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 Hydraulics Engineering II**
Academic Year	:	2024/2025
Date	:	07th February 2026
Time	:	0930-1230 h
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. **You are allowed to use an approved non-programmable calculator.**
3. This paper consists of **FOUR (4) questions** and **SIX (6) printed pages**.
4. Answer **ALL** questions. The marks associated with each question are 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.

The following information and the equations with usual notations may be useful in answering the questions.

— Assume discharge (Q) to be steady as applicable to ALL questions.

— Acceleration of gravity = 9.81 m/s^2 (or 32.185 ft/s^2)

— Density of water = 1000 kg/m^3

— Manning's formula: $V = \frac{1}{n} R^{2/3} S^{1/2}$ with usual notations

— Froude Number: $\frac{V}{\sqrt{gD}}$

Question 1 Q123

Figure Q1.1 shows a proposed canal by the Mahaweli Authority. It can be identified that, in irrigation projects, water conveyance is usually carried out using *open channels* rather than *pipes*.

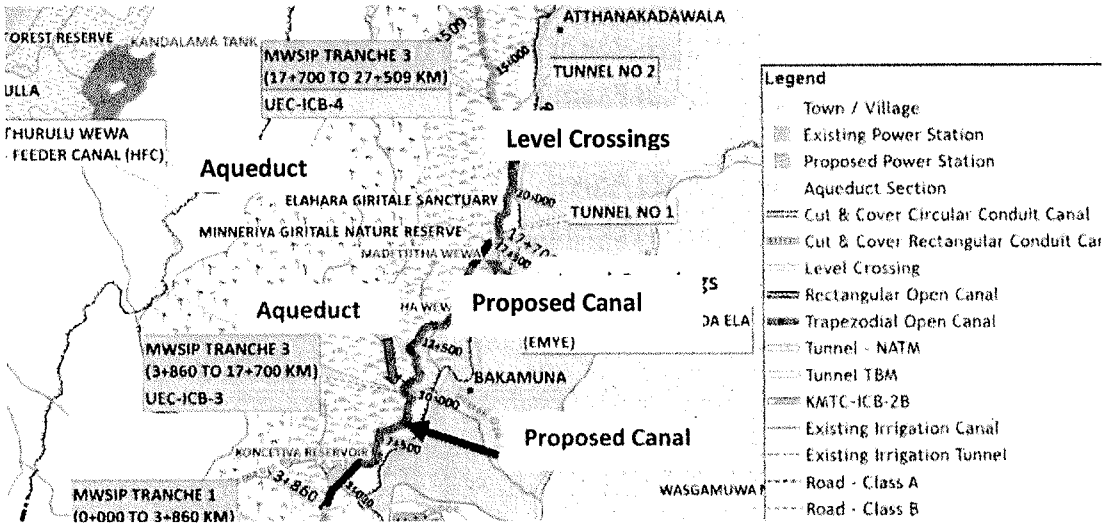

Figure Q1.1: Proposed irrigation project

a. i. State 2 key differences between pipe flow and open channel flow.

[2.0 Marks]

ii. Open channel flow can be classified based on *channel geometry*. Refer to the proposed canal system shown in Figure Q1.1 and identify 2 types of canals that exhibit *geometrically different shapes*.

[2.0 Marks]

iii. Open channel flow can also be classified based on *time variation* and *space variation*. Briefly explain the following classifications. (You may use sketches or mathematical conditions to support your answer.)

— Steady Flow vs. Unsteady Flow (Time Variation)

— Uniform Flow vs. Non- Uniform (Varied) Flow (Space Variation)

[4.0 Marks]

b. A *rectangular* channel section is proposed for the canal. The design requires the canal to carry a discharge of 8 m^3/s under uniform flow conditions. The bed slope of the canal is to be maintained at 0.00035, and the Manning's roughness coefficient is given as 0.012 representing the expected surface condition of the canal lining. A preliminary design suggests a channel of 4 m width.

i. Now, assuming uniform flow in accordance with the Manning's formula, determine the normal depth (y_n) for the given scenario by trials performed with depth of flow y = 1 m, 1.25 m, 1.45 m.

[8.0 Marks]

ii. Compute the Froude number and state if the flow at computed normal depth is critical, subcritical, or supercritical.

[3.0 Marks]

iii. Determine the specific energy associated with the flow at computed normal depth. [2.0 Marks]

c. The proposed irrigation project layout in Figure Q1.1 highlights various cross-drainage structures, including *Aqueducts* and *Level Crossings*, necessitated by the intersection of the canal with natural drainage paths. Q123

i. Briefly explain the primary function of an *Aqueduct* in this canal system and state the specific condition of relative bed levels that makes this design suitable.

[2.0 Marks]

ii. A *Level Crossing* is another critical structure shown on the map. State its function and how the flow is regulated during high-flood periods in the natural stream.

[2.0 Marks]

Question 2

a. Sketch a typical channel section and briefly explain the following modes of sediment transport in a channel:

— Dissolved Load
— Suspended Load
— Bed Load

[6.0 Marks]

b. In the design of stable irrigation channels, consideration of sediment transport is crucial. Two commonly used approaches for designing channels are the *Tractive Force Method* and the *Velocity Method.*

i. State 2 differences between *Tractive Force Method* and the *Velocity Method* approaches.

[4.0 Marks]

ii. Assume that a canal is excavated in *stiff clay.* According to velocity method, determine the mean allowable velocity under *clear water conditions* and *water with colloidal silts*. Hence, state why the allowable velocity (ms^{-1}) for canal transporting *water with colloidal silts* is higher than that for a canal transporting *clear water*? (You may use the chart presented in Figure Q2.1 in preparing your answer.

Original material excavated for canals	Mean velocity, after aging of canals with flow depths # 3 ft					
	Clear water, no detritus		Water transporting colloidal silts		Water transporting noncolloidal silts, sands, gravels or rock fragments	
	(ft/sec)	(m/sec)	(ft/sec)	(m/sec)	(ft/sec)	(m/sec)
1. Fine sand (noncolloidal)	1.5	0.46	2.5	0.76	1.5	0.46
2. Sandy loam (noncolloidal)	1.75	0.53	2.5	0.76	2.0	0.61
3. Silt loam (noncolloidal)	2.0	0.61	3.0	0.91	2.0	0.61
4. Alluvial silt (noncolloidal)	2.0	0.61	3.5	1.07	2.0	0.61
5. Ordinary firm loam	2.5	0.76	3.5	1.07	2.25	0.69
6. Volcanic ash	2.5	0.76	3.5	1.07	2.0	0.61
7. Fine gravel	2.5	0.76	5.0	1.52	3.75	1.14
8. Stiff clay	3.75	1.14	5.0	1.52	3.0	0.91
9. Graded, loam to cobbles (noncolloidal)	3.75	1.14	5.0	1.52	5.0	1.52
10. Alluvial silt (colloidal)	3.75	1.14	5.0	1.52	3.0	0.91
11. Graded, silt to cobbles (colloidal)	4.0	1.22	5.5	1.68	5.0	1.52
12. Coarse gravel (noncolloidal)	4.0	1.22	6.0	1.83	6.5	1.98
13. Cobbles and shingles	5.0	1.52	5.5	1.68	6.5	1.98
14. Shales and hard pans	6.0	1.83	6.0	1.83	5.0	1.52

Figure Q2.1: Design chart for stable channel design - Velocity method

[3.0 Marks]

c. You are designing an unlined *rectangular* irrigation canal in a region with non-cohesive, *moderately angular* shaped sandy soil. The sand has a median particle diameter of 12.7 mm. The specific gravity, G_s of the sand is 2.65. The canal must be stable enough to prevent both scouring of the bed and slumping of the side slopes.

i. Define "*Incipient Motion*" of sediments and briefly explain its importance in maintaining a stable irrigation channel.

[2.0 Marks]

ii. Briefly explain how the *Angle of Repose* limits the choice of side slopes for an irrigation canal. (You may use a suitable sketch to support your answer.)

[3.0 Marks]

iii. Using Figure Q2.2, determine the angle of repose for the type of soil associated with the proposed canal.

[1.0 Marks]

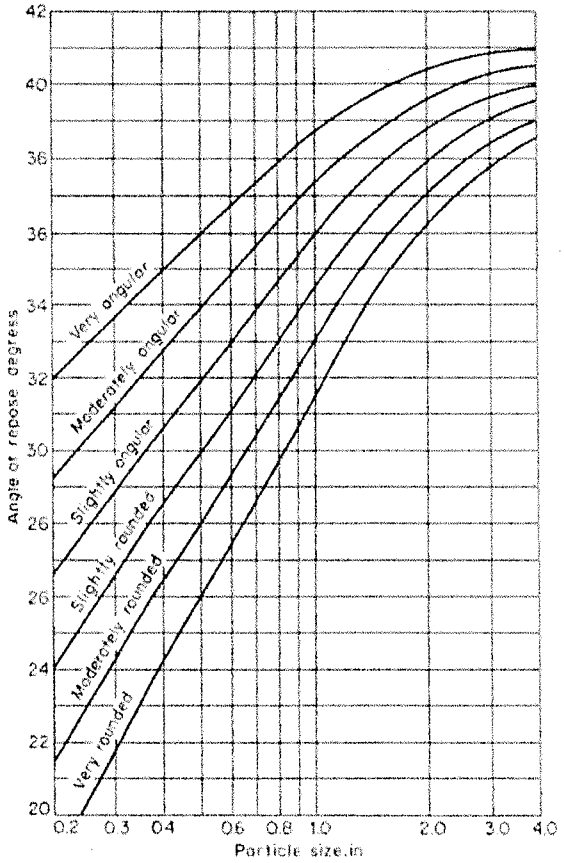

Figure Q2.2: Variation of the angle of repose with particle size

iv. State why the *Angle of Repose* is defined as a property applicable to *non-cohesive (sandy)* soils, but not as a property applicable to *cohesive (clay)* soils.

[2.0 Marks]

v. Estimate the depth of flow (y) in this canal which will cause *incipient motion.* [Assume shield parameter (C) = 0.06 and Channel Slope = 0.0003]

[4.0 Marks]

Question 3

During the *Ditwah* cyclone, the Kotmale region near Kandy experienced intense precipitation, recording a peak rainfall exceeding 300 mm. This event led to a sudden surge in groundwater through surface runoff, infiltration, and percolation; significant increase in pore-water pressures in the regime subsequently led to catastrophic failures of the hill slopes.

a. i. Define following terms related to above scenario.

— Surface Runoff

— Infiltration

— Percolation

[3.0 Marks]

ii. Briefly explain three factors that affect the rate of infiltration in soils.

[6.0 Marks]

b. Draw a labeled sketch showing the formation of groundwater, including the zone of aeration, capillary zone, zone of saturation, groundwater table, and the infiltrating flow paths. Q123

[6.0 Marks]

c. Differentiate between *confined aquifers* and *unconfined aquifers*, discussing their recharge mechanisms, pressure conditions, and implications for groundwater extraction.

[4.0 Marks]

d. Before starting reconstruction of structures in the area, it is critical to understand and monitor groundwater behavior.

i. Suggest 3 feasible continuous groundwater exploration and monitoring techniques for this area. Justify your suggestions technically and logically, highlighting suitability for reducing risks.

[6.0 Marks]

Question 4

a. A new high-rise building is proposed in an urban area which is located close to a lagoon, and a deep basement excavation is planned as part of the construction.

i. As engineers involved in the construction of the basement, briefly explain the importance of investigating groundwater conditions for excavation works.

[6.0 Marks]

ii. Describe the key difference between steady groundwater flow and unsteady groundwater flow.

[4.0 Marks]

iii. State whether groundwater flow would be steady or unsteady during above excavation and justify your answer briefly.

[3.0 Marks]

b. An unconfined aquifer has a hydraulic conductivity of 3.0 m/day and an initial saturated thickness of 15 m. The aquifer receives a uniform recharge of 4 mm/day over the area. A fully penetrating well pumps groundwater at a constant rate of 60 litres per minute. At steady-state conditions, the drawdown at a radial distance of 12 m from the well is observed to be 8 cm. Determine the drawdown immediately outside the well assuming the radius is 15 cm. The following equation would be useful in the calculations.

$$h^2 - {h_0}^2 = \frac{Q_w}{\pi K} ln\left(\frac{r}{r_0}\right) + \frac{q}{2K}({r_0}^2 - r^2)$$

r = Reference radius

h = Saturated thickness at radius r

Q_w = pumping rate of well

q = recharge rate

r_0 = Radius at which head is required

h_0 = Saturated thickness at radius r_0

K = hydraulic conductivity

[12.0 Marks]

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