National Exams December 2008

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. This is a CLOSED BOOK examination. The following are permitted:

   - **one** 8.5 x 11 inch aid sheet (both sides may be used); and
   - Any Casio or Sharp approved calculator permitted.

3. This examination has a total of **six** questions. You are required to complete any **five** of the six exam questions. Indicate clearly on your examination answer booklet which questions you have attempted. The first five questions as they appear in the answer book will be marked. All questions are of equal value. If any question has more than one part, each 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: $\Delta h = \frac{fL}{D}\cdot\frac{V^2}{2g} = 0.0826\frac{fL}{D^5}\cdot Q^2$
   - Loop Corrections: $q_l = -\frac{\sum_{\text{loop}} k_i Q_i |Q_i|^{n-1}}{n\sum_{\text{loop}} k_i |Q_i|^{n-1}}$, $n = 1.852$ (Hazen-Williams)
   - Total Dynamic Head: $\text{TDH} = H_s + H_f$, H_s=static head; H_f=friction losses

6. Unless otherwise stated, (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 ρ = 1,000 kg/m^3 and kinematic viscosity υ = 1.31 x 10^{-6} m^2/s.

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1. A network of reservoirs are connected by three pipes (P_1, P_2, and P_3) in Figure 1. Each pipe has a length of 1,000 m.

a) If each pipe is to convey a flow of 1 cms between reservoirs with fixed water elevations indicated, determine the minimum commercially-available diameter of each pipe. The set of commercially-available pipe diameters are indicated in the table below. Assume a Hazen-Williams 'C' factor of 130 for all pipes.

b) What commercially-available diameter is needed for pipe P_1 to convey a flow of 1 cms if the water elevation in the upstream reservoir is increased from 245 m to 250 m?

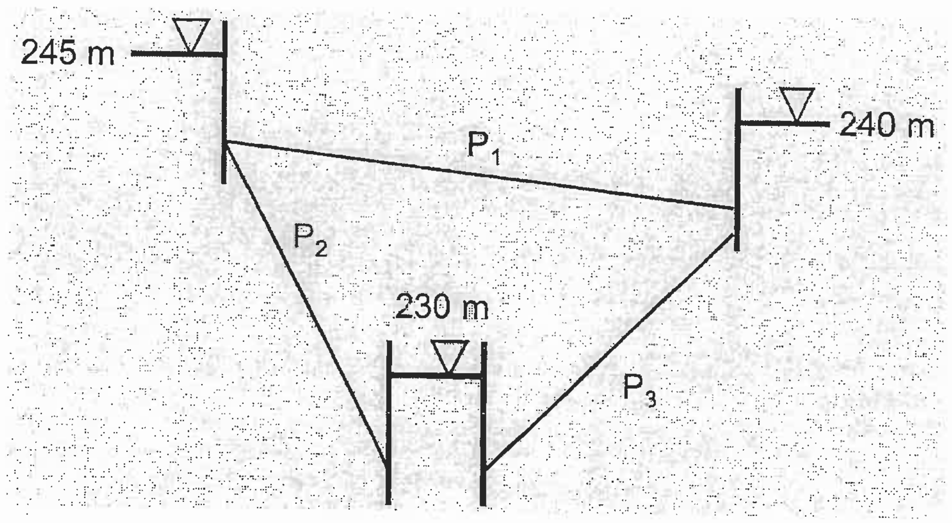

Table: Commercially-available pipe diameters.

Nominal Diameter (mm)	Inner Diameter (mm)	Nominal Diameter (mm)	Inner Diameter (mm)	Nominal Diameter (mm)	Inner Diameter (mm)
150	152	450	457	900	914
200	203	500	533	1100	1067
250	254	600	610	1200	1219
300	305	700	686	1400	1372
400	381	800	762	1500	1524

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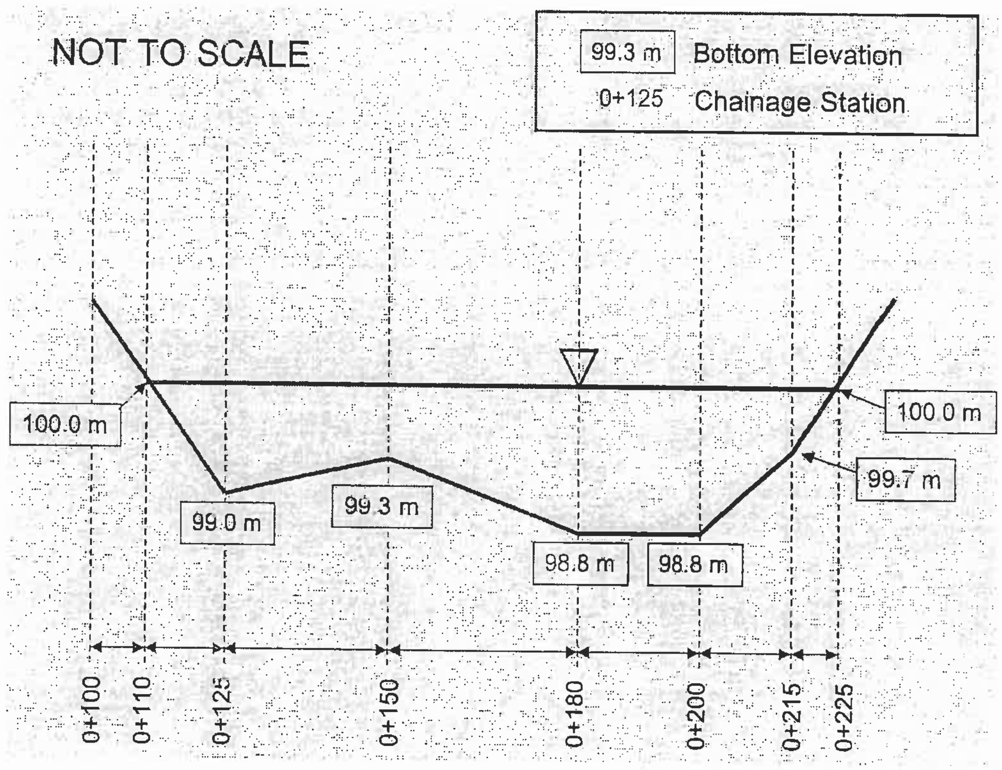
2. The river indicated below carries water under steady, uniform flow conditions. A survey crew has determined the elevation of the channel bottom. The chainage lengths and bottom elevations (at grade changes) are indicated in the figure below. The water level in the river is at elevation of 100.0 m.

a) If the average velocity in the river is 0.5 m/s, what is the total discharge?

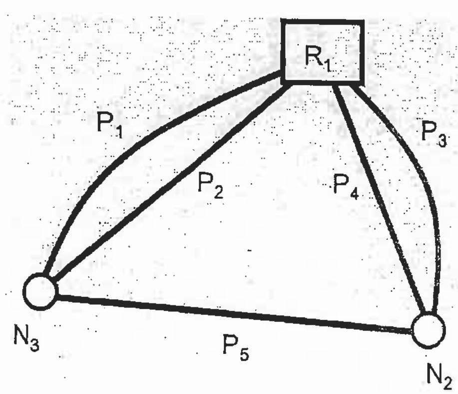
b) The river has a longitudinal slope of 0.05%. Using the river discharge in a), compute Manning's n.



/20 3. The water distribution network shown below is fed by a reservoir (R_1) with a fixed water level of 65 m. The network has 5 pipes with the following parameters: length = 500 m, Hazen-Williams 'C' factor = 120, and inner diameter = 254 mm. The 2 demand nodes in the network are at an elevation of 5 m. The demand at these 2 nodes is: Q_2 = 100 L/s, Q_3 = 200 L/s.

a) Calculate the pressure head at nodes 2 and 3.

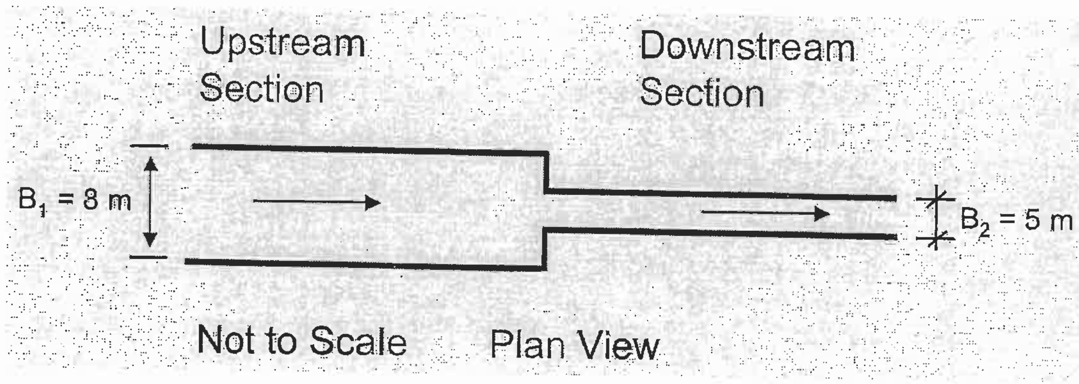
b) Calculate the pressure head at nodes 2 and 3 if valves along pipes 2 and 3 (P2 and P3) are closed gradually such that no transient pressures are produced.



/20 4. The plan view of an open channel transition is shown below. The upstream section of the rectangular channel has a width of B_1 = 8 m, and the downstream section of the rectangular channel has a width of B_2 = 5 m. The flow of water in the channel is 1 cms.

a) Compute the critical depth in the upstream section of the rectangular channel.

b) If the water depth in the upstream section of the channel is 0.30 m, compute the water depth in the downstream section of the channel. Assume that there is no energy loss at the channel transition. Is the downstream depth sub-critical or supercritical?



/20 5. A transmission pipeline that conveys water from an upstream reservoir to a downstream reservoir is indicated below. The transmission main has a valve along its length that controls the discharge in the system. The discharge through the valve is computed with the valve equation below. The pipeline has a length of 5,000 m, a Hazen-Williams 'C' factor of 120, and an inner diameter of 1067 mm. The upstream reservoir has a water level of 105 m. The valve discharge constant is E_s = 0.5 $m^{5/2}$/s.

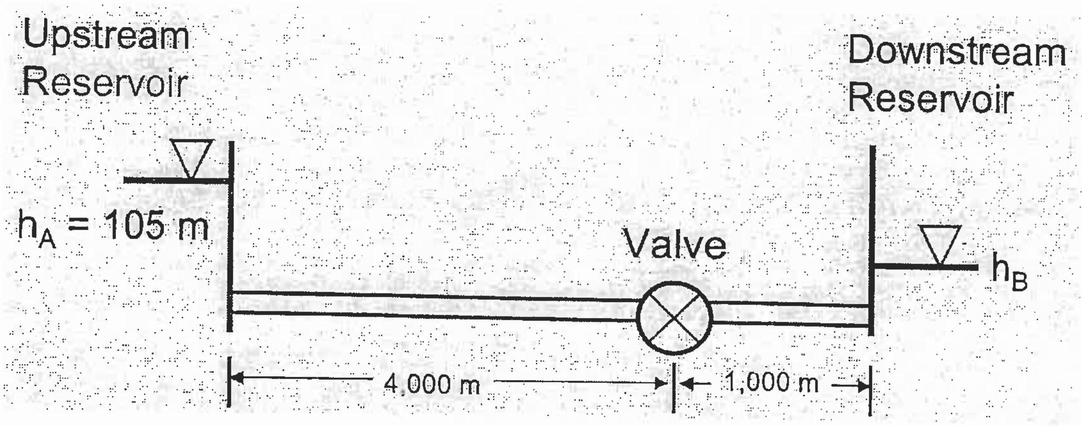
$$Q = \tau E_s \sqrt{H_{u/s} - H_{d/s}} \qquad \text{(valve equation)}$$

where Q = discharge (cms), E_s = valve discharge constant ($m^{5/2}$/s), $H_{u/s}$ = upstream head, $H_{d/s}$ = downstream head.

a) When the valve is partially closed, a steady state discharge of 1 m^3/s generates a headloss of 5 m across the valve. Given this data, compute the τ value of the partially-closed valve.

b) For the steady state discharge and τ value computed in a), compute the water level in the downstream reservoir.

c) When the valve is closed further, the τ value is lowered to τ = 0.3. If the water level in the downstream reservoir remains fixed at the level computed in b), compute the discharge in the transmission pipeline.



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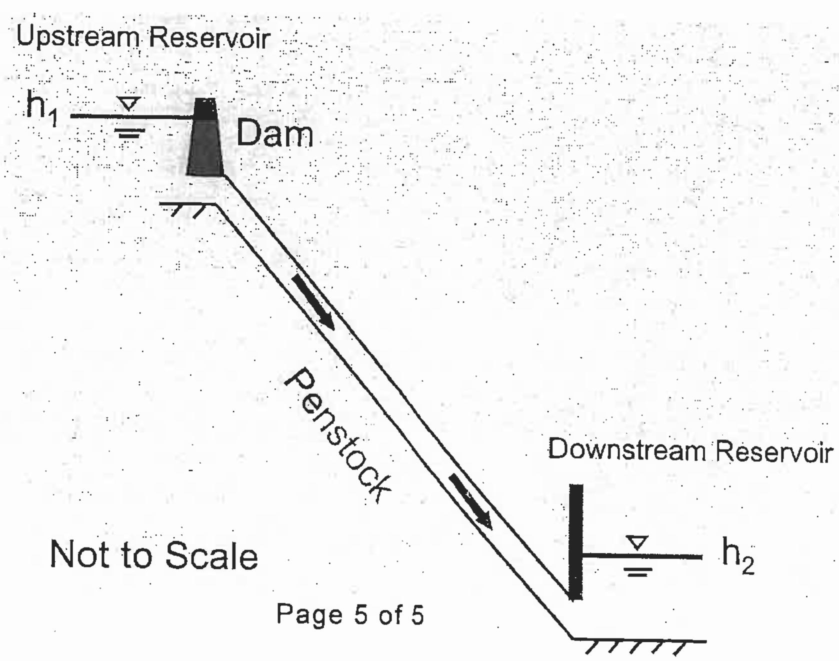
6. The penstock of a small hydropower generating station is shown below. An upstream reservoir with a fixed water level h_1 = 100 m supplies water to the penstock by gravity. Flow in the penstock is discharged to a downstream reservoir with water level h_2. The downstream reservoir has an area of 50 m^2. The penstock has a total length of 1,000 m, a diameter of 508 mm, and a Hazen-Williams 'C' factor of 130.

a) Write an equation that describes the rate of change of momentum in the penstock. Assume incompressible, unsteady flow conditions in the penstock.

b) If at time t = 0 the water level in the downstream reservoir is h_2 = 50 m and the flow in the penstock is 1.21 cms, compute the time it will take for the water level in the downstream reservoir to reach h_2 = 51 m. Suggestion: use a time step of 15 sec in your calculations.

c) Describe in words the hydraulic transient response in the penstock if the turbine vanes (not shown in diagram) were to suddenly stop rotating due to a blockage in the turbine or a mechanical failure.



Marking Scheme

1. 20 marks total (2 parts times 10 marks each)
2. 20 marks total (2 parts times 10 marks each)
3. 20 marks total (2 parts times 10 marks each)
4. 20 marks total (2 parts times 10 marks each)
5. 20 marks total (3 parts times roughly 7 marks each)
6. 20 marks total (3 parts times roughly 7 marks each)