UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: May 2023

Module Number: CE5303 **Module Name: Hydraulic Engineering**

[Three Hours]

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

Q1.

a) Briefly explain why the principle of conservation of energy shall not be used in developing the theory of hydraulic jump.

[02 Marks]

(b) Using clear sketches, explain how and why the hydraulic jump is formed. Discuss practical applications of hydraulic jump.

[02 Marks]

(c) 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 10° 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 2 m^3/s. The channel width is 1.5 m. Manning's n=0.015.

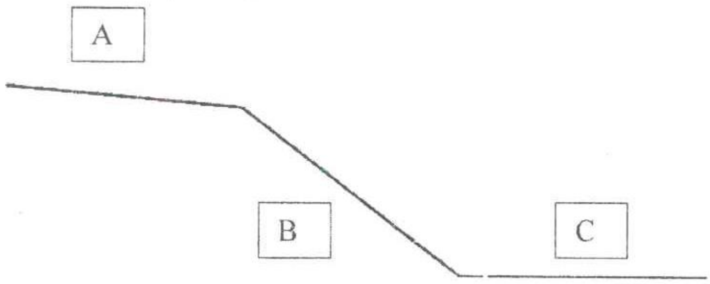


Figure Q1: Canal sections A, B, and C

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.

iv) Prove that a hydraulic jump occurs at the transition from section B to section C, with the support of above diagram.

v) Calculate the conjugate depths of the hydraulic jump.

vi) Draw the water surface profile curve and mark the depth of flow at A,B, and C.

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

[08 Marks]

Q2.

(a) Define the terms, total energy and specific energy. Define all the terms with the aid of a diagram.
Explain the difference between total energy and specific energy.

[02+ 01 Marks]

(b) A rectangular lined channel is 8 m wide and Manning's roughness coefficient can be taken as 0.015. The channel has a constant bed slope of 0.004. The channel has a uniform flow in the upstream and the flow encounters a 0.5 m high broad crested weir as shown in Figure Q2 at a certain point. The discharge equation for a broad crested weir can be taken as $Q = CL H^{3/2}$. Where C= 0.6, L is length of the weir and H is the height of water head upstream related to the weir crest.

i. Calculate the discharge along the channel if the height of water head upstream related to the weir crest is 1.5 m.

ii. Show that the channel slope is hydraulically mild.

iii. Determine the upstream location at which the depth of flow is 1.75 m. Use direct step method.

iv. Show that the depth of flow is equal to normal depth in an upstream location of nearly 630 m from the location of the weir.

v. If the weir height was 2 m what is the possible change in the location to return to the normal depth.

vi. Draw the surface profile variation relevant to section (iv) and prove that it is a M1 curve.

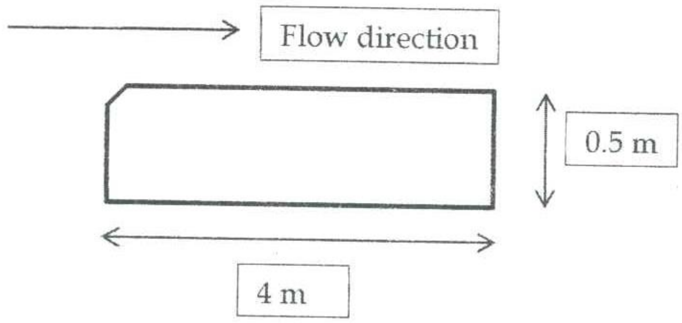


Figure Q2: Dimensions of the broad crested weir

Slope class determination is provided in the following sheet.

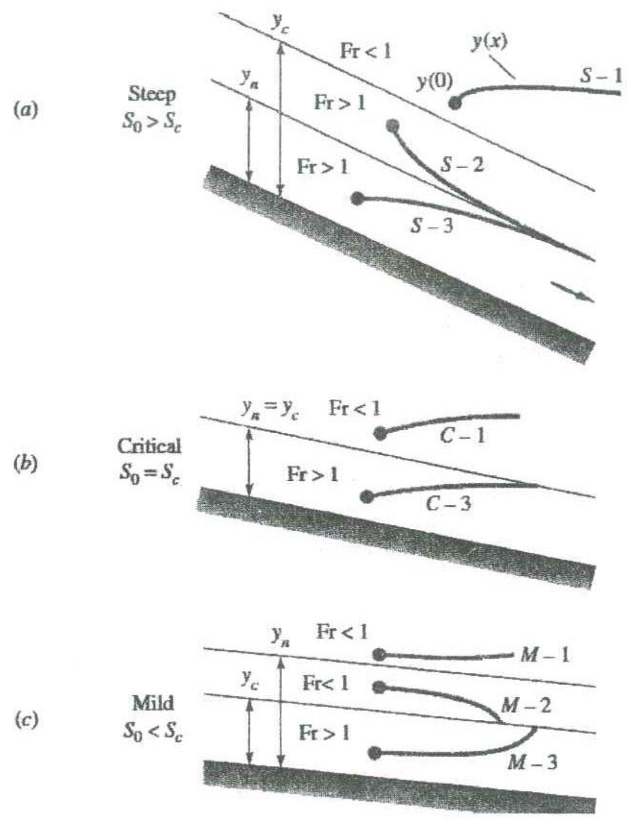
[09 marks]

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

$$\frac{d(y)}{dL} = \frac{S_0[1 - (\frac{y_n}{y})^{\frac{10}{3}}]}{[1 - \frac{y_c}{y}^3]}$$

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

Slope class	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



Gradually varied flow for three classes of channel slope

Q3.

(a) Briefly explain the significance of following terms in relation to design of channels.

i. Maximum permissible velocity

ii. Minimum permissible velocity

[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 use rectangular canal with concrete as the lining material to convey 1.5 m^3/s flow. The elevation drop of a 10 km canal section is estimated as 10 m. A uniform slope for the entire canal trace is proposed. Canal design parameters are given in Table Q3.1 and Table Q3.2. Design the canal if the Manning's rough coefficient can be 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) It has been proved that the most economical section for a trapezoidal canal is a half hexagon. Design the canal section of a trapezoidal canal for conveying same flow under above conditions given in section (c).

[02 Marks]

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

[02 Marks]

Q4.

(a) Reservoir routing is useful in determination of *attenuation* and *reservoir lag* for a given flood either in an 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 *attenuation* and *reservoir lag*.

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

[02 + 02 Marks]

(b) The following data related to a reservoir is to be used for an irrigation project.

Elevation (m)	298.0	298.5	299.0	299.5	300.0	300.5
Contour Area ($\times 10^6$ m^2)	1.250	1.280	1.320	1.360	1.388	1.428

The reservoir has a spillway of length (L) of 5 m and sill of the spillway is located at elevation 299.5 m. The discharge equation for the spillway is given as $Q = 2.68LH^{3/2}$ (SI units)

There is an irrigation outlet of circular cross section and diameter 0.30 m with its center at evaluation 287.5 m. The discharge equation for the outlet may be taken as $Q = C_d A\{2gH\}^{\frac{1}{2}}$ where $C_d = 0.78$; $A =$ area of outlet; H= head above the center of the outlet (for fully open condition)

At a certain instant when the irrigation outlet is open, a flood represented by the following hydrograph enters the reservoir:

Time (hrs)	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5
Flood discharge (m^3/s)	10	12	18	20	50	60	30	22

At time = 1.0 hr from the commencement of the entry of the flood into the reservoir, the reservoir water surface elevation is 300 m. Determine the total discharge at an instant 1.5 hrs from the commencement of the flood into the reservoir.

[06 Marks]

(c) Reservoirs play a main role in retention of sediments. Using your knowledge on sediment transport patterns along the rivers critically discuss above statement.

[02 Marks]

Q5.

(a) Show that the relationship for the flow depth over a bump (with negligible frictional effects), in standard notations is represented by; $y_2^3 - E_2 y_2^2 + \frac{v_1^2 y_1^2}{2g} = 0$ where $E_2 = \frac{v_1^2}{2g} + y_1 - \Delta h$

[02 Marks]

(b) Explain under what conditions the water surface might fall below its upstream position y_1 with diagrams.

[02 Marks]

(c) Consider the flow in a wide channel over a bump, as in below Figure Q5.

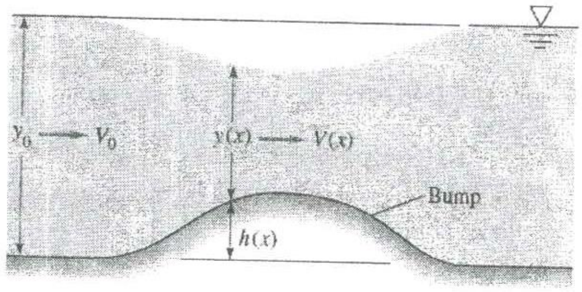


Figure Q5: Flow over bump in a wide channel

If the approach velocity $v_0 = 1$ m/s, depth of flow $y_0 = 1$ m and the maximum bump height is 15 cm,

(i) Estimate the Froude number over the top of the bump.

(ii) Estimate the maximum depression in the water surface.

(iii) For the same approach conditions, determine the bump height over which the conditions are exactly critical.

(iv) What would happen to the upstream flow if the bump height increased beyond the critical conditions?

[2x4= 08 Marks]