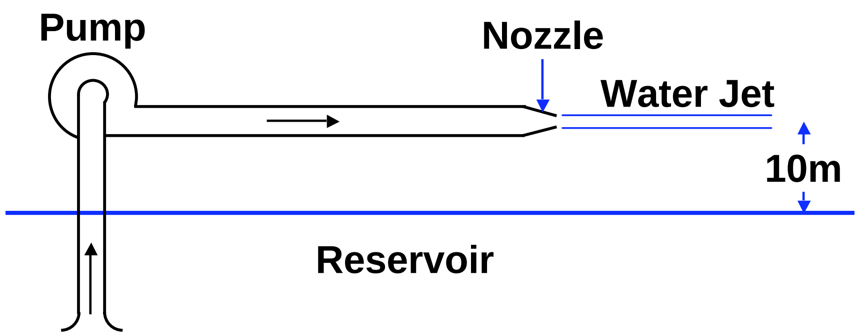
ME19b. **HOMEWORK.** **Jan. 14, 2010. Due Jan. 21**

PROBLEM B5

A fire nozzle is to be used at an elevation of 10 m above the level of a reservoir. The velocity of the jet is to be 20 m/s and the flow is provided by a pump: The density of the water may be taken to be 1000 kg/m^3, the



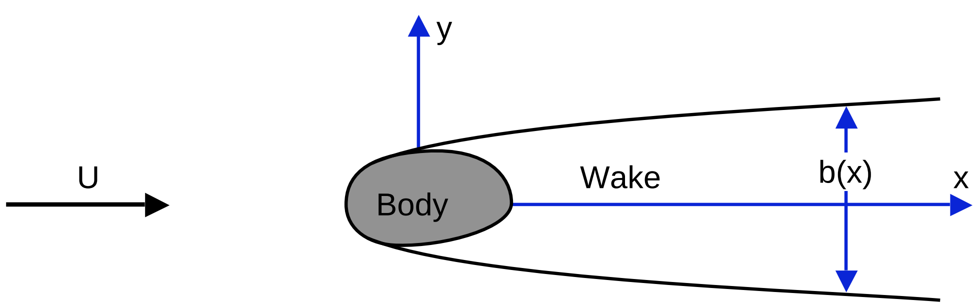
acceleration due to gravity may be taken to be 9.8 m/s^2 and the cross-sectional area of the pipes is 70 cm^2.

The loss coefficient between the reservoir and the inlet to the pump is 4 and the loss coefficient between the discharge from the pump and the end of the nozzle is 3. The ratio of the cross-sectional area of the jet to that of the pipes is 0.1. The inlet and discharge pipes leading to and from the pump have the same cross-sectional area.

- Find the head rise (in m) that the pump must provide.
- If the pump is 75% efficient find the power required to drive the pump in $kg \cdot m^2/s^3$.
- If the pump, pipes and nozzle are mounted on a vehicle find the horizontal force in $kg \cdot m/s^2$ required to hold the vehicle in place.

PROBLEM B6

Wake surveys are made in the two-dimensional wake behind a body (cylindrical) which is externally supported in a uniform stream of incompressible fluid approaching the cylinder with velocity, U:



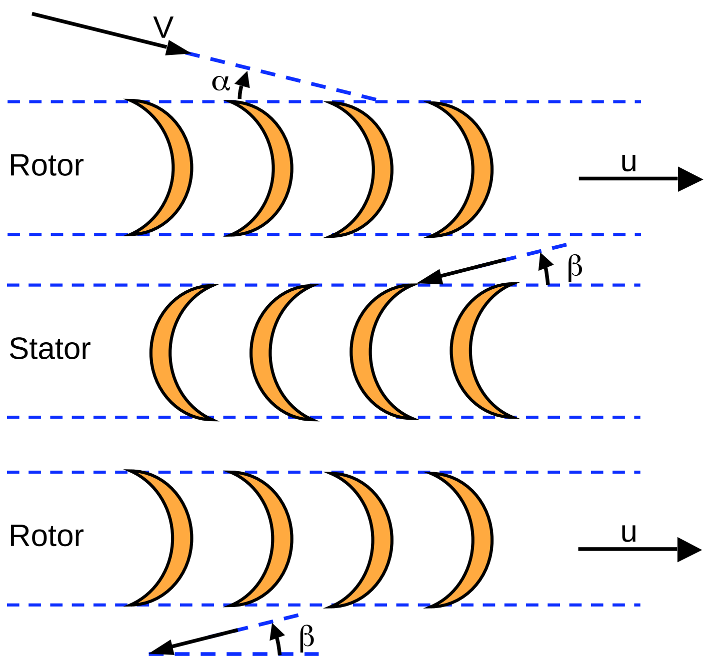
The surveys are made at x locations sufficiently far downstream of the body so that the pressure across the wake is the same as the ambient pressure in the fluid far from the body. They indicate that, to a first approximation, the velocity defect in the wake (the amount by which the velocity, u, is less than U) varies with lateral position, y, according to

$$u = U - A(x)\cos\left[\pi y/b(x)\right] \quad \text{for} \quad -\frac{b}{2} < y < +\frac{b}{2}$$

where $A(x)$ and $b(x)$ are the centerline velocity defect and wake width respectively both of which vary with position, x. If the drag on the body per unit distance normal to the plane of the sketch is denoted by D and the density of the fluid by ρ find the relation for $b(x)$ in terms of $A(x)$, U, ρ and D.

PROBLEM B7

A two-stage turbine (of a type known as an "impulse turbine") consists of a rotor followed by a stator followed by a second rotor:



Visualize that this view is looking down on the ends of the blade rows which are mounted on wheels that have a common axis running longitudinally up and down the page.

It will be assumed that all the angles α and β are sufficiently small so that $\cos\alpha$ and $\cos\beta$ can be approximated by unity. It is also assumed that frictional effects in both the rotors and the stator can be included using the same constant, C, for all three rows of blades where C is defined as follows: relative velocity leaving blades $= -C \times$ the relative velocity entering the blades. Also assume that the pressure is the same before, after and between the blade rows.

The "blade efficiency", η_{rotor}, of the turbine is defined as the ratio of the power transmitted to the rotor (force on the rotor multiplied by the velocity of the rotor) to the available energy in the impinging stream (one half of the mass flow rate of the impinging jet times the square of the velocity of the impinging jet). Evaluate the blade efficiency of the two-stage impulse turbine depicted above as a function of u/V where u is the blade velocity of both rotors and V is the velocity of the incoming jet. At what value of u/V will this 2-stage turbine have its maximum blade efficiency if $C = 0.9$?