Water Supply and Distribution Management

Question 1 (34 marks)

The following pipe network and the associated pipe and node data are given in Figure Q1 and Tables Q1a and Q1b. The fixed head reservoir (water elevation equal to 45 m) is located at node 1.

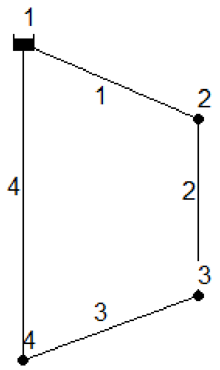

Figure Q1. Network Layout

Table Q1a. Network Pipe Data

Pipe	Length (m)	Diameter (mm)	Absolute Roughness (mm)
1	500	250	0.1
2	600	200	0.1
3	500	100	0.1
4	1000	150	0.1

Table Q1b. Network Node Data

Node	Elevation (m)	Demand (l/s)
2	10	10
3	20	20
4	18	15

(a) Calculate the unknown pipe flows and nodal pressure heads in the above system by performing the first two iterations of the Hardy-Cross method.

(i) Iteration 1 (20 marks)

(ii) Iteration 2 (6 marks)

(b) Assuming the target (head loss) accuracy of $\varepsilon_H = 0.01$ m, calculate the pipe flows. (4 marks)

(c) If the minimum pressure requirement at demand nodes is 25 m, comment on the system's ability to supply the specified demand with adequate pressure. (4 marks)

Question 2 (33 marks)

During a 24-hour period the river flows Qinf, shown in Table Q2a, were recorded immediately upstream of a water supply reservoir shown in Figure Q2.

Table Q2a. Reservoir Inflows

Time period	Qinf (m^3/s)
0 a.m.-4 a.m.	6.50
4 a.m. - 8 a.m.	5.00
8 a.m. - 12 p.m.	9.00
12 p.m. - 4 p.m.	7.00
4 p.m. - 8 p.m.	5.00
8 p.m. - 0 a.m.	4.50

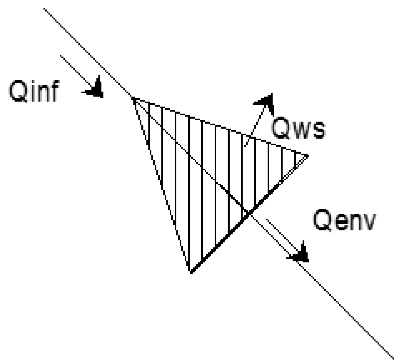

Figure Q2. Reservoir schematic

During the same period, the storage levels, shown in Table Q2b, were recorded for the reservoir.

Table Q2b. Reservoir Storage

Time	Storage (m^3)
0 a.m.	300,000
4 a.m.	350,400
8 a.m.	328,800
12 p.m.	350,400
4 p.m.	357,600
8 p.m.	292,800
0 a.m.	300,000

(a) Determine the water supply hydrograph, Qws(*t*) taken directly from the reservoir if the required environmental release is fixed at Qenv = 0.5 m^3/s and assuming that there were no spills from the reservoir during this 24-hour period.

(13 marks)

(b) Comment on the reservoir's ability to supply the specified demands on a long-term basis. (10 marks)

(c) Determine the uniform demand that can be supplied from the reservoir assuming that the inflow sequence will be repeated in the future.

(10 marks)

Question 3(33 marks)

Water is pumped from reservoir A to reservoir B through a 250 mm diameter pipeline AB, as shown in Figure Q3.

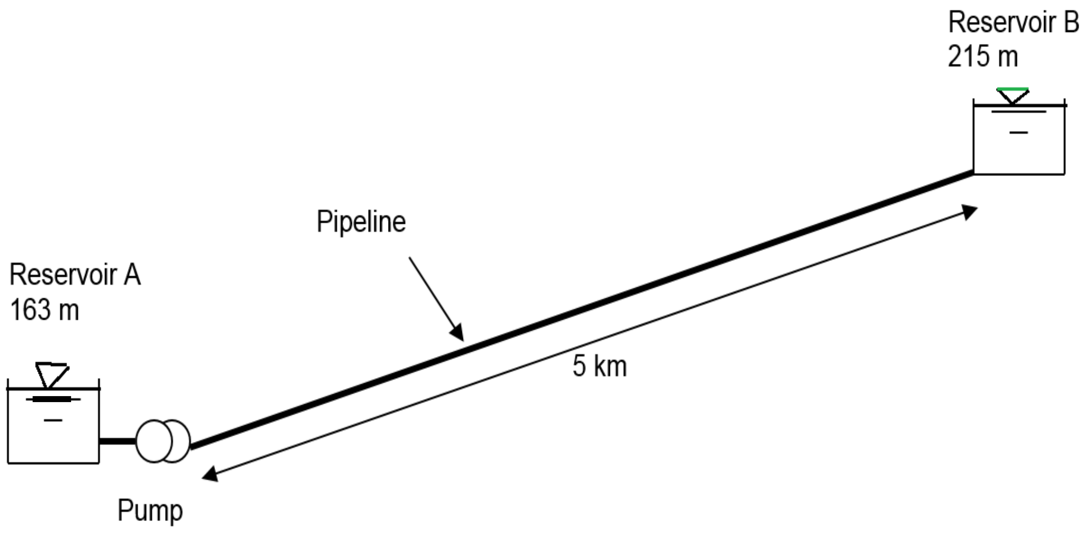

Figure Q3. Pump System

The pipeline's Hazen-William roughness coefficient is equal to 110. The pump characteristics are given in Table Q3.

Table Q3. Pump Characteristics

Flow (litres/s)	0	20	40	60	80	100
Head (m)	110	108	105	95	75	40
Efficiency	0	0.62	0.80	0.85	0.80	0.60

(a) Determine the flow rate through the system and the pump's head and efficiency at this flow rate. (25 marks)

(b) A second pump of identical characteristics is installed in parallel to the original one. Determine the flow rate through the new system and the head and efficiency of the pumps in parallel assuming that any additional head losses created by pump parallelisation are negligible.

(8 marks)

END OF QUESTION PAPER

ECMM133 Formula Sheet

Pipe Flow Formulae:

Darcy-Weisbach:

$h_f = \lambda L/D\, v^2/2g$

Laminar Flow: $\lambda = 64/R_e$

Turbulent Flow: $1/\sqrt{\lambda} = -2 \log_{10}[k/(3.7D) + 2.51/(R_e\sqrt{\lambda})]$ (Colebrook-White)

$1/\sqrt{\lambda} = -2 \log_{10}[k/(3.7D) + 5.74/(R_e^{0.9})]$ (Swamee-Jain)

Hazen-Williams:

$v = 0.355\, C\, D^{0.63}\, S_f^{0.54}$ where $S_f = h_f/L$

General Formulation:

$h_f = R \cdot Q \cdot |Q|^{n-1}$

Darcy-Weisbach: $R = 0.8106\, \lambda\, L / (gD^5)$ and $n=2.0$

Hazen-Williams: $R = 10.648\, L / (C^{1.852} D^{4.871})$ and $n=1.852$

Valve Flow:

$$Q = C_d A \sqrt{2g\Delta H_v}$$

Hydraulic Solvers:

Hardy-Cross Method:

$$\Delta Q_i^{(k)} = \frac{-\sum_i h_{f,i}^{(k)}}{n \sum_i \frac{h_{f,i}^{(k)}}{Q_i^{(k)}}} \qquad Q_i^{(k+1)} = Q_i^{(k)} + \sum_{l \supset i} \Delta Q_{li}^{(k)}$$

Linear Theory Method:

$$H_i^{(k+1)} = \frac{\sum_j^{N_i} \frac{H_j^{(k)}}{U_{ij}^{(k)}} - Q_{d,i}}{\sum_j^{N_i} \frac{1}{U_{ij}^{(k)}}} \qquad Q_{ij}^{(k+1)} = \frac{H_i^{(k+1)} - H_j^{(k+1)}}{U_{ij}^{(k)}} \qquad U_{ij}^{(k)} = R_{ij} \left| Q_{ij}^{(k)} \right|^{n-1}$$

Water Properties:

Density = 1000 kg/m^3

Kinematic Viscosity = 1.14 x 10^{-6} m^2/s

Bulk Modulus (Coefficient of Compressibility) = 2.15 x 10^9 N/m^2