National Exams December 2012

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 is 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. The following equations may be useful:

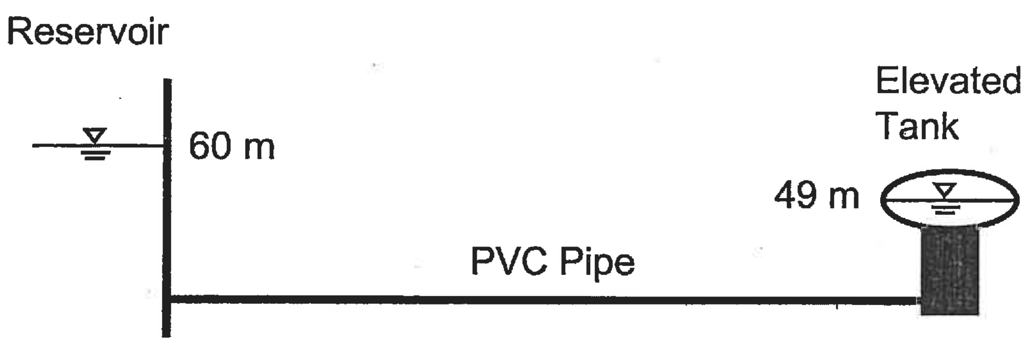
   - Hazen-Williams: $Q = 0.278CD^{2.63}S^{0.54}$, $S=\Delta h/L$
   - Manning's: $Q = \frac{A}{n}R^{2/3}S^{0.5}$, $S=\Delta h/L$
   - Darcy-Weisbach: $\Delta h = \frac{fL}{D}\cdot\frac{V^2}{2g}$
   - Loop Corrections: $q_l = -\frac{\sum_{\text{loop}} k_i Q_i |Q_i|^{n-1}}{n\sum_{\text{loop}} k_i |Q_i|^{n-1}}$, $n = 1.852$ (Hazen-Williams)
   - Total Dynamic Head: TDH = $H_s + H_f$, H_s=static head; H_f=friction losses

5. 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.

/20 1. A PVC pipe carries water from an upstream reservoir with constant water level of 60 m to an elevated tank. The water level in the elevated tank is 49 m. The cast iron pipe has a Hazen-Williams 'C' factor of 115, an internal diameter of 1057 mm, and a length of 1,200 m.

a) Determine the fluid velocity in the PVC pipe.

b) Design guidelines require the fluid velocity in the pipe to be below 3 m/s to prevent pipe wall erosion. Is the fluid velocity in a) below 3 m/s? If not, determine the internal pipe diameter needed to produce a fluid velocity equal to or lower than 3 m/s?



Not to Scale

/20 2. 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 110, and an inner diameter of 1067 mm. The upstream reservoir has a water level of 105 m. The valve discharge constant is $E_s = 0.35\ m^{5/2}/s$.

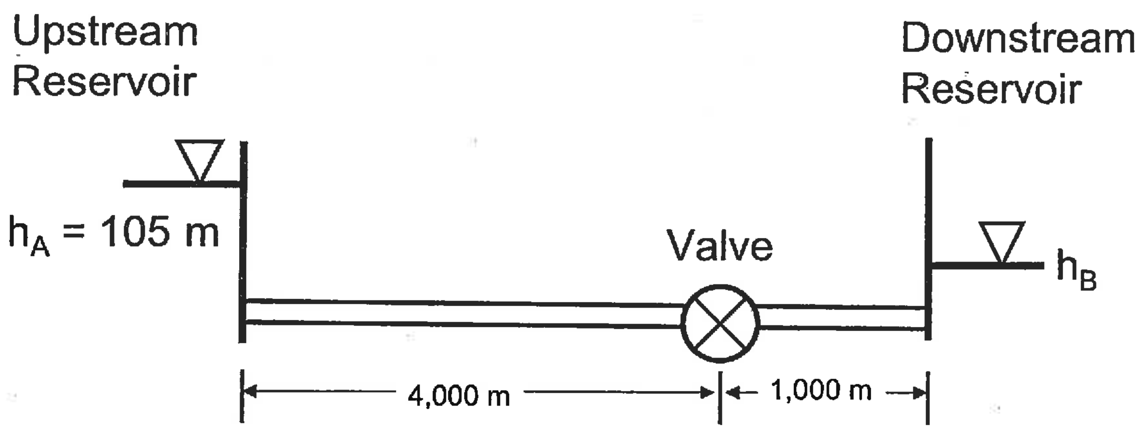
$$Q = \tau E_s \sqrt{H_{u/s} - H_{d/s}} \qquad \text{(valve equation)}$$

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.

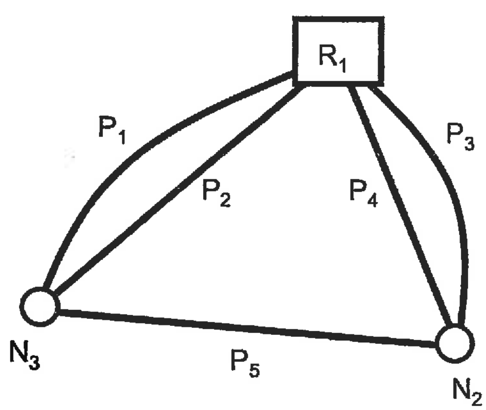
c) When the valve is closed further, the τ value is lowered to $\tau = 0.3$. If the water level in the downstream reservoir remains fixed at the level computed in b), compute the discharge in the transmission pipeline.



/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 = 475 m, Hazen-Williams 'C' factor = 110, and inner diameter = 305 mm. The 2 demand nodes in the network are at an elevation of 10 m. The demand at these 2 nodes is: Q_2 = 90 L/s, Q_3 = 187 L/s.

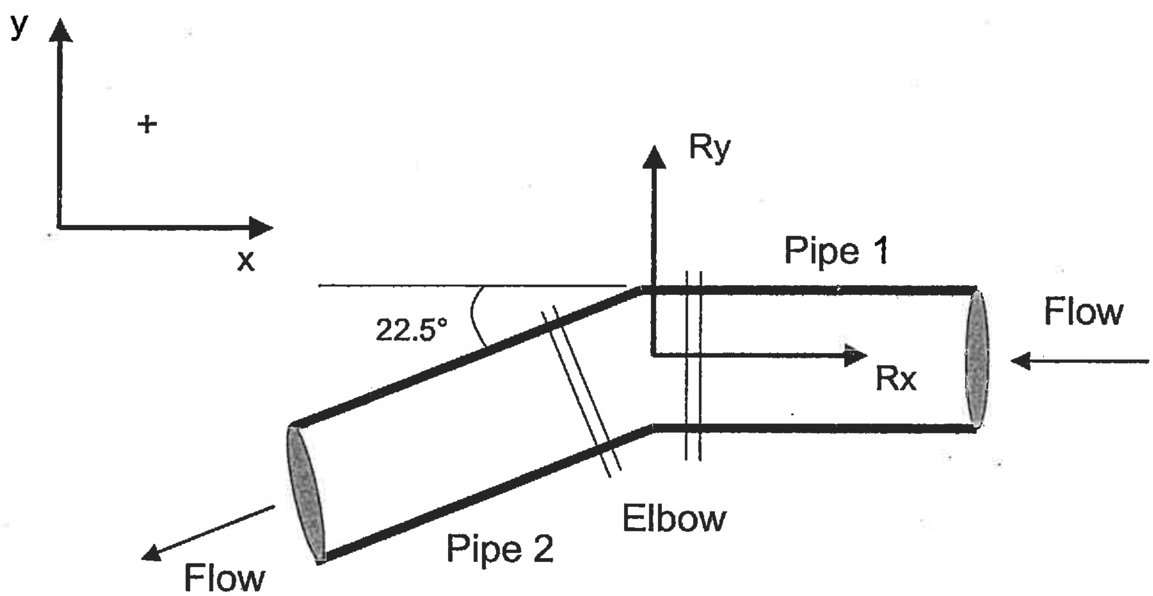
a) Calculate the pressure head at nodes 2 and 3.

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. Water levels in a river are controlled by a dam with spillways that discharge water to penstocks to produce hydroelectric power. Describe the hydraulic conditions just upstream and downstream of the dam when its sluice gate is closed suddenly. Structure your explanation in relation to the St. Venant equations and explain the flow conditions with respect to each term of these equations. Be as specific as possible.

/20 5. A water main conveys 1.35 m^3/s of water at 10°C. A section of the water main has an elbow that deflects the flow downward at an angle of 22.5 degrees from horizontal (see figure). The upstream pipe (Pipe 1) has a diameter of 600 mm and the downstream pipe (Pipe 2) has a diameter of 550 mm. The operating pressure in the water main is 750 kPa. Calculate the forces Rx and Ry that must be applied to the elbow to hold it in place?

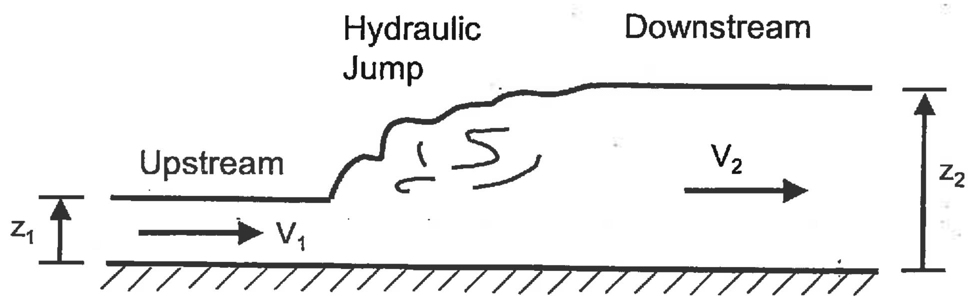


/20 6. The spillway of a dam discharges into a rectangular channel. The hydraulic jump indicated below occurs in the rectangular channel. The rectangular channel is B = 5 m wide. The flow from the spillway is 20 cms, and the depth z_1 upstream of the hydraulic jump is 0.2 m.

a) Write the momentum equation for the hydraulic jump.

b) What is the downstream depth z_2?

c) Why is the momentum equation a more suitable analysis tool than the energy equation for describing the hydraulic jump?



Side view

Not to Scale

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Marking Scheme

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