UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: July 2016

Module Number: CE5314 **Module Name: Hydraulic Engineering (OC)**

[Three Hours]

[Answer **all** questions, each question carries 12 marks]

Experimental values of Manning's n for different surfaces are provided

Q1.

(i) (a) Discuss the variation of velocity in the horizontal and vertical directions for a typical open channel.

(b) Explain with clear sketches how the variations mentioned in above part (i) (a) are captured experimentally in order to estimate the average velocity and hence the discharge across a typical cross section of an open channel.

(02 + 02 Marks)

(ii) (a) What is meant by a flow rating curve?

(b) Discuss the need to make adjustments to flow rating curves.

(c) Explain why and how the flow rating curve is extended.

(01 + 02 + 02 Marks)

(iii) As part of development of a flow rating curve, the discharge is to be estimated for a 200 m length of 10 m wide rectangular Rubble Masonry channel. The upstream and downstream water depths were measured as 3.0 m and 2.9 m. The drop in water surface elevation was found to be 0.12 m. Estimate the channel discharge.

(03 Marks)

Q 2.

(i) Explain the following terms, with reference to flow in open channels.

(a) Normal depth, y_n

(b) Critical depth, y_c

(c) Critical slope

(02 Marks)

(ii) Deduce and sketch the three surface flow profile shapes s_1, s_2 and s_3 for gradually varied steady flow in a wide rectangular channel under steep slope conditions. The depth gradient in gradually varied flow in a rectangular open channel with standard notations may be taken as;

$$\frac{d(y)}{dx} = \frac{(s_0 - s_f)}{\left(1 - \frac{BQ^2}{gA^3}\right)}$$

(03 Marks)

Q 2. Continued to page 2.

(iii) A wide rectangular excavated clean-earth channel has a longitudinal slope of $S_0 = 0.0048$ and carries a flow rate per metre width of $q = 15\ m^2/s$.

(a) Determine the corresponding critical depth.

(b) Along a reach JK of the channel the depth of flow varies from $y_j = 1.0$ m to $y_k = 1.5$ m. Determine the length JK and state whether K is upstream or downstream of J. Sketch and label the flow profile JK.

(2.0 + 5.0 Marks)

Q3.

(i) (a) Define the term 'specific energy'. Identify the associated parameters of specific energy curve.

(b) Show that the relationship for the flow depth over a bump height Δh (with negligible frictional effects), in standard notations is represented by;

$$y_2^3 - E_2 y_2^2 + \frac{v_1^2 y_1^2}{2g} = 0 \text{ where } E_2 = \frac{v_1^2}{2g} + y_1 - \Delta h$$

(01 + 02 Marks)

(ii) Water approaches a wide sluice gate (frictionless) at negligible approach velocity and upstream depth of flow of 2.27 m. The average velocity downstream of the gate is measured as 5.0 m/s.

(a) Estimate at the outlet to the sluice gate depth of flow and Froude number.

(b) After exiting from the sluice gate water flows into a wide channel fitted with a 10-cm-high bump. Estimate Depth of flow over the bump.

(c) If there is a hydraulic jump just downstream of the bump, determine the depth after the hydraulic jump.

Conjugate depths for a hydraulic jump on 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 + 01 + 03 + 02 Marks)

(iii) Using a clearly labeled specific energy diagram, indicate specific energy and depth of flow values corresponding to positions upstream and downstream of the sluice gate and upstream and downstream of the hydraulic jump.

(02 Marks)

Q 4.

(i) Figure Q4 shows a broad-crested weir, in a wide channel which creates a short run of nearly one-dimensional critical flow. The flow upstream is subcritical, accelerates to critical at the top of the weir, and spills over into a supercritical nappe.

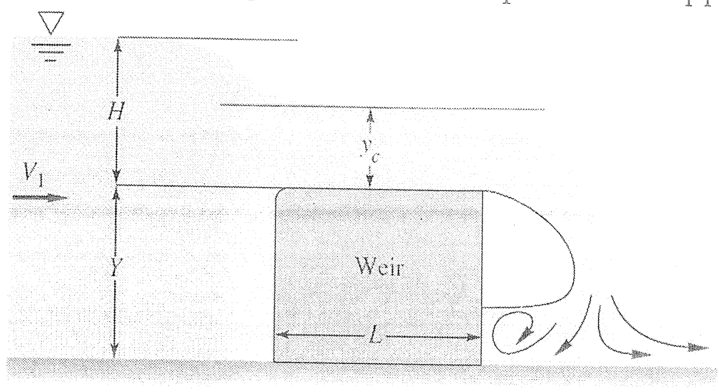

Figure Q4: Flow over wide, well ventilated broad-crested weir

(a) Show that the critical depth at the top of the broad crested weir for negligible approach velocity can be approximated by; $y_c = \frac{2H}{3}$

(b) State all the assumptions

(03 + 01 Marks)

(ii) (a) Using the results in above part (i) (a) or otherwise show that the flow discharge over a broad crested weir can be represented by $Q_{weir} = C_d\ b\sqrt{g}\ H^{3/2}$ with standard notations.

(b) Briefly explain, how the discharge coefficient for a weir is determined?

(04 + 01 Marks)

(iii) A round-nosed broad crested weir in a horizontal channel is 1.0 m high and 4.0 m wide. The water depth upstream is 1.6 m.

(a) Using the broad crested weir discharge formula derived in above part (ii), estimate the channel discharge. Take C_d as 0.528.

(b) Update the answer in above part (iii)(a) by incorporating the approach velocity.

(01 + 02 Marks)

Q 5.

(i) 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.

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

(b) Briefly explain the reservoir routing concept highlighting its mathematical representation.

(02 + 02 Marks)

Q 5. Continued to page 4

(ii) Storage-outflow relationship curves and related numerical-data developed for a multipurpose reservoir are given in Figure Q5 and Table Q5 respectively where;
O = Combined outflow through the dam.
S = Reservoir storage above full supply level.

Table Q5: Numerical data for reservoir storage characteristics

O (m^3/s)	S (m^3)	$S + O^*\Delta t/2$ (m^3)	$S - O^*\Delta t/2$ (m^3)
5.0	660,000	664,500	655,500
11.0	680,000	689,900	670,100
18.5	694,000	710,650	677,350
28.5	714,000	739,650	688,350
39.0	726,500	761,600	691,400
50.5	739,000	784,450	693,550

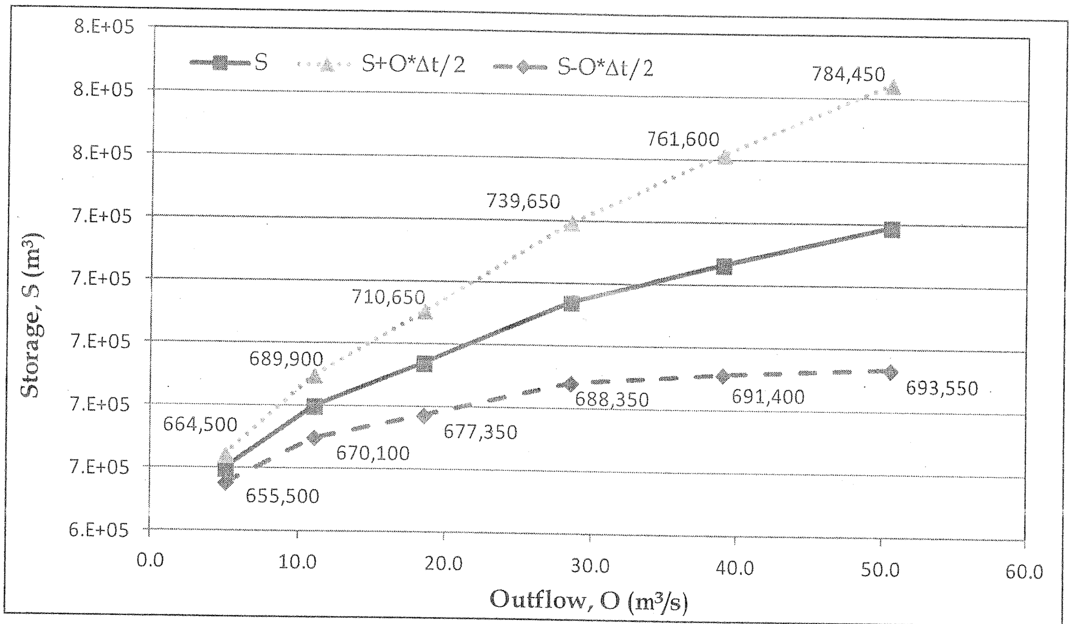

Figure Q5: Reservoir storage characteristic curves

(a) Explain the development procedure of Figure Q5 illustrating related equations.
(b) Briefly discuss the use of Figure Q5 in relation to reservoir routing.

(02 + 03 Marks)

(iii) At a certain instant a flood represented by the following hydrograph enters the reservoir:

Time (hours)	0	0.5	1.0	1.5	2.0	2.5
Flood discharge (m^3/s)	18.2	20.1	25.8	44.2	37.4	66.4

The reservoir water surface elevation at the commencement of the entry of the flood into the reservoir corresponds to a combined outflow = 5 m^3/s. Using the provided data in above part (ii), show that the outflow at an instant 0.5 hours from the commencement of the flood into the reservoir is approximately equal to 11.0 m^3/s.

(03 Marks)

Experimental values of Manning's n for different surfaces

Type of surface	Manning's n
Artificial lined canals:	
Glass	0.010
Brass	0.011
Steel, smooth	0.012
Painted	0.014
Riverted	0.015
Cast iron	0.013
Cement, finished	0.012
Unfinished	0.014
Planed wood	0.012
Clay tile	0.014
Brickwork	0.015
Asphalt	0.016
Corrugated metal	0.022
Rubble masonry	0.025
Excavated earch canals:	
Clean	0.022
Gravelly	0.025
Weedy	0.030
Stony, cobbles	0.035
Natual channels:	
Clean and straight	0.030
Sluggish, deep pools	0.040
Major rivers	0.035
Floodplains:	
Pasture, farmland	0.035
Light brush	0.050
Heavy brush	0.075
Trees	0.150