National Exams December 2019

16-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.

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: $Q = 0.278CD^{2.63}S^{0.54}$, $S=\Delta h/L$

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. 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.

c) The plots in Figures **Q4 – A and B** show the system response when the pipe has a diameter of 450 mm (Figure **Q4 – A**) and when the pipe diameter is increased to a 750 mm diameter (Figure **Q4 – B**). Explain the difference between these two responses. Base your explanation on the physical meaning of the mathematical terms in the rigid water column model and the initial amount of linear momentum of the water column at t = 0.

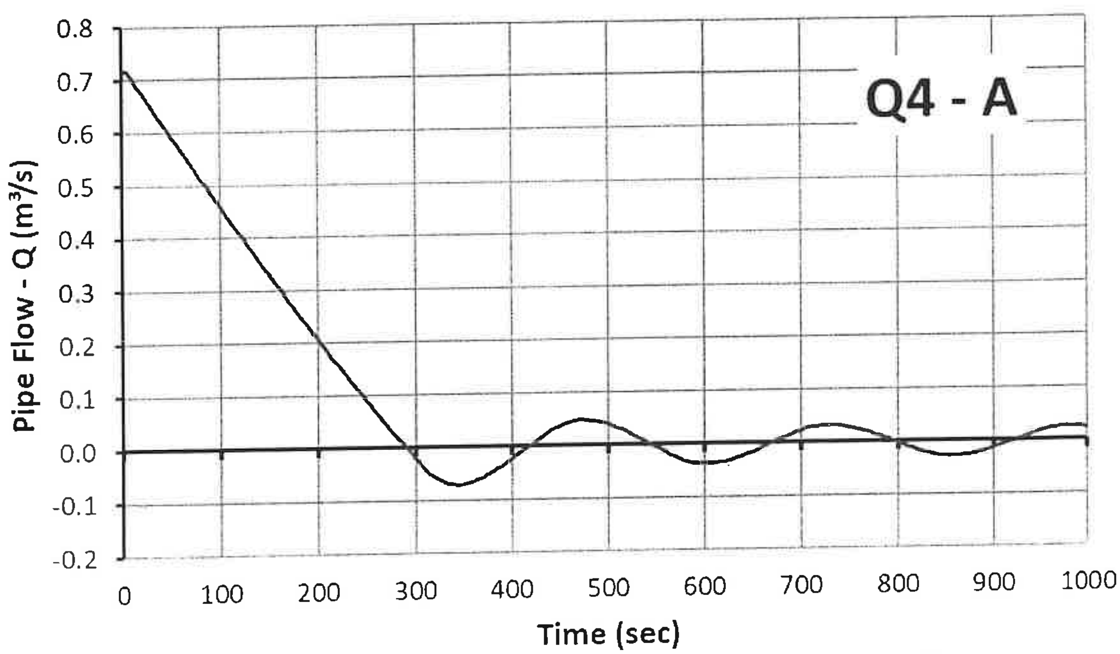


Figure **Q4 – A**. System response in a pipe with a 450 mm diameter

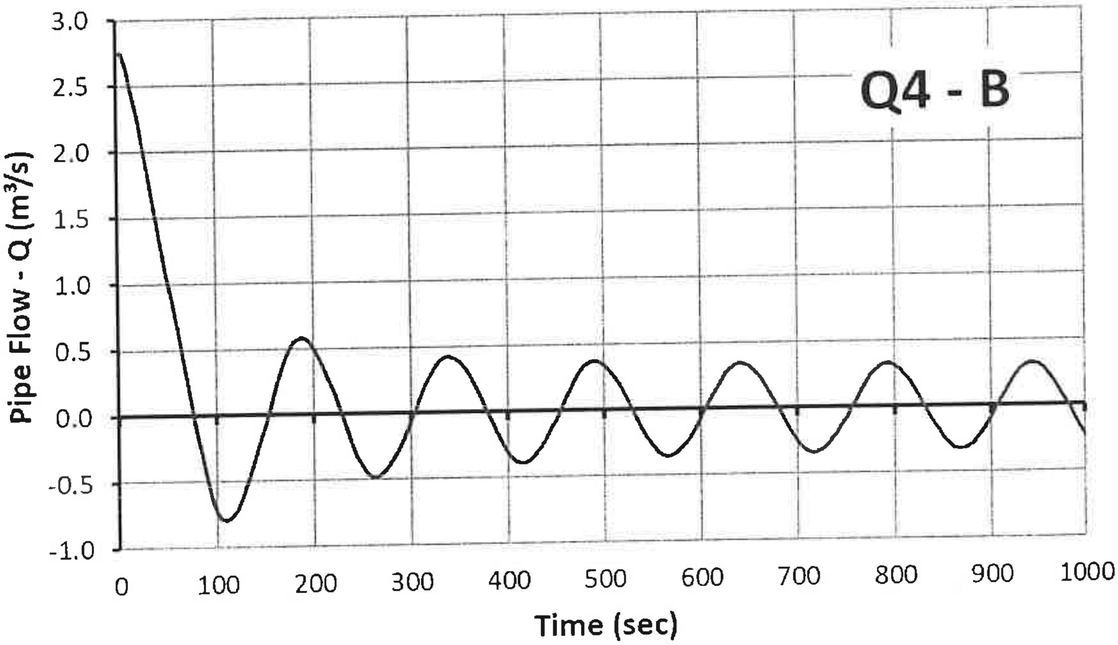


Figure **Q4 – B**. System response in a pipe with a 750 mm diameter.

/20 2. Using a force balance across a pipe, derive a closed-form equation that relates wall shear stress to average velocity in a pipe under steady-state conditions. The equation can be applicable to laminar or turbulent flow. For a pressure difference of 15 kPa across a length of 2 m in a pipe with a diameter of 150 mm, calculate the shear stress at the pipe wall.

/20 3. A transmission pipeline that conveys water from an upstream reservoir to a downstream reservoir is indicated in Figure 1. 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 100, and an inner diameter of 1,167 mm. The upstream reservoir has a water level of 105 m. The valve discharge constant is Es = 0.35 $m^{5/2}/s$.

$$Q = Es\ \tau\ [Hu/s - Hd/s]^{0.5}$$

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 0.92 m^3/s generates a headloss of 6 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.

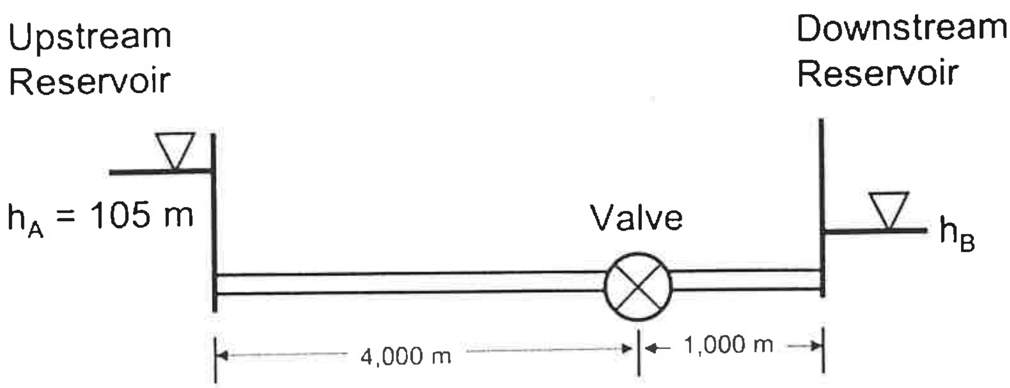


Figure 1.Tranmission pipeline.

/20 4.Ten identical pipes connect an upstream reservoir A (water elevation 95 m) to a downstream reservoir B (water elevation 70 m). The elevations of the pipe nodes are given by dashed contour lines with the contour elevations indicated (in metres). Each pipe has a 250 mm diameter, is 200 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.

c) Which branch conveys the highest flow: Branch P1-P2-P4-P5-P8 or Branch P3-P6-P7-P9? Why?

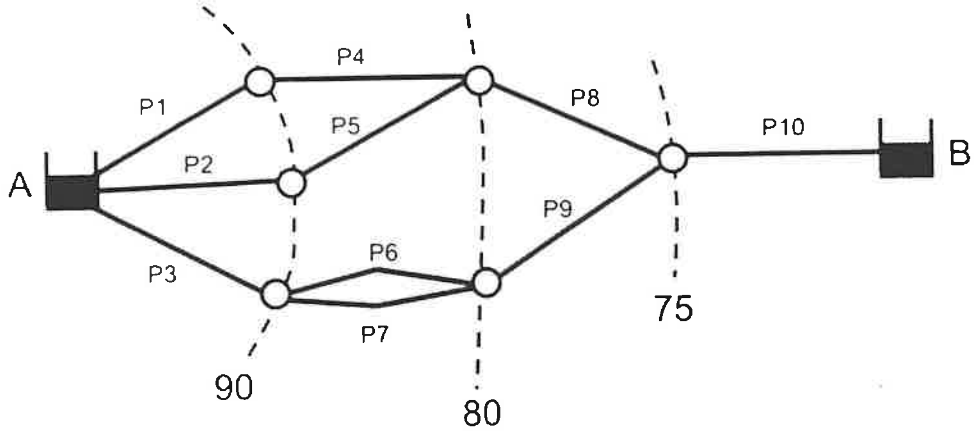


Figure 2. Network of pipes that carries flow from upstream reservoir A to downstream reservoir B.

/20 5. Consider a natural rectangular channel with a bottom width b = 150 m. The channel has a Manning's 'n' of 0.023 and a bed slope of S_0 = 0.001 m/m. The channel conveys a flow of 50 m^3/s.

A constriction produces a downstream water depth of 0.4 m in the channel and the resulting water surface profile shown in Figure 3. On the basis of the shape of the profile, the critical depth, the normal depth, the water surface slope and any other relevant parameter or equation, classify the water surface profile shown in Figure 3. Support your answer with calculations. (A table with water surface profile classifications is found below.)

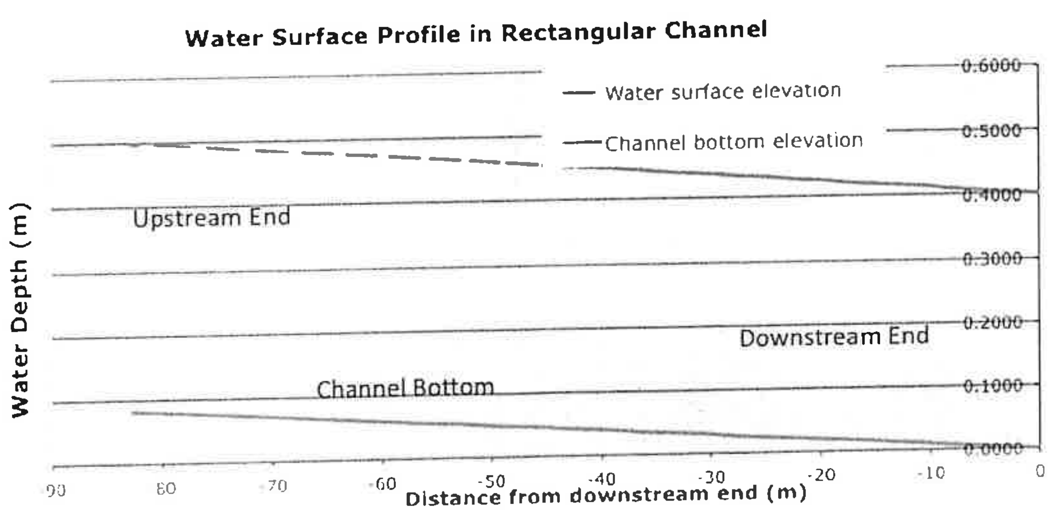
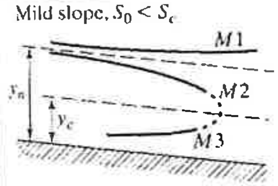
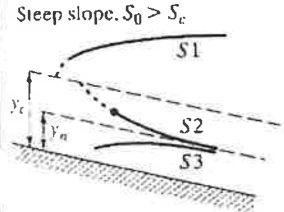
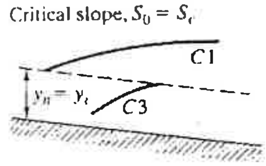
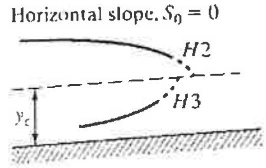
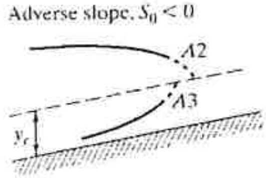


Figure 3. Water surface profile in open channel.

Table 1: Water surface profile classifications.

Table 7–2. Surface Profiles for Gradually Varied Flow

Surface Profiles	Curve	Depth	Flow	Surface Slope
Mild slope, $S_0 < S_c$ 	M1	$y > y_n > y_c$	Subcritical	Positive
	M2	$y_n > y > y_c$	Subcritical	Negative
	M3	$y_n > y_c > y$	Supercritical	Positive
Steep slope, $S_0 > S_c$ 	S1	$y > y_c > y_n$	Subcritical	Positive
	S2	$y_c > y > y_n$	Supercritical	Negative
	S3	$y_c > y_n > y$	Supercritical	Positive
Critical slope, $S_0 = S_c$ 	C1	$y > y_c = y_n$	Subcritical	Positive
	C3	$y < y_c = y_n$	Supercritical	Positive
Horizontal slope, $S_0 = 0$ 	H2	$y > y_c$	Subcritical	Negative
	H3	$y < y_c$	Supercritical	Positive
Adverse slope, $S_0 < 0$ 	A2	$y > y_c$	Subcritical	Negative
	A3	$y < y_c$	Supercritical	Positive

/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. 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 as they relate to the hydraulic occurrences in the river in the time following the rock slide. Structure your explanation in relation to continuity, momentum, and energy principles. Be as specific as possible.