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

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: CVX 4240 Hydraulic Engineering I**
Academic Year	: 2021/22
Date	: 10th February 2023
Time	: 14:00-17:00hrs
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. Answer for each question should commence from a **new page**.
5. **Clearly mention any assumptions** made for calculations.
6. This is a **Closed Book Examination**.
7. Answers should be in clear hand writing.
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) Briefly explain the three similarities between the model and the prototype in the model analysis. [*6 Marks*]

(ii) Mention three primary purposes of dimensional analysis. [3 *Marks*]

(iii) Consider a sphere moving through a gas chamber at high speed. It has been experimentally found 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. [**10 Marks**]

(iv) A wind tunnel test on a one-fifth scaled model car was carried out at a speed of 250 km/h. The recorded average drag force in the test was 150 N. **What is the drag force on the prototype at 100 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] A water distribution system in a factory is shown in **Figure Q2.** Water is supplied to the network at point 'A' and is taken out at points 'B', 'C', and 'D'. Determine the flow rate in each pipe using the quantity balancing method. (calculations should be performed **up to two iterations**) [**25 Marks**]

For the initial iteration take,

$Q_{AE} = 60m^3/s,\ \ Q_{BC} = 25\ m^3/s,\ \ Q_{ED} = 40\ m^3/s$

Additional information,

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

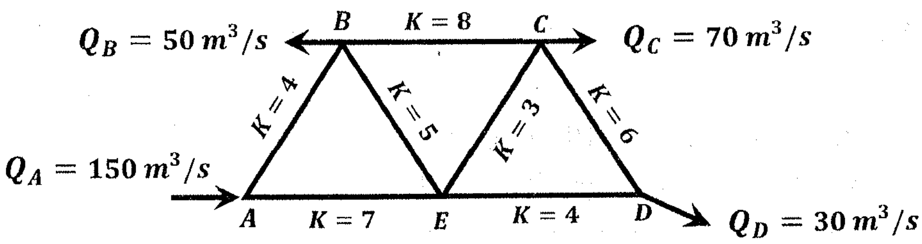


Figure Q2

[Q3]

(i) Show that the Darcy friction factor for laminar flow in a horizontal pipe, f = 64/Re. **[5 Marks]**

Additional information,

$$Q = \frac{\Delta P \times \pi D^4}{128\mu L} \quad and \quad \frac{\Delta P}{\rho g} = h_f$$

(ii) As shown in **Figure Q3**, water is taken from a large tank (B) using a galvanized iron pipe and is discharged at point 'C'. When the gate valve 'A' is fully opened, it is required to maintain a 0.5 m^3/s discharge at point 'C' at the ***initial steady flow conditions*** (i.e. water level in the tank does not change). Determine the **initial water height (*H*) need to be maintained above the centerline of the outlet pipe (see Figure Q3).** Assume the water is incompressible and the velocity of the water level in the tank $V_B \approx 0$. The pipe diameter is 300 mm and is constant along the whole length. **[15 Marks]**

Additional information,

- Take, Relative roughness of the galvanized iron pipe (ε) = 0.15 mm,
- Loss coefficients for pipe fittings,
  - Sharp edged inlet $K_L = 0.5$
  - 90° elbow $K_L = 0.9$
  - Fully opened Gate valve $K_L = 0.19$

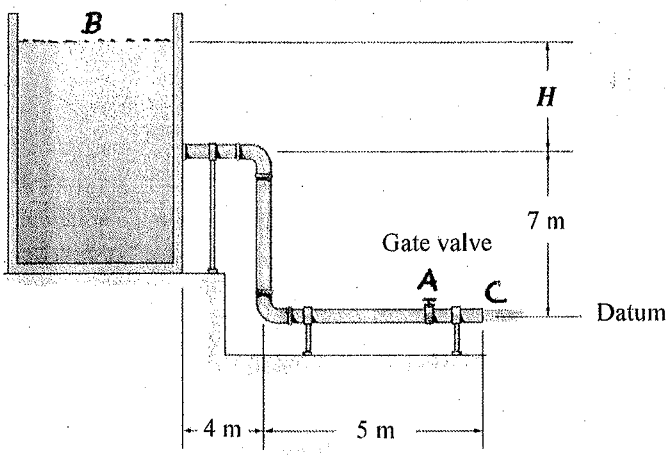


Figure Q3

(iii) Briefly describe what is meant by ***Energy grade line (EGL)*** and ***Hydraulic grade line (HGL)*** in open channel flow? Clearly show them in a sketch of a horizontal profile of an open channel flow. **[5 Marks]**

[Q4]

(i) Briefly explain the purpose of designing a 'Hydraulic Jump' to be formed at the downstream side of the sluice gates. **[4 Marks]**

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

(a) What is a sub-critical flow and a super-critical flow?
(b) What is the requirement to form a hydraulic jump? **[4 Marks]**

(iii) **Figure Q4** shows a sluice gate of a reservoir and the water is discharged through a 2 m wide channel. As shown in the **Figure Q4**, water passing under the gate forms a hydraulic jump and the height of the hydraulic jump (y_2) is 0.5 m. If the flowrate of the channel needs to be maintained at 1.5 m^3/s, determine the following.

(a) Froude number at the sluice gate.
(b) Water depth after the hydraulic jump (y_2).
(c) Froude number after the hydraulic jump.
(d) Percentage of head loss across the jump. **[17 Marks]**

Additional information:

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

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

$$Specific\ energy\ at\ the\ sluice\ gate\ = \frac{V_1^2}{2g} + y_1$$

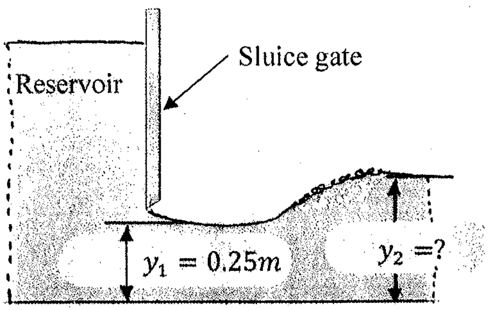


Figure Q4

[Q5]

(i) Determine the missing flowrates and the pump heads of the pump connection shown in **Figure Q5.** **[4 Marks]**

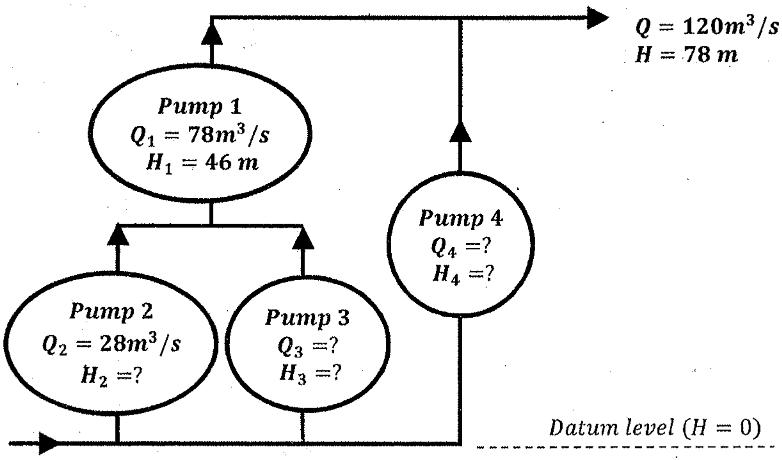


Figure Q5

(ii) Derive an expression for the specific speed of a turbine in terms of its speed, *N*, output power, *P*, and head, *H*. **[10 Marks]**

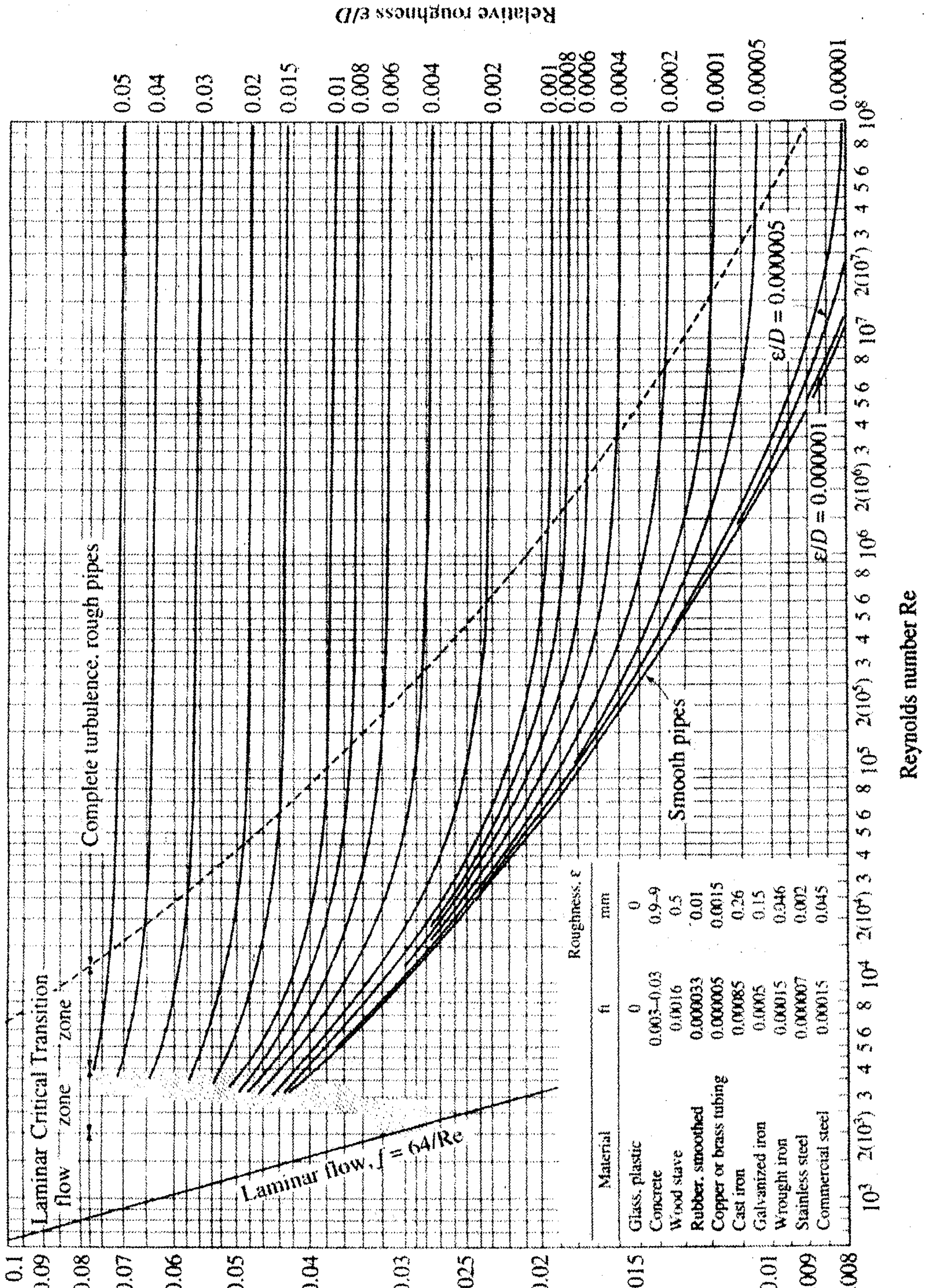
(iii) Briefly explain what is ***cavitation***? **[4 Marks]**

(iv) A water pump is to be installed to draw water from a well of maximum depth $7m$. 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 $9.8\ kN/m^2$. Maximum velocity at inlet of the pump (V_2) is $5\ ms^{-1}$ and the head loss is approximately $3\ m$ of water for every $5\ m$ of piping. **[7 Marks]**

$$\frac{P_2}{\rho g} = \frac{P_a}{\rho g} - \left(\frac{V_2^2}{2g} + H_s + h_{fs}\right)$$

Where,
H_s – *Net positive suction head*
h_{fs} – *frictional loss in the suction side of the pipe*



Moody's Diagram