National Exams December 2011

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
   - A 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 branched pipe network conveys water from reservoir R1 with constant water level of 60 m to 5 nodes, all at elevation of 10 m (Figure 1). All pipes are made of PVC material and have a Hazen-Williams 'C' factor of 141, an internal diameter of 406 mm, and a length of 250 m. Nodes 1 through 5 have a maximum day demand of 2 L/s. Node 5 also carries a fire flow of 33 L/s.

a) Determine the steady-state pressure head at Node 4 during maximum day demand + fire flow at Node 5.

b) Determine the steady-state pressure head at Node 5 during maximum day demand (no fire flow at Node 5).

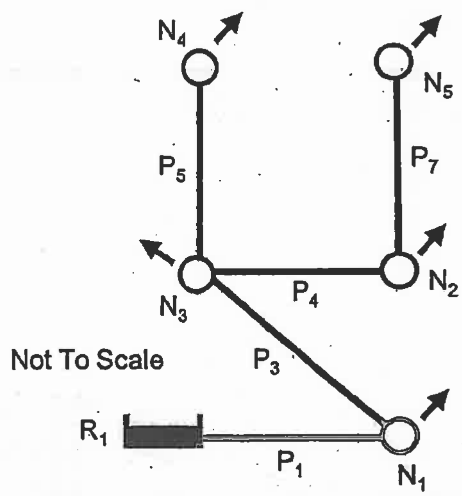


Figure 1. Branched network layout.

/20 2. The pipe network in Figure 2 distributes water from reservoirs R1 and R2 to nodes N1 through N4. The HGL in reservoir R1 is 185 m and the HGL in reservoir R2 is 160 m. All pipes have a length of 250 m, a Hazen-Williams 'C' factor of 140, and an inner diameter of 254 mm. The pipe centerline elevations and customer demands at each node are indicated in Table 1. Calculate the flow in pipes P3 and P4 and the pressure head at nodes N2, N3, and N4.

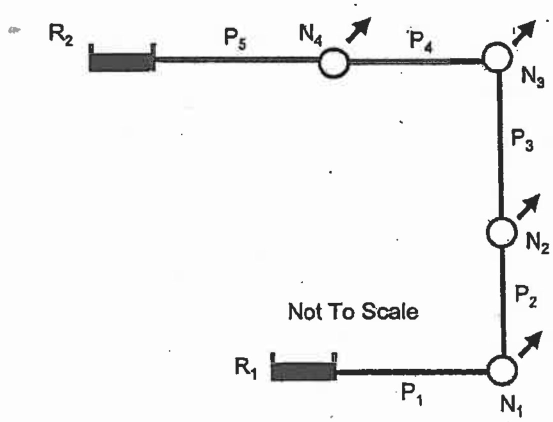


Figure 2. Layout of water pipe network.

Table 1. Pipe centerline elevations and demands at network nodes.

Pipe ID	Pipe Centreline Elevation (m)	Demand (L/s)
N1	120.0	20
N2	115.0	15
N3	110.0	19
N4	130.0	6

/20 3. The water surface in a large reservoir (A) is 70 m above datum while the surface elevation of a second reservoir (C) is at 40 m (Figure 3). The two reservoirs are connected by a pipe 5000 m long having a Hazen-Williams 'C' of 130 and a diameter of 810 mm. After leaving the upstream reservoir the pipeline climbs a hill to a maximum ground elevation of 50 m (point B) at distance of 1450 m from the upstream reservoir. A pumping station at A consists of two identical pumps having a head-discharge curve described by

$$H = 30 - 10\,Q^{1.8}$$

in which H is the total dynamic head of the pump (in metres) and Q is the pump discharge (in cubic metres per second).

a) Determine the flow in the pipeline for both series and parallel operation of the two pumps.

b) Would you recommend series or parallel operation of this system? Why?

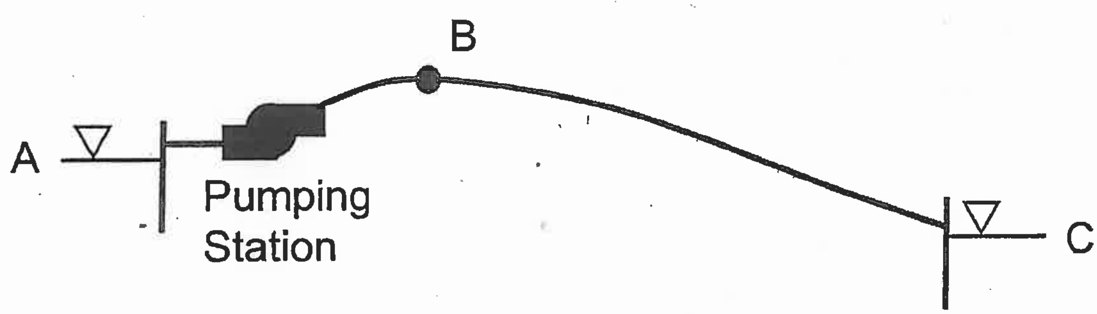


Figure 3. Layout of pipeline system.

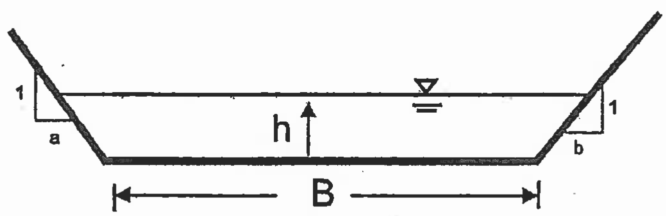
/20 4. The side slopes, bottom width, and lining material of the trapezoidal open channel shown below are being designed (Figure 4). Side slopes ranging from 1:2 (1 vertical to 2 horizontal) to 1:5 can be selected in the design. A bottom width that ranges from 50 m to 75 m is permitted. The Manning's n for the available lining materials is indicated in Table 2 below. The open channel has a longitudinal slope of 1.0% and is to carry a design flow of 2.5 m^3/s.

a) Choose side slopes, a bottom width, and a lining material to meet the design flow. What is the water depth in the designed channel for the design flow of 2.5 m^3/s?

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

Table 2: Manning's n for channel lining materials.

Channel Lining	Manning's n
Concrete	0.013
Rubble in cement	0.022
Asphalt, smooth	0.014
Asphalt, rough	0.015
Corrugated metal	0.025



Not To Scale

Figure 4. Cross-sectional area of trapezoidal channel.

/20 5. The open channel in Figure 5 carries flow under steady-state, uniform, and laminar conditions. Pressure in the fluid column is hydrostatic. Under these conditions, a momentum equation can be written to describe the balance between the self weight and shear force that act on the elemental volume of fluid such that

$$W \sin\theta - \tau \Delta s = 0$$

Starting from the momentum expression above, derive a closed-form equation that describes fluid velocity as a function of fluid depth y. You can assume that the shearing stress is proportional to the velocity gradient such that

$$\tau = \mu \frac{du}{dy}$$

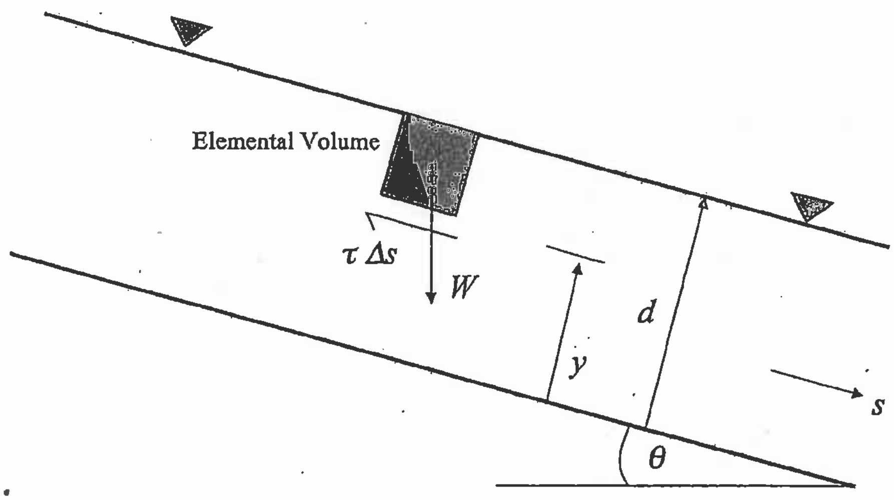


Figure 5. Elevation view of open channel.

/20 6. A sudden slope failure causes a large amount of gravel and rock material to slide into a river. This failure completely blocks the flow of the river.

a) Describe the hydraulic conditions just upstream and downstream of the blockage immediately following the slope failure. Structure your explanation in relation to continuity, momentum, and energy principles. Be as specific as possible.

b) Write the St-Venant equations that describe the unsteady, non-uniform flow conditions that might prevail immediately after the slope failure. Describe each term of the St-Venant equations.