National Exams May 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
    - one of two calculators is permitted, any 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: $q_i = -\dfrac{\sum\limits_{loop} k_i Q_i |Q_i|^{n-1}}{n\sum\limits_{loop} k_i |Q_i|^{n-1}}$, $n = 1.852$ (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 $\rho = 1{,}000$ kg/m^3 and kinematic viscosity $\upsilon = 1.31 \times 10^{-6}$ m^2/s.

/20   1. The hydraulic grade line in a water supply system at 7 am is as indicated in Figure 1. The water level in Reservoir 1 is 96 m and the water level in Reservoir 2 is 91 m. The demand at 7 am at the demand node is 20 L/s. Both water supply pipes have a Hazen-Williams 'C' factor of 120, and an internal diameter of 200 mm. Determine the flow in each pipe and the pressure head at the demand node at 7 am.
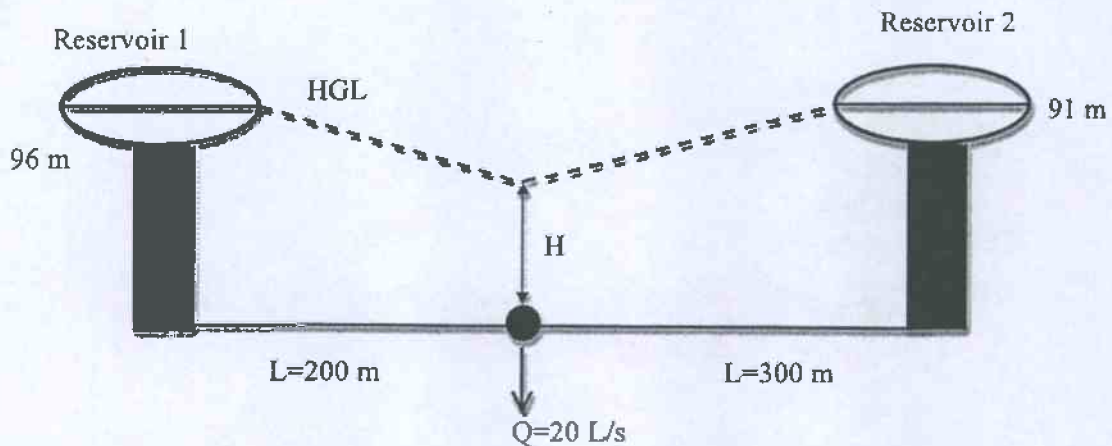

Figure 1. Water supply system.

/20   2.Ten identical pipes connect an upstream reservoir A (water elevation 90 m) to a downstream reservoir B (water elevation 85 m) . The elevations of the pipe nodes are given by dashed contour lines with the contour elevations indicated (in metres). Each pipe has a 300 mm diameter, is 250 m long and has a 'C' value of 140.

    a) Determine the total flow through this pipe system.

   b) Determine the maximum and minimum pressure head in the system.
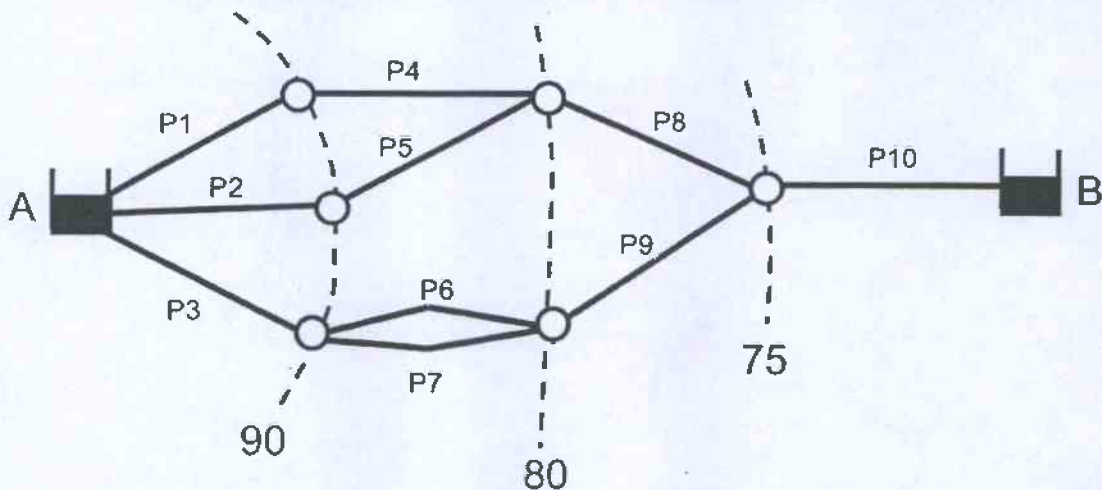
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3. The water surface in a large reservoir (A) is 50 m above datum while the surface elevation of a second reservoir (C) is at 40 m as indicated in the sketch below. The two reservoirs are connected by a pipe 6000 m long having a Hazen-Williams 'C' of 140 and a diameter of 800 mm. After leaving the upstream reservoir the pipeline climbs a hill to a maximum ground elevation of 55 m (point B) at distance of 1200 m from the upstream reservoir. A pumping station at A consists of two identical pumps having a head-discharge curve described by

$$H = 20 - 9\, Q^{1.8}$$

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) The minimum allowable pressure head at any point in the pipe is 14 m. For a series pump configuration, is the pressure at point B above the 14 m minimum?
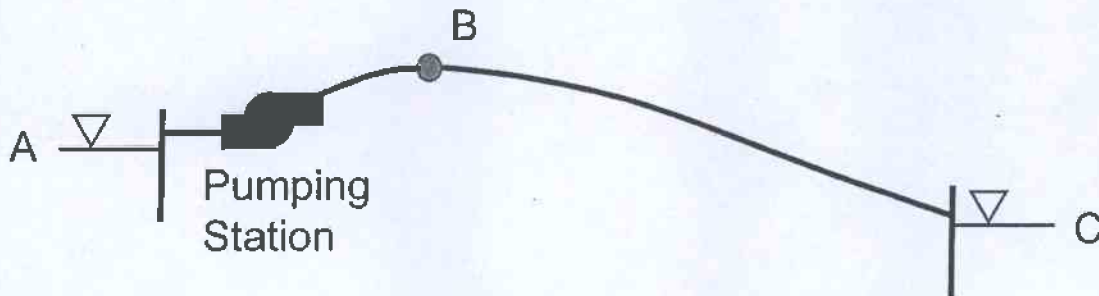
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4. Two elevated tanks supply water to a demand node with a valve at its outlet (Figure 2). The elevated tanks are cylindrical and have diameters of 5 m. The initial water level in Tank 1 is 96 m and the initial water level in Tank 2 is 89 m. The valve is half open and has a discharge coefficient of 0.13 $m^{5/2}$/s. The initial steady-state flow through the valve is 400 L/s. The valve discharges to the atmosphere. Both pipes have a Hazen-Williams 'C' factor of 110, an internal diameter of 250 mm, and a length of 300 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 10 seconds to carry out the quasi-steady state simulation.
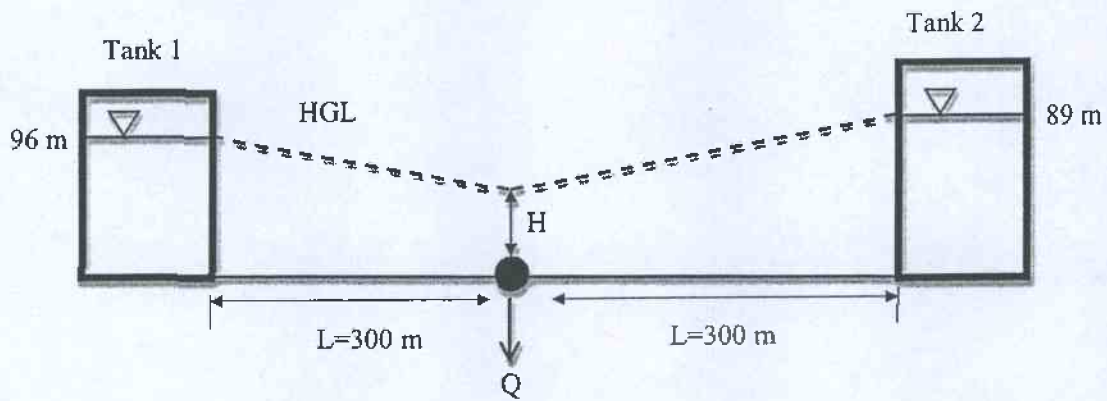
Figure 2. Water supply system.

/20   5. 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) Located immediately upstream of the blockage is a storm water sewer outfall from a small town. What potential impact(s) can the river blockage have on the sewer outfall and town? Be as specific as possible.

/20   6. The cross section of a flood protection system is shown in Figure 3. The flood protection system is comprised of Channels A and B. Channel A is designed to carry minor storm flows. When channel A is full, the surplus water from Channel A spills onto Channel B. The longitudinal slope of both channels is 0.001 and Manning's 'n' for both channels is 0.013.

a) When the flow is 21 m^3/s, calculate the water level in Channel A. Assume that Channel B does not carry any flow.

b) When the flow is increased to 60 m^3/s, can Channel A carry all of the flow? If not, what is the water level in Channel B?
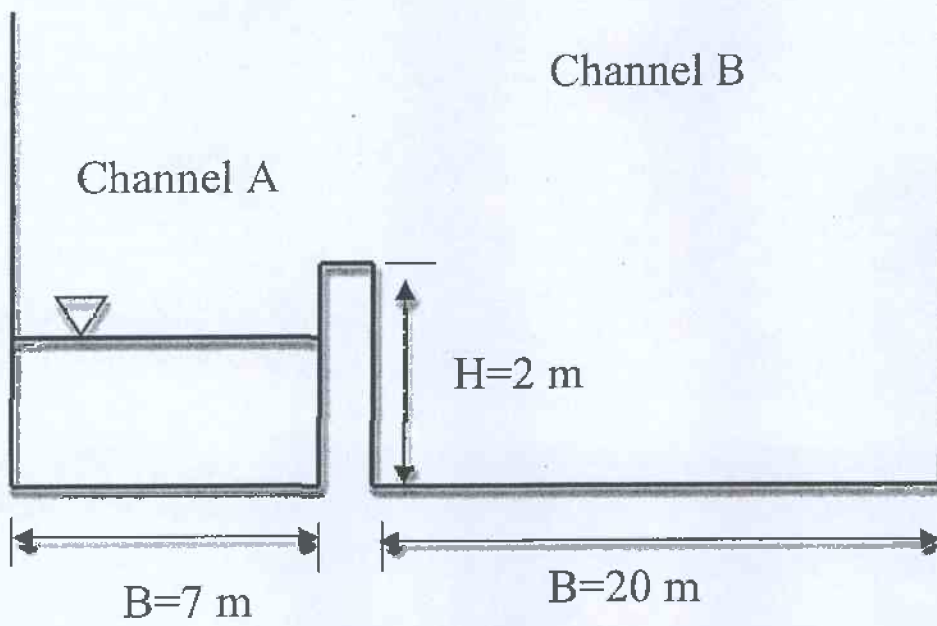
Figure 3. Flood protection system.

Marking Scheme

1. 20 marks total   (1 part)
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   (2 parts times 10 marks each)