National Exams May 2015

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. 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: $Q=\frac{A}{n}R^{2/3}S^{0.5}$, $S=\Delta h/L$
   - Darcy-Weisbach: $\Delta h = \frac{fL}{D}\cdot\frac{V^2}{2g} = 0.0826\frac{fL}{D^5}\cdot Q^2$
   - 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

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. The pipes indicated in Figure 1 carry flow from upstream reservoir A with a hydraulic head of 100 m to downstream reservoir B with a hydraulic head of 70 m. All the pipes have a length of 1,000 m, a 'C' factor of 120, and a diameter of 250 mm. Using equivalent pipe calculations, calculate the total flow through the system. Calculate the flow through pipe 5.

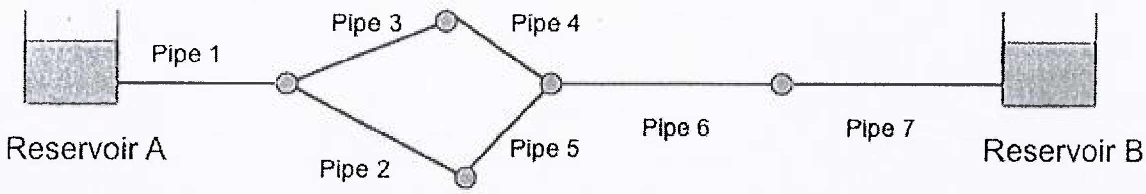

Figure 1. Network of pipes that carries flow from upstream reservoir A to downstream reservoir B.

/20 2. A transmission pipeline that conveys water from an upstream reservoir to a downstream reservoir is indicated below in Figure 2. 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 120, and an inner diameter of 450 mm. The upstream reservoir has a water level of 95 m. The valve discharge constant is Es = 0.45 $m^{5/2}/s$.

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

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

a) If the flow through the system is 0.2 m^3/s, and the valve is partially closed (τ-value is equal to 0.8), calculate the hydraulic grade line in the downstream reservoir.

b) When the valve is closed further, the τ value is lowered to τ = 0.6. If the water level in the downstream reservoir remains fixed at the level computed in b), compute the discharge in the transmission pipeline.

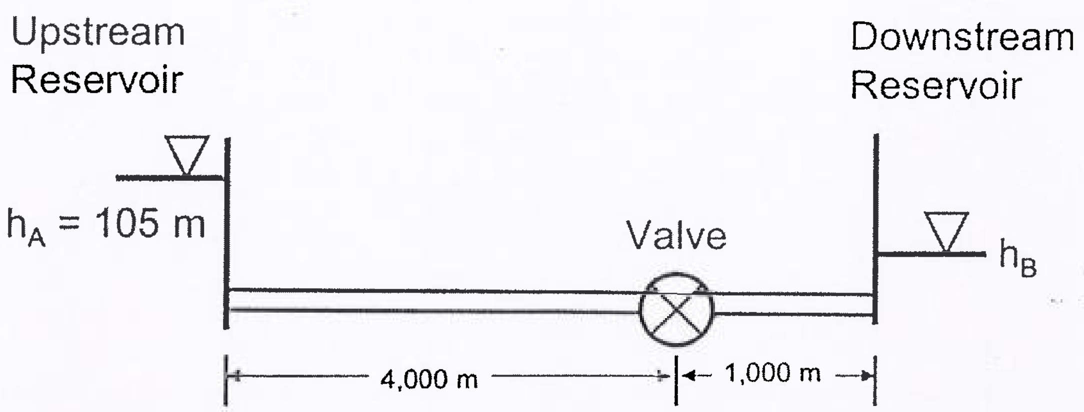

Figure 2. Schematic of water transmission system.

/20 3. A water supply reservoir with a constant but unknown water level supplies a water distribution network, as shown in Figure 3. The elevation and water demand at the nodes of the distribution network are indicated in Table 1. All pipes have a diameter of 203 mm, a Hazen-Williams 'C' factor of 130, and a length of 1,500 m.

a) If a pressure head of 25 m must be supplied at Node 3, what should the water level be at the supply reservoir?

b) If a valve along pipe 5 is shut-off such that there is no flow in pipe 5, will pressure head at Node 3 increase or decrease? Explain with hydraulic arguments.

c) Valves along pipes P5 and P6 have been closed such that pipes P5 and P6 carry no flow. Using hydraulic arguments, explain the implications for water quality, reliability, and fire protection for users located at Node N4. Use words, schematics, and equations (if possible) to make your case.

Table 1. Ground elevations and water demand at the nodes

Node ID	Node Elevation (m)	Water Demand (L/s)
N1	15	5
N2	15	10
N3	20	5
N4	15	30

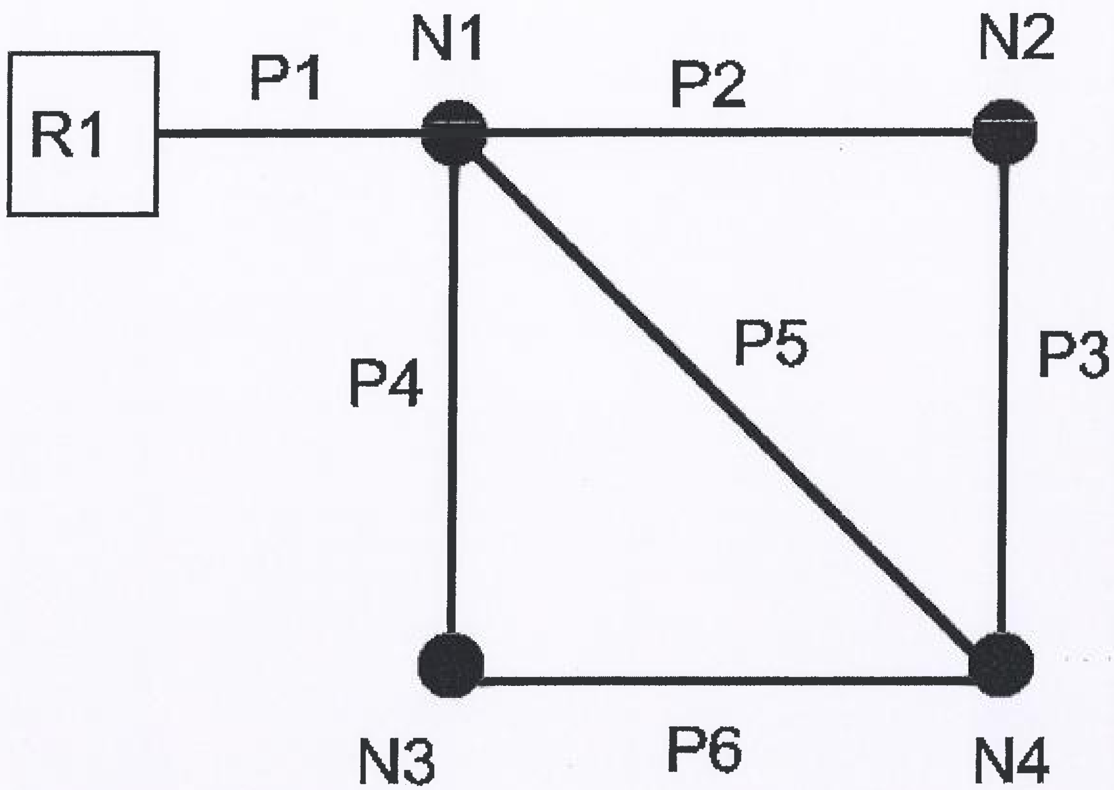

Figure 3. Schematic of water distribution system.

/20 4. An upstream reservoir with starting water level of 80 m drains into a downstream reservoir with starting water level of 40 m via a pipe. The pipe has a 450 mm diameter, a 1,000 m length, and a 'C' factor of 120. The upstream and downstream reservoirs each have a cross sectional area of 5 m^2.

a) Determine the steady state flow in the pipe at time t = 0.

b) Use the rigid water column model to determine the flow in the pipe and the water levels in the upstream and downstream reservoirs for the first two time steps $t1=\Delta t$ and $t2=2\Delta t$.

c) The plots in Figure 4a-b shows the system response when the pipe has a diameter of 450 mm (Figure 4a) and when the pipe diameter is increased to a 750 mm diameter (Figure 4b). Explain the difference between these two responses. Base your explanation on the physical meaning of the mathematical terms in the rigid water column model.

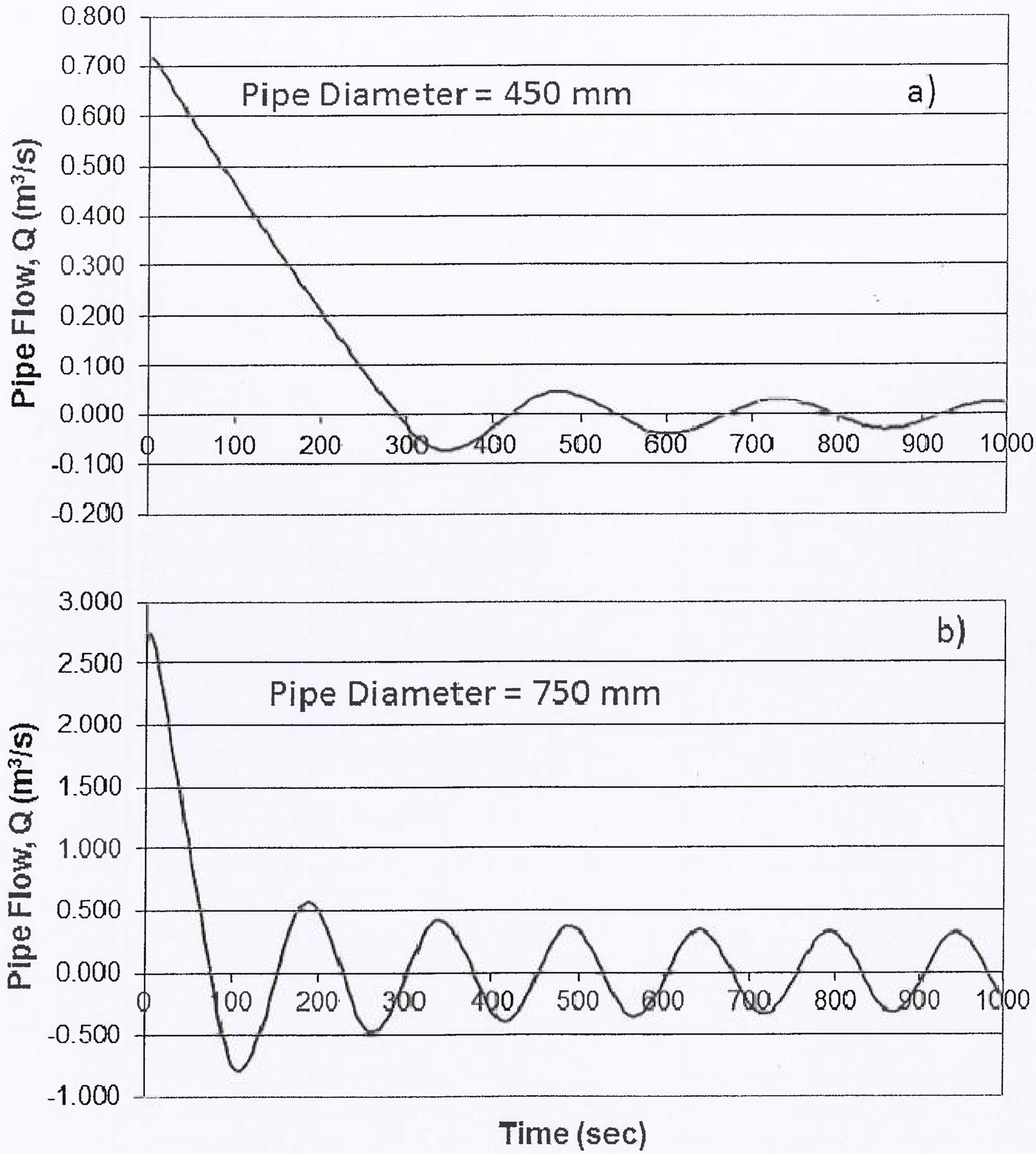

Figure 4a-b: Time series of flow in a) 450 mm pipe, and b) 750 mm pipe for the first 1,000 sec of the simulation.

/20 5. A sluice gate is closed suddenly downstream of a rectangular channel. During a brief period of time after the closure of the gate, the upstream water surface profile at times t = 0, t = Δt, and t = Δt (indicated in Figure 5) are observed. Based on the appearance of the water surface profiles in Figure 5, discuss whether the kinematic wave model or the dynamic wave model would be more appropriate to describe the hydraulic conditions in the channel. Structure your answer in terms of the mathematical terms in one of these models as well as key concepts such as steady flow, unsteady flow, uniform flow, non-uniform flow, momentum, inertia, compressibility and any other relevant concepts.

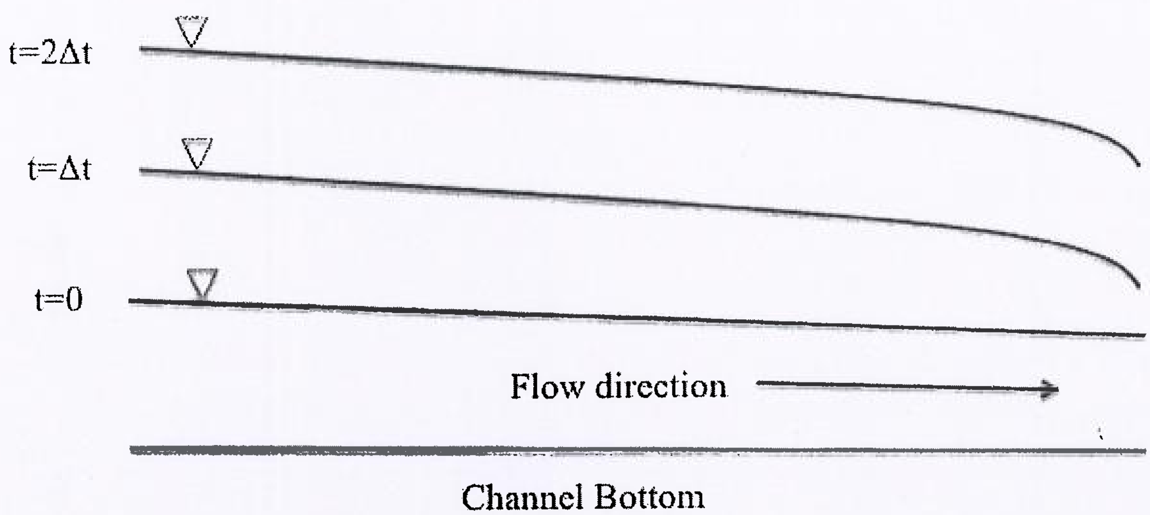

Figure 5. Water surface profile at times t = 0, t = Δt, and t = 2Δt in rectangular channel after sudden closure of sluice gate.

/20 6. A rectangular channel carries a flow of 3.0 m^3/s. The rectangular channel has a width of 11 m and sides of height 2.5 m. The Manning's 'n' for the channel is 0.015 and its longitudinal slope is 0.002.

a) Calculate the normal depth in the channel.

b) The channel leads to a broad-crested weir where flow measurements are taken and critical depth occurs. Calculate critical depth just upstream of the broad-crested weir.

c) Given your calculations in a) and b), are flow conditions well upstream of the broad-crested weir sub-critical or super-critical?

d) If you can, draw a diagram of specific energy and on this diagram show the progression from sub- or super-critical conditions to critical conditions between the upstream section and the broad-crested weir.

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Marking Scheme

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