UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: March 2026

Module Number: CE5303 **Module Name: Hydraulic Engineering (C-23)**

[Three Hours]

[Answer **all** questions, each question carries **TEN** marks]

Q1.

(a) Using clear sketches, explain how and why the hydraulic jump is formed?

[02 Marks]

(b) A man made channel has a certain section in which the slope varies as shown in the Figure Q1. Section A has a slope of 1°, section B has a slope of 2° and section C has a slope of 0.1°. The channel is a lined concrete channel with a rectangular shape. The channel is designed to carry 3 m^3/s. The channel width is 2.0 m. Manning's n=0.015.

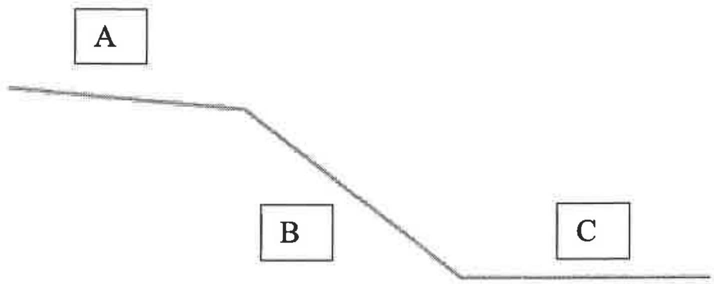


Figure Q1: Canal sections A, B, and C

(i) Calculate the critical depth for the channel.

(ii) Calculate the normal depths in section A, B and C.

(iii) Draw specific energy vs depth diagram for the channel based on the uniform flow condition.

(iv) With the support of the above diagram or else, explain the changes of the flow between supercritical and subcritical regions during the transitions from sections A to B and B to C.

(v) If your calculations prove that a hydraulic jump is generated at any transition between the sections, calculate the conjugate depths of the hydraulic jump. If not, explain why there are no possibilities for a hydraulic jump to occur.

Conjugate depths for a hydraulic jump in a horizontal bed in standard notations may be taken as; $\frac{2y_2}{y_1} = -1 + \left(1 + 8Fr_1^2\right)^{1/2}$.

[01+03+01+01+02 Marks]

Q2.

(a) Define the terms total energy and specific energy.

[02 Marks]

(b) A rectangular rubble masonry lined channel, 8 m wide, with a flow rate of 30 m³/s, encounters a 4 m high weir across the channel (Figure Q2). The channel is having a constant bed slope of 0.0004. The discharge equation for a sharp crested full width weir can be taken as $Q = C_d\, b\, g^{1/2} H^{3/2}$. Where C_d= 0.6, b is width of the weir and H is the depth of water above the weir crest. Manning's roughness coefficient of a rubble masonry channel can be taken as 0.025.

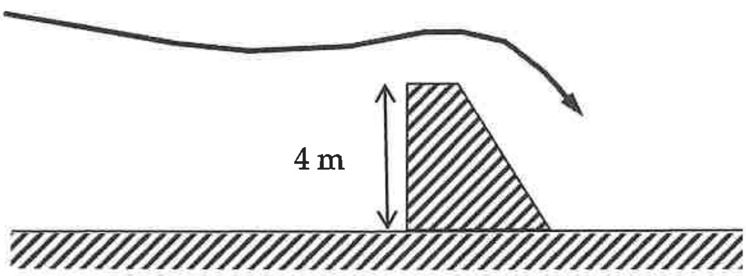


Figure Q2: Flow at the weir

Slope class determination is provided in the page 3 of this question paper.

(i) Calculate the normal depth in the channel and show that the slope is hydraulically mild.

(ii) Show that the depth of flow 2 km upstream of the weir is about 5 m.

(iii) From the weir, how far upstream will the depth be 3.30 m ?

(iv) Discuss the significance of the above answer in (iii) with respect to the change of surface profiles due to hydraulic structures.

[02x4=08 marks]

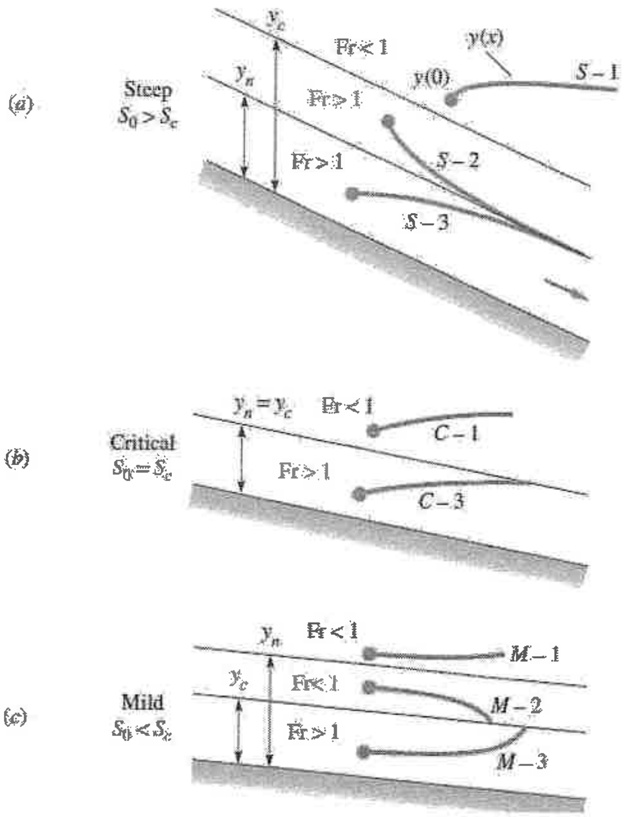
For rectangular channel sections, following equations can be used with usual notations to estimate water surface profile.

$$\frac{d(d)}{dL} = \frac{(S_0 - S_f)}{\left(1 - \frac{Q^2 B}{g A^3}\right)}$$

$$\frac{\left(d_2 + \frac{V_2^{\,2}}{2g} + S_0 \times \Delta L\right) - \left(d_1 + \frac{V_1^{\,2}}{2g}\right)}{\Delta L} = \frac{S_{f1} + S_{f2}}{2}$$

Slope class determination data sheet

Slope class	Slope notation	Depth class	Solution curves
$S_0>S_c$	Steep	$y_c>y_n$	S-1, S-2, S-3
$S_0=S_c$	Critical	$y_c=y_n$	C-1, C-3
$S_0<S_c$	Mild	$y_c<y_n$	M-1, M-2, M-3



Q3.

(a) A water conveyance structure is to be planned between a multipurpose reservoir to an irrigation field. Two alternative canal traces are suggested; first alternative is a tunnel drilled through mountainous area with relatively shorter path. Second alternative is an open channel running around the hilly terrain. After investigation with a comprehensive study of the topography/geology of the area, the second alternative has been selected. Briefly explain the possible reasons for not selecting the first alternative for the canal trace.

[02 Marks]

(b) Show that for a rectangular channel section, the most economical section is represented by $d = b/2$, where d and b are *depth* of flow and *width* of the canal section considered.

[02 Marks]

(c) It has been suggested to construct a rectangular canal with concrete as the lining material to convey 2.5 m^3/s flow. The elevation drop of the canal trace between 10 km apart extreme points were estimated as 20 m and a uniform slope for the entire canal trace was proposed. Canal design parameters are given in Table Q3.1 and Table Q3.2. Design the canal with the Manning's rough coefficient taken as 0.014.

Table Q3.1: Recommendations for free board

Q (m^3/s)	< 0.75	0.75 ~ 1.5	1.5 ~ 8.5	> 8.5
Free board (m)	0.45	0.6	0.75	0.90

Table Q3.2: Permissible velocities

Canal material	**Maximum Velocity (m/s)**	**Minimum Velocity (m/s)**
For Stratified Rock	2.40	1.0
For Hard Rock	3.96	
For Concrete	4.57	

[04 Marks]

(d) Briefly discuss the major hydraulical design modification(s) to be adopted if the conveyance structure is designed as erodible earthen canal.

[02 Marks]

Q4.

(a) Reservoir routing is useful in several aspects such as determination of *attenuation* and *reservoir lag* for a given flood either in existing reservoir or a reservoir that is being designed. It can also establish the variation of reservoir level versus time for a given inflow hydrograph which will be useful in design of spillways.

(i) With the aid of a clear sketch, identify flood attenuation and reservoir lag.

(ii) Briefly explain the reservoir routing concept using its mathematical representation $I - O = dS/dt$.

[02+02=04 Marks]

(b) Table Q4.1 shows the data related to a reservoir to be used for an irrigation project.

Table Q4.1: Elevation and storage data of the reservoir

Elevation (m)	55	58	60	61	62	63
Storage ($\times 10^3$ m^3)	250	650	1000	1250	1500	1800

The reservoir has a 5 m long (L) spillway. The sill of the spillway is located at elevation 60 m. The discharge equation for the spillway is given as $Q = 3LH^{\frac{3}{2}}$ (SI units).
At a certain instant, a flood represented by Table Q4.2 flood hydrograph, entered the reservoir.

Table Q 4.2: Flood hydrograph

Time (hrs)	0	6	12	18	24	30	36	42	48
Flood discharge (m^3/s)	5	20	50	60	50	32	22	15	10

At time = 6.0 hrs from the commencement of the entry of the flood into the reservoir, the reservoir water surface elevation was 61 m.

Determine the discharge at an instant 12.0 hrs from the commencement of the flood into the reservoir.

[04 Marks]

(c) Discuss the influence of reservoirs in altering sediment transportation patterns along the rivers.

[02 Marks]

Q5.

(a) Define Submerged Flow, Free Flow, Head water and Tail water related to hydraulic structures.

[02 Marks]

(b) Discuss the differences between a sharp-crested weir and a broad-crested weir.

[02 Marks]

(c) Water approaches a 2 m wide sluice gate. The upstream depth of flow is 3 m, while the downstream depth of flow is 0.5 m.

Determine the discharge through the sluice gate for the following cases.

(i) Case (i) - Neglecting energy losses at the gate.
(ii) Case (ii) - Assuming the energy loss at the gate is 20% of the upstream depth.

(iii) Draw the variation of the energy grade line through the sluice gate for Case (i) and Case (ii) separately.

[02x3=06 Marks]