Wastewater Treatment
Lecture 7

Pipe Network Analysis

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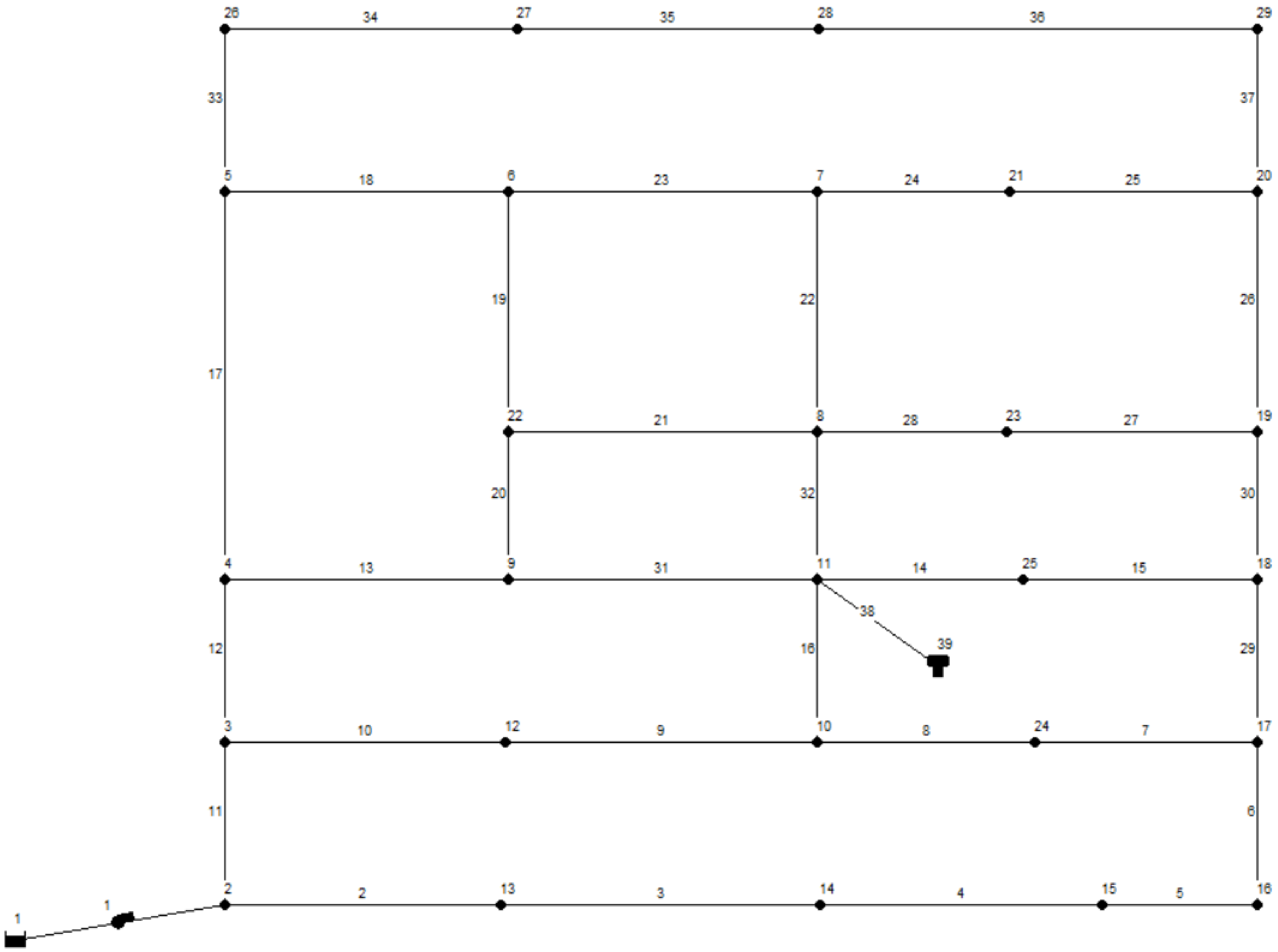
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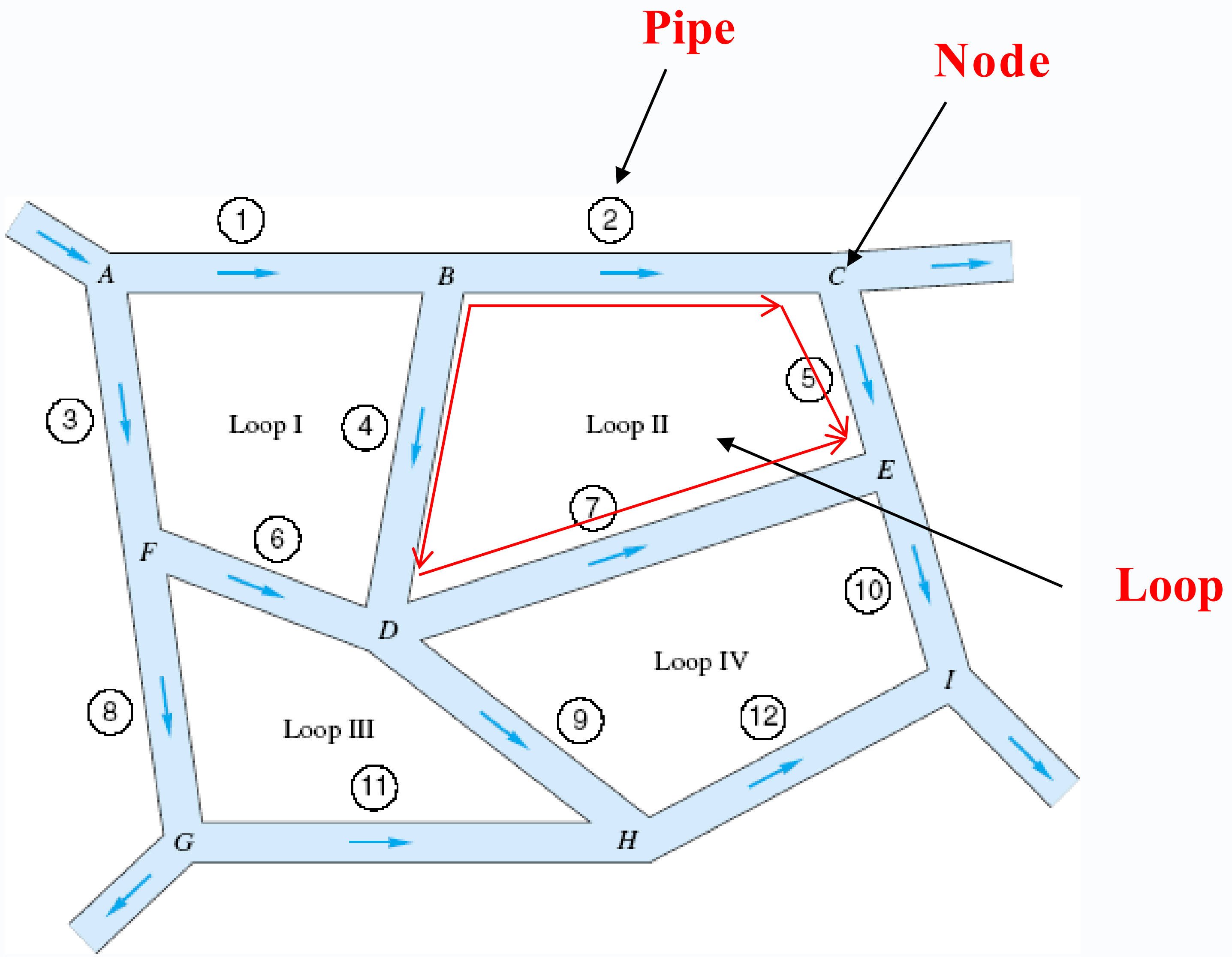
Node, Loop, and Pipes



Fundamental Principles of Pipe Networks

1. **Conservation of Mass**

   Net flow into any junction must equal zero, ensuring fluid continuity throughout the system.

2. **Energy Conservation**

   Net head loss around closed loops is zero, maintaining hydraulic grade line consistency.

3. **Friction Losses**

   All head losses must adhere to Moody diagram and minor-loss correlations for accuracy.

Hydraulic Analysis: Purpose and Scope

1

Preliminary Studies

Gather data on system requirements, topography, and flow demands to inform network design.

2

Layout Drawing

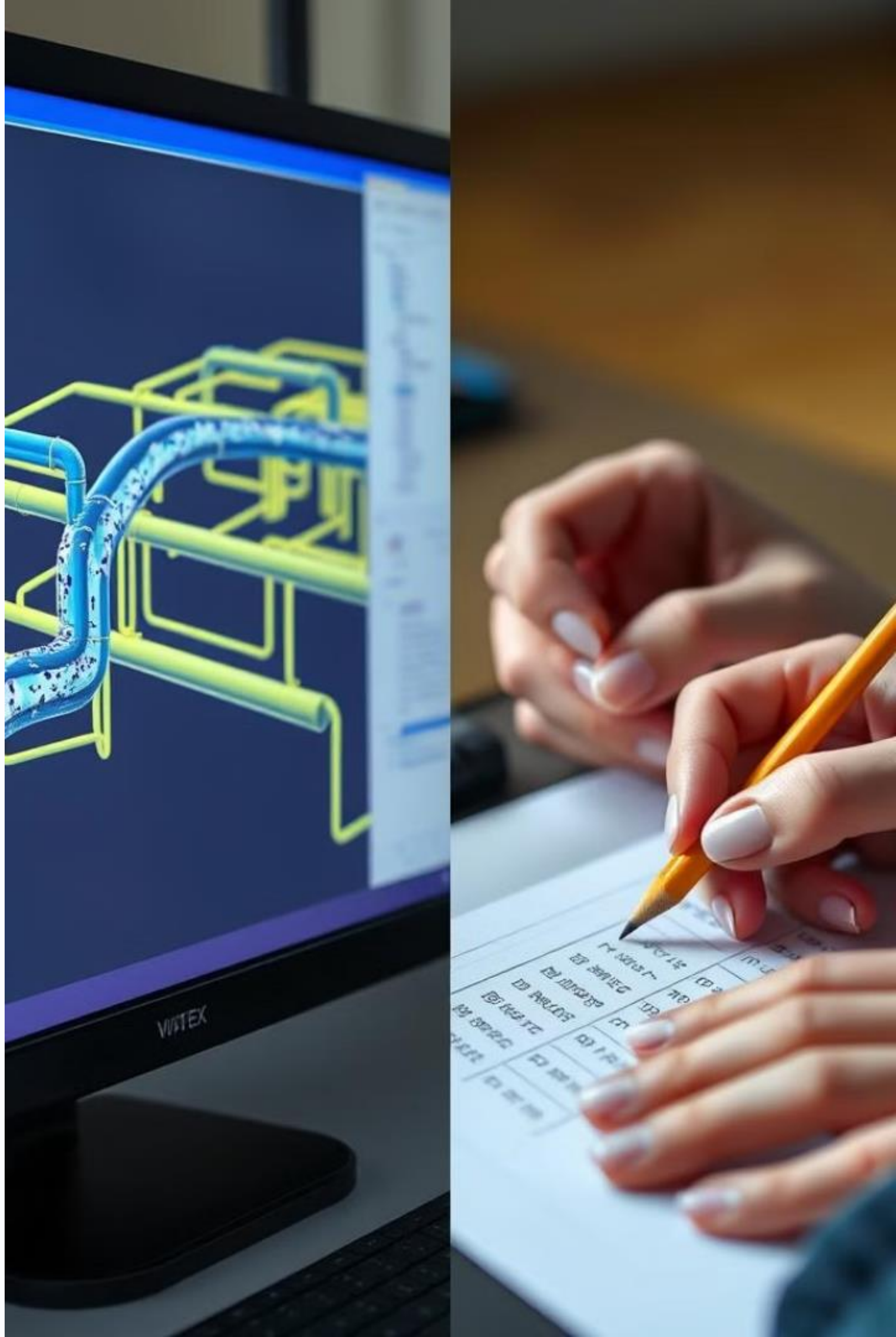
Create detailed schematics of the proposed network, identifying key components and connections.

3

Hydraulic Analysis

Apply analytical methods to size pipes and determine pressures and velocities throughout the network.

Common Methods for Hydraulic Analysis



Hardy Cross Method

Iterative technique for balancing flows and head losses in looped networks.

Sections Method

Divides network into sections for simplified analysis of complex systems.

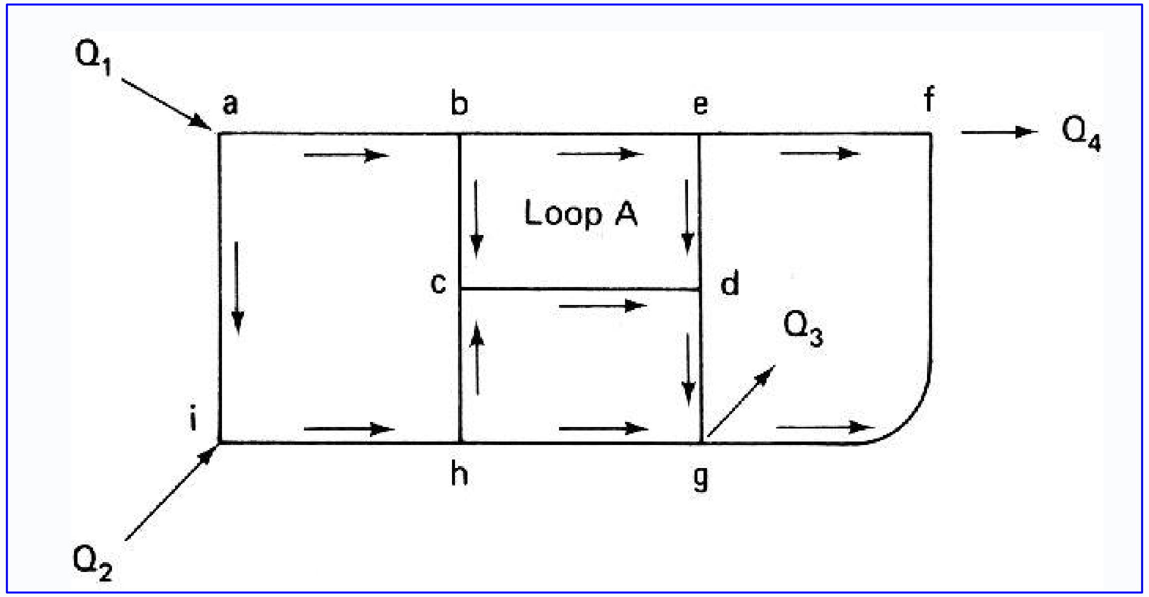
Circle Method

Utilises circular paths to analyse flow distribution in interconnected pipes.

Computer Programs

Software like EPANET and WaterCAD for advanced, large-scale network simulations.

Hardy Cross Method



This method based on:

$$\sum_{Junction} Q = 0 \qquad \sum_{\text{Loop}} h_f = 0$$

1. A distribution of flows in each pipe is estimated such that the total inflow must be equal to the outflow at each junction throughout the network system

- The interflow in the network has +ve sign ↻
- The outflow from the network has -ve sign ↺

- Exponential friction formula Hazen-Williams

- $HL\ (Pipe) = KQ^{n}$,

- $n = 1.85$,

- $K = \frac{10.67 * L}{C^{1.85} * d^{4.87}}$

- $HL = Head\ Loss\ (m)$,
- $Q = Flow\ (m^{3} / \sec)$
- $d = diameter\ (m)$,
- $L = Length\ (m)$,
- *C=Roughness coefficient,*

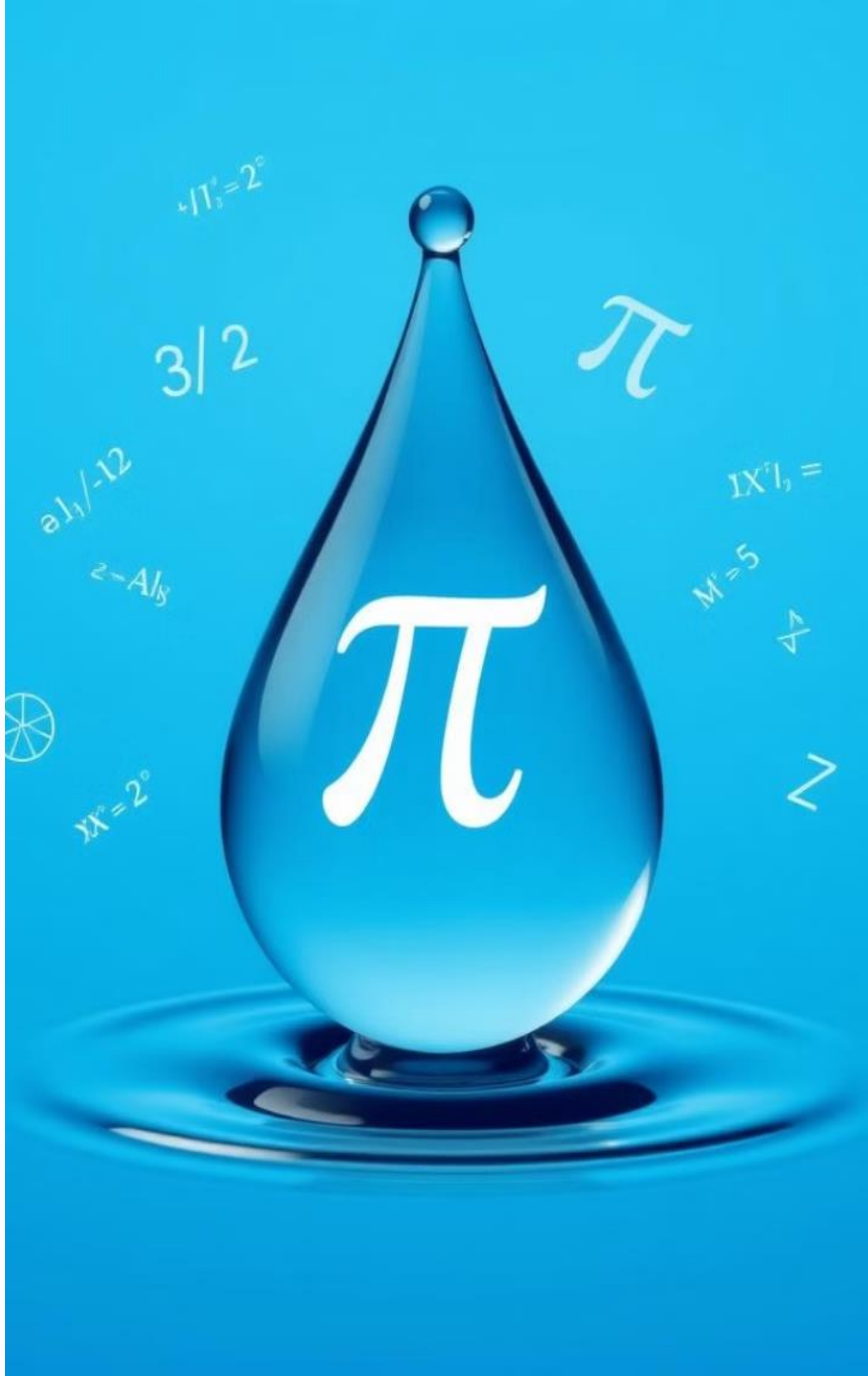
Material	Hazen-Williams coefficient
Asbestos cement (AC)	140
Cast iron	100
Ductile iron (DI)	140
Polyethylene (PE)	140
Polyvinyl chloride (PVC)	150
Unknown, other	100

For Hazen Williams

$$\Delta = \frac{-\sum h_f}{1.85 * \sum \frac{h_f}{Q}}$$

After calculation Δ correct Q_o and check $\sum_{loop} h_f \approx 0$

$$Q = Q_o + \Delta$$



1- التدفق لازم يكون متر مكعب لكل ثانية

2- افرض قيم التدفق (Q) اذا كانو مش موجودات على الشبكة

3- حدد اتجاه التدفق و الحلقات في الشبكة

4- اعمل جدول خاص بالمحاولة الأولى وضع القيم المطلوبة في الأعلى

5- احسب قيم الK

6- وضع قيم التدفق على الجدول ومراعاة إشارة التدفق (مع عقارب الساعة موجب)(عكس عقارب الساعة سالب)

7- نحسب قيم hf باستخدام المعادلة التالية

8- قيم ال hf تكون نفس إشارة قيم التدفق ونجمع قيم ال hf لكل حلقة لوحدها

9- قسمة قيم ال hf على التدفق Q وإيجاد مجموعهم

10- إيجاد قيمة تصحيح التدفق باستخدام العلاقة

11- تصحيح التدفق للانابيب على الشبكة

12- الانبوب المشترك يأخذ تصحيح من الحلقتين المشترك بينهما الانبوب

$$K = \frac{10.67 * L}{C^{1.85} * d^{4.87}}$$

$$HL\ (Pipe) = KQ^{1.85}$$

$$\Delta = \frac{-\sum h_f}{1.85 * \sum \frac{h_f}{Q}}$$

for pipe 2 in loop1

$$\Delta = \Delta_1 - \Delta_2$$

for pipe 2 in loop2

$$\Delta = \Delta_2 - \Delta_1$$

Preparation Steps:

1. Ensure all flow units are in cubic meters per second ($\mathbf{m^3/sec}$).
2. Assign initial flow values (0) if they are not already given on the network diagram.
3. Determine the direction of flow and identify all loops in the network.
4. Create a table for the first iteration, listing all necessary values at the top.
5. Calculate the constant $\mathbf{K}$ for each pipe:
   $$\mathbf{K = \frac{10.67 \cdot L}{C^{1.85} \cdot d^{4.87}}}$$

Iterative Calculation Steps:

6. Place initial flow values ($\mathbf{Q}$) in the table, following the sign convention (clockwise flows are positive (+), counter-clockwise are negative (-)).
7. Calculate head loss ($\mathbf{h_f}$) for each pipe using the equation:
   $$\mathbf{HL\ (Pipe) = KQ^{1.85}}$$
8. Ensure the sign of $\mathbf{h_f}$ matches the sign of $\mathbf{Q}$ for that pipe, then sum the $\mathbf{h_f}$ values for each loop individually (Σh_f).
9. Divide the $\mathbf{h_f}$ values by the absolute flow value ($|\mathbf{Q}|$) and find their sum ($\Sigma h_f/Q$).

10. Calculate the flow correction factor (Δ) using the formula:

$$\Delta = \frac{-\Sigma h_f}{1.85 \cdot \Sigma(h_f/Q)}$$

11. Apply the flow correction (Δ) to all pipes in the network: $Q_{new} = Q_{old} + \Delta$.

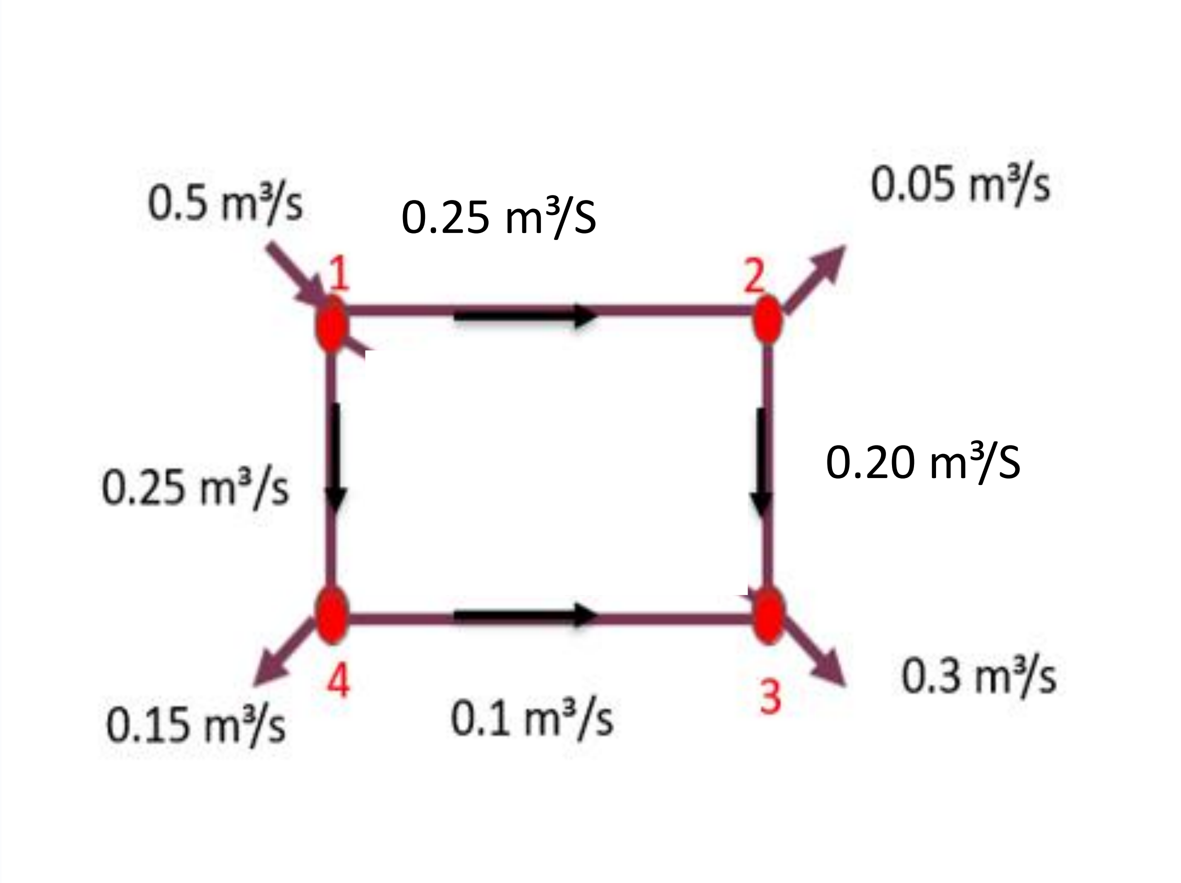
Shared Pipe Rule:

12. A common pipe shared between two loops receives a correction from both loops (e.g., $\Delta_{total} = \Delta_1 - \Delta_2$, subtracting if corrections flow in opposite directions within the pipe).

Example 1

Solve the following pipe network using Hazen William Method C_{hw}=100

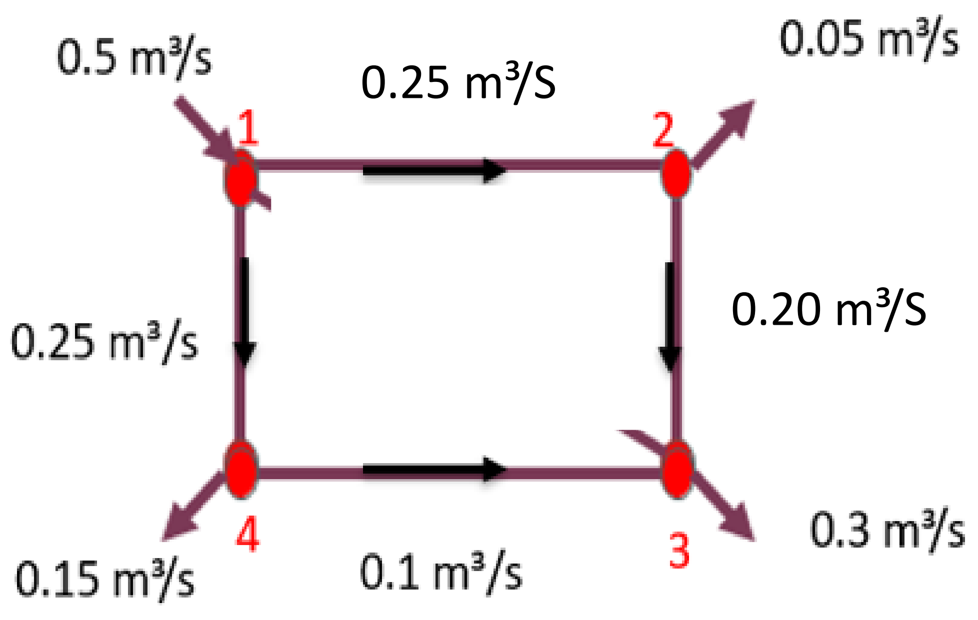
Pipe	Diameter (mm)	Length (m)
(1-2)	500	750
(2-3)	400	500
(3-4)	450	600
(4-1)	350	450



First Loop								
Pipe	**L (m)**	**D (m)**	**k**	**Q (m3/sec)**	**hf**	**hf/Q**	**Δ**	**Q correct**
1-2	750	0.5						
2-3	500	0.4						
3-4	600	0.45						
1-4	450	0.35						

First Loop								
Pipe	**L (m)**	**D (m)**	**k**	**Q (m3/sec)**	**hf**	**hf/Q**	**Δ**	**Q correct**
1-2	750	0.5	46.69192					
2-3	500	0.4	92.27887					
3-4	600	0.45	62.39801					
1-4	450	0.35	159.1349					

$$K = \frac{10.67 * L}{C^{1.85} * d^{4.87}}$$



First Loop								
Pipe	**L (m)**	**D (m)**	**k**	**Q (m3/sec)**	**hf**	**hf/Q**	**Δ**	**Q correct**
1-2	750	0.5	46.69192	0.25				
2-3	500	0.4	92.27887	0.2				
3-4	600	0.45	62.39801	-0.1				
1-4	450	0.35	159.1349	-0.25				

First Loop								
Pipe	**L (m)**	**D (m)**	**k**	**Q (m3/sec)**	**hf**	**hf/Q**	**Δ**	**Q correct**
1-2	750	0.5	46.69192	0.25	3.592781			
2-3	500	0.4	92.27887	0.2	4.699025			
3-4	600	0.45	62.39801	-0.1	-0.8814			
1-4	450	0.35	159.1349	-0.25	-12.2449			
				∑	-4.83447			

$$HL\ (Pipe) = KQ^{1.85}$$

First Loop								
Pipe	**L (m)**	**D (m)**	**k**	**Q (m3/sec)**	**hf**	**hf/Q**	**Δ**	**Q correct**
1-2	750	0.5	46.69192	0.25	3.592781	14.37113		
2-3	500	0.4	92.27887	0.2	4.699025	23.49513		
3-4	600	0.45	62.39801	-0.1	-0.8814	8.813953		
1-4	450	0.35	159.1349	-0.25	-12.2449	48.97952		
				∑	-4.83447	95.65973		

First Loop								
Pipe	**L (m)**	**D (m)**	**k**	**Q (m3/sec)**	**hf**	**hf/Q**	**Δ**	**Q correct**
1-2	750	0.5	46.69192	0.25	3.592781	14.37113	0.027318	
2-3	500	0.4	92.27887	0.2	4.699025	23.49513	0.027318	
3-4	600	0.45	62.39801	-0.1	-0.8814	8.813953	0.027318	
1-4	450	0.35	159.1349	-0.25	-12.2449	48.97952	0.027318	
					-4.83447	95.65973		
		Δ1	0.027318					

$$\Delta = \frac{-\sum h_f}{1.85 * \sum \frac{h_f}{Q}}$$

First Loop								
Pipe	**L (m)**	**D (m)**	**k**	**Q (m3/sec)**	**hf**	**hf/Q**	**Δ**	**Q correct**
1-2	750	0.5	46.69192	0.25	3.592781	14.37113	0.027318	0.277318
2-3	500	0.4	92.27887	0.2	4.699025	23.49513	0.027318	0.227318
3-4	600	0.45	62.39801	-0.1	-0.8814	8.813953	0.027318	-0.07268
1-4	450	0.35	159.1349	-0.25	-12.2449	48.97952	0.027318	-0.22268
					-4.83447	95.65973		
		Δ1	0.027318					

$$Q = Q_o + \Delta$$