National Exams May 2009

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 non-communicating calculator.

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: $\text{TDH} = H_s + H_f$, 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.

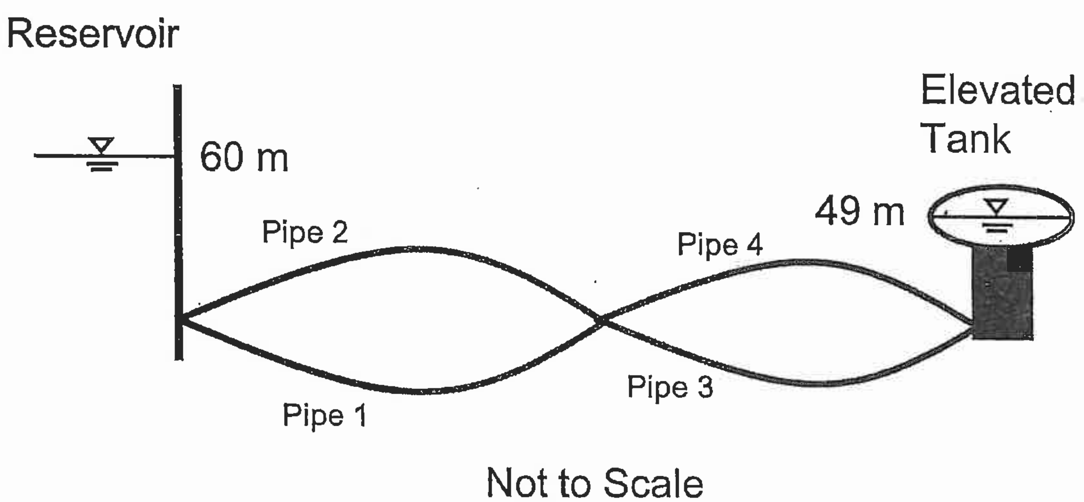
/20 1. A water transmission system comprised of 4 PVC pipes conveys water from an upstream reservoir with constant water level of 60 m to an elevated tank with water level at 49 m. All PVC pipes have a Hazen-Williams 'C' factor of 125 and a length of 1,200 m. The nominal and inner diameters of the PVC pipes are indicated in the table below.

a) If a valve is closed in Pipe 1, determine the total flow in the transmission system.

b) If all pipes convey water (no closed valves), determine the flow in Pipes 1 through 4.

Table: PVC pipe diameters.

Pipe Number	Nominal Diameter (mm)	Inner Diameter (mm)
1	400	381
2	200	203
3	250	254
4	300	305

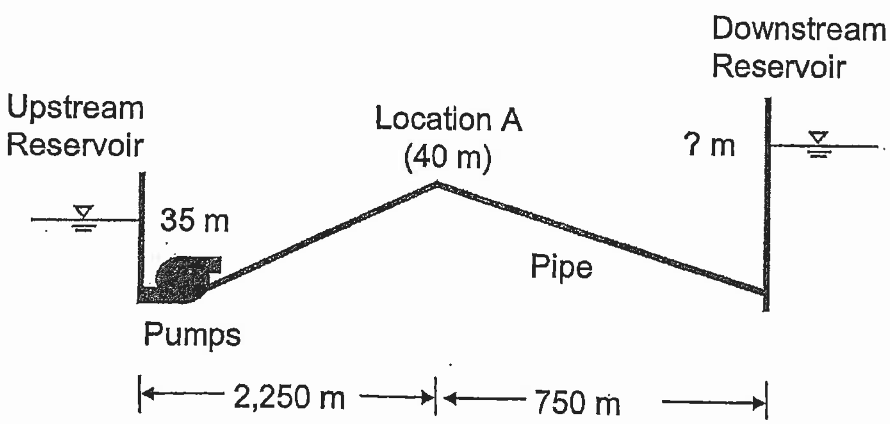


/20 2. A pump forces water through a 3 km long pipeline. Water is conveyed from an upstream reservoir (water level of 35 m) to a downstream reservoir. The high point in the pipe-pump system (location A) has a ground elevation of 40 m. The pipe has an internal diameter of 381 mm and a Darcy-Weisbach friction factor of 0.015. Two pumps are connected in series at the upstream reservoir. Each pump has a characteristic curve described by TDH = 80 - 10 Q^2, in which TDH is the total dynamic head of the pump (in metres) and Q is the pump discharge in m^3/s. Assuming that friction losses in the system are accurately determined by the Darcy-Weisbach equation:

a) Estimate the total flow supplied by the two pumps in series that will produce a pressure head equal to or higher than 20 m at the high point location.

b) For the flow calculated in a), what is the water level in the downstream reservoir?

c) Estimate the total flow supplied by the two pumps in parallel that will produce a pressure head equal to or higher than 20 m at the high point location. What is the water level in the downstream reservoir?

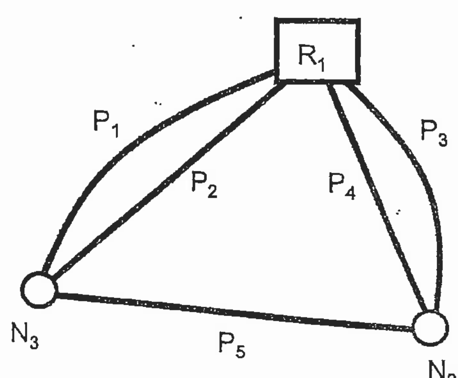


Not to Scale

/20 3. The water distribution network shown below has 5 pipes with the following parameters: length = 750 m, Hazen-Williams 'C' factor = 115, and inner diameter = 381 mm. The reservoir (R_1) has a water level of 60 m. All nodes are at elevation of 15 m. The demand at node 2 is Q_2 = 150 L/s, and the demand at node 3 is Q_3 = 500 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.



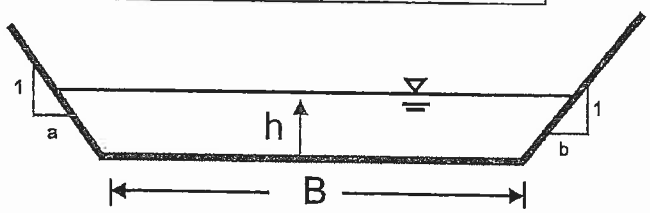
/20 4. The side slopes, bottom width, and lining material of the trapezoidal open channel shown below are being designed. Side slopes ranging from 1:2 (1 vertical to 2 horizontal) to 1:5 can be selected in the design. A bottom width that ranges from 50 m to 100 m is permitted. The Manning's n for the available lining materials is indicated in the table below. The open channel has a longitudinal slope of 0.5% and is to carry a design flow of 2 m^3/s.

a) Choose side slopes, a bottom width, and a lining material to meet the design flow. In your design, the water depth must be between 5 m and 8 m.

b) For your design in a), calculate the water depth for a longitudinal channel slope of 0.7%.

Table: Manning's n for channel lining materials.

Channel Lining	Manning's n
Concrete	0.013
Rubble in cement	0.020
Asphalt, smooth	0.013
Asphalt, rough	0.016
Corrugated metal	0.024



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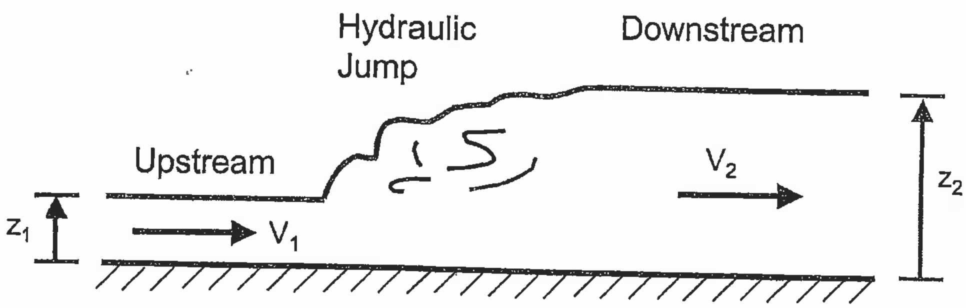
/20 5. The flow in a trapezoidal open channel is 5 m^3/s. The trapezoidal section has a bottom width of 14 m and side slopes of 1 vertical to 3 horizontal. The water depth z_1 upstream of the hydraulic jump is 0.1 m.

a) Apply the control mass/control volume to find the momentum equation for the hydraulic jump in the trapezoidal channel.

b) Compute the water depth z_2 downstream of the hydraulic jump.



Side view

Not to Scale

/20 6. Pipes 1 and 2 convey water from two reservoirs to a downstream location controlled by a valve. Pipe 1 has a diameter of 381 mm, a 'C' factor of 120, and a length of 500 m. Pipe 2 has a diameter of 203 mm, a 'C' factor of 125, and a length of 400 m. Reservoir 1 has a cross sectional area of 300 m^2 and Reservoir 2 a cross sectional area of 75 m^2. Flow through the valve (in m^3/s) is approximated with the valve equation

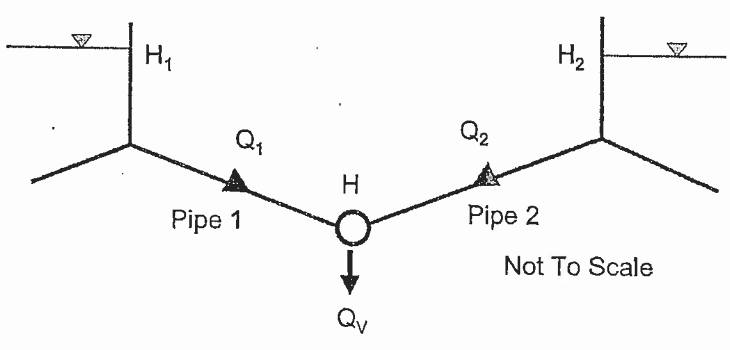
$$Q_v = \tau E_s \sqrt{H - H_0}$$

where Q_v = discharge (in m^3/s), E_s = valve discharge constant (E_s = 0.5 m$^{5/2}$/s), H = hydraulic head upstream of valve, H_0 = hydraulic head downstream of valve. The hydraulic head downstream of the valve is equal to 0 m since the valve discharges to the atmosphere.

a) When the valve is partially closed (τ = 0.3), determine the head, H, upstream of the valve, the flow, Q_v through the valve, and the flows Q_1 and Q_2 in Pipes 1 and 2. Assume steady state conditions and that reservoir levels H_1 = 61 m and H_2 = 45 m are constant.

b) Write the governing equations that describe the quasi-steady state conditions in the reservoir-pipe-valve system.

c) If initial water levels are H_1 = 61 m and H_2 = 45 m, compute the water levels H_1 and H_2 at time 240 s after the starting time in a) assuming quasi-steady state conditions.



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