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MADE EASY CIVIL ENGINEERING Open Channal Flow BY-Badal Sony Sir

- Theory
- Explanation
- Derivation
- Example
- Shortcuts
- Previous Years Question With Solution

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Gate: 2-4 marks.

ESE: OBJ → 5-6 Q

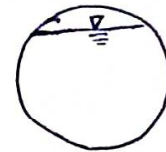
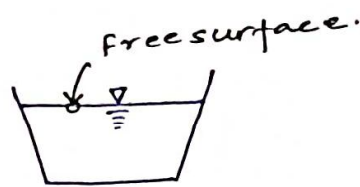
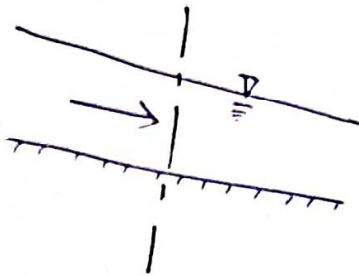
CONV → 50-60 marks

1. Introduction:
2. Uniform Flow
3. Energy Depth Relationship.
4. Gradually varied flow.
5. Rapidly varied flow → Hydraulic Jump
6. Surges

Introduction:

→ Open channel flow refers to the flow of liquid in channel open to atmosphere or in a partially filled conduit.

→ It is characterized by the presence of liquid-gas interface called free surface.



partially filled conduit.

NOTE: • The driving force in an open channel flow is gravity.
• Shear stress on the free surface is zero.

Types of channels:

(i) Prismatic and Non-prismatic channel:

If cross-section, shape, size, bed slope remains constant in the direction of flow then the channel is called prismatic otherwise non-prismatic.

(ii) Rigid and Mobile Boundary channel:

A. Rigid Boundary channel: Only depth varies with space and time.

Boundaries not deformable.

→ Shape and roughness parameter are not function of flow.

eg: lined canal and sewer.

b. Mobile Boundary channel:

→ In this case the depth, width, bed slope as well as layout are functions of space and time.

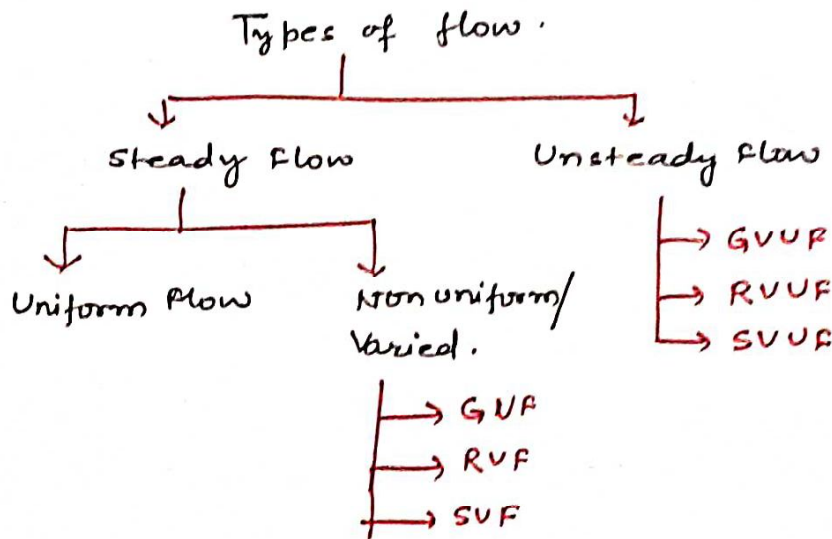
eg: Unlined canals.

NOTE: The rigid boundary channel has one degree of freedom while mobile boundary has four degrees of freedom.

We will study only rigid boundary channels.

Rigid Boundary ~~→~~ Prismatic
Prismatic → Rigid Boundary.

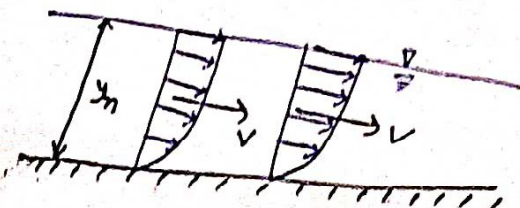
Types of flow:



Uniform flow:

→ Flow is called steady uniform if the depth of flow does not vary in space.

→ The underlined assumption that is that the velocity also does not vary which means that the cross-section parameter, roughness parameter, slope parameter are not varying.

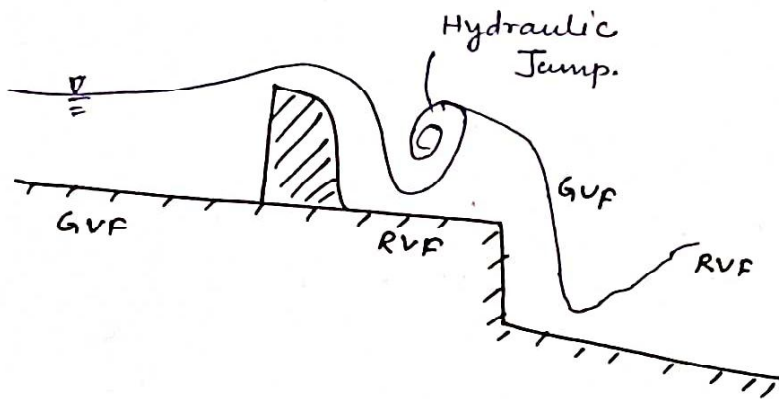


y_n = depth of flow.

V = Avg. velocity of flow.

- In uniform flow the energy gained due to elevation fall is lost due to flow i.e. frictional losses.
- In prismatic channel, constant depth flow means uniform flow and the depth of flow is called normal depth of flow. (y_n)

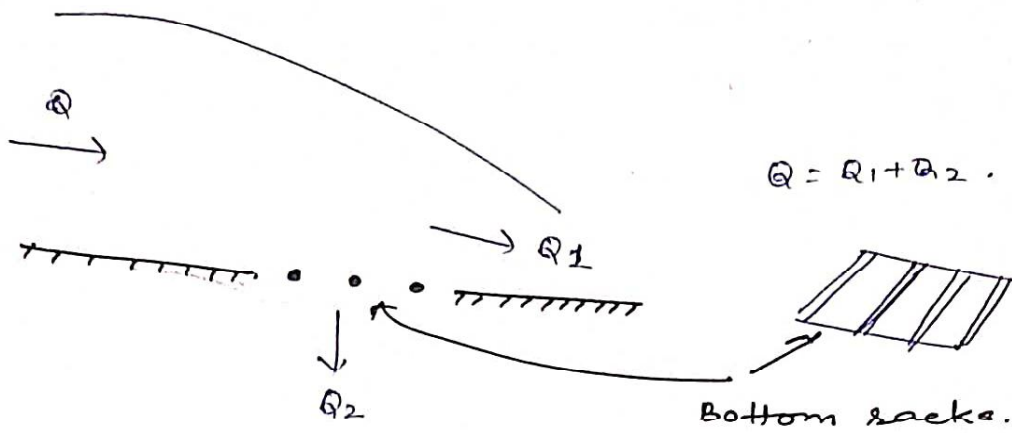
2. Non-uniform / Varied flow:



- Presence of obstruction in channel such as weir, dropping bed, change in slope or cross-section causes the flow to vary, this flow is called non-uniform flow or varied flow.
- Flow is called gradually varied if the depth changes gradually over a long distance of channel.
- Curvature of streamline is gentle in this case.
- If the depth of flow changes significantly over a short distance such that the curvature changes rapidly, the flow is called rapidly varied flow.
eg: Hydraulic Jump.

NOTE: Friction plays an important role but in GVF but not important case of RVF.

If some flow is added or extracted from the system, the flow is called spatially varied flow.
eg: flow over bottom rack.



Unsteady flow:

a. Gradually varied Unsteady flow:

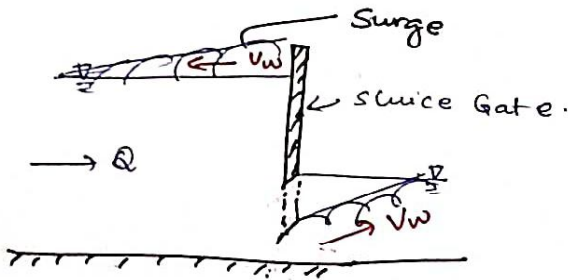
eg: Passage of flood wave in river.

b. Rapidly varied unsteady flow:

eg: surges, tidal bores, breaking of waves on shore.

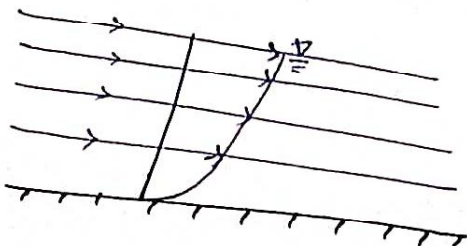
c. Spatially varied Unsteady flow:

eg: surface runoff due to rain fall.



Laminar Flow and Turbulent Flow:

→ when the flow occurs such that one layer of the liquid slides past the other as if one lamina is sliding over the other, the flow is called Laminar flow, where there would be no momentum transfer between different layers.



→ However if water from one layer goes into the other and vice-versa, there could be momentum transfer between different layers such a flow is called turbulent flow.

$$Re = \frac{VR}{\nu}$$

Re = Reynold's number. (dimensionless)

V = Avg. velocity.

R = Hydraulic Radius.

$$= \frac{A}{P}$$

A = Area of x-section.

P = Wetted Perimeter.

ν = Kinematic viscosity. (m^2/s)

$\nu = \frac{\mu}{\rho}$ μ = Dynamic viscosity. (Pa-s)

if $Re < 500$ Laminar flow.

$500 < Re < 2000$ Transition flow.

$Re > 2000$ Turbulent flow.

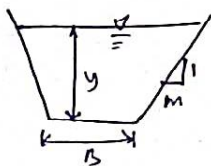
Critical / Subcritical / Super-critical flow:

$$Fr = \frac{V}{\sqrt{gA/T}}$$

Fr = Froude's no. (Dimensionless)

A = Area of x-section.

T = Top width.



$$T = B + 2my$$

$$A = By + my^2$$

Critical

$$Fr = 1$$

$$V = V_c$$

$$y = y_c$$

Subcritical

$$Fr < 1$$

$$V < V_c$$

$$y > y_c$$

Super-critical

$$Fr > 1$$

$$V > V_c$$

$$y < y_c$$

$$V_c = \text{critical velocity} = \sqrt{gA/T}$$

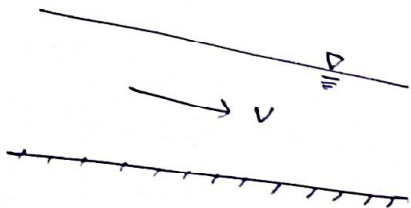
y_c = critical depth.

Celerity (C_0):

Denominator of Froude's no. represents a speed with which disturbance created to flow travels in still water, is called Celerity (C_0).

$$C_0 = \sqrt{gA/T} = \sqrt{g L_c}$$

L_c = characteristic length.



$$\left(V_{\text{wave/ground}} \right)_{\text{u/s}} = \left(V_{\text{wave/water}} \right)_{\text{u/s}} + \left(V_{\text{water/ground}} \right)_{\text{u/s}}$$

$$\left(V_{\text{wave/ground}} \right)_{\text{u/s}} = C_0 - V$$

For subcritical flow.

~~For super-critical:~~

$$Fr < 1$$

$$\frac{V}{C_0} < 1$$

$$C_0 - V > 0$$

d/s control.

→ At low flow velocity ($Fr < 1$) a small disturbance to the flow will cause disturbance wave which travels ~~to~~ u/s with the velocity ~~base~~ $C_0 - V$ wrt a stationary observer.

→ Due to upstream movement of water, upstream condⁿ gets affected. Thus in case sub-critical flow condition upstream is affected by the condⁿ at downstream. and the down stream section is taken as control section.

For super-critical flow:

$$Fr > 1$$

$$\frac{V}{C_0} > 1$$

$$C_0 - V < 0$$

ups control.

At high flow velocity $Fr > 1$, the upstream flow velocity of wave $(C_0 - V)$ will become negative i.e. the disturbance wave will not travel upstream, it will travel downstream with a velocity of $(V - C_0)$

Hence, flow condⁿ downstream will be affected and super-critical flow has upstream control.

NOTE: Sub-critical flow has downstream control while super-critical flow has upstream control.

When $Fr = 1$, flow is critical and the disturbance velocity $C_0 - V = 0$ i.e. disturbance wave will not travel at all.

Q: A wide sect. channel is 1m deep and has a velocity of flow $V = 2.13$ m/s. If the disturbance is caused and elementary wave can travel upstream with a velocity of

a) 1 m/s

b) 3.13 m/s

c) 2.13 m/s

d) 5.26 m/s.

$$C_0 = \sqrt{gA/T} = \sqrt{g \times \frac{By}{B}}$$

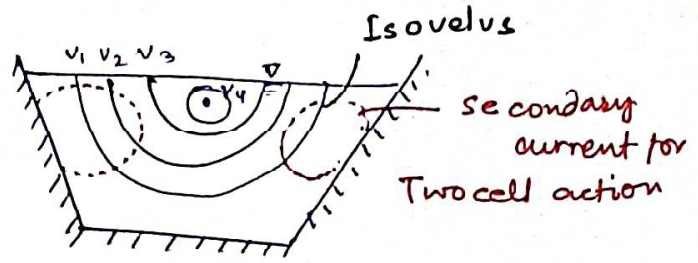
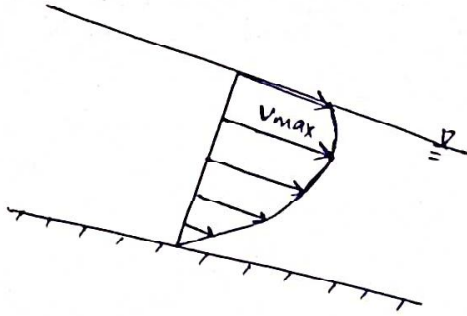
$$= \sqrt{g \cdot y}$$

$$C_0 = \sqrt{9.81}$$

$$3.13 \text{ m/s.}$$

$$(V_{\text{wave/ground}}) = C_0 - V = 3.13 - 2.13 = 1 \text{ m/s}$$

Velocity Distribution:



$$v_4 > v_3 > v_2 > v_1$$

Isovels: contours of equal velocity

$$\text{Aspect Ratio} = \frac{\text{Depth}}{\text{width}}$$

Reduction or dip in the velocity is because of secondary current which is a function of aspect ratio.

If aspect ratio is large, depth at which max velocity occurs is deeper.

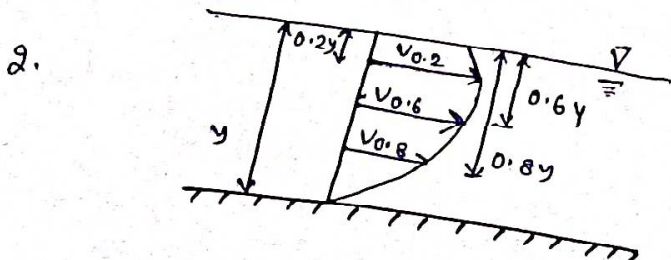
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Average Velocity

$$1. \quad V_{avg} = \frac{\int v \, dA}{A}$$

V = Average velocity.

v = Actual velocity.



$$V_{avg} = \frac{v_{0.2} + v_{0.8}}{2}$$

OR

$$V_{avg} = v_{0.6} \quad (\text{less reliable})$$