# MADE EASY

## CIVIL ENGINEERING

### OPEN CHANNAL FLOW

### BY- RAM SIR

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

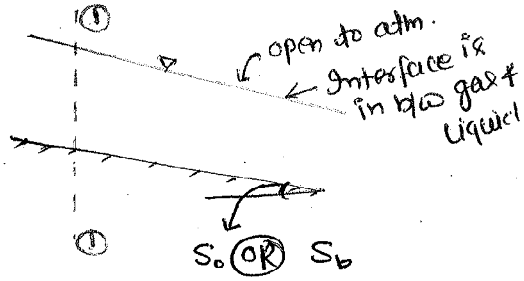
## Syllabus

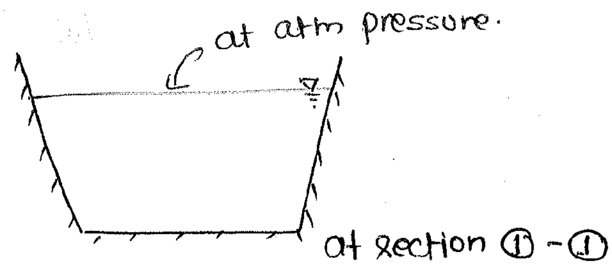
1. Introduction
2. Uniform flow
3. Energy - depth relation.
4. Gradually varried flow
5. Rapid varried flow
6. Surges. (Only ESE)

# OPEN CHANNEL FLOW

## Introduction

- Open channel flow means a flow through channel that is open to atmosphere & have a free surface.



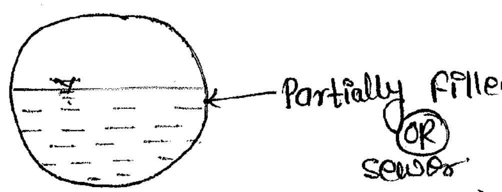




* Driving force in open channel is gravity.

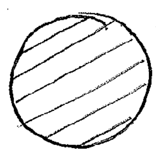
- Flow takes place from higher elevation to lower elevation.

* Shear stress on the surface is zero.

NOTE: flow through open channel partially filled ~~or~~ sewer & himp pipe takes place than top surface is at atm. pressure hence it is reffered as open channel flow.



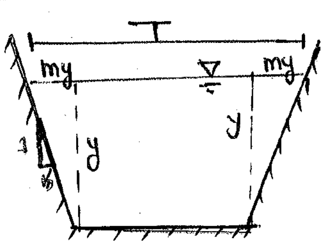

**Pipe flow :-** Liquid flows under pressure through any conduit without having a free surface.



Pressure > Atm. pressure.

Pipe flow

## Important Geometric Parameters of the open channel :-




1. Base width (B)
2. Top width (T)
3. Wetted Area (A) → perpendicular c/s. Area
4. Wetted perimeter (P) → Perimeter of section which becomes wet.

$T = B + 2my$

$A = \frac{1}{2} \times my \cdot y + B \cdot y + \frac{1}{2} m \cdot y^2$

$= By + my^2 = y(B + my)$

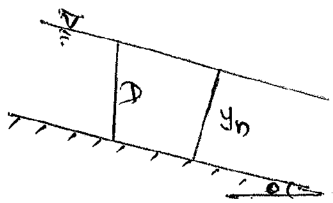
$P = B + 2y\sqrt{1+m^2}$

⑤ Hydraulic Radius (R) = $\frac{A}{P}$ = $\frac{\text{Wetted Area}}{\text{Wetted perimeter}}$ $R = \frac{A}{P}$

⑥ Hydraulic depth (D) = $\frac{A}{T}$ = $\frac{\text{Wetted Area}}{\text{Top width}}$ $D = \frac{A}{T}$

⑦ Normal depth of flow section ($Y_n$/y) Normal to channel flow.

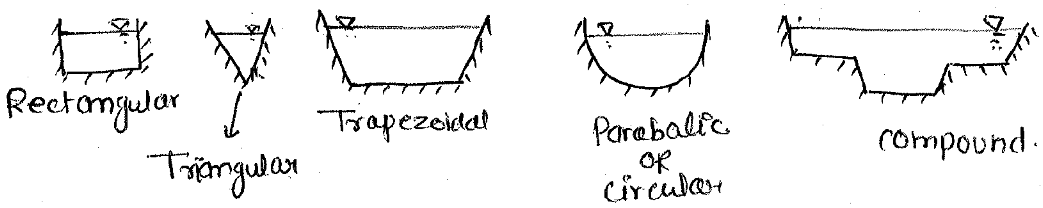
⑧ Depth of flow (d) vertical depth of flow.



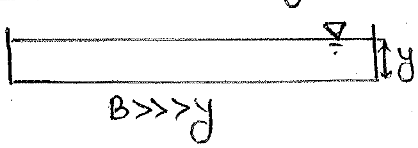

Classification of open channel based upon their characteristic :-

① Shape
② Natural OR artificial
③ Prizmatic OR Non prizmatic
④ Based upon boundary characteristics.

① Based upon shape :-



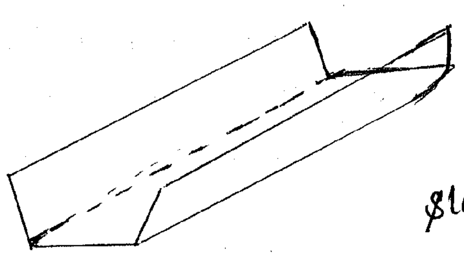

NOTE: Wide rectangular channel.




$$\left\{R = \frac{A}{P} = \frac{By}{B+2y} = y\right\} = \{B\}$$

$$B + 2y \simeq B$$

Prismatic channel :- If slope & cross section (size & shape) do not change with the length of channel then it is called prismatic channel.



slope & c/s. of channel same.

**Non-prismatic channel :-** Slope & c/s changes with length of channel.

Classification based upon boundary characteristics —

① Rigid boundary channel :- Boundary are not deformable (NO scouring OR errosion takes place). One degree freedom is there. (only depth of flow section

② Mobile boundary channel :- Boundaries can deform, depth, facewidth, slope, bed layout of channel, plan view changes. 4 degree freedom.

**Ex:** unlined channel or river.

Classification as per flow characteristics :-

① Variation of flow parameter with time ② variation of flow parameter with space.

③ Base upon turbulance

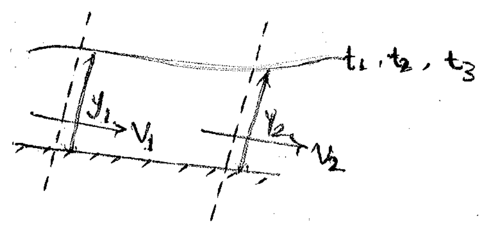
④ Based upon critical flow.

⑤ Based upon direction of flow (1-D, 2-D OR 3-D).

**Classification of flow with time :-**

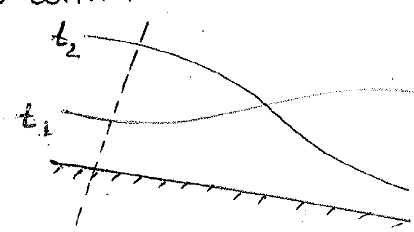
ⓐ **Steady flow :-** Flow parameter at a section do not vary with time.

$$\frac{dy}{dt} = 0, \quad \frac{dv}{dt} = 0, \quad \frac{dQ}{dt} = 0$$




ⓑ **Unsteady flow :-** Flow parameter at a section varies with time.

$$\frac{dy}{dt} \neq 0, \quad \frac{dv}{dt} \neq, \quad \frac{dQ}{dt} \neq 0$$

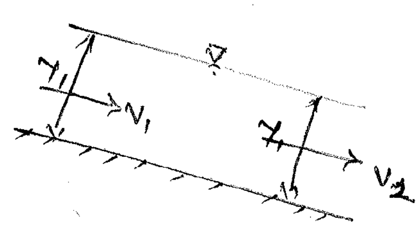



② Classification based upon variation of flow parameter with space —

ⓐ Uniform flow :- Flow parameter in a channel reach donot varies with space at any instant of time.

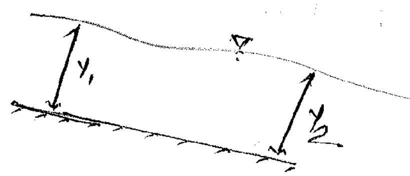
⇒ It is possible in prismatic section.

$$\frac{dy}{dx} = 0, \quad \frac{dv}{dx} = 0, \quad \frac{dQ}{dx} = 0$$



## Non-uniform flow / Varied Flow :- Flow parameter in a channel varies with space.

$$\frac{dy}{dx} \neq 0, \quad \frac{dv}{dx} \neq 0, \quad \frac{dQ}{dx} \neq 0$$




**FLOW**

- Steady Flow
  - Uniform Flow
  - Varied Flow
    - ② Gradual V.F.
    - ③ Rapid V.F.
    - ④ Spaced V.F
- Unsteady Flow
  - ⑤ ~~Uniform~~ Flow
  - Varied Flow
    - ⑥ Gradual V.U.F.
    - ⑦ Rapid V.U.F.
    - ⑧ Spaced V.U.F.

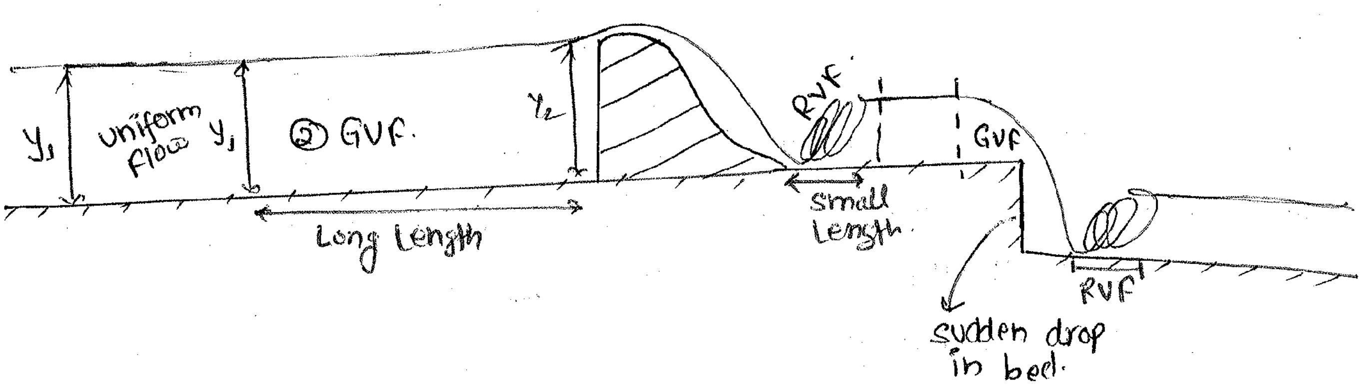
#① Steady uniform flow :- Flow parameters are same with time & space

$$\frac{dy}{dt} = 0, \quad \frac{dv}{dt} = 0, \quad \frac{dQ}{dt} = 0, \quad \frac{dy}{dx} = 0, \quad \frac{dv}{dx} = 0, \quad \frac{dQ}{dx} = 0$$

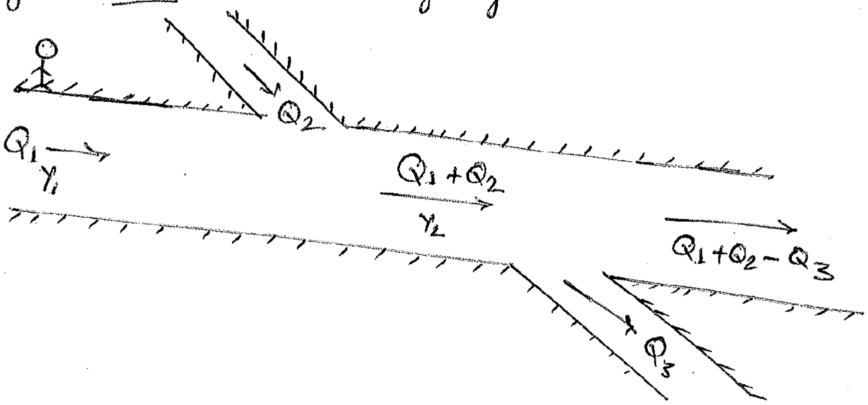
② Gradually varied flow :- If depth of flow varies gradually over a long length of channel (in K.M).

Curvature of stream line is gentle

③ Rapidly varied flow :- If depth of flow changes in short distance such that curvature changes suddenly ex: hydraulic jump.



④ Spatially Varied Flow (SVF) :- Flow is added OR extracted from the system ex: cross-drainage system.

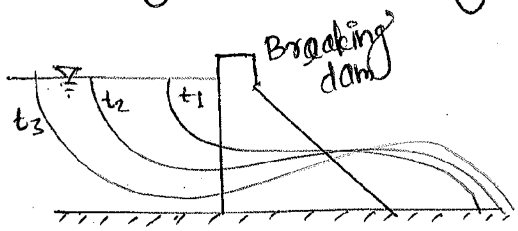


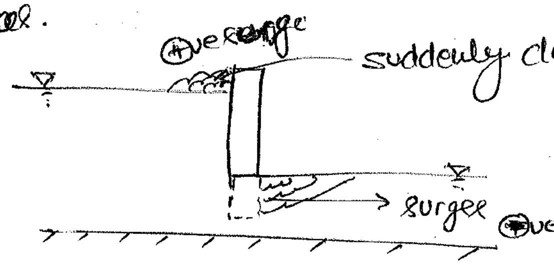

⑤ Unsteady uniform flow :- It is not possible in natural condⁿ. if with time variation of depth is taking place that it can not be same everywhere in the space.

⑥ Gradually varied unsteady flow :-

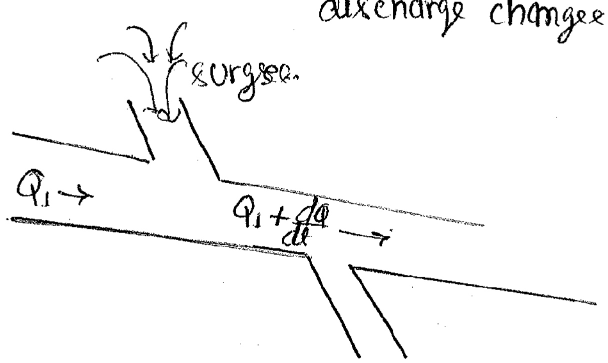
- Passes of flood ~~wave~~ wave in region.

⑦ Rapidly varied unsteady flow :- Sudden dam failure, surges., tidal bore.



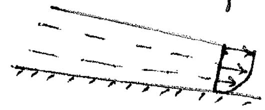




⑧ Spatially Varied unsteady flow :- Rate of adding OR extraction of discharge changes with time.



③ Classification based upon turbulance :-

Ⓐ Laminar flow :- flow with low velocity such that layers are gliding smoothely over eachother.



Ⓑ Turbulent flow :- Water donot moves in layers.

- Totaly mixed up.
- Momentum Transfer in b/w the layers.

NOTE: Reynold's No. :- $= \frac{\rho V R}{\mu} = \frac{VR}{\nu}$

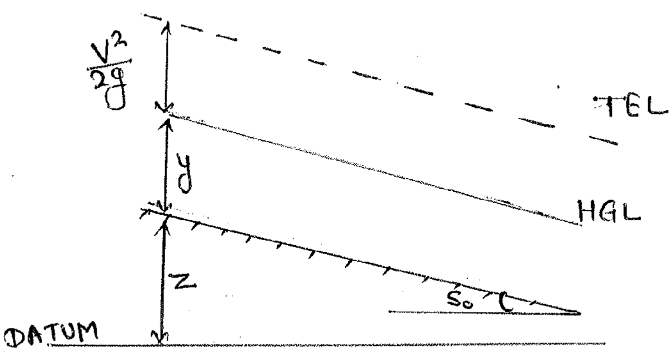
$R \rightarrow$ Hydraulic radius $= \frac{A}{P}$

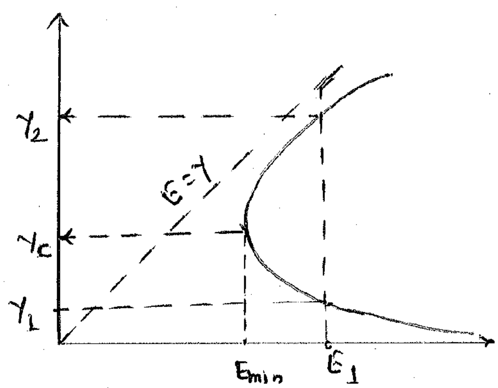
For Laminar flow in open channel = $Re < 500$

" turbulent " " " " = $Re > 2000$

" Transition " " " " $500 < Re < 2000$

# Classification based upon critical flow :-




sp. energy

Energy w.r.t. datum (TH.) $= Z + y + \frac{V^2}{2g}$

Energy w.r.t. channel bed (E) $= Y + \frac{V^2}{2g}$

sp. energy (E) $= Y + \frac{V^2}{2g}$

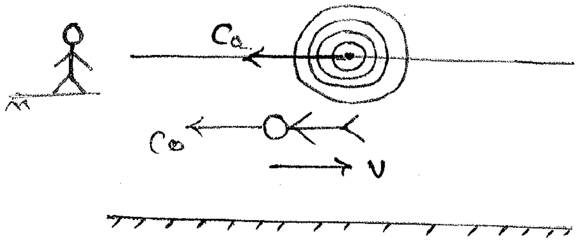
$\Rightarrow y_1$ & $y_2$ are the alternate depth.

$f_r = \frac{V}{\sqrt{gD}} = \frac{V}{\sqrt{g \cdot \frac{A}{T}}} = \frac{V}{C_0}$

| | Energy | Depth | velocity | Froude's |
|---|---|---|---|---|
| critical flow | $E = E_c = E_{min}$ | $Y = Y_c$ | $V = V_c$ | $f_r = 1$ |
| super critical | $E = E_1$ | $Y < Y_c$ | $V > V_c$ | $f_r > 1$ |
| Sub critical | $E = E_1$ | $Y > Y_c$ | $V < V_c$ | $f_r < 1$ |

# Celerity ($C_0$):- Denominator of froude's No. represent the speed with which disturbance created to flow in steel water it is called celerity $C_0$.

$$C_0 = \sqrt{gD} = \sqrt{g \cdot \frac{A}{T}} = \sqrt{gL_c}$$ $L_c \rightarrow$ charatristics length.

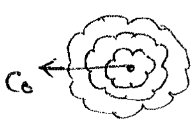



$V_{wave/ground} = V_{wave/water} + V_{water/ground}$

$V_{w/ground} = C_0 - V$

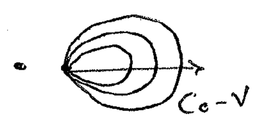
W.r.t. upstream —

| No flow | Subcritical | Supercritical | critical |
|---|---|---|---|
| $V_{w/ground} = C_0$ | $\left\{ fr = \frac{V}{C_0} \right\} < 1$ | $\left\{ fr = \frac{V}{C_0} \right\} > 1$ | $\left\{ fr = \frac{V}{C_0} \right\} = 1$ |
| Sted water | $V < C_0$ | $V > C_0$ | $V = C_0$ |
| | $\therefore C_0 - V = \oplus ve$ | $(C_0 - V) = \ominus ve$ | $C_0 - V = 0$ |





wave will move towards upstream



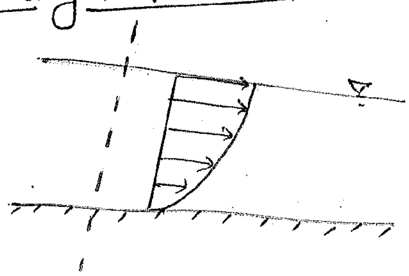

wave will not move in U/s.

No wave

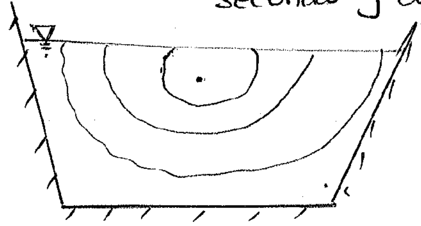
No wave will develope.

07/09/2022

## Velocity Distribution:-



2-cell secondary current.



"Isovels" curves of same velocity.

This velocity distribution is quite non-uniform due to —

1. Non uniform shear stress along the wetted perimeter.
2. Presence of free surface on which shear stress is zero.
3. Due to above reasons velocity is zero at the boundaries & gradually increases with increase in distance from the boundary.

* We mainly deal in avg. velocity / mean velocity

## Determination of Avg./mean velocity :-

Let area of element is dA & it moves distance 'v' in unit time.

$$\text{Discharge} = \frac{\text{Volume}}{\text{Time}} = \frac{V \cdot dA}{1}$$

$$dq = V \cdot dA$$

$V \rightarrow$ velocity at that section.

$$\text{Discharge } (Q) = \int dq = \int_A V \cdot dA \quad \text{---} (1)$$

$$\text{Discharge } (Q) = \text{Area} \times \text{velocity} = A \times (V)_{Avg} = A \times V_m \quad \text{---} (2)$$

from (1) & (2)

Avg. velocity / Mean velocity $\boxed{V_m \text{ (OR) } V = \frac{\int_A V \cdot dA}{A}}$

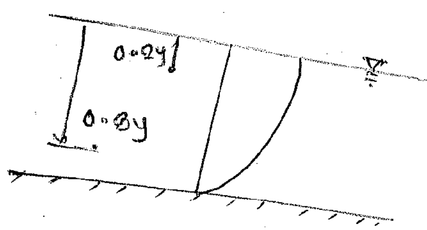
(2) $\boxed{V_m = K \cdot V_{surface}}$ $K \rightarrow$ coefficient $\rightarrow$ 0.8 – 0.95

(3)

$\boxed{V_m = V_{0.6y}}$

(OR)

$\boxed{V_m = \frac{V_{0.2y} + V_{0.8y}}{2}}$

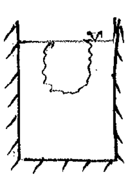


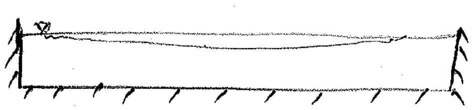

NOTE: The velocity reduction due to the production of secondary current is the f^n of aspect ratio

$$\text{Aspect ratio} = \frac{\text{Depth}}{\text{Width}}$$

more is the aspect ration dipper is the maximum velocity.

In wide channel aspect ratio is less hence max^m velocity is found near the surface.





wide rectangular channel.