National Exams May 2011

07-Str-B11, 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
   - approved Casio or Sharp 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 (Figure 1). The water level in the elevated tank is 49 m. The PVC pipe has a Hazen-Williams 'C' factor of 135, an internal diameter of 520 mm, and a length of 1,200 m.

a) Determine the steady-state flow in the PVC pipe.

b) Determine the internal pipe diameter needed to produce a fluid velocity equal to or lower than 3 m/s?

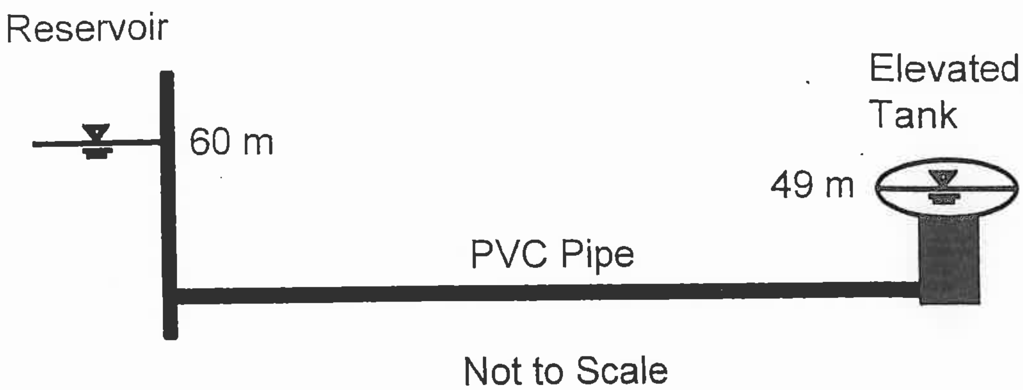


Figure 1. Pipeline layout.

/20 2. The pipe network in Figure 2 distributes water from reservoirs R1 and R2 to nodes N1 through N5. The HGL in reservoir R1 is 185 m and the HGL in reservoir R2 is 170 m. Gate valves in pipes P7, P8, and P9 have been closed to isolate these pipes from the rest of the network. All pipes have a length of 250 m, a Hazen-Williams 'C' factor of 130, 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 P6 and the pressure head at nodes N2 and N4.

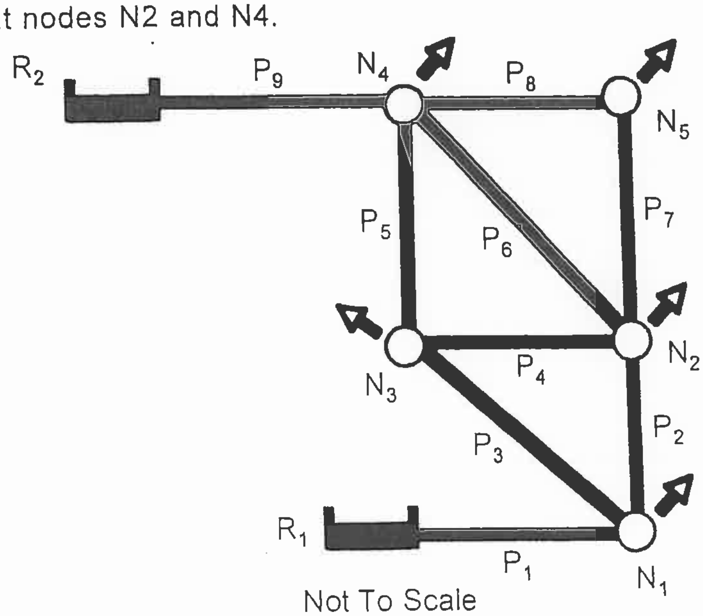


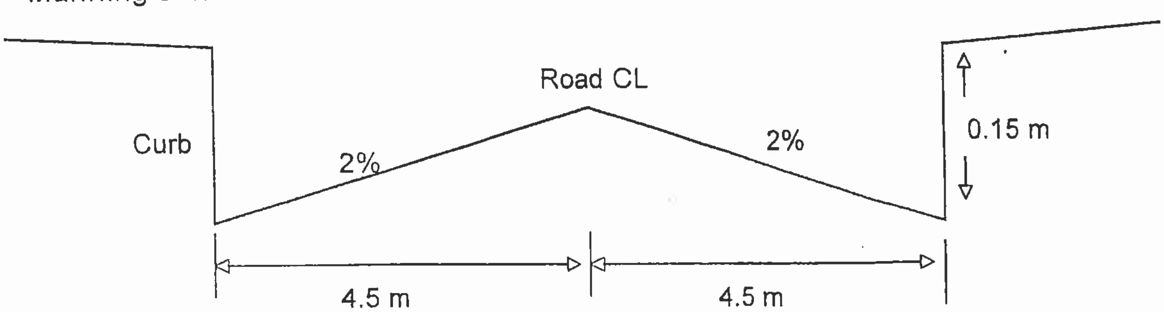
Figure 2. Layout of water pipe network.

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

Pipe ID	Pipe Centreline Elevation (m)	Demand (L/s)
N1	120.0	40
N2	115.0	35
N3	110.0	39
N4	130.0	12
N5	135.0	11

/20 3. Gate valves in pipes P2, P5, P7, and P8 of the network in Figure 2 have been closed. Gate valves along all other pipes are fully open and cause no local losses. Calculate the flow in pipes P6 and P9 and the pressure head at node N2.

/20 4. The road indicated in Figure 3 carries a 100-year flood flow of 2.3 m^3/s. The road bed is bounded by 15 cm curbs. The longitudinal slope of the road is 3%. Determine if all the flow is carried within the road bed (between the curbs). Support your answer with detailed calculations. Assume that asphalt has a Manning's 'n' of 0.015.



Road Cross Section
(Not to Scale)

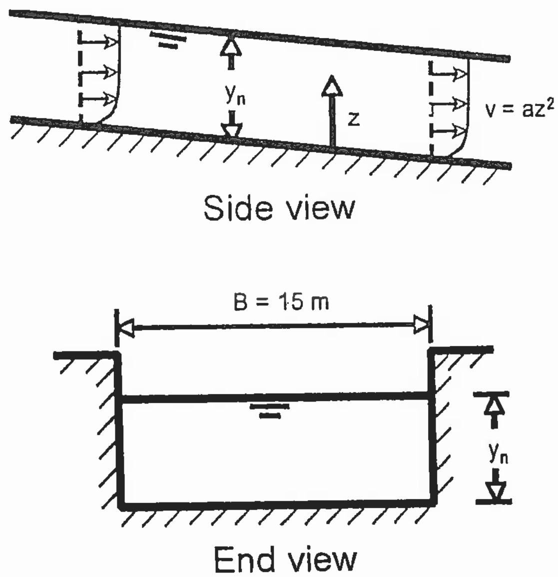
Figure 3. Road cross-section.

/20 5. The open channel in Figure 4 carries water under steady, uniform flow conditions. The channel is B = 15 m wide, and its bottom and walls are lined with smooth asphalt. The channel has a Manning's coefficient of n = 0.013. The normal depth in the channel is y_n = 2 m.

a) Field measurements have shown that the velocity of the water increases with water depth in the channel. By virtue of the no-slip condition, velocity is zero at the channel bottom and velocity is at its maximum at normal depth y_n = 2 m. The relationship between water depth z and velocity v is

$$v = a\,z^2 \qquad 0 \le z \le y_n$$

where z = water depth measured from the bottom of the channel in metres; v = velocity in metres per second; a = empirical coefficient equal to 0.25 with units $m^{-1}s^{-1}$. What is the flow in the channel when the normal depth is y_n = 2 m? What is the fluid velocity at normal depth y_n = 2 m?



Not to Scale

Figure 4. Side view and cross-sectional view of open channel.

/20 6. A pipe connects two reservoirs with water levels of 70 m and 20 m, respectively in Figure 5. The pipe centerline is at a fixed datum of 0 m. The pipe has a length of 1,500 m and a 'C' factor of 115.

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

b) Write the rigid water column model equations that describe incompressible, uniform and unsteady flow conditions in the reservoir-pipe system.

c) Write the full waterhammer equations for compressible, non-uniform and unsteady flow conditions in the reservoir-pipe system.

d) Discuss the similarities and differences between the three flow conditions in a), b), and c).

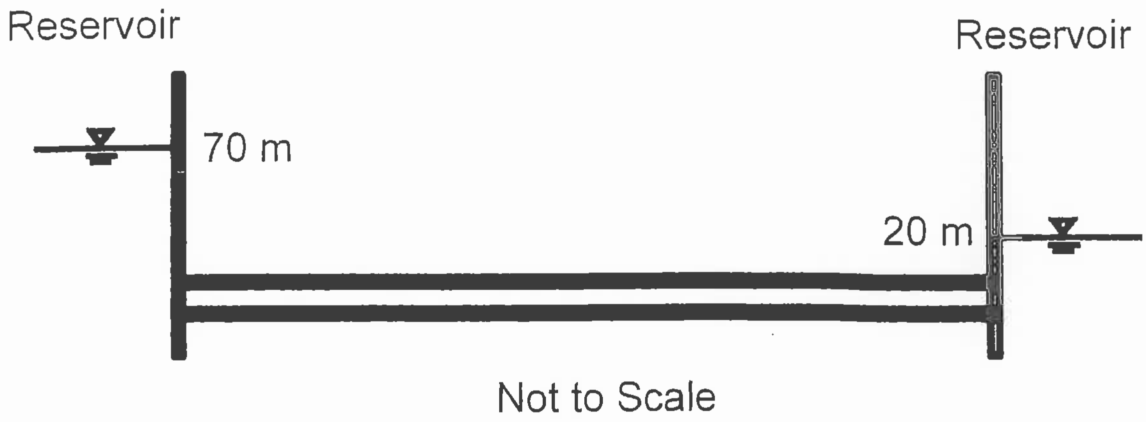


Figure 5. Pipeline layout.