NATIONAL EXAMINATIONS—DECEMBER 2005

98-Env-A1 /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 or SHARP approved models.

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: $Q = 0.278CD^{2.63}S^{0.54}$, $S = \Delta h/L$
   - Mannings: $Q = \frac{A}{n}R^{2/3}S^{0.5}$, $S = \Delta h/L$
   - 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.

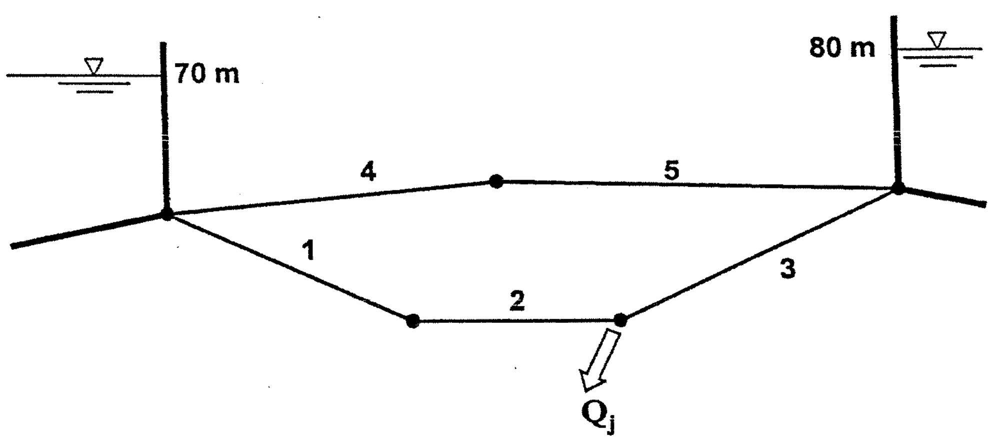
1. Not only does water have a high density, but pipelines often must move water over long distances and with considerable increases in elevation. As a result, the electrical energy associated with the pumping of water is often a critical financial and environmental cost associated with system operation and service. Discuss a variety of ways or reducing or controlling pumping costs in water supply systems. Also briefly discuss how you might go about a more detailed assessment of these energy costs, and the potential for cost reduction through energy management.

2. Consider the five pipe system shown below, where the water level in the two reservoirs is shown and all pipes are installed at the elevation of the datum. Each pipe has a diameter of 0.305 m and a Hazen-Williams C factor of 120; the lengths of the pipes are as follows: $L_1 = 1000$ m, $L_2 = 600$ m, $L_3 = 1600$ m, $L_4 = 1800$ m, and $L_5 = 1500$ m. Local losses are negligible.

   (a) Estimate the flow in each pipe if the demand Q_j is 0.1 m^3/s.

   (b) Estimate the required value of the demand Q_j that would be required to make the flow in pipe 2 zero.

   (c) Estimate the required value of the demand Q_j that will make the flow in pipe 3 equal to the flow in pipe 5.



Not to Scale

3. A rectangular 20 m canal is designed to carry a flow of 60 m^3/s. It is built on a 0.3% slope, and it has a Manning's roughness n of 0.018. At one point of the channel the flow must pass through a smooth restricted section having a reduced width of only 16 m. Estimate the depth of flow in the channel upstream and at the restricted section. What additional data would most easily be obtained or estimated if you wished to improve these depth calculations? Explain how this additional data would be used in the computation of depths both upstream and at the restricted section.

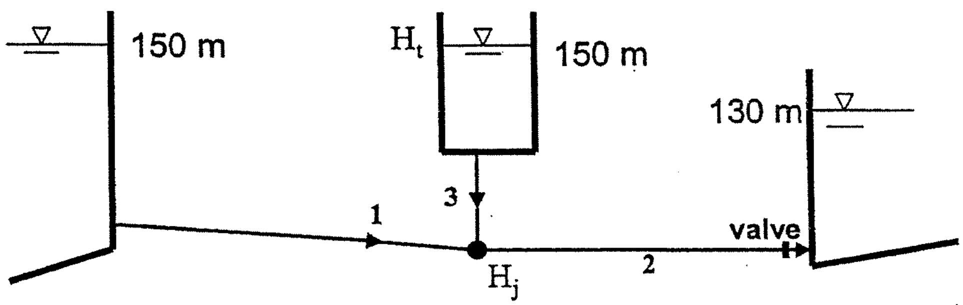
4. A flow of 20 m^3/s takes place in a 10 m wide rectangular channel with a Mannings $n = 0.040$. The channel has two very long sections at a slope of 0.2%. In between of these two sections, there is a short 500 m long section that is on a slope of 10%. Being as specific and quantitative as possible, sketch the water profile from just upstream to just downstream of the steep section.

5. Water must be pumped from a suction reservoir to an outflow location 10 km away; the outflow occurs at 25 m above the elevation of the suction reservoir. Two identical pumps are available to produce the flow; each pump has the characteristic equation of

$$H_p = 35 - Q^{1.9}$$

and the pumps can be connected in series or in parallel. The pipeline is 0.686 m in diameter with an estimated Hazen-Williams value of $C = 120$. Estimate the maximum flow that can be obtained. If it were desired at some later time, after the line has been built, to increase the flow by say an additional 20%, what options would you consider to achieve this higher value?

6. Two reservoirs are connected by the three pipe and one tank system shown below. The central tank has a 20 m^2 cross sectional area. Pipes 1 and 2 are both 0.585 m in diameter, 2000 m long, and have an estimated Darcy-Weisbach friction factor $f = 0.017$. Pipe 3, which connects to the central tank, has the same basic properties but is only 100 m long.



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Arrows show assumed flow direction only

Initially the level in the central tank is equal to the left reservoir level of 150 m and a valve near the right reservoir is closed; so, initially, there is no flow in the system. The valve at the downstream end near the right reservoir is gradually and smoothly opened to establish flow in the system; when fully open, the valve has a negligible head loss.

(a) Determine the long-term or steady state distribution of pressure, flow and water level in the system.

(b) Suppose after the flow in (a) has been established, the downstream valve were then to be suddenly closed. Estimate the maximum head in the downstream pipe, assuming its wave speed is 1200 m/s. In general terms, explain what would happen to the water hammer wave when it reaches the central reservoir?

(c) Answer **either** of these two questions: (i) How could you go about estimating the maximum water level that would occur in the central tank as a result of the sudden closure of the downstream valve in (b)? (ii) Alternatively, estimate how long it will take the tank to go from its initial to within about 1 cm of its steady state value in (a).