NATIONAL EXAMINATIONS—MAY 2003

98-Civ-A5, Hydraulic Engineering

3 Hours Duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a clear statement of any assumptions made.

2. CLOSED BOOK Examination. However, the following are permitted:

   - ONE $8\frac{1}{2} \times 11$ inch aid sheet (both sides may be used); and
   - Candidates may use one of two calculators, a Casio FX-991 or Sharp EL-540.

3. This examination has **six** questions, of which **any four** are required to be completed. Indicate clearly on your examination answer book which questions you have attempted. Only the first four questions as they appear in your answer book will be marked. All questions are of equal value. If any question has more than one part, each part is of equal value.

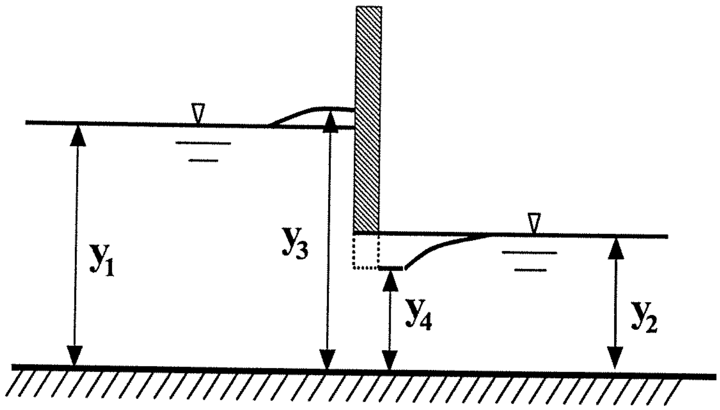
4. Note that 'cms' means cubic metres per second; 1 inch = 2.54 cm.

5. The following equations may be useful:

   - Hazen-Williams: $Q = 0.278CD^{2.63}S^{0.54}$, $S = \Delta h/L$
   - Darcy-Weisbach: $\Delta h = \frac{fL}{D} \cdot \frac{V^2}{2g} = 0.0826\frac{fL}{D^5}Q^2$
   - Loop Corrections: $q_l = -\frac{0.54\sum_{\text{loop}} \Delta h_i}{\sum_{\text{loop}} |\Delta h_i/Q_i|}$
   - Node Corrections: $\Delta H_n = \frac{\sum_{\text{node}} Q_i}{0.54\sum_{\text{node}} |Q_i/\Delta h_i|}$

6. Unless stated to the contrary, (i) assume that local losses and velocity head are negligible, (ii) that the given values for pipe diameters are nominal pipe diameters and (iii) that the flow involves water with a density $\rho = 1000$ kg/m^3.

1. In the 1.0 m wide rectangular channel shown below, the original upstream depth y_1 is uniform at 2.0 m and the original downstream depth is uniform at $y_2 = 1.0$ m. Friction is negligible and the steady flow initially 1.0 m^3/s. This discharge at the gate is suddenly decreased to 50% of its initial value by suddenly partially closing the gate, thus creating two surge waves that propagate upstream and downstream from the gate. Estimate the height of both surge waves y_3 and y_4 and their associated speeds of propagation.



2. Urbanization creates stresses in the receiving waters typically found downstream of the region undergoing economic development. Some of these impacts are associated with the quantity of the water discharged, and others with the quality of this water. Briefly discuss the nature of both these impacts and what general characteristics of the urban area might affect their detrimental affect on the receiving water. Also, briefly outline what might be done from an engineering standpoint to reduce or eliminate two or three of these impacts.

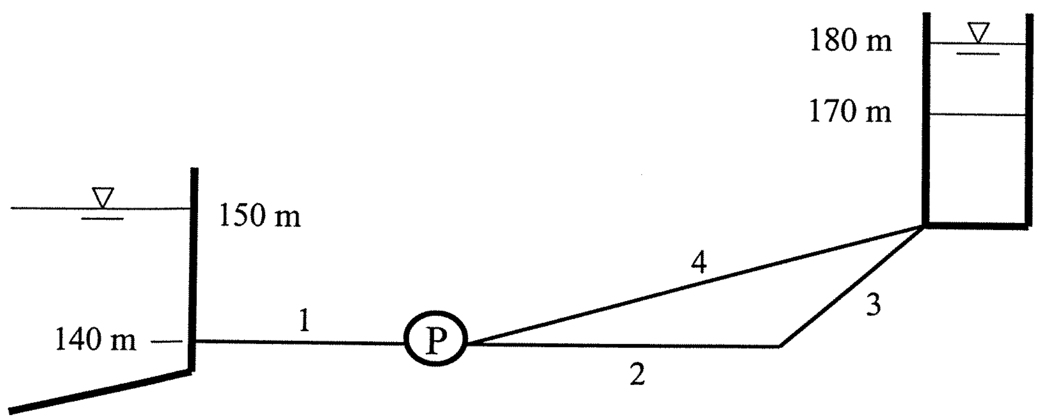
3. The flow in a 1 m diameter pipe (Mannings $n = 0.012$) is critical when the normal depth in it is exactly at its "half full" value (i.e., a depth of 0.5 m). (a) Determine the flow in the pipe and slope the pipe is laid on. What do you have to assume to compute this value? (b) Using your result in (a), estimate the flow in the pipe when the normal depth of water is (i) 0.2 m and (ii) 0.8 m. (c) Determine whether the flow is supercritical or subcritical for cases (i) and (ii) from part (b) for this pipe. (d) Why does it matter whether the flow is supercritical or subcritical? What would you do, if anything, to adjust this flow characteristic?

4. As sketched below, a large suction reservoir (at the left) at 150 m elevation is attached by a single suction pipe to a pump station (at 'P'), and from there to a terminal tank (at the right hand side) via a three pipe system. Each of the four pipes is 12 inches in diameter and has a Hazen-Williams C of 115; the lengths of the pipes are as follows: $L_1 = 250$ m, $L_2 = 500$ m, $L_3 = 300$ m, and $L_4 = 700$ m. The total dynamic head H_p (m) for a single pump (pumping left to right) can be approximated by the equation

$$H_p = 40 - 800Q_p^{1.9}$$

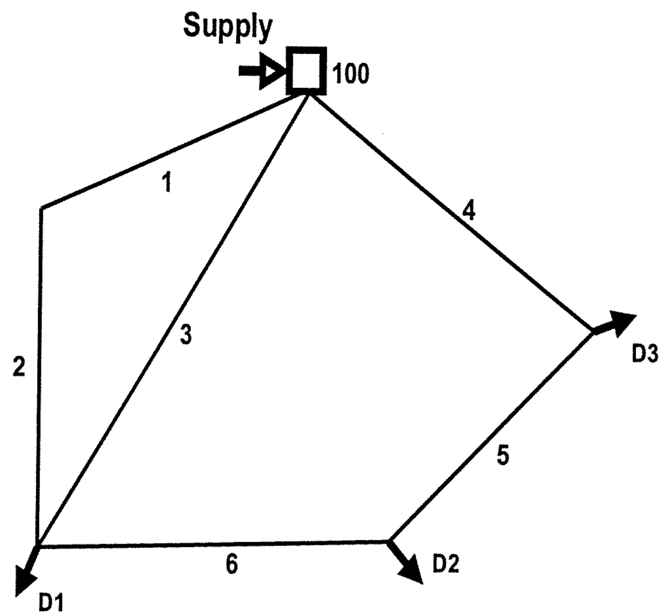
where Q_p is the pump discharge in m^3/s. Either one pump or two pumps in parallel operate in this system, depending on the level in the receiving tank. When the water level in the tank is between 170 and 175 m elevation, two pumps are operated; once the level exceeds 175 m, only one pump is operated, and all pumps are turned off once the level reaches 180 m.

Determine the total flow in the system, (a) with two pumps operating and the level in the receiving tank is 172.5 m, and (b) with one pump operating and the level in the receiving tank at 177.5 m. (c) Estimate both the power requirements and the NPSH (available) at the pump(s) for these two operating conditions, assuming that the atmospheric pressure head is 10.1 m, that the vapour pressure of the water is 1.6 m, and that the pumps are 85% efficient. Which of these two NPSH conditions is likely most critical for system operation? (d) Finally, approximate the time required for the level in the receiving tank to increase from 170 to 180 m, assuming the terminal tank has a cross sectional area of 100 m^2.



5. Determine **all** flows and nodal heads in the 6 pipe system shown below (not to scale). All pipes are 24 inches in diameter, have a $C = 130$ and are constructed at a 200 m elevation. The pipe lengths are as follows: $L_1 = L_5 = 1000$ m, $L_2 = L_4 = L_6 = 1500$ m, and $L_3 = 2000$ m. The demand D_1 is 0.6 m^3/s and the other two demands shown are 0.4 m^3/s. The total head at the source node (node 100) is 300 m.

   Also, discuss in general terms how the problem could be solved if there were a demand specified at the junction of pipes 1 and 2. (Be specific about how approach above would have be adjusted.)

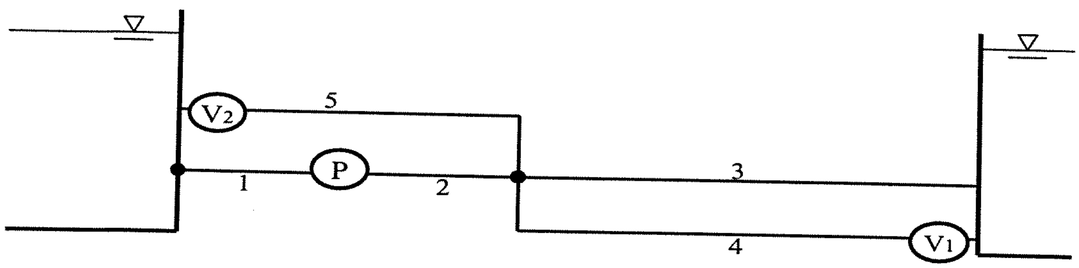


6. Each of the five pipes shown below is 12 inches in diameter and has a Darcy-Weisbach f value of 0.016; pipes 1 and 2 are both 500 m long, pipes 3 and 4 are 1500 m long, and pipe 5 is 1000 m long. One of more pumps may be operated at P, with the normal direction of pumping from left to right. The total dynamic head H_p (in m) of a single pump is given by

$$H_p = 20 - 400Q^2$$

where Q is the flow through the pump (in cms, m^3/s). The water level in both of the large reservoirs shown is at exactly the **same elevation.** The valves shown are either fully open or fully closed; when fully open, the valves offer negligible resistance to flow.

For the three cases indicated below, determine both the **total flow** passing through pipe 1, and the **water power** at each pump in the system. The specific cases are as follows: (a) One pump; both valves V_1 and V_2 are closed; (b) Two pumps in series; valve V_2 is closed and V_1 is open; (c) Two pumps in parallel; both valves V_1 and V_2 are open. (d) Is the assumption of constant f likely a good one? How could this approximation be improved? Be as specific as possible.



10 MM/CM