

124

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 : CVX5241 Hydraulic Engineering II
Academic Year : 2023/24
Date : 15th February 2025
Time : 0930 – 1230 hours
Duration : 3 hours

General instructions

1. Read all instructions carefully before answering the questions.
2. This is a **Closed Book Test**; texts or other printed material and electronic communication devices are not permitted to be kept in your possession.
3. This paper consists of **FOUR (4) questions** and **SIX (6) printed pages**.
4. Answer **ALL** questions. The marks associated with each question is indicated.
5. Please remember to write your registration number in the answer script. **Do not write your name.**
6. In case of doubt, consult the supervisor or an invigilator conducting the examination.

Q1. An irrigation project is to consider a lined rectangular channel for conveyance of water.

a) The Manning's formula for uniform flow suggests that, channel dimensioning can be performed such that the required discharge is conveyed at minimum resistance leading to design of an optimum channel when the wetted perimeter is a minimum for a given set of values of slope, roughness, and flow area. Considering optimum design of the rectangular channel in concern, derive the relationships between following parameters.

i. The width of the channel and the flow depth

[5.0 Marks]

ii. The flow area and the flow depth

[1.0 Marks]

iii. The wetted perimeter and the flow depth

[1.0 Marks]

iv. The hydraulic radius and the flow depth

[2.0 Marks]

b) The channel is expected to convey water at a discharge rate of 5.5 m³/s. Also, it is required to maintain a bed slope of 0.00032 while, the Manning's roughness coefficient for the channel can be taken as 0.013. Using the design chart provided in Figure Q1.1 obtain suitable width and the corresponding depth of flow for the channel that facilitate the optimization considered in Section (a).

[7.0 Marks]

c) Compute the Froude number for the above flow conditions and state if the flow is critical, subcritical, or supercritical and if the slope is critical, mild, or steep.

With usual notations, Froude Number is given by $\frac{V}{\sqrt{gD}}$.

[4.0 Marks]

Q2. a) Briefly explain the difference between the terms "conjugate depths" and "alternate depths".

[6.0 Marks]

b) For hydraulic jump occurring in a rectangular channel, derive the following equation with usual notations.

$$\frac{y_2}{y_1} = \frac{1}{2} \left[\sqrt{1 + 8F_{r1}^2} - 1 \right]$$

The Froude Number is given by $\frac{V}{\sqrt{gD}}$.

[10.0 Marks]

c) The discharge from a sluice gate enters into the stilling basin where a hydraulic jump is facilitated for energy dissipation. The flow can be modelled as conveyed by a rectangular channels section having a width of 8.0 m in both upstream and downstream regions of the hydraulic jump. A discharge of 20 m³/s with a flow depth of 0.2 m is recorded upstream of the jump.

i. Estimate the depth and velocity of flow downstream of the jump. If any assumptions would be made in the calculations, clearly state those.

[8.0 Marks]

ii. Estimate the energy loss associated with the jump.

[4.0 Marks]

- Q3. a) Define the following terms:
 Porosity (n)
 Specific yield (S_y)
 Storage coefficient (S)
 Hydraulic conductivity (K)
 Transmissivity (T)
 [8.0 Marks]
- b) Determine the rise in water level in an unconfined aquifer resulting from a seasonal precipitation of 500 mm, given the aquifer's porosity is 20% and its specific retention is 9%.
 [6.0 Marks]
- c) Development of an industrial zone demands a large quantity of water for daily consumption. It is proposed to investigate the possibility of meeting this water demand by pumping water from wellpoints installed within a confined aquifer located beneath the proposed site itself. A pump test was therefore, conducted to determine the hydraulic conductivity of the 30 m thick confined aquifer. Water was pumped out at a steady discharge of 120 m³/hr from a 1.0 m diameter well which penetrates the entire depth of the aquifer. The initial piezometric level was 40 m above the datum (taken at the top of the confined aquifer). Respective drawdowns of 2.5 m and 1.0 m were recorded at observation wells located 20 m and 50 m away from the pumping well.
- i. Derive the following relationship for discharge at the pumped well expressed in terms of hydraulic heads measured at the observation wells, using usual notations. Use a suitable sketch to support your derivation.
- $$Q = 2\pi K b \frac{[h_2 - h_1]}{\ln(r_2/r_1)}$$
- [Note that the negative sign of the above equation is ignored.]
 [4.0 Marks]
- ii. Estimate the hydraulic conductivity and the transmissivity of the aquifer.
 [3.0 Marks]
- iii. Compute the approximate drawdown in the pumped well.
 [2.5 Marks]
- iii. Determine the radius of influence of the pumping well.
 [2.5 Marks]
- d) Briefly explain the consequences of long-term pumping of groundwater.
 [4.0 Marks]
- Q4. a) Briefly explain desirable and undesirable effects of sediment transport.
 [4.0 Marks]
- b) Briefly explain different modes of sediment transport in rivers recognizing sediment and flow characteristics that promote each mode of transport.
 [6.0 Marks]
- c) An irrigation project considers construction of an unlined channel at a slope of 0.0015. The channel takes the form of a wide rectangular channel with protected banks. The design of the channel needs to consider prevention of bed erosion.
- i. Study the Shields entrainment function (given in Figure Q4.1) for critical conditions for initiation of sediment motion and obtain a relationship between the critical bed shear stress (τ_{ocr}) and the particle size (d) when

the non-dimensional parameter, $\pi_1 = \frac{\rho U_{cr}^* d}{\mu} \geq 400$, density of sediment (ρ_s) and density of water (ρ_w) are 2650 kg/m³ and 1000 kg/m³. The acceleration of gravity (g) on Earth can be taken as 9.81 N/kg.

[4.0 Marks]

- ii. Given the viscosity of the fluid (i.e., water) is 10⁻³ Pa.s, obtain the particle size (d) that corresponds to the limiting value of $\pi_1 = \frac{\rho U_{cr}^* d}{\mu} = 400$.

[2.0 Marks]

- iii. A part of the proposed channel runs over a bed of fine gravel. For design purposes, the particle of size (d) of fine gravel can be taken as 7 mm. Determine the maximum allowable bed shear stress (τ_{ocr}) for no bed erosion.

[1.0 Marks]

- iv. Determine the minimum channel width to convey water at a discharge rate of 6.5 m³/s without causing bed erosion. Manning's formular for uniform flow with usual notations is given as

$$V = \frac{1}{n} R^{2/3} S^{1/2}; \text{ where the roughness coefficient can be taken as 0.02.}$$

Also, bed shear stress, $\tau_o = \rho g h S$ with usual notations.

[5.0 Marks]

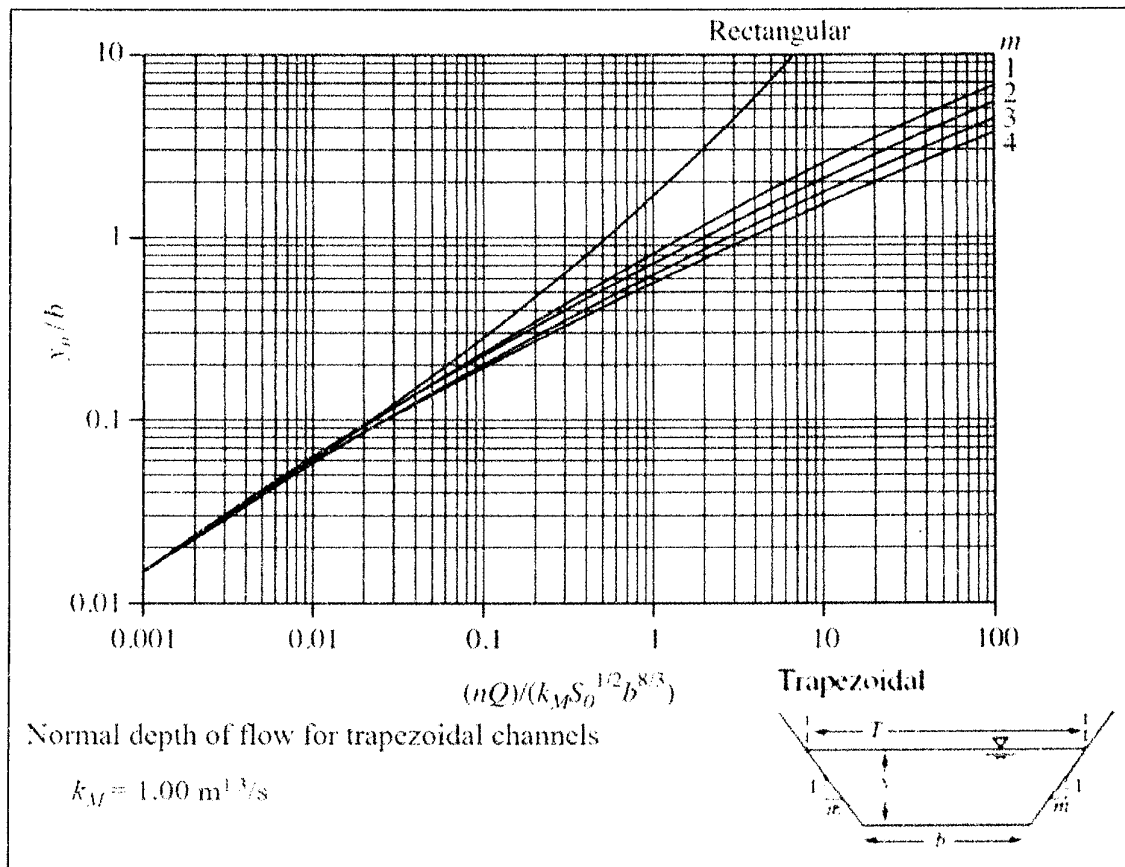


Figure Q1.1: Channel dimensioning based on Manning's formula

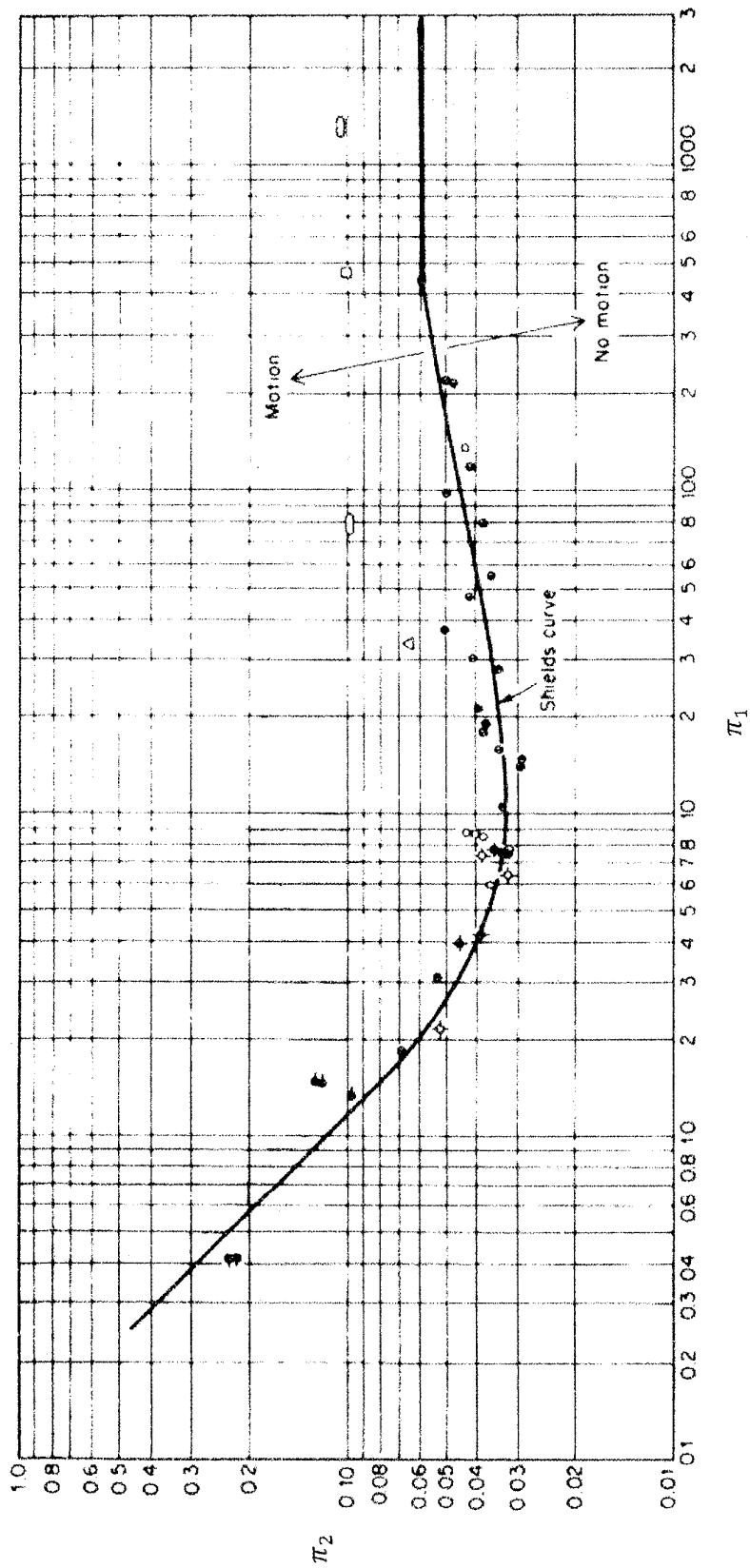


Figure Q4.1: Shield's Diagram [X axis: $\pi_1 = \frac{\rho U_{cr}^2}{\mu}$, Y axis: $\pi_2 = \frac{\rho U_{cr}^2}{\gamma_s d} = \frac{\tau_{ocr}}{\gamma_s d}$]