1 **Basic Fluid Properties** (score: 10 points)

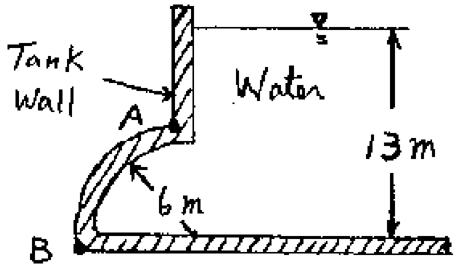
(a) Please write down the (SI) units of the following fluid properties: (i) Mass diffusivity, D; (ii) Thermal diffusivity, α; (iii) Momentum (kinematic) viscosity, ν. (2 points)

(b) From their units, please briefly comment the physical importance of the above three transport properties. (2 points)

(c) Using D, ν, and α to construct (write down) the one-dimensional transport equations of mass (Fick's law of diffusion), momentum (Newton's second law of diffusion), and heat (Fourier's law of conduction). (6 points)

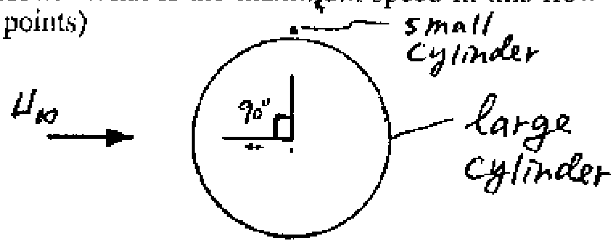
Hydrostatics (score: 10 points)

2 A tank wall has the shape shown below. Please determine the vertical and horizontal components of the force of the water on a 1 meter length of the curved section AB.



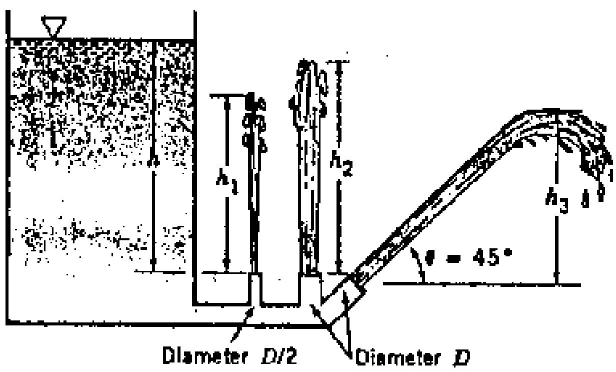
Potential Flow (score: 15 points)

3 (a) Consider potential flow past a large circular cylinder. Suppose a very small circular cylinder is located as sketched below. What is the maximum speed in this flow field, and where does it occur? (6 points)



(b) (i) Please sketch the flow streamlines of a two dimensional stagnation flow on a solid plate. (ii) How long will it take a particle traveling on an ideal stagnation streamline to reach the stagnation point? (9 points)

4 Water flow from the large open tank shown below. If viscous effects are neglected, determine the heights, h_1, h_2, and h_3, to which the three streams rise. (15%)



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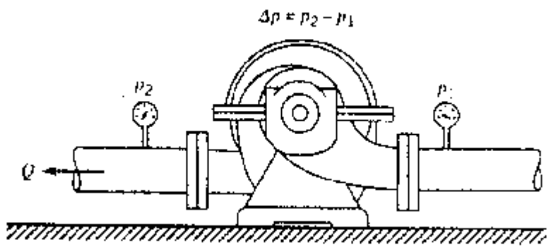
5 (15%) The pressure rise, Δp, across a centrifugal pump (see Fig. a) can be expressed as

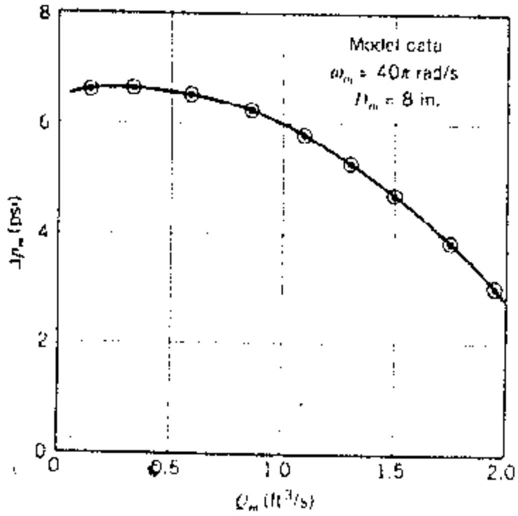
$$\Delta p = f(D, \omega, \rho, Q)$$

where D is the impeller diameter, ω the angular velocity of the impeller, ρ the fluid density, and Q the volume rate of flow through the pump. A model pump having a diameter of 8 in. is test in the laboratory using water. When operated at an angular velocity of 40π rsd/s the model pressure rise as a function of Q is shown in Fig. b. Use this curve to predict the pressure rise across a geometrically similar pump (prototype) for a prototype flowrate of 6 ft^3/s. The prototype has a diameter of 12 in. and operate at an angular velocity of 60π rsd/s. The prototype fluid is also water.



Centrifugal pump

(a)

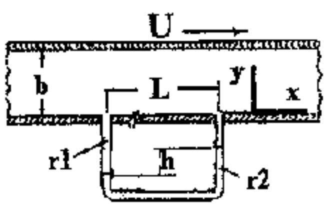


6 (20 %) A viscous fluid (specific weight=r1, viscosity coefficient μ) is contained between two infinite horizontal parallel plates (height=b) as shown in the figure. The fluid moves between the plates under the action of a pressure drop (dp). And the upper plate moves with a velocity U while the bottom plate is fixed. A U-tube manometer (specific weight=r2) connected between two points (distance=L) along the bottom indicates a differential reading of h.

(a) Derive the expression of velocity profile u in terms of above given values (r1, r2, y, b, h, L, μ, U). You can derive the expression based on the given diagram of force balance. (8%)

(b) Describe the effect of pressure drop on the velocity profile. (4%)

(c) Find the distance from the bottom which maximum velocity occurs. (8%)



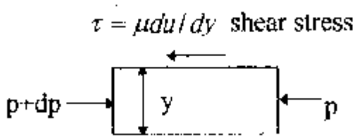


diagram of force balance

7 (15%) Consider a convergent-divergent nozzle and assume the flow is adiabatic and inviscid. Briefly plot p/p_o vs. x (like the one shown in the figure) and briefly explain how is it occur (e.g. inlet and exit conditions) for the following conditions (a) and (b). The symbols used are: p=static pressure, p_o=stagnation pressure, h_o=stagnation enthalpy, p^*=static pressure at throat.

(a) The normal shock appears inside the divergent portion of the nozzle. (5%)

(b) The expansion wave appears at the exit plane of the nozzle. (5%)

(c) Explain the choking condition, and which condition (a) or (b) has choking phenomena. (5%)