GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Quarter 1998

Fluids
EXAM AREA

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Assigned Number (DO NOT SIGN YOUR NAME)

- **Please sign your name on the back of this page—**

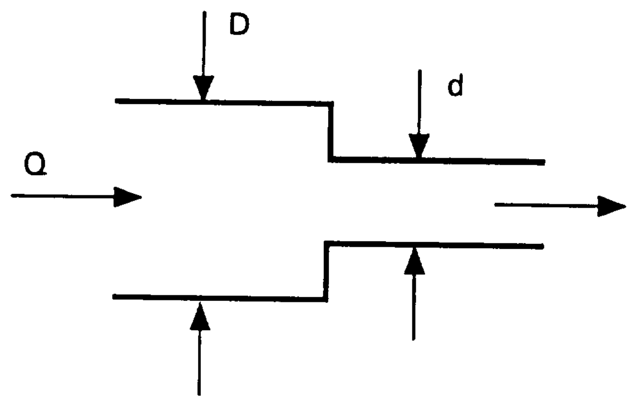
Please **p r i n t** your name here.

The Exam Committee will get a copy of this exam and will not be notified whose paper it is until it is graded.

1. Consider the flow of a fluid of viscosity μ and density ρ at volume flow rate Q through a section of a circular pipe where the pipe diameter undergoes a concentric stepwise change from D to d (D > d) as shown below. As a result of the change in the cross sectional area there is a drop Δp in the static pressure of the fluid.

(a) Using dimensional analysis, determine the relationship between Δp and the relevant dimensionless parameters.

(b) For a given prototype in a water system ($\nu_{water} = 10^{-6}$ m^2/sec) for which D = 10 cm and d = 5 cm, it is desired to measure the pressure drop Δp using oil ($\nu_{oil} = 10^{-5}$ m^2/sec, and the specific gravity is 0.88) flowing through a 1/10 scale model. If the measured average velocity and pressure drop in the model are V_m and Δp_m, respectively, determine the average velocity and pressure drop in the prototype. Comment briefly on the feasibility of the test.

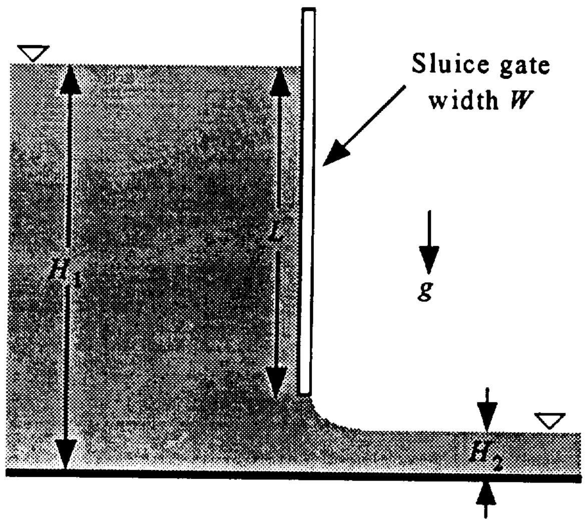


2. A sluice gate, essentially a flat plate of width W which extends to a depth L below the free surface, is used to control the flow of water (density ρ) in an open channel, also of width W. You are given the volumetric flow rate through the channel Q and the upstream and downstream water depths H_1 and H_2, respectively.

a) What is the force $\vec{\mathbf{F}}$ required to hold this sluice gate against the flow? Clearly state all your assumptions!

b) What is the force $\vec{\mathbf{F}}_s$ which would be required to hold this gate if the water on the left was at rest (assuming that we somehow plug the bottom gap)?

c) Physically, what does the difference between $\vec{\mathbf{F}}$ and $\vec{\mathbf{F}}_s$ represent (please be brief)?

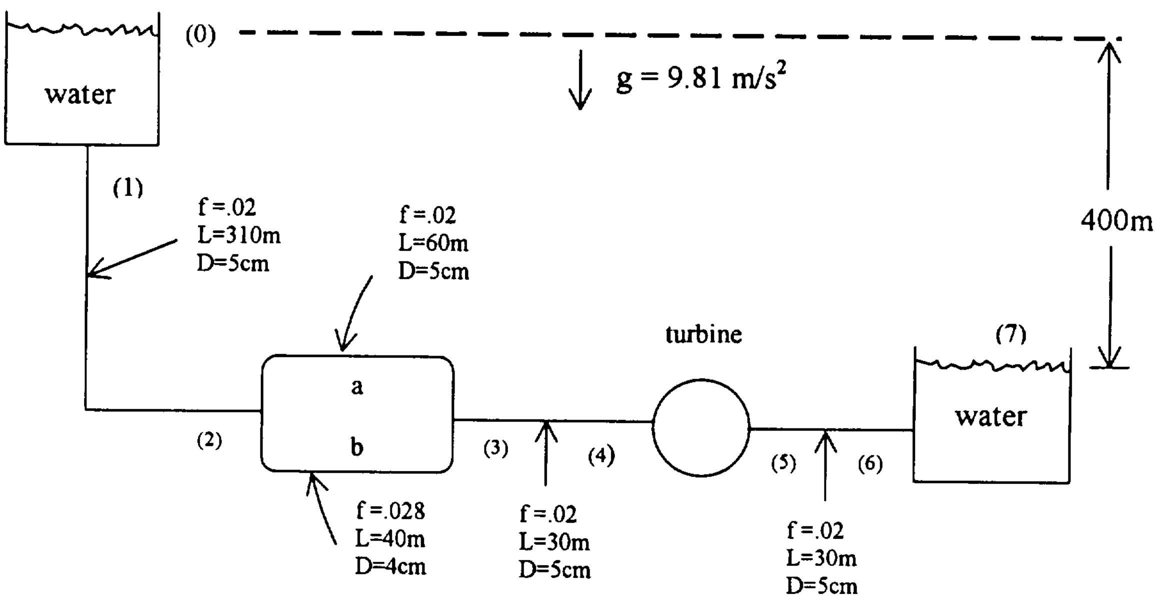


3. Consider the piping system shown below. Water from the upper reservoir flows through the parallel pipes a and b, through the turbine, and then into the lower reservoir. The total volumetric flow rate is $Q = 0.005\ m^3/s$. The pipe characteristics, including the friction factors, are given on the sketch. Ignore minor component losses, and assume turbulent flow.

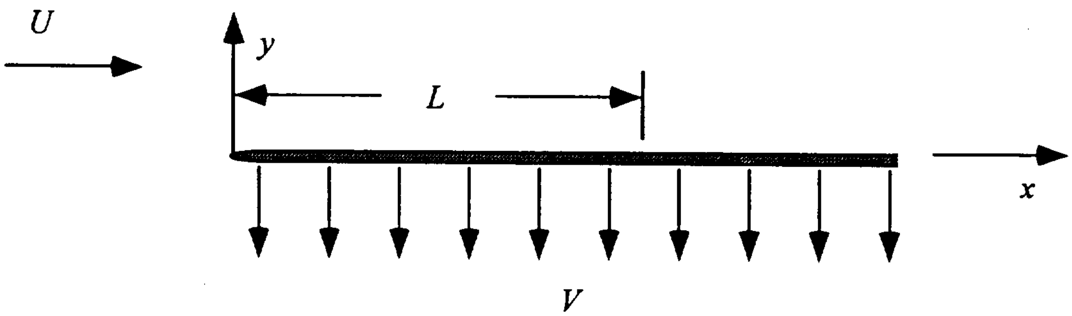
a) Compute the flow rate through each of the two parallel pipes a and b.

b) Find the power extracted from the flow by the turbine.

$\rho = 1000\ kg/m^3$
$\nu = 1.12 \times 10^{-6}\ m^2/s$



4. Consider the problem of boundary-layer flow over a *porous* plate with *suction*, as shown below:



The suction is applied in the negative y-direction with a constant magnitude V, independent of the x-coordinate. The boundary-layer equations for steady, two-dimensional flow with no pressure gradient are:

$$uu_x + vu_y = \nu u_{yy},$$

$$u_x + v_y = 0.$$

SCALE the above equations, using U as the velocity scale and L, the distance from the leading edge of the plate, as the length scale. POSE THE BOUNDARY CONDITIONS in dimensionless form. Then, *assuming a solution which is also independent of* x (like the suction profile), SOLVE the resulting problem.