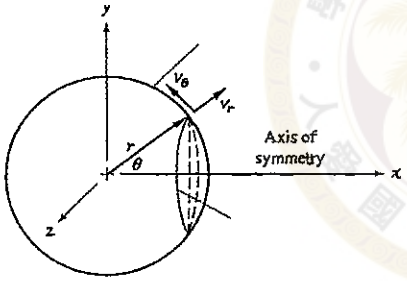
(b) Express v_r and v_θ in terms of the stream function ψ (4%).

(c) Find ψ for the combination of a uniform stream U_∞ in the x direction and a point doublet with strength $U_\infty a^3/2$ at the origin (6%).

(d) Based on (c), sketch the streamlines (3%).

(e) Based on (c), find the velocity components v_r and v_θ (6%).

(f) Calculate the maximum velocity (2%).



3. (30%) Consider a small solid sphere of diameter D is released in a large liquid tank. At very low Reynolds number ($Re_D < 1$), the drag coefficient of a sphere could be estimated as $C_D = 24/Re_D$, where C_D is drag coefficient and Re_D is Reynolds number based on sphere diameter. Please draw a free body diagram of the sphere (5%) and estimate all the forces exerted on the sphere and write down the unsteady force equation for the sphere in the falling process(10%). Please find the terminal velocity (acceleration = 0) of the sphere, if D =20 μm, the specific gravity of the sphere is 5.5, the dynamic viscosity and density of liquid are 10^{-3}N · sec/m^2 and 10^3kg/m^3, respectively. (7%). Could you design a viscometer based on the above-mentioned phenomenon, draw a sketch of your design and what you need to measure? (8%).

4. (20%, 5% each) Read the following statements carefully and answer them with 'True' or 'False'. If your answer is 'False', please briefly explain your reasons.

(a) By doubling the circular pipe diameter for laminar flow of an incompressible fluid, the flow rate will increase four times under the same pressure drop condition.

(b) The higher the flow speed of a laminar circular pipe flow is, the larger are the friction factor (or friction coefficient).

(c) For a compressible flow, we may mount a converging duct after a converging sonic nozzle in order to increase the maximum flow speed.

(d) The water has higher value of kinematic viscosity than air at 1 atm and 25℃.

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