1. A circular disk can be lifted up by blowing on it with the device shown in Fig. 1. Explain why this happens. 15%

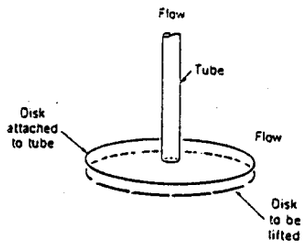

Fig. 1

2. The velocity potential

$$\phi = -k(x^2 - y^2), \quad (k = constant)$$

may be used to represent the flow against an infinite plane boundary as illustrated in Fig. 2. For flow in the vicinity of a stagnation point, it is frequently assumed that the pressure gradient along the surface is of the form

$$\frac{\partial p}{\partial x} = Ax$$

where A is a constant. Use the given velocity potential to show that this is true. 15%

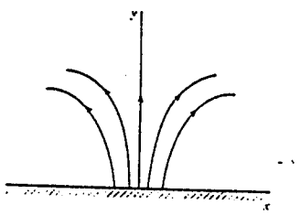

Fig. 2

3. An incompressible, Newtonian fluid flows steadily between two infinitely long, concentric cylinders as shown in Fig. 3. The outer cylinder is fixed, but the inner cylinder moves with a longitudinal velocity V_0 as shown. For what value of V_0 will the the drag on the inner cylinder be zero? Assume that flow is laminar, axisymmetric, and fully developed. 20%

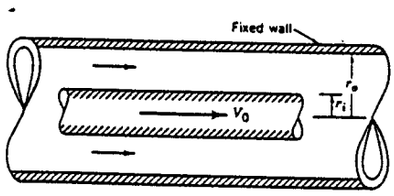

Fig. 3

4. Consider laminar steady flow of an incompressible fluid past an infinite plate. The fluid is withdrawn by a steady constant suction velocity v_w through the plate, which is slightly porous. Under this circumstance the boundary layer does not grow with distance along the plate but remains constant, so that $\partial u / \partial x = 0$.

   (a) Starting with the boundary layer equation show that

$$u(y) = u_\infty[1 - \exp(\frac{v_w y}{\nu})]$$

   where u_∞ is the free stream velocity. (15%)

   (b) Find the displacement and momentum thickness. (10%)

   (c) Find the drag on one side of the plate of length L. (5%)

5. The time-averaged velocity profile $\bar{u}(r)$ in a turbulent pipe flow is approximated as a power-law form of

$$\frac{\bar{u}(r)}{V_c} = (1 - \frac{r}{R})^{1/n}$$

   Where V_c is the centerline velocity. Show that this approximation cannot be accurate at the centerline or at the pipe wall. Explain. (10%)

6. According to a test a baseball weighting 0.15 kg with a diameter of 74-mm spinning 1400 rpm while traveling 70 km/hr was observed to follow a path with a 244-m horizontal radius of curvature. For standard atmospheric condition density of air is given as 1.23 kg/m³. Based on the data shown in the following figure do you agree with this test result? Explain. (10%)

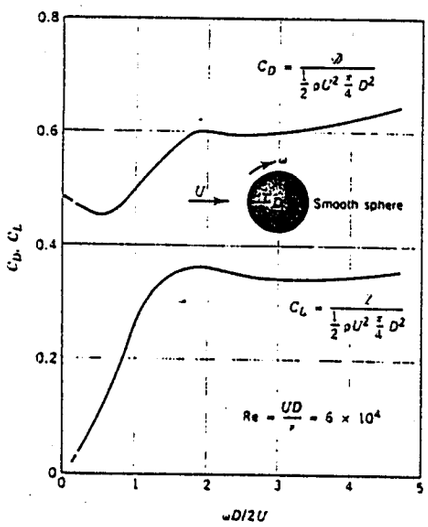

FIGURE Lift and drag coefficients for a spinning smooth sphere