UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: March 2022

Module Number: CE 5303 **Module Name: Hydraulic Engineering (C-18)**

[Three Hours]

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

Q1. (a) With the aid of a sketch depicting the specific energy curve explain the meaning of critical depth (y_c) at an open channel section. [3 marks]

(b) Prove following the usual notation, Froude number (F)=1 and, hence, $u^2/2g = D/2$ at critical state of flow, where $D=A/T$ is hydraulic depth. [4 marks]

(c) For a trapezoidal open channel of base width, B and side slope 1(V): Z(H), calculate the value of Z for the most economical cross section.

[5 marks]

Q2. A rectangular Channel has a width of 2.0m and carries a discharge of 4.8 m^3/s with a depth of 1.6m. It is required to investigate the effect of a proposed hump on water levels. Neglect energy losses in the calculations. A definition sketch is provided in Figure Q2.

(a) At a certain cross-section a small, smooth hump with a flat top and a height 0.10m is proposed to be built. Calculate the likely water depth over the hump and check if there is a depression in water surface above the hump relative to upstream water level. [4 marks]

(b) If the height of the hump, Δz is to be raised to obtain critical flow above the hump, what is the required maximum height of the hump (Δz_{max}) ?. [4 marks]

(c) If the height of the hump is 0.5m, estimate the water surface elevation on the hump (i.e., section 2) and at a section immediately upstream of the hump (i.e., section 1). What has happened to the water surface elevation and specific energy upstream compared to no-hump condition? [4 marks]

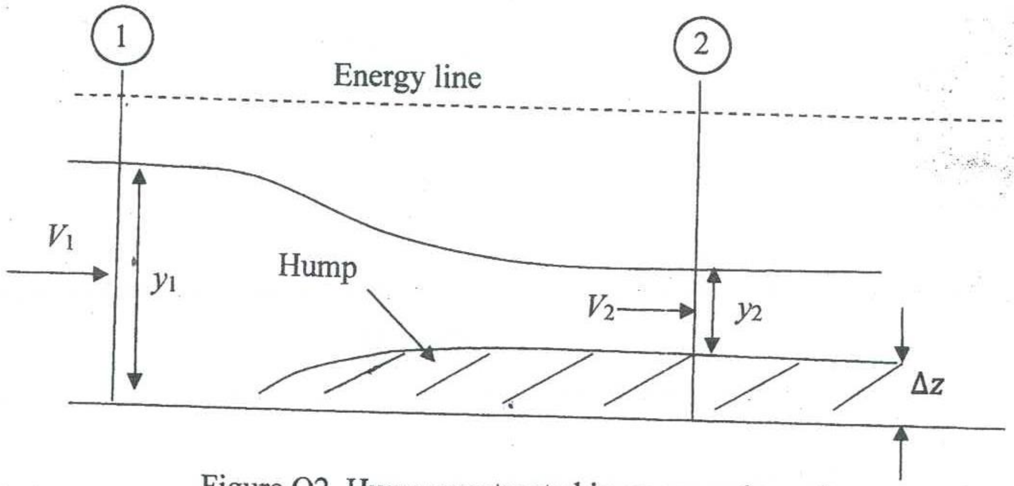

Figure Q2. Hump constructed in an open channel

Q3. A rectangular channel, 6m wide, consists of three reaches of different slopes. The channel has a roughness coefficient n=0.015 and carries a discharge of 14 m^3/s:

(a) Determine the normal and critical depths in each reach. [6 marks]

(b) Sketch possible flow profiles for the three reaches. [6 marks]

(Classification of flow profiles are given as Appendix-A and B)

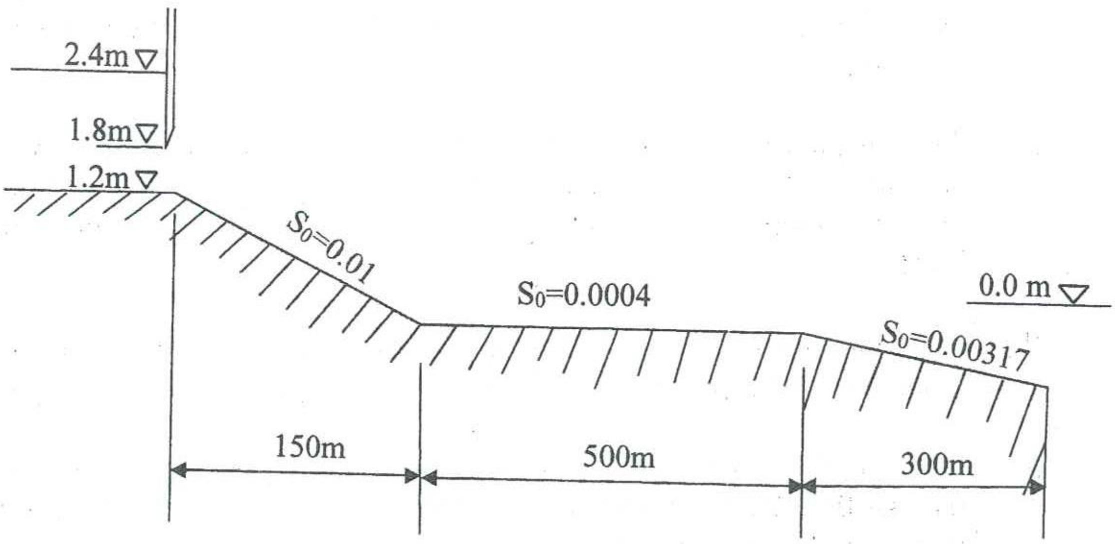

Figure Q3. Channel reaches of different slopes

Q4. (a) Briefly explain (i) critical shear stress (ii) different modes of bed load sediment transport in rivers using sketches if necessary. [2 marks]

(b) Assuming frictional resistance force at the impending motion of a sediment particle on the channel bed is equal to μR where, R is the force normal to the surface, $\mu = \tan\theta$ is the friction coefficient and θ is angle of repose, calculate the tractive force ratio, τ_S/τ_L. Effective area of a sand particle is a and unit tractive force on the side slope and level bed of the channel are τ_s and τ_L respectively. W_s is submerged weight of the particle.

[4 marks]

(c) (i) For a trapezoidal open channel with bottom width b=6m excavated in earth, calculate permissible unit tractive force on the slope, τ_s if the same for the level bed $\tau_L = 25$ N/m^2.

[2 marks]

(ii) If the longitudinal slope of the channel mentioned in (i) is S=0.0016 and Manning roughness coefficient, n=0.025 check whether the slope will be eroded for a design discharge of 14 m^3/s under uniform flow. The maximum tractive force on the slope exerted by water flow can be assumed as, $\tau_s = 0.75(\rho g)yS$ where y is uniform water depth, density of water = 1000kg/m^3, side slope, $\tan\phi$ =0.5, angle of repose, θ = 33 deg, g=gravity.

[4 marks]

Figures Q4(i) and Q4 (ii) are applicable for questions Q4 (b) and Q4(c).

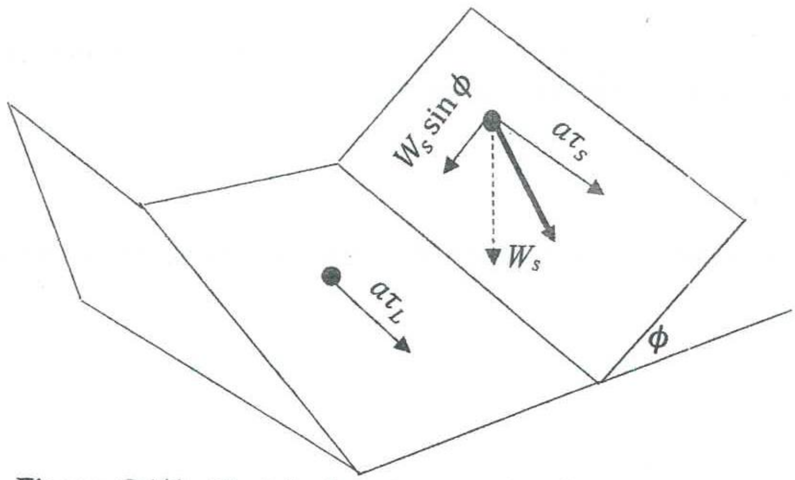

Figure Q4(i). Sketch showing tractive force on slope and level bed

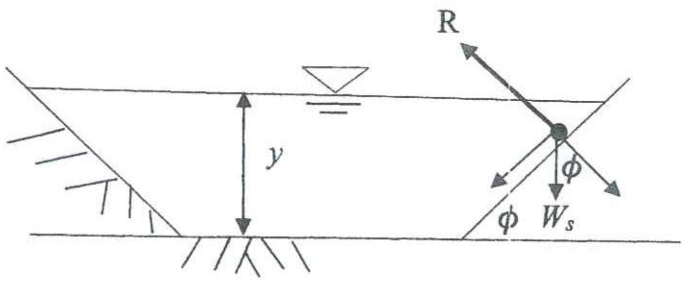

Figure Q4(ii). Cross section of the channel

Q5 (a) Explain the essential difference between hydraulic method of flood routing and hydrologic method of flood routing giving their strengths and weaknesses.

[4 marks]

(b) What is the name given to equation 5.2 and what type of flows does it describe?

[2 marks]

(c) Linearised form of the velocity potential of a surface gravity wave, written in usual notation, is given by:

$$\phi = \frac{gH}{2\omega}\frac{\cosh k(z+h)}{\cosh(kh)}\sin(kx - \omega t) \text{ ------------ Eq. 5.1}$$

(i) At $z=\eta$ make appropriate assumptions to equation 5.2 to obtain equation 5.3:

$$\frac{P}{\rho} + \frac{1}{2}(u^2 + w^2) + gz + \frac{\partial\phi}{\partial t} = C(t) \text{ --------- Eq. 5.2}$$

$$\frac{P}{\rho} + gz + \frac{\partial\phi}{\partial t} = 0 \text{ --------- Eq. 5.3}$$

[3 marks]

(ii) The dynamic wave pressure (P_d) is equal to total pressure, P (relative to atmospheric) minus hydrostatic pressure:

$$P_d = P - \rho g(-z) \text{ --------- Eq. 5.4}$$

Obtain a relationship for dynamic wave pressure (P_d) in terms of variables x, z and t. A definition sketch is shown in Figure Q5.

[3 marks]

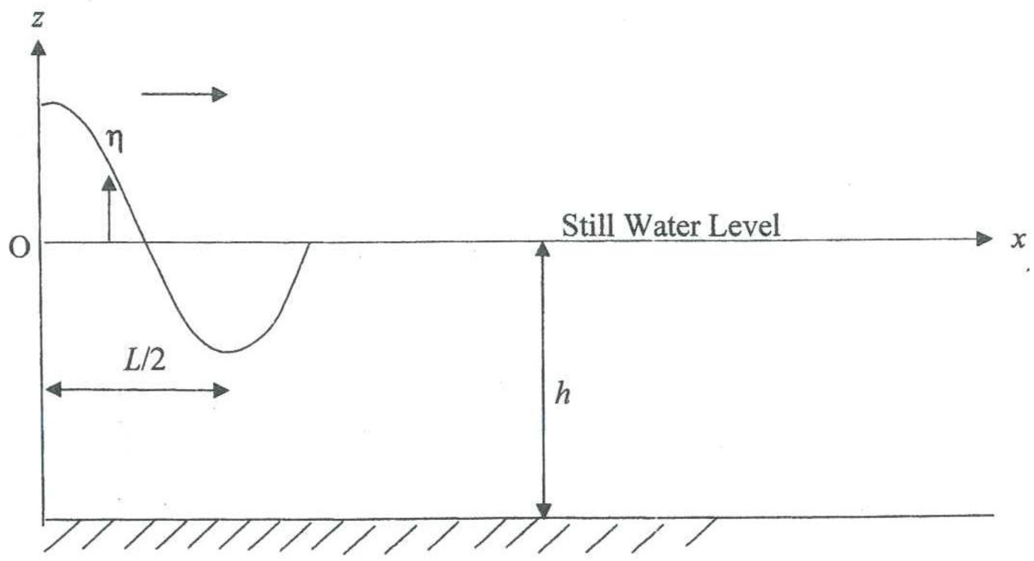

Figure Q5

TABLE 9-1. TYPES OF FLOW PROFILES IN PRISMATIC CHANNELS

Channel slope	Designation: Zone 1	Designation: Zone 2	Designation: Zone 3	Relation of y to y_n and y_c (Zone 1 / Zone 2 / Zone 3)	General type of curve	Type of flow
Horizontal $S_0 = 0$	None			$y > y_n > y_c$	None	None
		$H2$		$y_n > y > y_c$	Drawdown	Subcritical
			$H3$	$y_n > y_c > y$	Backwater	Supercritical
Mild $0 < S_0 < S_c$	$M1$			$y > y_n > y_c$	Backwater	Subcritical
		$M2$		$y_n > y > y_c$	Drawdown	Subcritical
			$M3$	$y_n > y_c > y$	Backwater	Supercritical
Critical $S_0 = S_c > 0$	$C1$			$y > y_c = y_n$	Backwater	Subcritical
		$C2$		$y_c = y = y_n$	Parallel to channel bottom	Uniform-critical
			$C3$	$y_c = y_n > y$	Backwater	Supercritical
Steep $S_0 > S_c > 0$	$S1$			$y > y_c > y_n$	Backwater	Subcritical
		$S2$		$y_c > y > y_n$	Drawdown	Supercritical
			$S3$	$y_c > y_n > y$	Backwater	Supercritical
Adverse $S_0 < 0$	None			$y > (y_n)^* > y_c$	None	None
		$A2$		$(y_n)^* > y > y_c$	Drawdown	Subcritical
			$A3$	$(y_n)^* > y_c > y$	Backwater	Supercritical

* y_n in parentheses is assumed a positive value.

it can be shown that the theoretical behavior of the flow profile at or near $y = 0$ depends on the type of uniform-flow formula used in the computation. For a wide rectangular channel, Eq. (9-17) represents the slope of flow profile if the Manning formula is used. By this equation, it can be shown that dy/dx becomes infinite when $y = 0$. This means that the curve is vertical at the channel bottom. If the Chézy formula is used, it can be shown that $dy/dx = S_0(y_n/y_c)^3$ for $y = 0$. This means that the curve will make a certain angle with the bottom. It is apparent that ... profile when $y < y_c < y_n$.

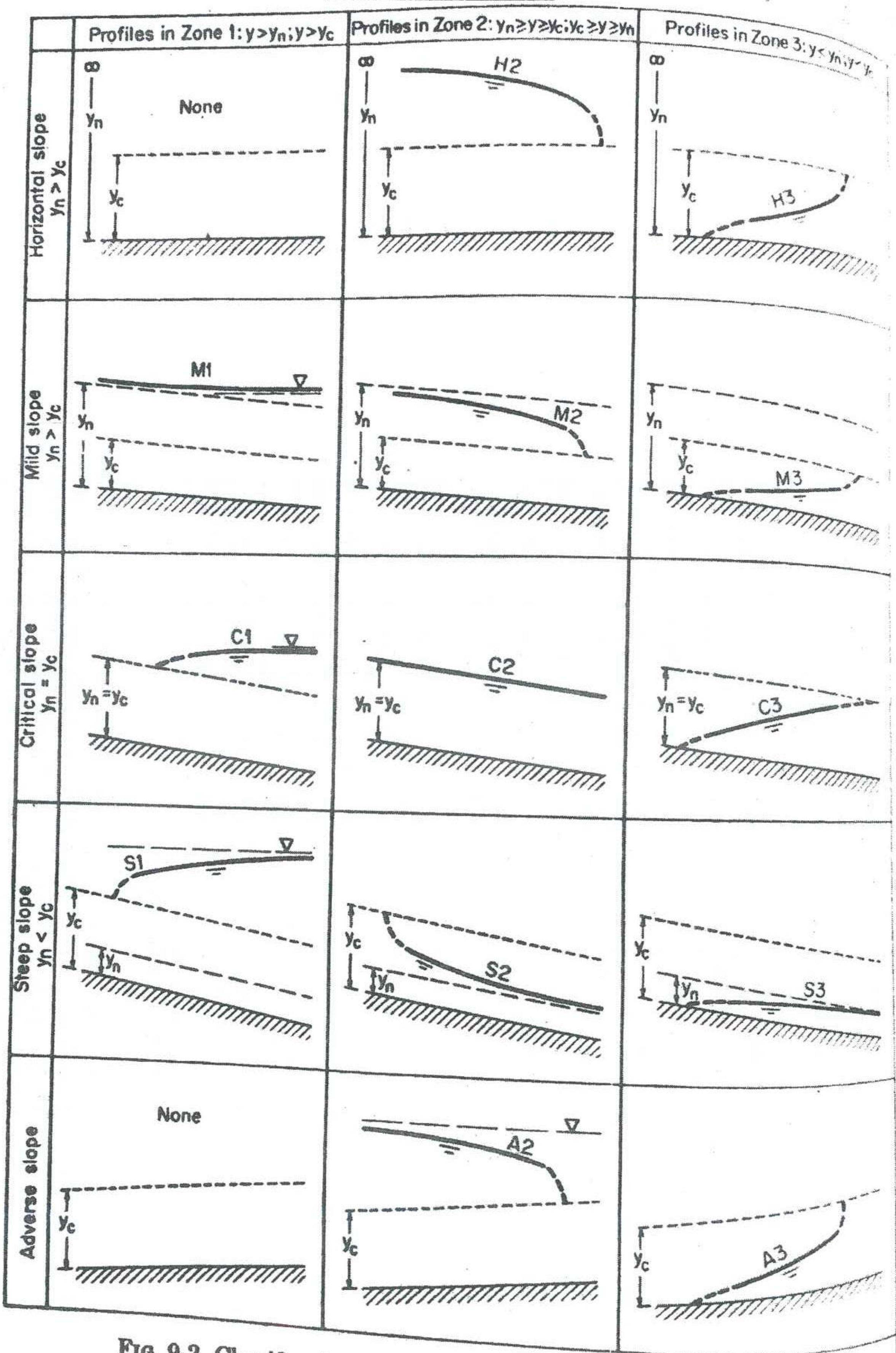

Fig. 9-2. Classification of flow profiles of gradually varied flow.