National Exams December 2013

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. A Casio or Sharp approved models.

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: $Q = \dfrac{A}{n}R^{2/3}S^{0.5}$, $S{=}\Delta h/L$
   - Darcy-Weisbach: $\Delta h = \dfrac{fL}{D}\cdot\dfrac{V^2}{2g} = 0.0826\dfrac{fL}{D^5}\cdot Q^2$
   - Loop Corrections: $q_l = -\dfrac{\sum_{\text{loop}} k_i Q_i |Q_i|^{n-1}}{n\sum_{\text{loop}} k_i |Q_i|^{n-1}}$, n = 1.852 (Hazen-Williams)
   - Total Dynamic Head: TDH = $H_s + H_f$, H_s=static head; H_f=friction losses

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.

/20 1. A branched pipe network conveys water from reservoir R1 with constant water level of 70 m to 5 nodes, all at elevation of 20 m (Figure 1). All pipes are made of PVC material and have a Hazen-Williams 'C' factor of 138, an internal diameter of 406 mm, and a length of 255 m. Nodes 1 through 5 have a maximum day demand of 1.5 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).

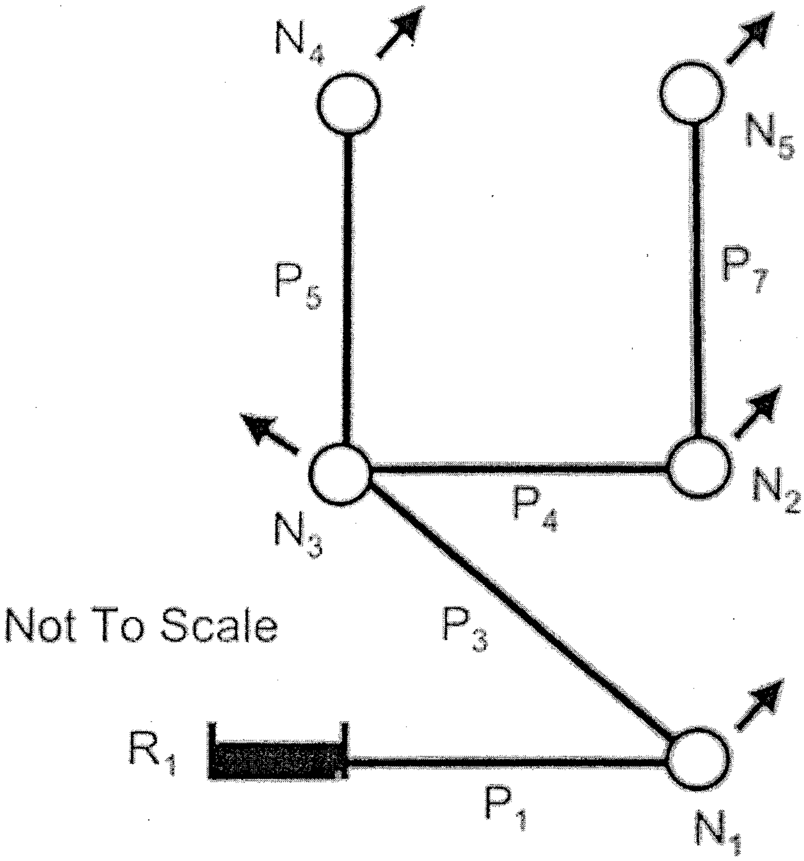
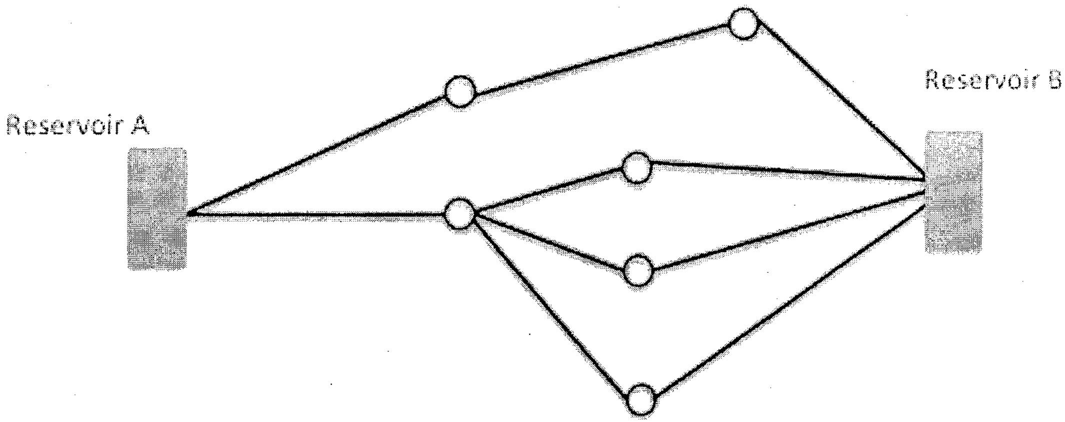


Figure 1. Water supply system.

/20 2. Ten identical pipes connect an upstream reservoir A (water elevation 80 m) to a downstream reservoir B (water elevation 70 m). All the pipes are at 25 m elevation. Each pipe has a 300 mm diameter, is 250 m long and has a 'C' value of 130.

a) Determine the total flow through this pipe system.

b) Determine the maximum and minimum pressure head in the system.



/20 3. 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 1,067 mm. The upstream reservoir has a water level of 105 m. The valve discharge constant is Es = 0.35 $m^{5/2}/s$.

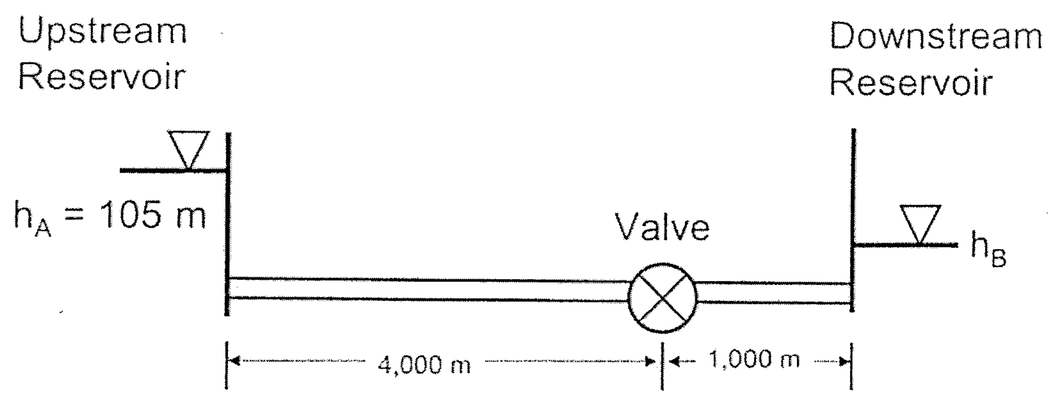
$$Q = \tau E_s \sqrt{H_{u/s} - H_{d/s}}$$

where Q = discharge (m^3/s), Es = valve discharge constant ($m^{5/2}/s$), Hu/s = upstream head, Hd/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.



/20 4. Two elevated tanks supply water to a demand node with a valve at its outlet (Figure 2). The elevated tanks are cylindrical and have diameters of 5 m. The initial water level in Tank 1 is 96 m and the initial water level in Tank 2 is 91 m. The valve is half open and has a discharge coefficient of 0.15 $m^{5/2}/s$. The initial steady-state flow through the valve is 350 L/s. The valve discharges to the atmosphere. Both pipes have a Hazen-Williams 'C' factor of 100, an internal diameter of 300 mm, and a length of 350 m. Assuming quasi-steady conditions in the system, determine the pressure head at the demand node and the flow in the pipes in the first three time steps of the simulation. Use a time step of 15 seconds to carry out the quasi-steady state simulation.

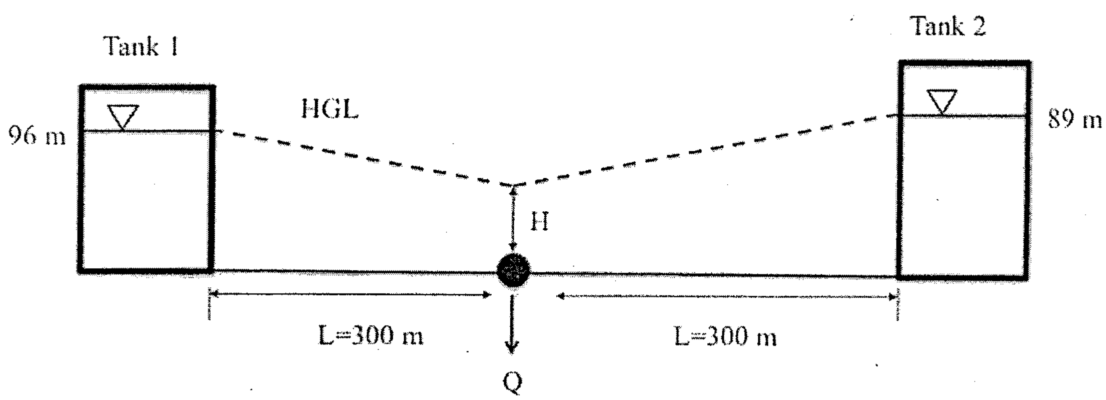


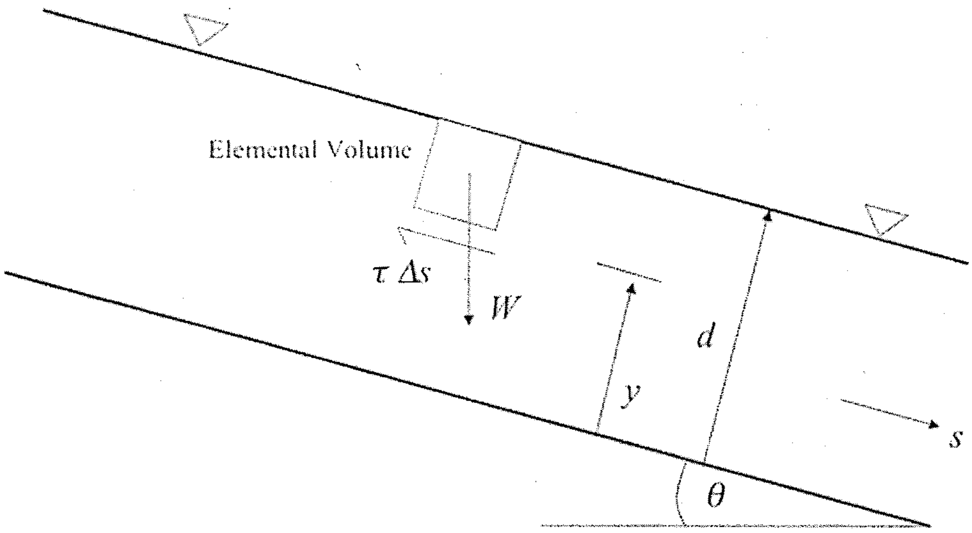
Figure 2. Water supply system.

/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

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



/20 6. A road cross-section is 8 m wide (from edge to edge of pavement), with a 2% crossfall slope from the centreline and is bounded by curbs. The Manning's 'n' for asphalt is 0.013 and the longitudinal slope of the roadway is 0.01.

a) Calculate the water depth in the road cross-section when the flow is 1 m^3/s.

b) The flood flow is expected to increase by 15% with a change in climate. Under these new conditions, calculate the water depth in the road cross-section. Can the road "contain" the new climate-adjusted flow within the roadway section?

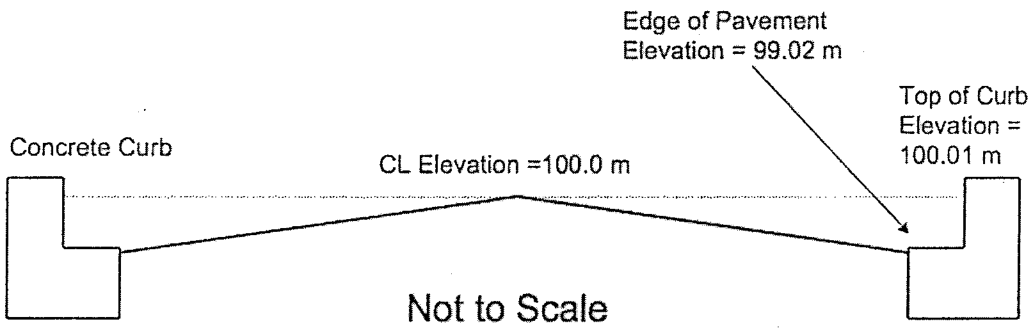


Figure 3. Roadway cross-section.