

University of Asia Pacific
Department of Civil Engineering
Final Examination Spring 2013
Program: B.Sc. Engineering (Civil)

Course title: Open Channel Flow

Course code: CE 361

Time: 3 hours

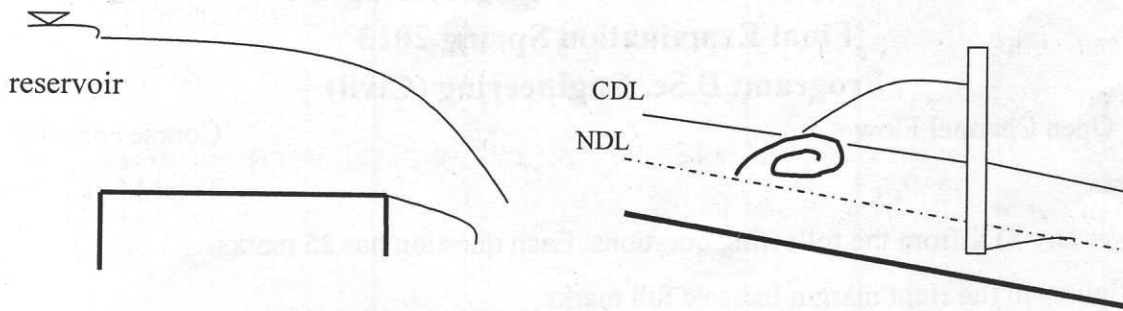
Total Marks: 150

Answer any **SIX** from the following questions. Each question has **25** marks.

The figures in the right margin indicate full marks.

1. (a) What is a lined channel? What are the reasons for lining a channel? 5
- (b) Show that the best hydraulic rectangular section is one half of a square. 4
- (c) Compute the wetted perimeter of the best hydraulic section for a lined channel to carry a discharge of $15 \text{ m}^3/\text{s}$ with $n=0.013$ and $S_0=0.001$ if the section is i) rectangular, ii) trapezoidal and iii) circular. Which section has the minimum wetted perimeter? 12
- (d) Differentiate between 'maximum permissible velocity' and 'non-silting velocity'. 4
2. (a) A lined channel ($n=0.015$) is to be laid on a slope of 1 in 2000. The side slope of the channel is to be maintained at 1.5 (H):1(V). Determine the depth of flow of a triangular section with rounded corner to carry a discharge of $40 \text{ m}^3/\text{s}$. 8
- (b) An erodible channel has to carry a discharge of $30 \text{ m}^3/\text{s}$ through a coarse non-cohesive material having $d_{75}=3 \text{ cm}$ and $n=0.025$. It is to be laid on a slope of 1 in 1000 and is to be excavated in earth containing slightly rounded coarse non-cohesive particles. Determine the channel dimensions using the method by Lane. 12
- (c) Define the following terms: 5
 - i. Critical shear stress
 - ii. Angle of repose
3. (a) Derive the following equation for gradually varied flow in an open prismatic channel. State the assumptions you made to derive the equation. 8
$$\frac{dy}{dx} = \frac{S_0 - S_f}{1 - Fr^2}$$
- (b) A rectangular channel 7 m wide has three reaches arranged serially. The bottom slopes of the reaches are 0.0016, 0.015 and 0.0064. The 'n' values for the middle reach is 0.015 and for the others is 0.025. For a discharge of $20 \text{ m}^3/\text{s}$, sketch the resulting flow profiles. 10
- (c) Sketch the possible flow profiles produced on a critical slope and a horizontal slope. 7

4. (a) Define a control section. Locate control sections in the following two flow profiles. 4



- (b) Sketch the possible water surface profiles in the following cases: 9

- i. Mild --- Steep --- Milder Steep --- Free Overfall
- ii. Mild --- Steeper Mild --- Steep

- (c) A rectangular channel having bottom width $b=6\text{m}$, $n=0.025$ and channel slope $S_0=0.0025$ carries a discharge of $40\text{ m}^3/\text{s}$. At a section A of this channel the depth of flow is 2m . How far upstream or downstream from this section will the depth be 2.25 m ? Use the direct step method (use three steps). 12

5. (a) List the characteristics of Rapidly Varied Flows. 4

- (b) For a hydraulic jump on a horizontal, rectangular channel, derive the following expression of the sequent depth ratio. 6

$$\frac{y_2}{y_1} = \frac{1}{2} \left(\sqrt{1 + 8Fr_1^2} - 1 \right)$$

- (c) Water flows at a velocity of 6.1 m/s and a depth of 1m in a horizontal rectangular channel that is 6.1m wide. Find 15

- a. The downstream depth necessary for hydraulic jump
- b. The type of jump
- c. The height of jump
- d. Length of jump
- e. Efficiency of the jump

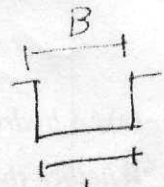
6. (a) Differentiate between different types of hydraulic jumps based on Froude number. 8

- (b) Water flows at a depth of 1m in a horizontal trapezoidal channel having a base width 6 m and side slope $s=2$. The discharge is $120\text{ m}^3/\text{s}$. If a hydraulic jump occurs in this channel, compute the downstream depth that will create a hydraulic jump. 12

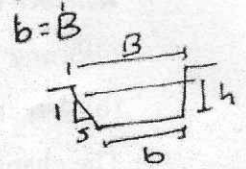
- (c) Briefly describe a 'Stilling Basin'. Use a sketch to show different components of a 'Stilling Basin'. 5

7. (a) 'A hydraulic jump occurs on a channel comprises of a sloping bed and a horizontal bed. Whether the jump will take place on the sloping part or the horizontal part depends on the tailwater condition'. Do you agree with this statement? Justify your answer. 6
- (b) A rectangular channel is 1 m wide, and inclined at an angle of 3.5 degree with the horizontal. The channel carries a discharge of $0.15 \text{ m}^3/\text{s}$ at an initial depth of flow section (d_1) 0.02 m and the tailwater depth is 0.7 m. If a hydraulic jump occurs in this channel, compute the sequent depth. 12
- (c) Prove that for critical flow condition in a rectangular channel,
- $$E_c (\text{specific energy}) = 1.5 * y_c (\text{critical depth}) \quad 7$$
8. (a) A rectangular channel has a bottom width of 4.5 m. Construct the specific energy curve (use a graph paper) for $Q = 12 \text{ m}^3/\text{s}$ and determine the critical depth and minimum specific energy. 6
- (b) A rectangular channel 2.5 m wide carries $6 \text{ m}^3/\text{s}$ of flow at a depth of 0.5 m. Calculate the height of a flat topped hump required to be placed at a section to cause critical flow. The energy loss due to the obstruction by the hump is 0.1 times the upstream velocity head. 12
- (c) Using the 'Specific Energy' equation [$E = y + Q^2/(2gA^2)$], prove that critical flow condition corresponds to the condition for maximum discharge in a channel for a fixed specific energy. 7

$$1. A = bh ; P = b + 2h ; B = b$$

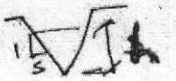


$$2. A = (b + sh)h ; P = ~~b~~ b + 2\sqrt{1+s^2}h$$



$$B = b + 2sh ;$$

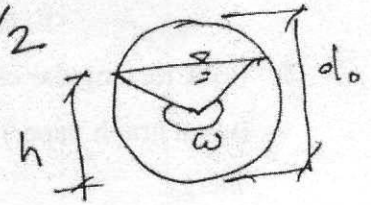
$$3. A = sh^2 ; P = (2\sqrt{1+s^2})h ; B = 2sh$$



$$4. h = d_o [1 - \cos(\frac{\omega}{2})] / 2$$

$$A = (\omega - \sin \omega) d_o^2 / 8$$

$$P = \omega d_o / 2$$



$$5. Q^2/g = \frac{A_c^3}{B_c} ; \frac{dQ}{g} = \frac{A_c^3}{B_c} \text{ (when } d \neq 1.0)$$

$$6. h_f = f \frac{L}{D} \frac{V^2}{2g} ; n = \frac{d_{50}^{1/6}}{21.1}$$

$$7. Re = \frac{VD}{\nu}$$

(d in meters)

$$8. C = \sqrt{89/f}$$

$$9. C = \frac{1}{n} R^{1/6}$$

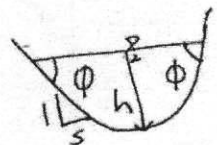
$$10. \tau_o = \gamma R S_o$$

$$11. u_* = \sqrt{\frac{\tau_o}{\rho}} = \sqrt{g R S_o}$$

$$12. S_{ov} = \frac{11.6 \nu}{u_*^2}$$

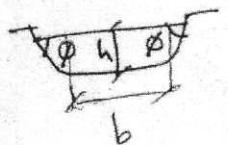
$$13. A = h^2 (\phi + \cot \phi)$$

$$P = 2h (\phi + \cot \phi)$$



$$14. A = bh + h^2 (\phi + \cot \phi)$$

$$P = b + 2h (\phi + \cot \phi)$$



15. Best Hydraulic Sections

	A	P	B	D
Rectangle	$2h^2$	$4h$	$2h$	h
Triangle	h^2	$2\sqrt{2}h$	$\frac{\sqrt{2}b}{2h}$	$h/2$
Trapezoid	$\sqrt{3}h^2$	$2\sqrt{3}h$	$4\sqrt{3}h/3$	$3h/4$
Circle	$\pi h^2/2$	πh	$2h$	$\pi h/4$

16. For a trapezoidal ~~section~~ best hydraulic section:

$$A = (2\sqrt{1+s^2} - s)h^2$$

$$b = 2(\sqrt{1+s^2} - s)h$$

$$P = 2h(\sqrt{1+s^2} * 2 - s)$$

17. Erodible channel:

$$\Rightarrow \tau_0 = \gamma R S_0$$

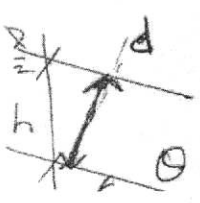
$$\Rightarrow K = \frac{\tau_s}{\tau_b} = \sqrt{1 - \frac{\sin^2 \phi}{\sin^2 \psi}}$$

where
 ψ = angle of repose
 ϕ = side slope angle.

\Rightarrow permissible shear stress = $0.4 d_{75}$
 (d_{75} in inches)

$$\Rightarrow \bar{S}_F = (S_{F1} + S_{F2})/2$$

$$\Rightarrow x_2 = x_1 + \frac{E_2 - E_1}{S_0 - \bar{S}_F}$$



18. $\frac{y_2}{y_1} = \frac{1}{2} (\sqrt{1 + 2G^2} - 1)$

19. $G^2 = K_1 Fr_1^2$ where $K_1 = 10$
 (θ is in deg) 0.027θ

21. $\frac{y_2}{y_1} = \frac{1}{2} (\sqrt{1 + 8Fr_1^2} - 1)$

or, $\frac{y_1}{y_2} = \frac{1}{2} (\sqrt{1 + 8Fr_2^2} - 1)$

Horizontal rectangular channel

22. $h_L = \frac{(y_2 - y_1)^3}{4y_1 y_2}$

23. $\frac{L_j}{y_1} = 9.75 (Fr_1 - 1)^{1.01}$

24. $\frac{E_2}{E_1} = \frac{(1 + 8Fr_1^2)^{3/2} - 4Fr_1^2 + 1}{8Fr_1^2 (2 + Fr_1^2)}$

25. $\frac{h_3 \text{ (submerged)}}{h_t \text{ (tailwater)}} = \left[1 + 2Fr_1^2 \left(1 - \frac{h_t}{h_g} \right) \right]^{1/2}$

26. $Fr^2 = \frac{Q^2 B}{g A^3}$

$Fr = 1$ (critical flow cond)

27. \bar{z} for different sections

Rectangle - $h/2$

triangle - $h/3$

trapezoid - $\frac{h}{6} \left(\frac{3b + 2sh}{b + sh} \right)$

28. Specific force $F = \frac{Q^2}{gA} + \bar{z}A$

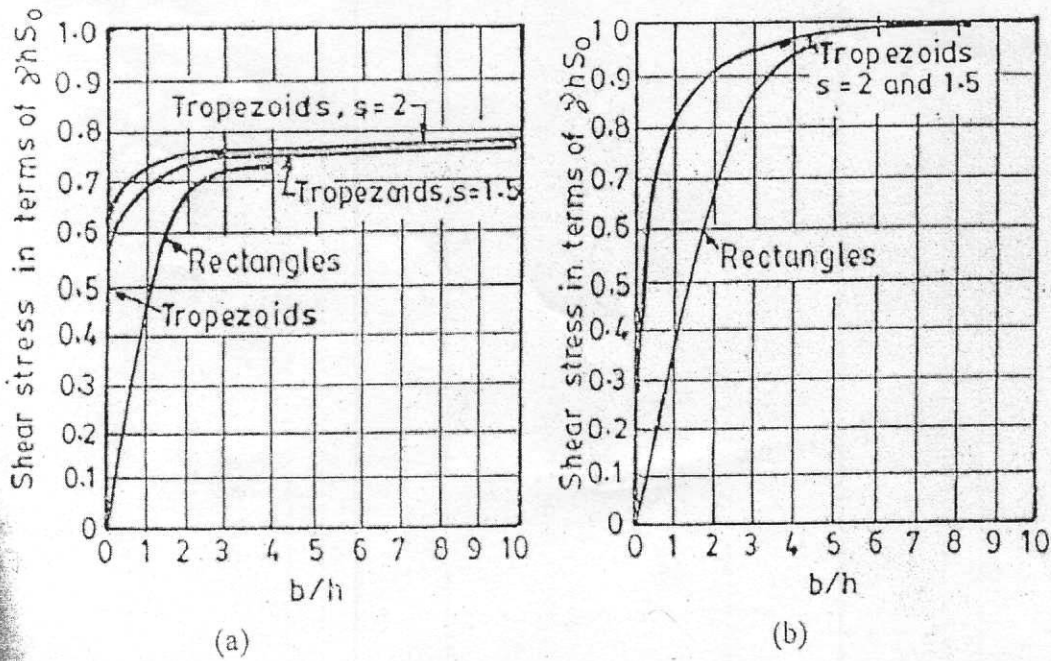
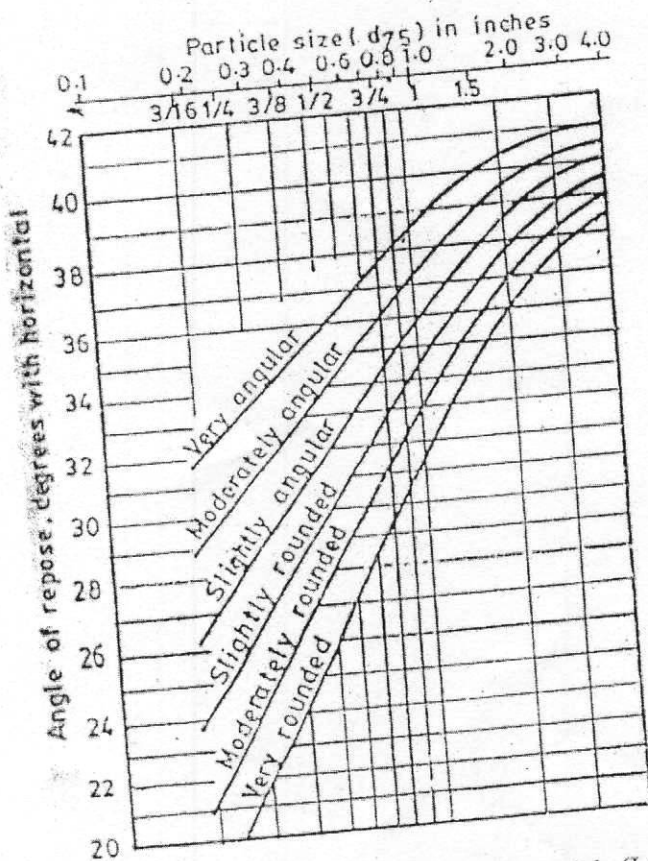


Fig. 5.4 Maximum shear stresses on (a) sides and (b) bottom of trapezoidal channels



5.6 Angle of repose of non-cohesive materials (Lane, 1955)