# M.E. (Water Resources & Hydraulic Engineering) Exam. 2024

(1st Semester)

## FREE SURFACE FLOW

(Paper - VI)

Time: Three Hours Full Marks: 100

Answer any ***five*** questions.

1. (a) The velocity distribution in a wide rectangular channel may be approximated by the equation $u = 0.4 + 0.6\, y/h$ *m/s*. Find U, α and β if $h = 1.0$ m.

(b) The following pressures were measured on a wall. Find the force per unit length of the wall, pressure coefficient at the base of the wall and force in excess of the hydrostatic value.

| Distance below free surface, mm | Pressure of water, mm |
|---|---|
| 0 | 0 |
| 50 | 51 |
| 100 | 104 |
| 150 | 159 |
| 200 | 216 |
| 250 (Base of Wall) | 275 |

(c) State whether the following flows are steady or unsteady and uniform or non-uniform:

i. River flow around a bridge pier.
ii. Flow in a long, prismatic irrigation canal.
iii. Movement of water around a boat in a lake.

8+9+3 = 20

2. (a) Design a canal to carry 41.50 $m^3/s$ of clear water through 3.0 mm gravel (angle of repose = 31°) on a slope of $10^{-4}$. The canal is to be trapezoidal in shape having side slopes of 2H : 1V. The average temperature = 20°C ($\nu = 10^{-6}$ $m^2/s$, permissible bed shear stress = 1.97 $N/m^2$)

(b) Show that a hydraulically efficient triangular channel section has $R_e = \frac{y_e}{2\sqrt{2}}$

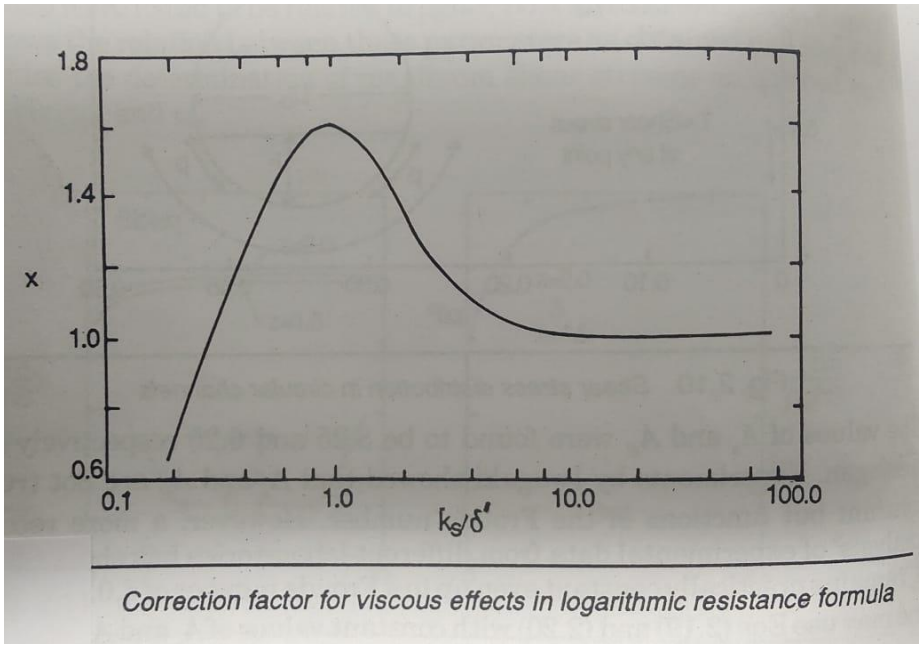
(c) A channel has multiple roughness types in its perimeter. Assuming that the total discharge in the channel is equal to the sum of discharges in the partial areas, show that the equivalent roughness is given by

$$n = \frac{PR^{5/3}}{\sum_1^N \left( \frac{P_i R_i^{5/3}}{n_i} \right)}$$

10+2+8=20

3. (a) A trapezoidal channel has a bottom width of 2.50 m and a depth of flow 0.80 m. The side slopes are 1.5 H: 1 V. The channel is lined with bricks ($k_s$ = 3 mm). If the longitudinal slope of the channel is 0.0003, estimate (i) the average shear stress (ii) the hydrodynamic nature of the surface, (iii) Chezy constant using f (iv)Manning's constant. The average temperature = 20°C ($\nu = 10^{-6}$ m$^2$/s).

(b) What should be the bottom width of a trapezoidal canal (side slope 2 H: 1 V) having uniform slope of $1x10^{-3}$ if it is to carry 60 m³/s at a depth of 2.5 m? Find the maximum shear stresses on the bed and sides of this channel n =0.015. 12+8=20



Correction factor for viscous effects in logarithmic resistance formula

4) Define open channel flow/free surface flow and distinguish between open channel flow and pipe flow.

b) A rectangular channel 6 m wide with a depth of flow of 3 m has a mean velocity of 1.5 m/s. The channel undergoes a smooth, gradual contraction to a width of 4.5 m.

i. Calculate the depth and velocity in the contracted section.

ii. Calculate the net fluid force on the walls and floor of the contraction in the flow direction.

In each case identify any assumption that you make.

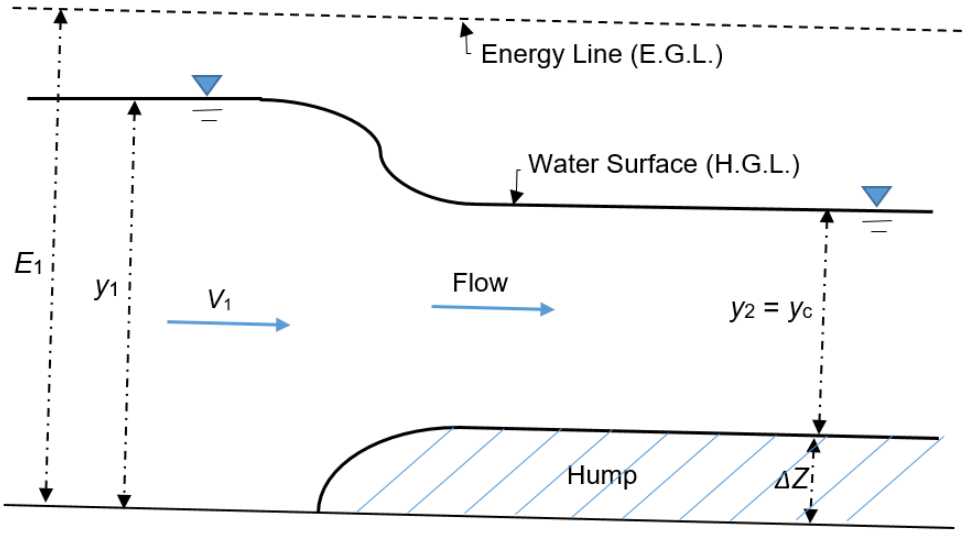
4+16 = 20

5.a) What do you mean by (Choked condition) "Chocking" in case of free surface flow?

b) With the help of a specific energy curve only show the condition of choking for a free surface flow over a hump.

c) A 2.25 m wide rectangular channel has a flow with a velocity of 1.4 m/s and a depth of 1.3 m. A small hump is to be built at a section to create critical flow conditions over the hump.

Calculate i) the minimum height of the hump required to achieve this and ii) the resulting change in the water surface elevation.




3+6+11 = 20

6.a) Show that for a wide rectangular channel the slope is mild or steep according to $S_0$ being less than or greater than $\frac{n^2 g^{10/9}}{q^{2/9}}$.

b) Find out the basic equation to calculate the water surface elevation in case of gradually varied flow using the Standard Step Method.

8+12 = 20

7.a) Find out the GVF differential equation by direct integration method.

b) In a very long, wide rectangular channel the discharge intensity is 3.2 $m^3$/s/meter width. The bed slope of the channel is 0.004 and Manning's $n$ = 0.014. At a certain section in this channel, the depth of flow is observed to be 0.90 m. What type of GVF profile occurs in the neighbourhood of this section?

c) In a wide river the depth of flow at a section is 3 m, $S_0$ = 2 in 10000 and $q$ = 3.5 $m^3$/s/meter width. If the Chezy formula with C = 70 is used, then what will be the water surface slope relative to the bed at the section?

10+5+5 = 20

8. a) Establish that the GVF profile in a frictionless rectangular channel is given by

$$x = \frac{y}{S_0}\left[1 + \frac{1}{2}\left(\frac{y_c}{y}\right)^3\right] + \text{Constant}$$

b) Prove that the GVF profile for a horizontal channel can be expressed as

$$x = \left[-\frac{C_2}{Q^2(N+1)}y^{N+1} + \frac{C_2 y^{N-M+1}}{gC_1(N-M+1)}\right] + \text{Constant}$$

9+11 = 20

9. a) Establish a relationship between the depths of flow upstream and downstream of hydraulic jump in terms of upstream Froude number ($F_1$) in the case of a horizontal rectangular channel.

b) A spillway discharges a flood flow at a rate of 7.95 $m^3$/s per metre width. At the upstream horizontal apron, the depth of flow was found to be 0.52 m. What tailwater depth is needed to form a hydraulic jump? If a jump is formed, find its (a) type of jump (b) head loss (c) energy loss as a percentage of the initial energy.

c) In a hydraulic jump taking place in a horizontal apron below an Ogee shaped weir the discharge per unit width is 2.5 $m^3$/s/m and the energy loss is 2.75 m. Estimate the depths at the toe and heel of the jump

8+4.5+7.5 = 20