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IES MASTER

Civil Engineering

Toppers Handwritten Notes

Open Channel Flow

BY- KANCHAN SIR

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

Open channel flow

obj (1) Introduction

obj + conv (2) Uniform flow

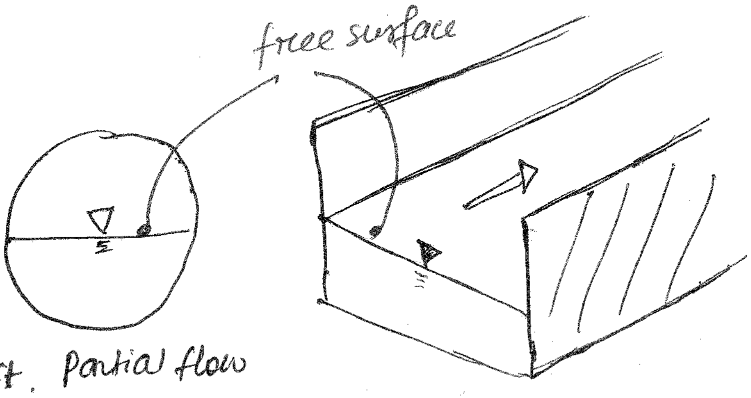
(3) Energy depth relationship → obj + $\overset{**}{\text{conv}}$

(4) Gradually Varied flow → $\overset{**}{\text{obj}}$ + conv

(5) Rapidly Varied flow (Hydraulic flow) → obj + conv

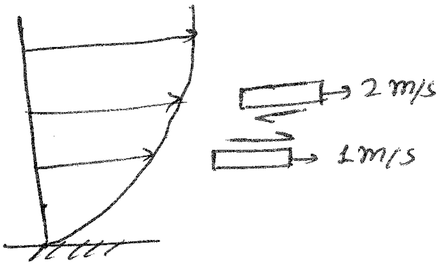
(6) Surges → $\overset{**}{\text{obj}}$ + conv

① Introduction



- Open channel flow (OCF) refers ~~of~~ to flow of liquid in channel open to atmosphere or in a partially filled closed conduit. Partial flow

- open channel is characterised by a liquid-gas interface called free surface.



obj
- Free surface will have no shear stress on it.

obj
- In case of open channel flow, the driving force for the flow is Gravity.

loss of PE = gain in K.E

in pipe → differencein pressure is driving force

- Close conduit flow will always be pressure flow → False.

flow तभी occur करेगा जब fluids के बीच relative motion है ~~नहीं~~

Classification of channels

channel

(A) Prismatic and Non prismatic channel

(B) Rigid Boundary & Mobile Boundary channel.

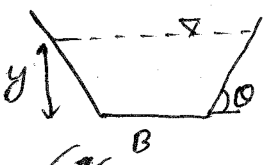
- A channel in which cross sectional shape$^{\square}$, size^{L,B} and bed slope are constant throughout the channel length is termed as Prismatic

Exp → Man made channel

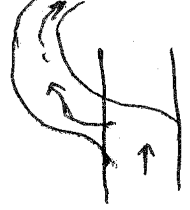
- Natural channels are non prismatic.

$\tan\theta = S_0 =$ bed slope

- If the boundary of channel are non deformable like lined canal or non erodible unlined canal then the channel is called rigid boundary channel. In this case the roughness and geometry is constant w.r.to time and does not very ~~w.r.to~~ with ~~tim~~ discharge.
- In rigid boundary channel only depth of flow varies with discharge hence it is said to have single degree of freedom.
- In case of mobile boundary channel, depth, width, slope (side slope, bedslope) and layout can change [4 DOF].



- In our course will study only Prismatic Rigid boundary channel.



Layout

Prismatic and Q → constant (assume always in our course

Type of Flow

Type of Flow

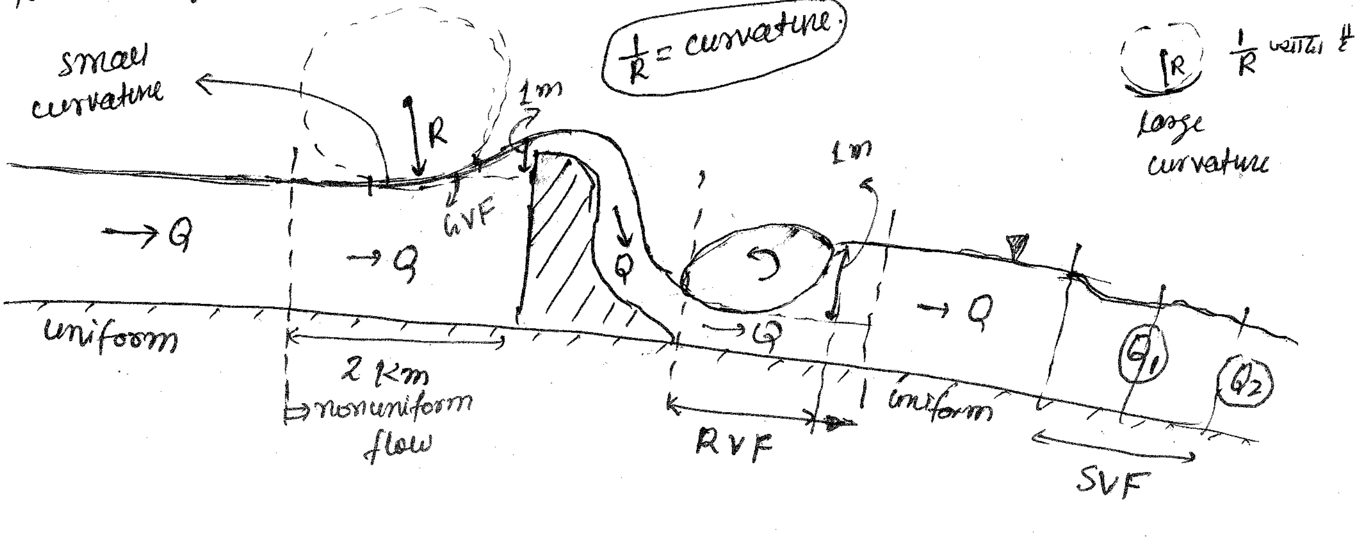
- (A) Steady Flow
  - (1) uniform flow ✓
  - (2) Gradually varied flow (GVF) ✓
  - (3) Rapidly varied flow (RVF) ✓
  - (4) Spatially varied flow (SVF)
- (B) unsteady flow
  - → unsteady uniform ✗ not possible Practically
  - → GVUF
  - → RVUF
  - → SVUF

varied flow

Steady → location fixed और अलग-2 time

uniform → fixed time (instant time)

$\frac{1}{R}$ = curvature.



Ⓐ Steady and Unsteady Flow :⇒

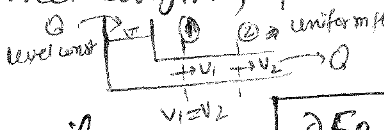
- Steady flow occurs when the flow parameter such as depth & discharge do not change with time.

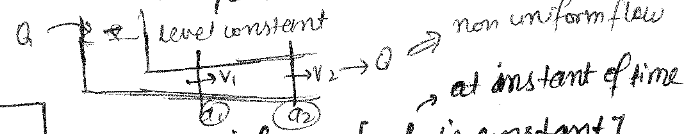
Flow parameter → depth, discharge
Fluid parameter → density, viscosity

$$\boxed{\frac{\partial F_P}{\partial t} = 0} \rightarrow \text{for steady flow}, \quad \underset{\text{flow property}}{F_P} = f(x, t)$$

- If $\boxed{\frac{\partial F_P}{\partial t} \neq 0}$; flow will be unsteady
- steadyness and unsteadyness are not absolute property. They depend on the frame of reference also.

Uniform & Non uniform flow :⇒ • If the flow parameter such as depth and discharge remains constant ~~do~~ along the channel length, flow is called uniform otherwise nonuniform.





$\boxed{\frac{\partial F_P}{\partial x} = 0}$; uniform $\boxed{\frac{\partial F_P}{\partial x} \neq 0}$; non uniform [t is constant] → at instant of time
(varied flow)

- Normally prismatic rigid boundary channel with constant discharge will have uniform flow if the flow is unobstructed.
- we can have uniform flow setup only when if we have sufficient length of unobstructed flow.

(bcz पूरे Length पे same depth का change होना at instant of time पे possible नहीं है)

- Unsteady uniform flow is ~~so~~ practically not possible hence uniform flow practically means steady uniform flow.

uniform flow का अपने आप ही मतलब है steady क्योंकि कभी भी unsteady uniform flow नहीं होता

$$\boxed{\frac{dF_P}{dt} = 0} = \overset{0 \text{ for steady}}{\cancel{\frac{\partial F_P}{\partial t}}} \cdot \frac{dt}{dt} + \overset{0 \text{ for uniform}}{\cancel{\frac{\partial F_P}{\partial x}}} \cdot \frac{dx}{dt}$$

(for ↳ steady-uniform)

$\frac{\partial F_P}{\partial x} = 0$ → possible

$\frac{\partial V}{\partial t} = 0$, $\frac{\partial V}{\partial x} = 0$ ⇒ For steady uniform

Properties of uniform flow

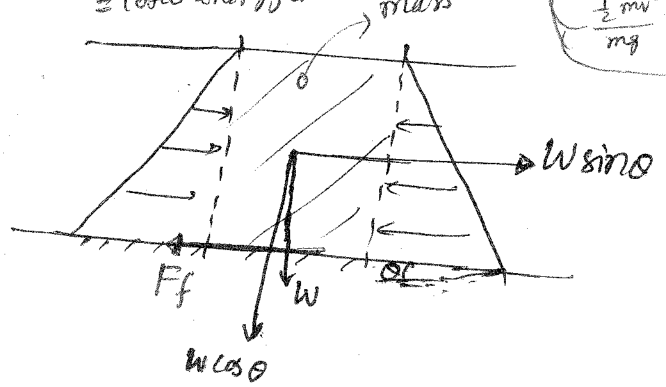
~~In~~ y, V → constant

- Uniform flow, weight component in the dirⁿ of flow is exactly balanced by frictional force. (Bed slope = water surface slope = Total energy line slope)

$\frac{mgh}{mg} = h$

$\frac{\frac{1}{2}mv^2}{mg} = \frac{V^2}{2g}$

$$\boxed{F_f = W\sin\theta}$$

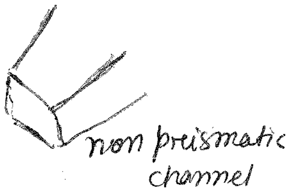


अगर every instant पे depth change होगा → मतलब unsteady flow

- depth of flow under uniform flow condition is called Normal depth of flow
- Total Head = H = $\frac{\text{energy (Power)}}{\text{wt. of fluid}}$

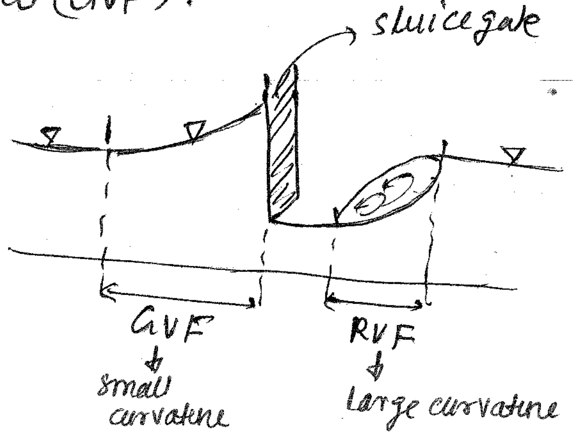
Varied flow → depth of flow, Velocity of flow is not same along the length of channel.

Gradually Varied flow :⇒ • Flow in mobile boundary, non prismatic channel and in flow with varying discharge / velocity will be a varied flow.

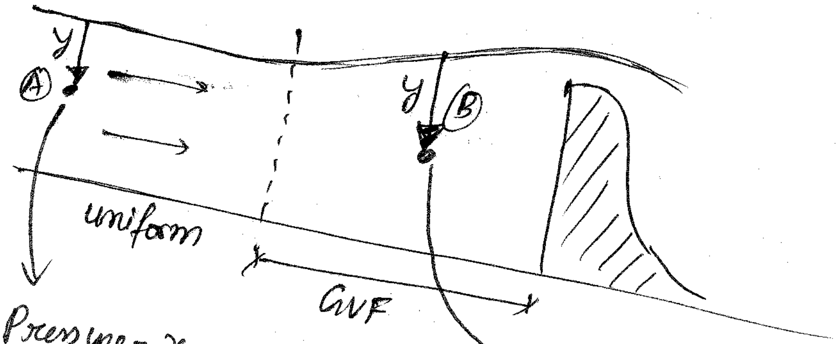


- Varied flow is called non uniform flow.
- Steady non uniform flow can be GVF, RVF and SVF.
- If depth of flow changes gradually over a long distance along the channel length such that the curvature of free surface is small then the flow is called gradually varied flow (GVF).

Exp of GVF → Flow upstream of a weir or sluice gate



- * In GVF, loss of energy is mainly due to boundary friction [generally eddy loss is neglected]
- ** In case of GVF, pressure distribution across the depth is hydrostatic.
- If the depth of flow varies rapidly along the channel length then the flow is called RVF i.e. rapidly varied flow.



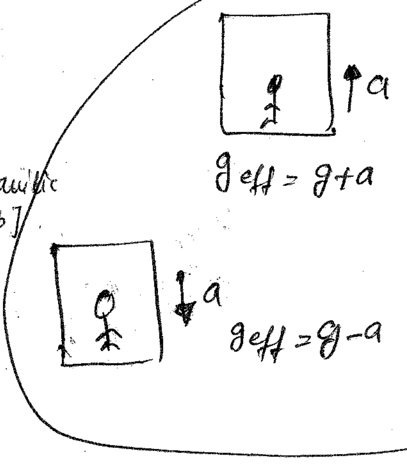
Pressure = $\gamma_w y = \rho_w \cdot g \cdot y$

Hydrostatic stress

$P_B \cong \rho_w g y$. ($\frac{1}{R}$ कारण होता है)

- In this case free surface will have large curvature [for RVF].

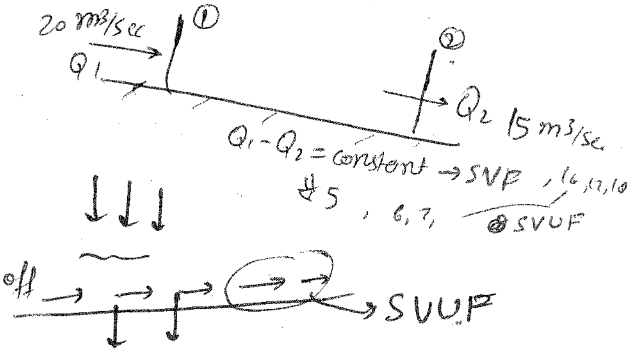
Exp of RVF → • It generally occurs at the downstream of weir or spillway or sluice gate. [i.e Hydraulic jump].

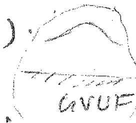


- ** Since the RVF stretch is small, frictional resistance are insignificant.
- The flow is also assume no flow is externally added to or taken out of channel [in GVF also]

- If some flow is added or extracted from the system along the channel length the flow is called <u>spatially varied flow (SVF)</u>.
- SVF can be steady or unsteady.
- Uniform extraction of flow along the channel length like flow over side weir can be called SVF.
- Flow over the bottom rack is SVF.
- surface runoff due to rainfall is SVUF

(Spatially varied unsteady flow)



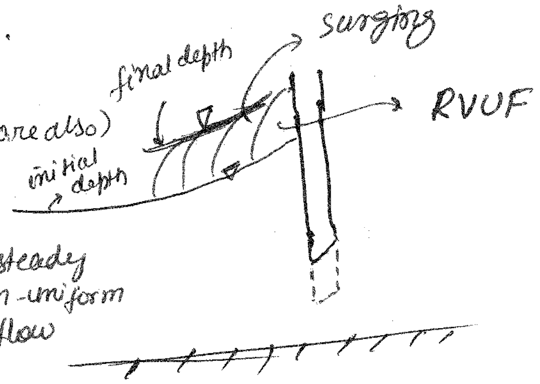


infilmation rate varying with time.

GVUF → passage of flood way in a river when the river bank are not breached is GVUF

If river bank are breached then SVUF.

RVUF → Surges are example of RVUF (Bare also)



GVUF → gradually varied unsteady flow
RVUF → Rapidly varied unsteady flow
SVUF → spatially varied unsteady flow.

} unsteady non-uniform flow

eg Breaking of wave on the sea shore

Laminar and Turbulent Flow

- When flow is occuring in such a way that one layer of fluid slightly passed the other layer without their being any intermixing b/w different layers, the flow is said to be laminar.
- If how ever their is intermixing b/w diff. layers, flow is said to be turbulent.

$$Re = \frac{F_I}{F_V} = \frac{\rho V^2 L^2}{\mu V L}$$

viscous force

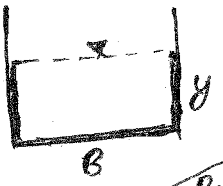
$$\boxed{Re = \text{Reynold number} = \frac{VR}{\nu} = \frac{\rho VR}{\mu}}$$

V = avg velocity of flow

$$\boxed{R = \text{Hydraulic radius} = \frac{\text{area of flow}}{\text{wetted perimeter}}}$$

μ = dynamic viscosity

ν = kinematic viscosity



Hydrallic radius (R) $= \frac{B \cdot y}{B+2y}$

obj In open channel flow, flow will be laminar if $Re < 500$ and turbulent if $Re > 2000$. in b/w cases will be Transitional ($500 < Re < 2000$)

- OCF will generally be generally turbulent (i.e $Re > 2000$).

Critical, sub critical and super-critical flow

$$\text{Froud No} = \sqrt{\frac{\text{Inertial force}}{\text{gravity force}}} = \sqrt{\frac{\rho L^3 \cdot \frac{L}{T^2}}{\rho L^3 \cdot g}} = \sqrt{\frac{\rho L^2 V^2}{\rho L^3 g}} = \frac{\overset{\text{avg velocity}}{V}}{\sqrt{g L}} = \text{Froud No.}$$

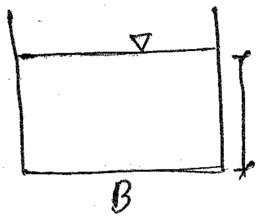
- In OCF, flow is under gravity therefore gravity force plays imp. role. Hence Froud no is more imp than reynold no.

L → Characteristic Length

↓ In OCF

Hydraulic Depth

$= \frac{\text{area}}{\text{Top surface width}}$



$A = B \cdot y$

T = Top surface width = B

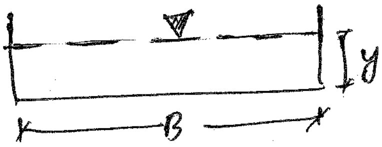
$$\boxed{\frac{A \xrightarrow{} B\cdot y}{T} = \text{hydraulic depth} = y}$$

In Rectangular channel

$$\boxed{Fr = \frac{V}{\sqrt{g y}}}$$

→ in general channel $\boxed{Fr = \frac{V}{\sqrt{g \cdot \frac{A}{T}}}}$

For wide rectangular channel



$R = \text{Hydraulic radius} = \frac{By}{B+2y}$

$y << B$

$R \simeq \frac{B \cdot y}{B} = y \Rightarrow \boxed{R = y}$

*** Note: In wide rectangular channel, hydraulic radius is taken as depth of flow = y

$Co = \text{celerity} = \sqrt{g \cdot \frac{A}{T}}$

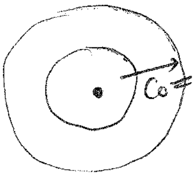
↓ संचरण wave की velocity है

$$\boxed{Fr = \frac{V}{\sqrt{g \cdot \frac{A}{T}}} = \frac{V}{Co}}$$ $\boxed{Co = \text{celerity}}$

- Celerity (Co) is the speed of ~~dis~~ small disturbance wave w.r.to water.

disturbance wave → पानी में जो ripple आते है

✓ $\boxed{Co = m/s}$



Co = velocity of disturbance wave w.r.to still water (in pond)