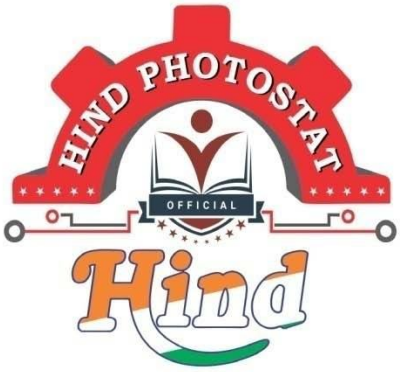

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Open Channel Flow

Written By-Jaspal Sir

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

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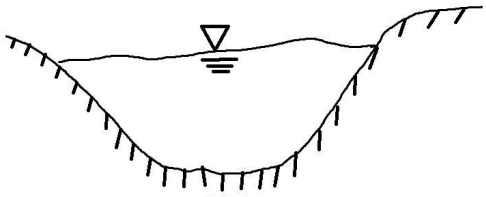
OPEN CHANNEL FLOW

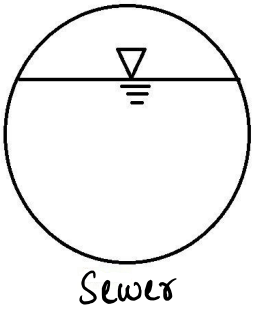
-JASPAL SINGH
(EX IES)

CONTENTS

1. INTRODUCTION

An open channel flow is a conduit in which liquid flows with a free surface.





NOTE:

The free surface is an interface between the moving liquid and overlying fluid which will have constant pressure.

In our case, Moving liquid in most of time is water.
And in terms of gauge pressure it is zero.

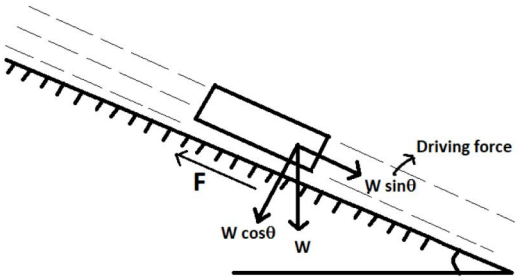
Gauge Pressure = Absolute Pressure − Reference Pressure. (ATM)

flow in natural rivers, stream, rivulets, Torrent, Canal, sewers carrying the sewage, road side drain / gutter etc., are the examples of open channel flow, as there exists free water surface.

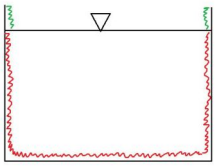
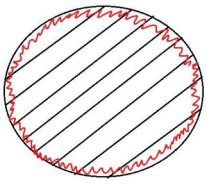
Basically, all open channel have a bottom slope and the mechanism of flow is similar to the movement of mass down an inclined plane, due to gravity.

The component of weight of liquid along the slope act as a driving force and the boundary resistance at the perimeter act as a Resisting force.

Since, flow in open channel is generally turbulent, effect of surface tension is negligible; hence gravitational force becomes the driving force.



Comparison of OCF and Pipe flow.

OCF	PIPE FLOW
•OCF must have a free surface	No free surface is available.
•A free surface is subjected to atmospheric pressure.	No direct atmospheric pressure is available. Only Hydraulic pressure exist.
•Here flow take place due to gravity.	Here flow take place due to pressure difference.
•Since gravitational force is governing force here analysis is done by FROUDES NUMBER.	Here Analysis done by Reynold's number.
• The depth of flow, discharge, slope of channel at bottom & of the free surface are interdependent.	Here, there is no dependency in between these parameters.
•The c/s may be of any form circular, rectangular, triangular compound or incase of natural stream it is irregular along the flow direction.	The c/s of pipe is generally kept circular.
•The relative roughness changes with level of free surface.	The relative roughness is a fixed quantity.
	
•Flow area is determined by geometry of channel plus the level of free surface which is likely to change along the flow direction and with time as well.	Flow area is fixed by pipe dimension and is usually same along the flow direction.
•Hydraulic gradient line coincide with free water surface.	HGL is usually above the conduit.

NOTE:

Total Energy E_T = Datum (elevation) energy + Pressure energy + Kinetic energy

$$E_T = mgz + P_w V + \frac{1}{2}mv^2$$

$$\text{Energy / weight } (H) = z + \frac{p}{\gamma} + \frac{v^2}{2g}$$

H = Datum head + Pressure head + Kinetic head.

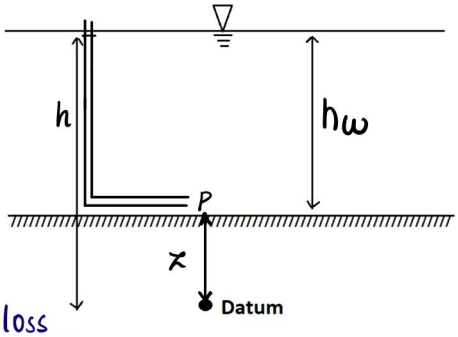
Hydraulic Head.

Sum of datum head and Pressure head = Hydraulic head (h).

$$h = z + p/\gamma$$

$$P_w = \frac{W_w}{A_w} = \frac{\gamma_w V_w}{A_w} = \frac{\gamma_w A_w h_w}{A_w} = \gamma_w h_w$$

$$\frac{P_w}{\gamma_w} = h_w$$

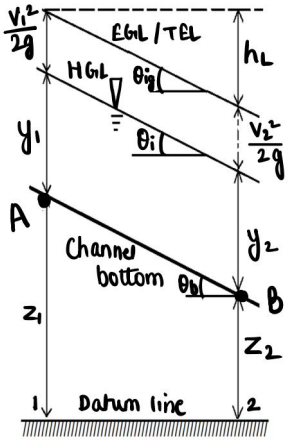


i = Hydraulic Gradient = $\frac{\text{Hydraulic Head loss}}{\text{length of flow}}$

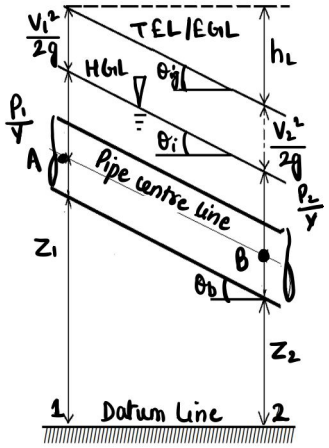
$$i = \frac{h_1 - h_2}{L} = \frac{(z_1 + h_{w_1}) - (z_2 + h_{w_2})}{L} = \frac{\left(z_1 + P_1/\gamma + \frac{V_1^2}{2g}\right) - \left(z_2 + P_2/\gamma + \frac{V_2^2}{2g}\right)}{L}$$

Line, Slope of which indicates Hydraulic gradient is termed as HGL.

Line, Slope of which indicates energy gradient is termed as TEL.

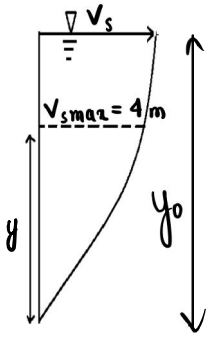


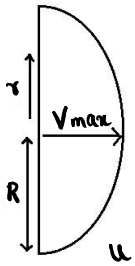
Velocity distribution in case of OCf is logarithmic or power law distribution.



In case of pipe flow velocity distribution is parabolic (for laminar flow).

$$\frac{u_m - u}{u^*} = \frac{1}{k} \ln \frac{y}{y_0}$$





$$u = u_{max}\left(1 - \frac{r^2}{R^2}\right)$$

NOTE :

Different forces which may act over the fluid flowing in conduit are as follows:

1. Inertia force : It is the property common to all the body that remains in their state either rest or motion unless some external cause is introduce. to make them alter their state.

It is a product of mass and acceleration.

$$f_i = ma = \rho . L^3 . \frac{v}{T}$$

$$\boxed{F_i = \rho L^2 V^2}$$

2. Gravity force : It is the force due to own weight of body.

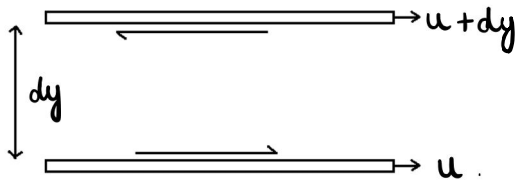
$$f_g = mg = \rho V g = \rho L^3 g$$

$$\boxed{f_g = \rho L^3 g}$$

3. Viscous force : This force is due to resistance of fluid against deformation which develops between different layer of fluid.

$$f_\mu = LA = \mu \frac{du}{dy} L^2 = \mu \frac{V}{L} L^2$$

$$\boxed{f_\mu = \mu V L}$$



Reynold's Number :

It is a dimensionless number that signifies the dominance of inertial force over viscous force

$$Re = \frac{f_i}{f_\mu} = \frac{\rho L^2 V^2}{\mu V L}$$

$$\boxed{Re = \frac{\rho V L}{\mu}}$$

- **Froudes Number :**

It is a dimensionless number that signifies the dominance of inertial force over the gravitational force.

$$f_e = \sqrt{\frac{\text{Inertial force}}{\text{Gravitational force}}}$$

$$= \frac{\rho L^2 V^2}{\rho L^3 g}$$

$$\boxed{f_e = \frac{V}{\sqrt{gL}}}$$

Different types of open channel flow

Open channel can be classified on the basis of following

I On the basis of formation

1. **Natural Channel :**

These are the channel which are formed by the action of Natural force/act.

They possess irregular geometry of cls uniform depth of flow and bed slope

Example : River, Rivulets, creeks etc.

2. **Artificial Channel :**

These channels being constructed artificially to carry the water at desired operation in designed working condition are termed as Artificial channel.

These channels are usually designed to have uniform cls, bed slope, depth etc.

Example : Canals, sewer, culverts etc.

II. On the basis of change in properties of channel :

1. **Prismatic Channel**

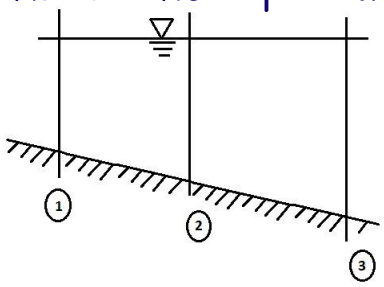
A channel in which the cross sectional shape, size, bed slope, side slope, planiform are constant is termed as prismatic channel.

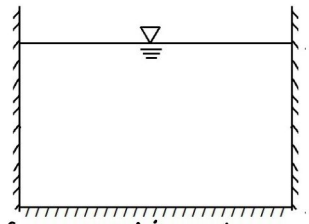
Most of the man made channel are prismatic.

2. **Non - prismatic Channel**

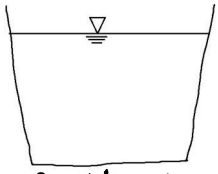
A channel in which almost all the properties of channel (mentioned above) vary along its length is termed as Non - prismatic channel.

Most of all natural channel are Non - prismatic channel.

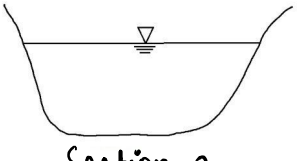




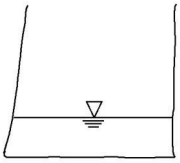
Cross section at 1, 2, 3



Section 1



Section 2



Section 3

III. On the basis of type of boundary.

1. Rigid Boundary Channel

Rigid channels are those in which the boundary is not a deformable and shape and roughness is not a function of flow parameter.

In these channels, the flow velocity, shear stress distribution will be such that no major scouring, erosion, deposition will take place in channel and channel geometry and roughness essentially constant w.r.t time.

Example : Lined canals, Non erodable unlined canals.

* In rigid boundary channels only depth of flow vary with space and time depending upon nature of flow. Hence, these channels have only 1 degree of freedom.

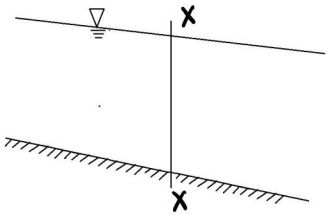
2. Mobile Boundary Channel.

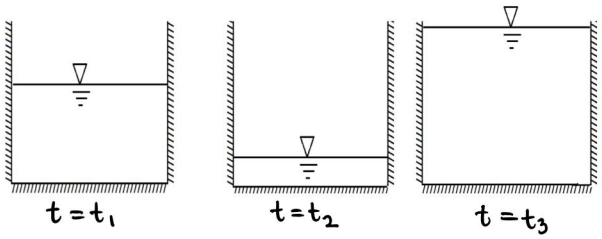
These channels are those in which the boundary undergoes change due to continous erosion or deposition.

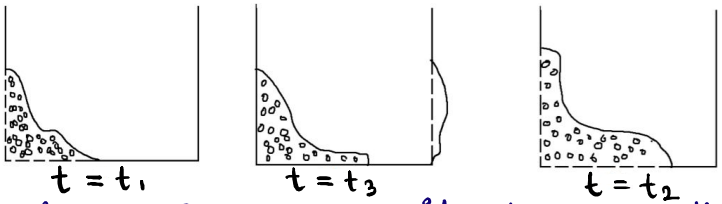
In these channels the resistance of flow quantity of sediments transport channel geometry all depends on interaction of flow with channel boundaries.

In mobile channel depth, bed width, bed slope, planiform (layout) changes with space and time depending upon nature of flow. Hence, these channels are 4 degree of freedom.

In mobile channels flow carries considerable amount of sediment through suspension and in contact with bed.







NOTE: In analysis of OCF, channels considered are artificial, prismatic and rigid boundary channel.

Types of open channel flow.

1. Steady and Unsteady flows.

A steady flow occurs when the flow properties such as depth, velocity & discharge at a section do not change with time.

$$\frac{dy}{dt} = 0 \quad \frac{dV}{dt} = 0 \quad \frac{dQ}{dt} = 0 \quad \text{etc}$$

If these flow properties varies with time it is termed as unsteady flow.

$$\frac{dy}{dt} \neq 0 \quad \frac{dV}{dt} \neq 0 \quad \frac{dQ}{dt} \neq 0 \quad \text{etc}$$

Flow during floods in rivers, rapidly varying surges in canals are case of unsteady flow.