The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Civil Engineering

Study Programme	: Bachelor of Science Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: CVX 4240 Hydraulic Engineering I**
Academic Year	: 2023/24
Date	: 5th March 2025
Time	: 13:30-16:30hrs
Duration	: **3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **FIVE (5)** questions on **Five (5)** pages.
3. Answer **ANY FOUR (04)** questions. Each question carries **25 Marks**.
4. The answer for each question should commence from a **new page**.
5. **Mention any assumptions** made for calculations.
6. This is a **Closed Book Examination**.
7. Answers should be in clear handwriting.
8. Do not use Red colour pen.
9. An electronic non-programmable calculator may be used.
10. Take,

    Density of water = $1000\ kg/m^3$

    Acceleration due to gravity = $9.81\ m/s^2$

    Dynamic viscosity of water = $1.0 \times 10^{-3}\ kg.m^{-1}.s^{-1}$

[Q1]

(i) List the seven primary dimensions along with their corresponding SI units.

[7 *Marks*]

(ii) Consider a sphere moving through a gas chamber at high speed. The experimental studies have shown that the drag force (F_D) depends on the density of the gas (ρ), pressure in the chamber (P), velocity of the sphere (U), and diameter of the sphere (D). Using Buckingham's Pi Theorem, derive an expression for drag force in cooperating the above variables. **[12 Marks]**

(iii) A wind tunnel test on a one-tenth-scale model car was carried out at a speed of 200 km/h. The recorded average drag force in the test was 160 N. **What is the drag force on the prototype at 120 km/h?** Assume both the test model and prototype are at the same temperature conditions. Take the density of air (ρ) as 1.184 kg/m^3.

[6 *Marks*]

Consider drag coefficient similarity where, Drag coefficient $(C_D) = \frac{F_D}{1/2\rho V^2 A}$

[Q2] **Figure Q2** shows a schematic diagram of a water distribution system in a factory. Water enters the network at points A and D, while water is withdrawn at points B, C, and E. Determine the flow rate in each pipe using the **quantity balancing method. Perform calculations until the error is less than 0.05** ($\Delta Q < 0.05$).

[25 Marks]

For the initial iteration take, $Q_{AC} = 40\ m^3/s$, $Q_{DC} = 30\ m^3/s$.

Additional information,

$$\Delta Q = \frac{\sum K_i Q_i^2}{2\sum |K_i Q_i|}$$

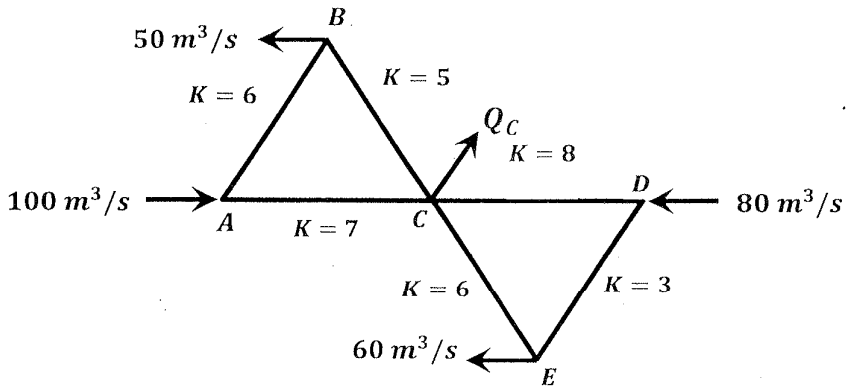


Figure Q2

[Q3]

(i) Find the **wetted perimeter** (p) and the **hydraulic mean depth** (m) of a **triangular** open channel section shown in **Figure Q3(a).** **[8 Marks]**

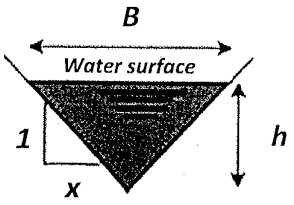


Figure Q3(a)

(ii) **Figure Q3(b)** shows a horizontal profile of an open channel flow. Use the Bernoulli equation to **prove that** the elevation difference along the channel length is equal to the energy lost due to friction $(h_f = Z_1 - Z_2)$. Assume uniform flow conditions in the open channel. **[5 Marks]**

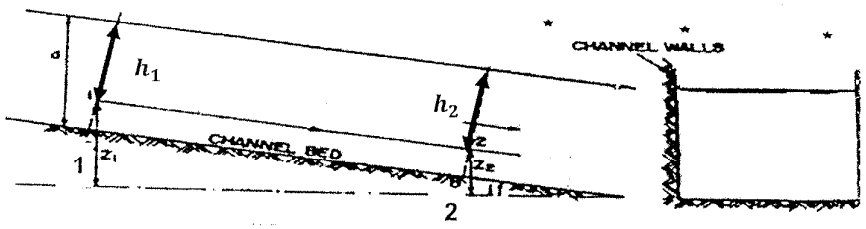


Figure Q3(b)

(iii) A rectangular channel, 9 m wide and 7 km long, conveys water from one reservoir to another. The channel bed slope is 1:1500 and the flowrate in the channel is 22 m^3/s at a depth of 1.2 m.

(a) Calculate the total head loss due to friction along the channel.

(b) To ensure safe operation, the maximum allowable water depth in the channel is 2.2 m. Using Chezy's formula, determine the maximum discharge in the channel. **[12 Marks]**

Additional information,

Chezy's formula $V = C\sqrt{mi}$

Chezy's coefficient (C) is related to the depth of flow (d) and roughness of the channel (k) by, $C = 5.75\sqrt{g}\ log_{10}(13.2d/k)$

[Q4]

(i) Using the Froude Number, briefly explain the following.

(a) What is a sub-critical flow and a super-critical flow?
(b) What conditions need to be satisfied for forming a hydraulic jump?

[5 Marks]

(ii) **Figure Q4** shows a sluice gate of a reservoir and water is discharged through a 5 m wide channel. As shown in **Figure Q4**, water passing under the gate forms a hydraulic jump. If the flowrate of the channel needs to be maintained at 3.5 m^3/s, determine the following. Assume rectangular cross-section at the sluice gate and in the channel.

(a) Froude number at the sluice gate.
(b) Water depth after the hydraulic jump (y_2).
(c) Froude number after the hydraulic jump.
(d) Height of the hydraulic jump.
(e) Specific energy at the sluice gate.
(f) Percentage of head loss across the jump. **[20 Marks]**

Additional information:

$$\frac{y_2}{y_1} = \frac{1}{2}\left(\sqrt{1 + 8Fr_1^2} - 1\right)$$

$$Head\ loss\ in\ the\ jump\ (h_L) = \frac{(y_2 - y_1)^3}{4y_1y_2}$$

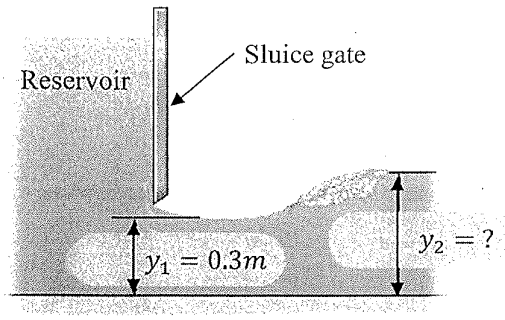


Figure Q4

[Q5]

(i) Explain the purpose of a surge tank in hydroelectric power plants? **[4 Marks]**

(ii) Determine the missing flowrates and the pump heads of the pump connection shown in **Figure Q5(a)**. **[6 Marks]**

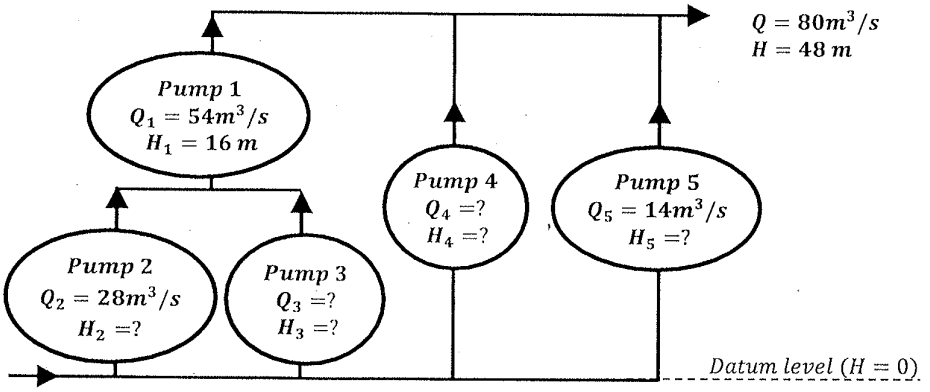


Figure Q5(a)

(iii) As shown in **Figure 5(b)**, a water pump (P_1) draws water from a reservoir and discharges it into a pipeline. The suction head of the pump is H_S. Point ① is located at the water surface level of the reservoir and point ② is located at the pump inlet.

By applying the Bernoulli equation between the points ① and ②, show that,

$$Suction\ Head\ (H_S) < \frac{P_a}{\rho g} - \frac{P_v}{\rho g} - \frac{V_2^2}{2g} - h_{fs}$$

[9 Marks]

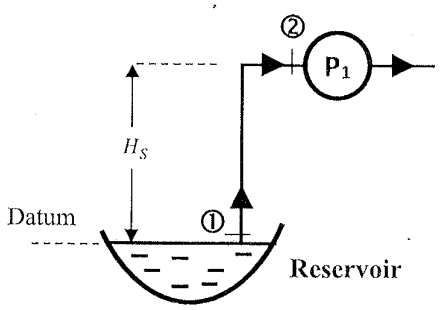


Figure Q5(b)

Where,

P_a – Atmospheric pressure

P_v – Vapor pressure of water

h_{fs} – Friction loss in the pipe of the suction side

V_2 – Velocity at pump inlet

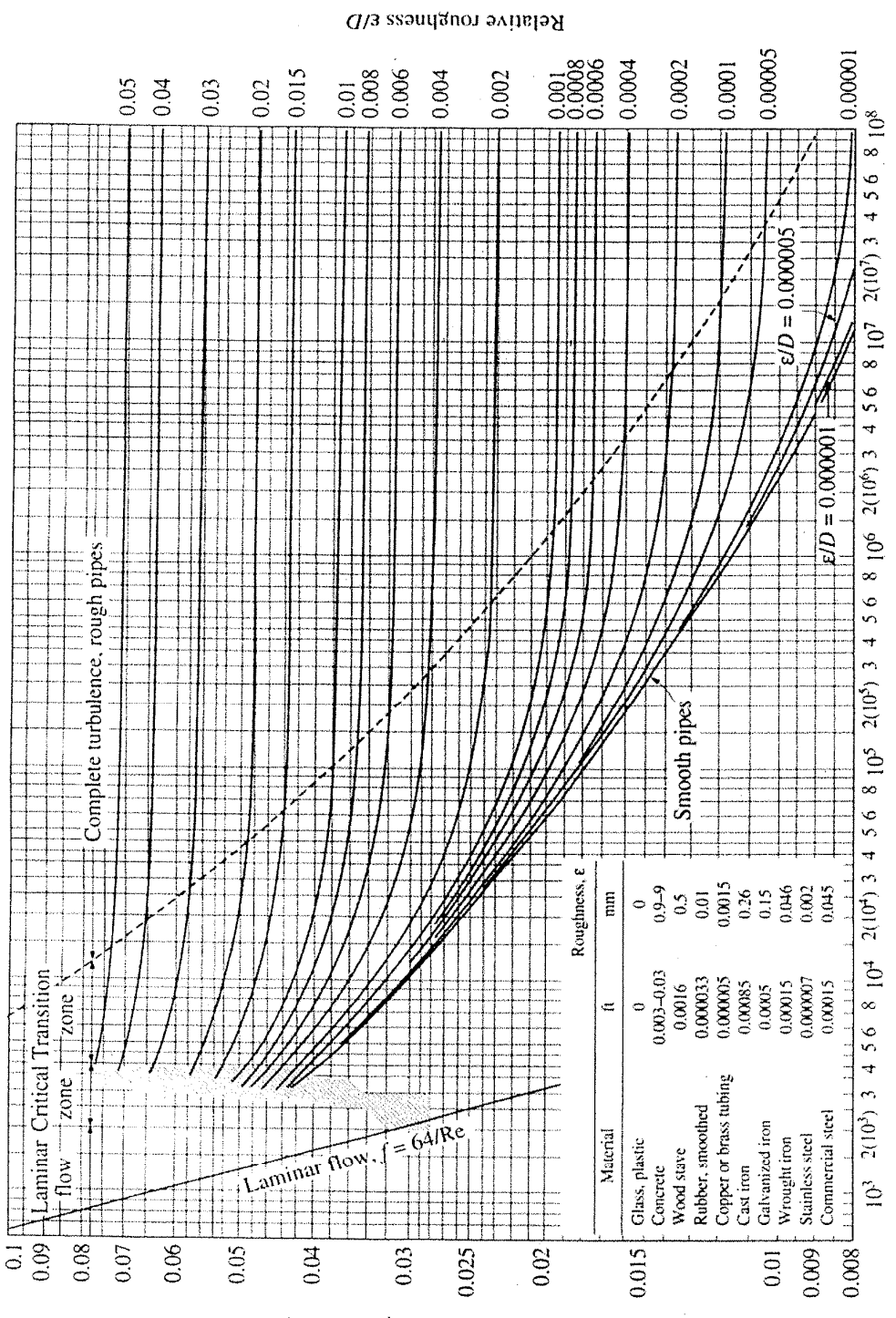
ρ – Density of water

g – Acceleration due to gravity

(iv) A water pump is to be installed to draw water from a well with a maximum depth of 7.5 m. Using the following information, determine whether the **pump can be located at the ground level without causing cavitation.**

The atmospheric pressure (P_a) is 100 kN/m^2 and the vapor pressure of the water (P_v) is 9.8 kN/m^2. The maximum velocity at the inlet of the pump (V_2) is 7 ms^{-1} and the head loss is approximately 0.5 m of water for every 10 m of piping. **[6 Marks]**

– End of Paper –



Moody's Diagram