National Exams May 2016

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. 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).

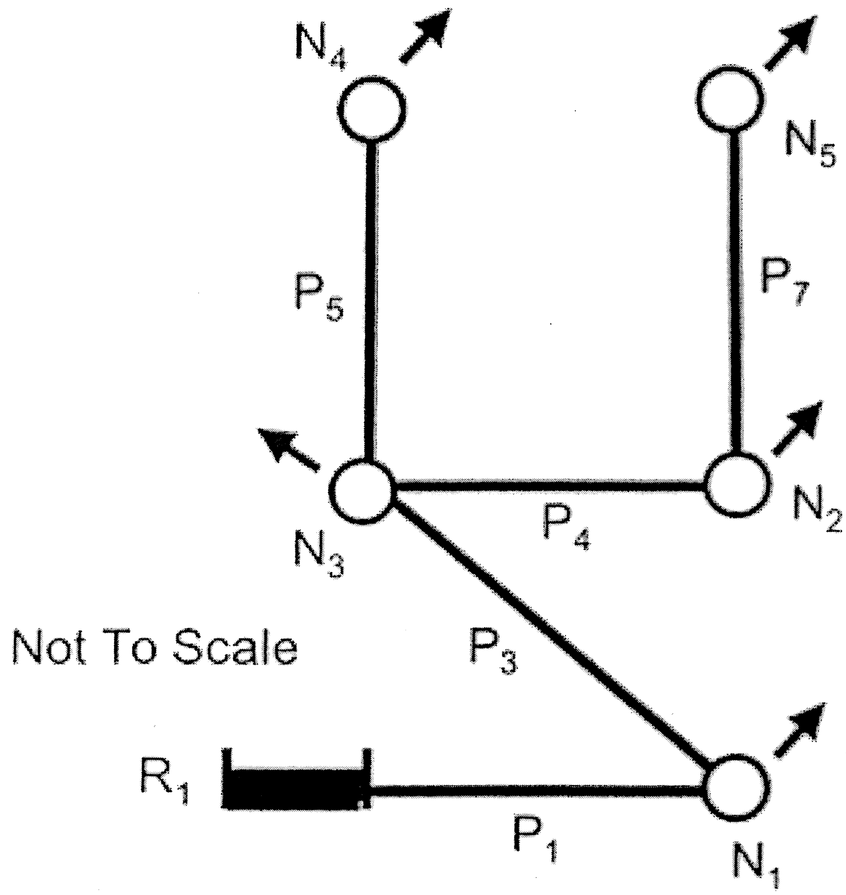


Figure 1. Water supply system.

/20 2. 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 21 kPa across a length of 2 m in a pipe with a diameter of 200 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 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 $m^{5/2}/s$.

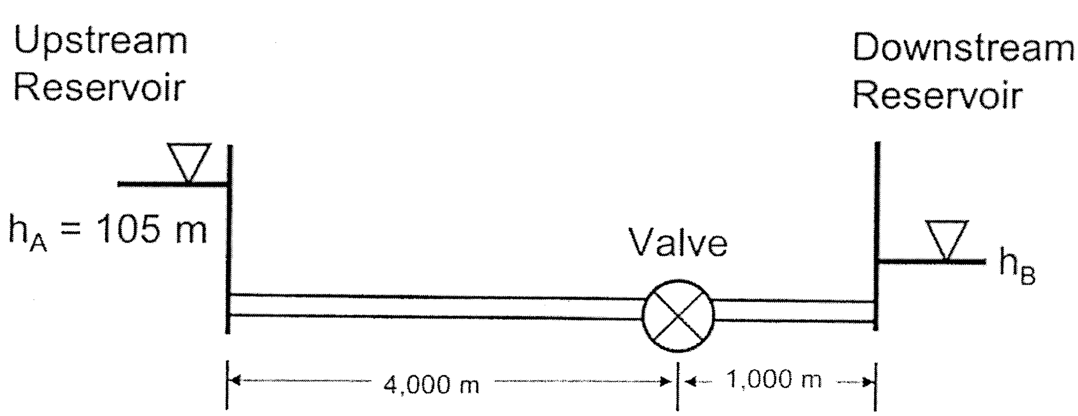
$$Q = \tau E_s \sqrt{H_{u/s} - H_{d/s}}$$

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.



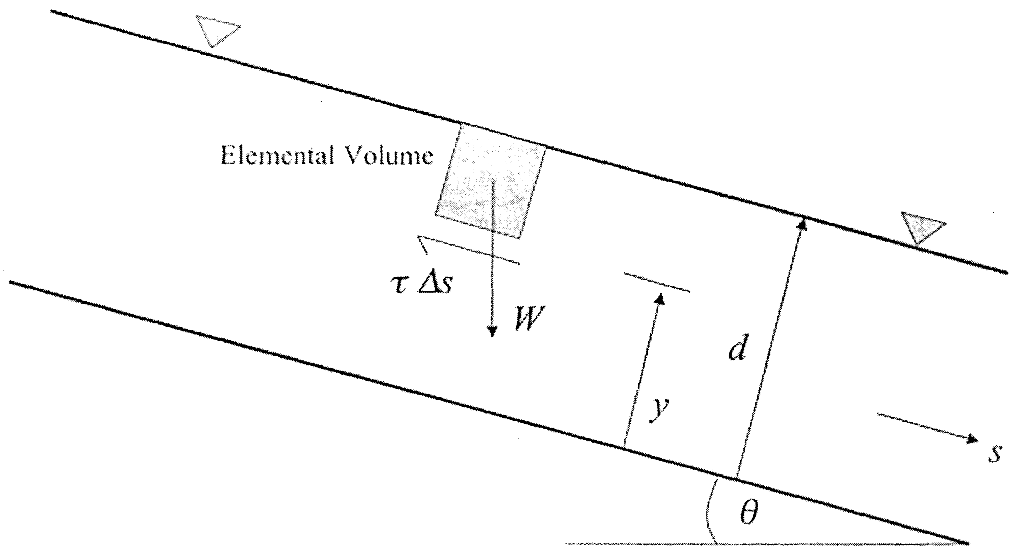
/20 4. A three-pipe network is indicated in the figure below. The pipes in the network have a diameter of 200 mm, a ‘C’ factor of 100, and a length of 500 m. The nodal demands are all 1 L/s. The source reservoir has a water level of 110 m. Calculate the flows in the pipes and the pressure heads at the nodes.

/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 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 m. The Manning's 'n' for the channel is 0.013 and its longitudinal slope is 0.001.

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