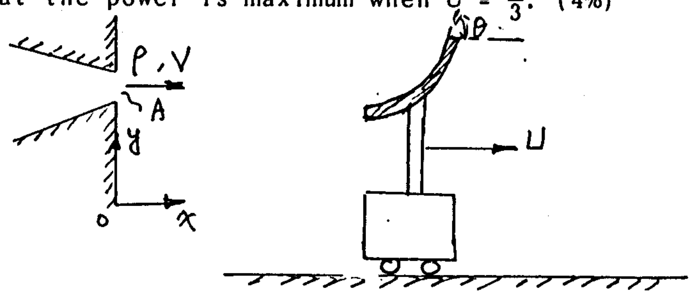
1. Answer as indicated:
   (a) What is the mathematical and physical difference between Bernoulli's equation and the energy equation? (3%)
   (b) What is the physical difference between thermodynamic pressure and mechanical pressure of fluid in motion? (3%)
   (c) If the streamlines and the pathlines are identical, then it can be concluded that the flow is steady. True or False. Why? (3%)
   (d) What is the best geometric shape for minimum drag in (1) incompressible flow, (2) subsonic flow, (3) supersonic flow, and (4) hypersonic flow? (4%)

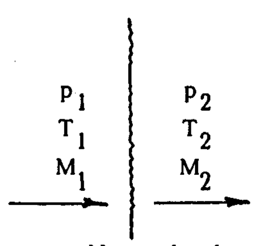
2. An impinging jet issuing from a stationary nozzle encounters a vane with turning angle θ. The vane moves horizontally at constant speed U and the absolute speed of the jet is V.
   (a) Using a reference coordinate fixed with the jet to obtain an expression for the resultant force and power that tha vane can produce. (8%)
   (b) Show that the power is maximum when $U = \frac{V}{3}$. (4%)



3. Consider a laminar flow past a wedge of half-angle θ as shown in the sketch.

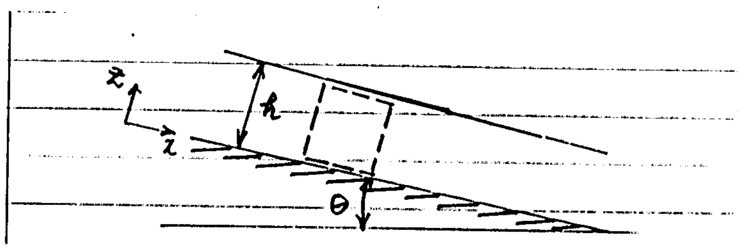
   (a) What is the free stream velocity profile U(x)? Use the inviscid flow theory. (2%)
   (b) Is the pressure gradient advrese or favorable? (1%)
   (c) List the basic assumptions of the boundary-layer approximation and write down the boundary-layer equation with appropriate boundary conditions for the problem. (5%)
   (d) For $\theta = 0$, calculate the ratio of the displacement thickness to boundary thickness by assuming the velocity profile within the boundary layer as $u = A\sin(By) + C$. (7%)

4_ Consider flow of an ideal gas at a supersonic speed. A normal shock occurs. Starting with an appropriate control volume and assumptions, develop expressions for (p_2/p_1) and (T_2/T_1) in terms of M_1, M_2, and γ(the ratio of specific heat) (10%)



Normal shock

5. Consider a uniform open-channel flow in a prismatic channel at steady conditions. The flow is fully turbulent and is assumed to be one-dimensional i.e., the velocity is a constant at any point in a given cross section. The sketch given below illustrates the situation with the x direction along the channel bottom, the z direction upward and normal to the channel bottom. The y direction is into the paper. Let τ_w be the wall shear stress, A be the cross-sectional area of the flow, p* the wetted perimeter. The friction factor in flow is f/4. It is further assumed that the pressure gradient is negligible along the flow direction. Determine the velocity V. (5%)

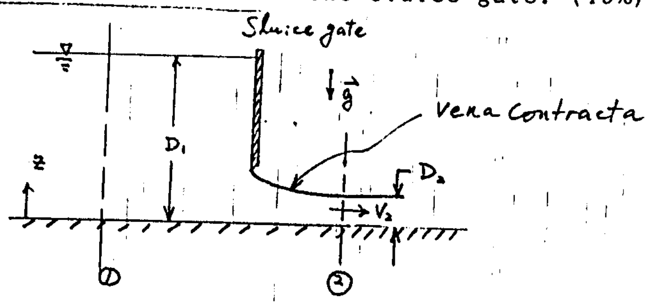


6. Consider the flow for which the potential is given by

$$\phi = \frac{2ar^{3/2}}{3}\cos\frac{3}{2}\theta \qquad a > 0$$

(a) Find the velocity components V_r and V_θ.
(b) Find the stream function for this flow.
(c) Is there a stagnation point in this flow? If so, where is it?
(d) Assuming that the body in question is determined by $V_\theta=0$ except $\theta=0$, sketch the body and some stream with arrows indicating the flow direction.
(e) What is the pressure distribution along the body surface?(15%)

7. Water flows under a sluice gate on a horizontal bed at the inlet to a flume. Above the gate, the water level is D_1, and the velocity is negligible. At the vena contracta below the gate, the flow streamlines are straight and the depth is D_2. Hydrostatic pressure distribution and uniform flow may be assumed at each section; friction is negligible.
(1) Determine the flow velocity downstream from the gate.
(2) Determine the horizontal force on the sluice gate. (15%)



8. A rigid-body ratation of the fluid in a tank about the z axis without any translation, as shown in the sketch. It is assumed that the container has been rotating long enough at constant Ω for the fluid to have attained rigid-body rotation. Determine the pressure distribution in the fluid and the maximum and minimum heights of the free surface. (15%)