JAIPUR ENGINEERING COLLEGE AND RESEARCH CENTER

Class – B.Tech Civil (IV SEM)
Subject –Hydraulics Engineeging
Unit – 3
Presented by – Ashish Boraida (Assistant Professor)

VISION AND MISSION OF INSTITUTE

VISION OF INSTITUTE

To became a renowned centre of outcome based learning and work towards academic professional ,cultural and social enrichment of the lives of indivisuals and communities

MISSION OF INSTITUTE

Focus on evaluation of learining ,outcomes and motivate students to research apptitude by project based learning.

- Identify based on informed perception of indian ,regional and global needs ,the area of focus and provide plateform to gain knowledge and solutions.
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- Offer oppurtunites for interaction between academic and industry .
- Develop human potential to its fullest extent so that intellectually capable and imaginatively gifted leaders may emerge.

VISION AND MISSION OF DEPARTMENT

Vision

To become a role model in the field of Civil Engineering for the sustainable development of the society.

Mission

1)To provide outcome base education.

2)To create a learning environment conducive for achieving academic excellence.

3)To prepare civil engineers for the society with high ethical values.

Introduction, Objective and Outcome of Fluid Mechanics

Objective:

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The primary purpose of the study of Fluid mechanics is to develop the capacity to understand important basic terms used in fluid mechanics, understand hydrostatics and buoyancy with practice of solving problems. Student could be able to understand Kinematics of flow and fluid dynamics, Bernoulli's equation and laminar flow with practice of solving problems in practical life for the benefit of society and mankind.

Outcomes

- Student will be able to understand Dimensional, Model Analysis and Turbulent Flow with problems.
- Student will be able to understand variable Flow in open channels , Gradually and Rapidly Varied Flow.
- Student will be able to understand Impact of Jets and hydraulic machines
- Student will be able to understand Hydrology, Ground water and Canal Hydraulics.

CONTENTS

- Gradually Varied Flow
- Dynamic Equation of GVF
- Hydraulic Jump

General assumption for GVF

- 1 . Flow is steady

- 2. The streamlines are practically parallel

Basic Assumption for GVF

- 1. Head loss for GVF as similar for a uniform flow

- 2. The slope of the channel is small
  - vertical depth of flow consider from bottom
  - $\cos\theta$ is equal to unity
  - No air entrance to occurs

Basic Assumption for GVF

- 3. flow in prismatic channel having constant alignment and shape

- 4. velocity-distribution coefficients are constant

Basic Assumption for GVF

- 5. Similarly for GVF, conveyance K and section factor Z are exponential functions of the depth of flow

- 6. roughness coefficient is independent of depth and constant throughout the channel reach

Dynamic equation of Gradually varied flow

- Consider the profile of gradually varied flow

- *dx* elementary length of the open channel

- Now, total head above the datum of the channel

$$H = z + d\cos\theta + \alpha\frac{V^2}{2g} \quad \text{............. (1)}$$

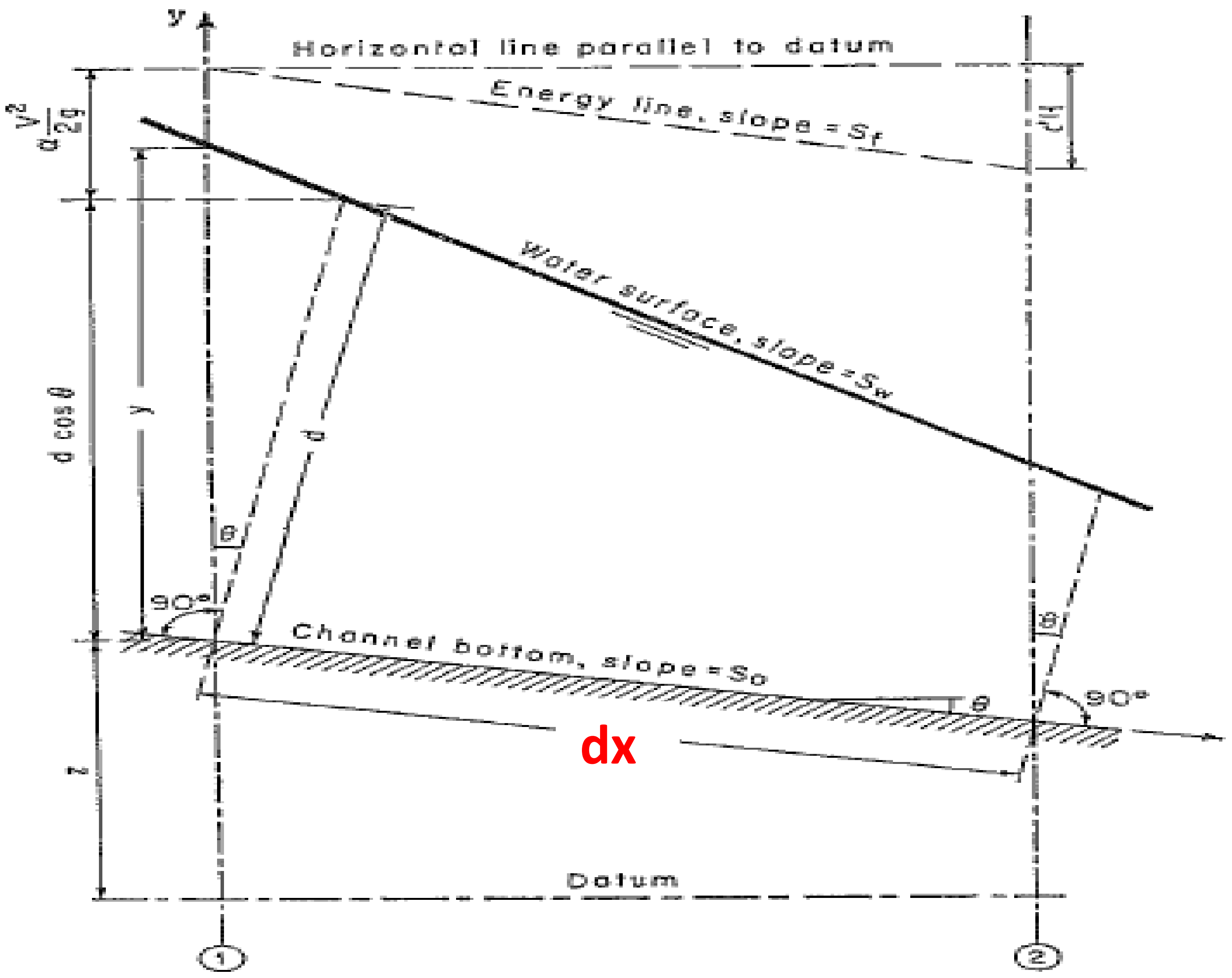


Fig. 01

Dynamic equation of GVF

- Taking the bottom of the channel as x-axis and differentiating equation (1) with respect to *x*, we get

$$\frac{dH}{dx} = \frac{dz}{dx} + \cos\theta \frac{dd}{dx} + \alpha \frac{d}{dx}\left(\frac{V^2}{2g}\right)$$

…………….(2)

Now S_f is the slope of energy line, it is assumed to be positive if it is descends in the direction of flow and negative if it ascends.

Hence, from Fig. energy slope (as flow descending) $S_f = -\frac{dH}{dx}$

Dynamic equation of GVF

- And the slope of the channel bottom $$S_0 = \sin\theta = -\frac{dz}{dx}$$

Substituting these slopes in quation (1) we found,

$$-S_f = -S_0 + \cos\theta \frac{dd}{dx} + \alpha \frac{d}{dx}\left(\frac{V^2}{2g}\right)$$

$$or, \quad \cos\theta \frac{dd}{dx} + \alpha \frac{d}{dx} \cdot \frac{dd}{dd}\left(\frac{V^2}{2g}\right) = S_0 - S_f$$

$$or, \quad \frac{dd}{dx}(\cos\theta + \alpha \frac{d}{dd}\left(\frac{V^2}{2g}\right)) = S_0 - S_f$$

$$or, \quad \frac{dd}{dx} = \frac{S_0 - S_f}{\cos\theta + \alpha \frac{d}{dd}\left(\frac{V^2}{2g}\right)}$$ ....(3)

Dynamic equation of GVF

$$or, \quad \frac{dd}{dx} = \frac{S_0 - S_f}{\cos\theta + \alpha \frac{d}{dd}\left(\frac{V^2}{2g}\right)} \quad \text{......................(3)}$$

This the *general differential equation* for gradually varied flow also known as the *dynamic equation for gradually varied flow*.

Here depth d is measured from the bottom of the channel and

Dynamic equation of GVF

$$or, \quad \frac{dd}{dx} = \frac{S_0 - S_f}{\cos\theta + \alpha \frac{d}{dd}\left(\frac{V^2}{2g}\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

- **Thus**

$$\frac{dd}{dx} = 0$$

- s_f **=** S_0 **if**

$$\frac{dd}{dx} = +$$

- s_f **<** S_0 **if**

$$\frac{dd}{dx} = -$$

- s_f **<** S_0 **if**

$$\frac{dd}{dx} = 0 \qquad \frac{dd}{dx} = + \qquad \frac{dd}{dx} = -$$

- **In other word water surface profile parallel to the channel bottom when , rising when , and lowering**

Dynamic equation of GVF

$$or, \quad \frac{dd}{dx} = \frac{S_0 - S_f}{\cos\theta + \alpha \frac{d}{dd}\left(\frac{V^2}{2g}\right)}$$ ....(3)

For small θ , cos θ ≅ 1, and $d \cong$ *y and* $\frac{dd}{dx} \cong \frac{dy}{dx}$

Putting these values in equation (3) we get,

$$or, \quad \frac{dy}{dx} = \frac{S_0 - S_f}{1 + \alpha \frac{d}{dy}\left(\frac{V^2}{2g}\right)}$$ ....(4)

Dynamic equation of GVF

$$or, \quad \frac{dy}{dx} = \frac{S_0 - S_f}{1 + \alpha \frac{d}{dy}\left(\frac{V^2}{2g}\right)} \quad \text{.....................(4)}$$

$$\alpha \frac{d}{dy}\left(\frac{V^2}{2g}\right)$$

•The term in the varied flow equation represents the change in velocity head and coefficient α has been assumed to be constant from section to section of the

$$\alpha \frac{d}{dy}\left(\frac{V^2}{2g}\right) = \frac{\alpha Q^2}{2g}\frac{dA^{-2}}{dy} = -\frac{\alpha Q^2}{gA^3}\frac{dA}{dy} = -\frac{\alpha Q^2 T}{gA^3}$$

Since, V= Q/A where, Q is

Dynamic equation of GVF

∴ Velocity term, $$\alpha \frac{d}{dy}\left(\frac{V^2}{2g}\right) = \frac{\alpha Q^2}{2g}\frac{dA^{-2}}{dy} = -\frac{\alpha Q^2}{gA^3}\frac{dA}{dy} = -\frac{\alpha Q^2 T}{gA^3}$$

Since $Z = \sqrt{A^3/T}$, the above may be written

$$\alpha \frac{d}{dy}\left(\frac{V^2}{2g}\right) = -\frac{\alpha Q^2}{gZ^2}$$

................(5)

Suppose that a critical fow of discharge equal to Q occurs at the section, then we can write,

$$Q = Z_c \sqrt{\frac{g}{\alpha}}$$

..............................(6)

From equation (5) and (6) $$\alpha \frac{d}{dy}\left(\frac{V^2}{2g}\right) = -\frac{Z_c^2}{Z^2}$$

(6)

Dynamic equation of GVF

So we can rewrite our equation (4) as

$$or, \quad \frac{dy}{dx} = \frac{S_0 - S_f}{1 - (Z_c/Z)^2}$$

$$or, \quad \frac{dy}{dx} = S_0 \frac{(1 - S_f/S_0)}{1 - (Z_c/Z)^2} \qquad \text{...............(7)}$$

From Mannings formula we know, S

When Manning's or Chezy's formula express in terms of conveyance, K the discharge can be written as

$$Q = K\sqrt{S_f}$$

$$\therefore \quad S_f = \frac{Q^2}{K^2} \qquad \text{....................(8)}$$

Dynamic equation of GVF

- Suppose that a uniform flow of a discharge equal to Q occurs in the section. The energy slope would be equal to the bottom slope, and equation (9) may be written as

$$S_0 = \frac{Q^2}{K_n^2}$$

$$\therefore \qquad \frac{S_f}{S_0} = \frac{K_n^2}{K^2}$$

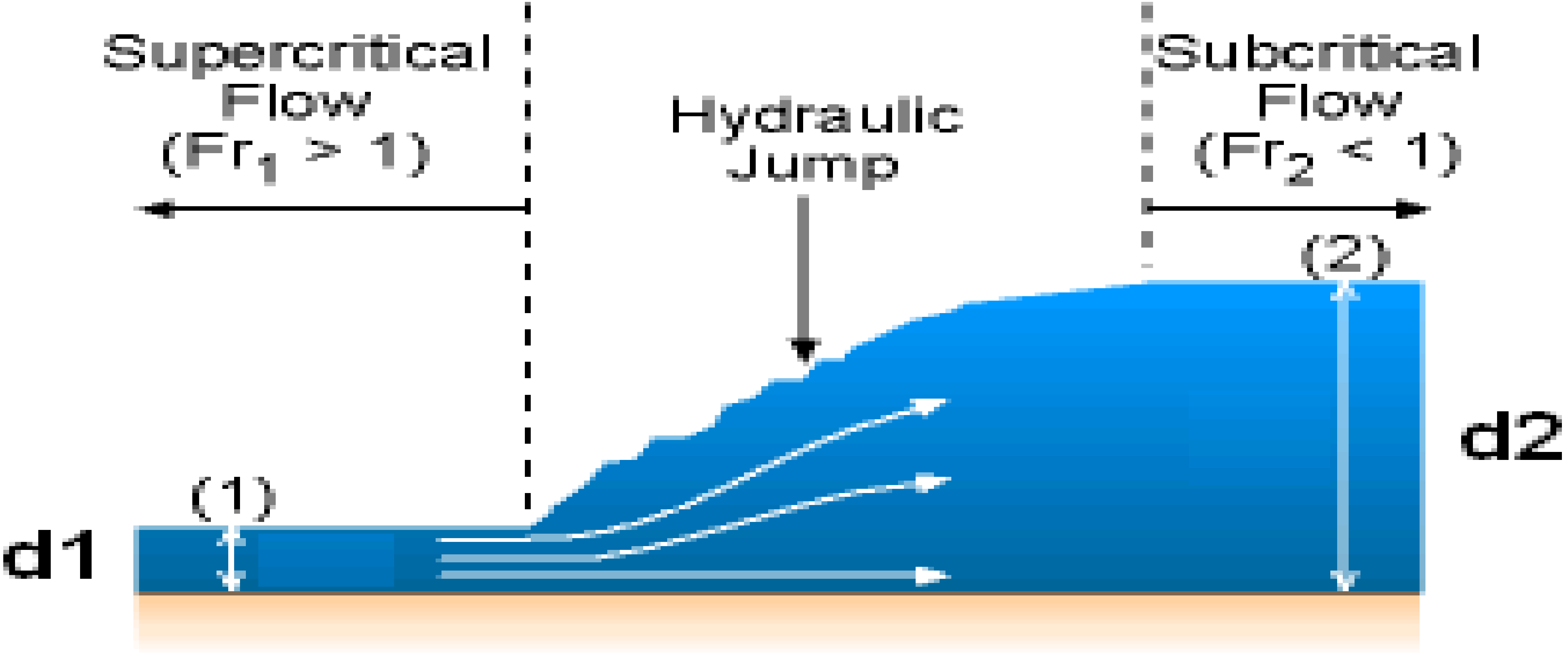
Substituting above value in equation (8), we found that

$$or, \qquad \frac{dy}{dx} = S_0 \frac{1-(K_n/K)^2}{1-(Z_c/Z)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(11)$$

Hydraulic Jump

- The hydraulic jump is defined as the rise of water level, which takes place due to transformation of the unstable shooting flow (super-critical) to the stable streaming flow (sub-critical).

- When hydraulic jump occurs, a loss of energy due to eddy formation and turbulence flow occurs.



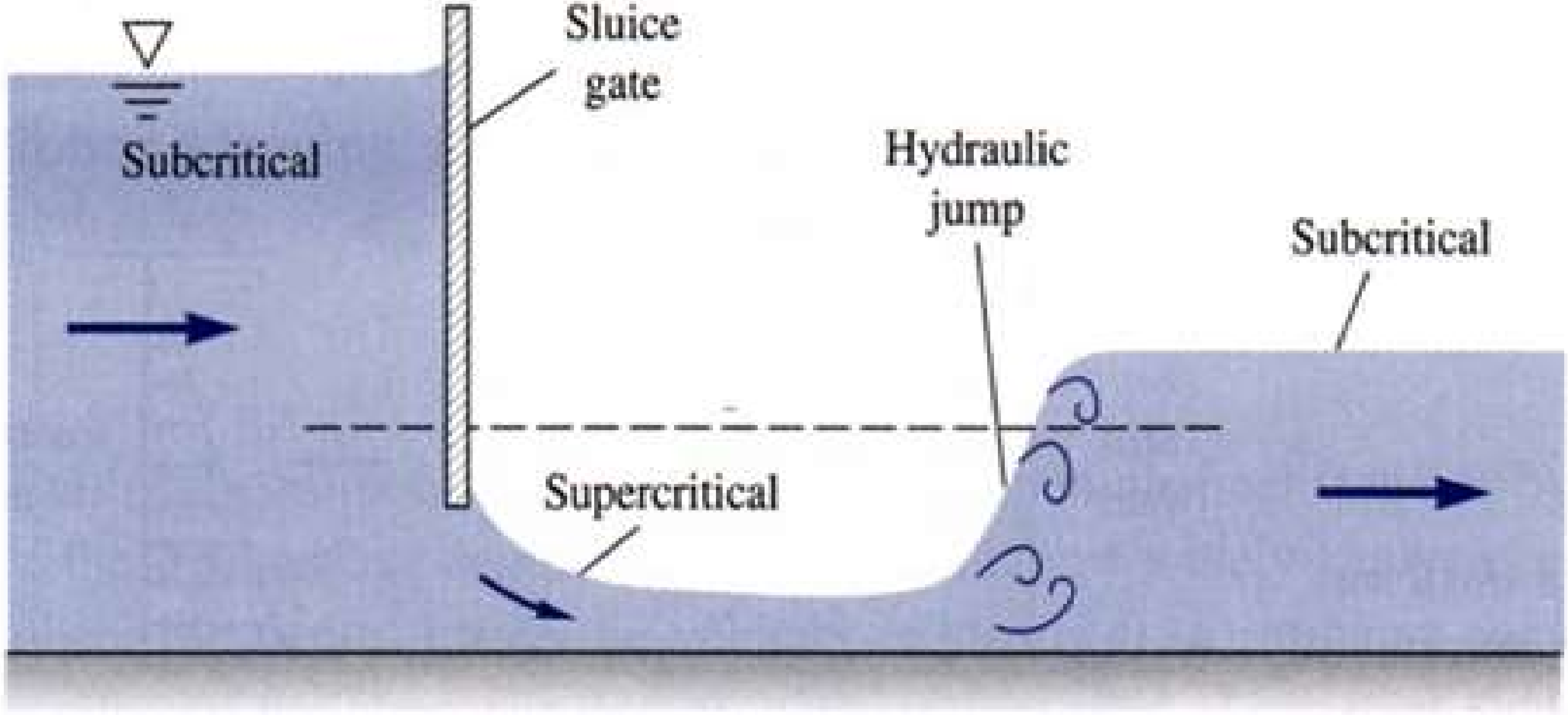
Froude Numbers and Fluid Depths across a Hydraulic Jump

Uses of Hydraulic Jump

- Hydraulic jump is used to dissipate or destroy the energy of water where it is not needed otherwise it may cause damage to hydraulic structures.

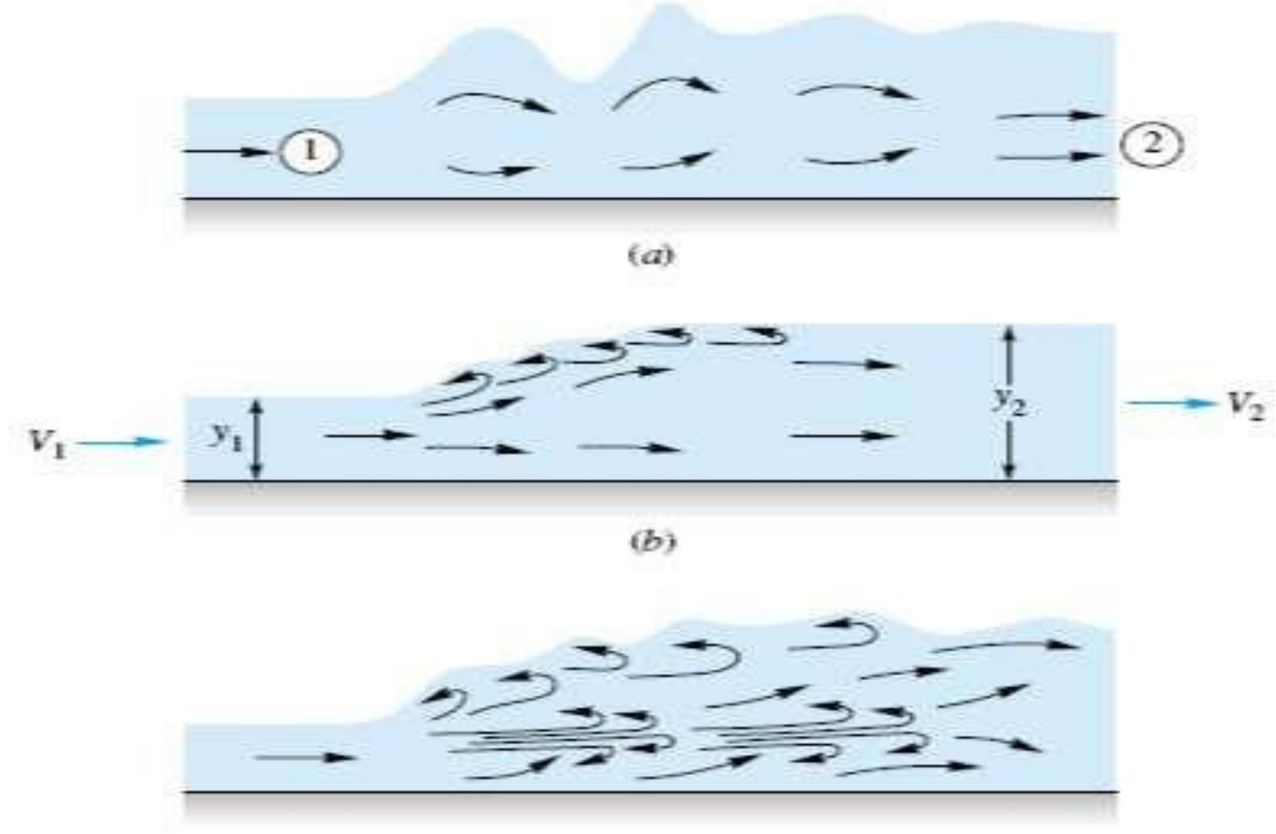
- It may be used for mixing of certain chemicals like in case of water treatment plants.

- It may also be used as a discharge measuring device.

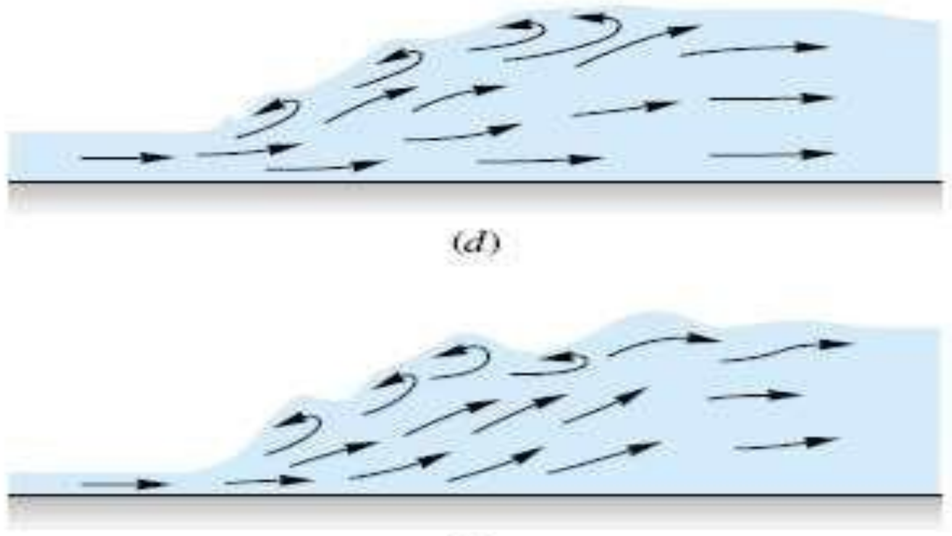


Flow under a sluice gate accelerates from subcritical to critical to supercritical and then jumps back to subcritical flow

Classification of Hydraulic jump



(a) (b) (c)



(d) (e)

Classification of hydraulic jumps:

(a) Fr =1.0 to 1.7: undular jumps;

(b) Fr =1.7 to 2.5: weak jump;

(c) Fr =2.5 to 4.5: oscillating jump;

(*d*) Fr =4.5 to 9.0: steady jump;

(e) Fr =9.0: strong jump.

Classification of Hydraulic jump

- F_{r1} <1.0: Jump impossible, violates second law of thermodynamics.
- F_{r1}=1.0 to 1.7: Standing-wave, or *undular, jump* about $4y_2$ long; low dissipation, less than 5 percent.
- Fr1=1.7 to 2.5: Smooth surface rise with small rollers, known as a *weak jump*; dissipation 5 to 15 percent.
- F_{r1}=2.5 to 4.5: Unstable, *oscillating jump*; each irregular pulsation creates a large wave which can travel downstream for miles, damaging earth banks and other structures. Not recommended for design conditions. Dissipation 15 to 45 percent.
- F_{r1}=4.5 to 9.0: Stable, well-balanced, *steady jump*; best performance and action, insensitive to downstream conditions. Best design range. Dissipation 45 to 70 percent.
- F_{r1}>9.0: Rough, somewhat intermittent *strong jump*, but good performance. Dissipation 70 to 85 percent.

Applications of Hydraulic Jump

- Usually hydraulic jump reverses the flow of water. This phenomenon can be used to mix chemicals for water purification.
- Hydraulic jump usually maintains the high water level on the down stream side. This high water level can be used for irrigation purposes.
- Hydraulic jump can be used to remove the air from water supply and sewage lines to prevent the air locking.
- It prevents the scouring action on the down stream side of the dam structure

Location of Hydraulic Jump

The most typical cases for the location of hydraulic jump are:

1. **Below control structures like weir, sluice are used in the channel**
2. **when any obstruction is found in the channel,**
3. **when a sharp change in the channel slope takes place.**
4. **At the toe of a spillway dam**

Effect of Hydraulic Jump

- Actually the hydraulic jump usually acts dissipator. It clears the surplus energy of water
- Due to the hydraulic jump, many noticeable able disturbances are created in the flowing water like eddies, reverse flow.
- Usually when the hydraulic jump takes place, the considerable amount of air is trapped in the water. That air can be helpful in removing the wastes in the streams that are causing pollution.
- Hydraulic jump also make the work of different hydraulic structures, effective like weirs, notches and flumes etc.

Height of hydraulic jump (h_j):

The difference of depths before and after the jump is known as the height of the jump,

$$h_j = y_2 - y_1$$

Where,

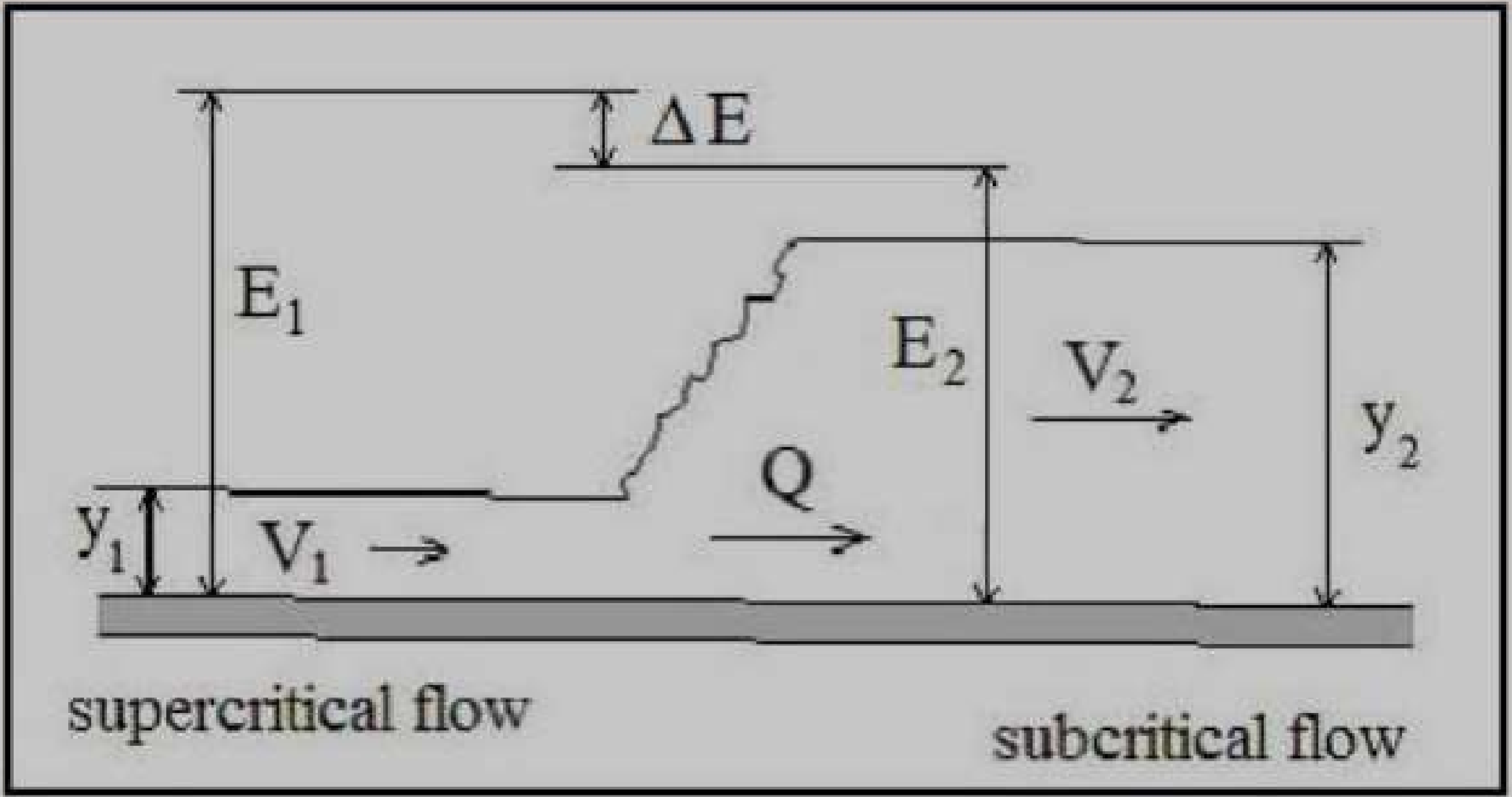
$$y_2 = \frac{y_1}{2}\left(\sqrt{1+8Fr_1^2}-1\right)$$

Length of hydraulic jump (L_j):

The distance between the front face of the jump to a point on the downstream where the rollers (eddies) terminate and the flow becomes uniform is known as the length of the hydraulic jump. The length of the jump varies from 5 to 7 times its height. An average value is usually taken:

$$L_j \cong 6h_j$$

Energy Loss Diagram



Hydraulic Jump (with Heads and Head Loss)

The diagram above illustrates a hydraulic jump and the energy loss from E1 to E2. The supercritical depth (y1) jumps to a larger depth, subcritical depth (y2), as the velocity decreases from V1 to V2.

Head Loss in a hydraulic jump *(H_L)*:

Due to the turbulent flow in hydraulic jump, a dissipation (loss) of energy occurs:

$$H_L = \Delta E = E_1 - E_2$$

Where, *E* = specific energy

For rectangular channels: $E_s = y + \dfrac{q^2}{2gy^2}$

hence, $$H_L = y_1 + \frac{q^2}{2gy_1^2} - \left(y_2 + \frac{q^2}{2gy_2^3} \right)$$

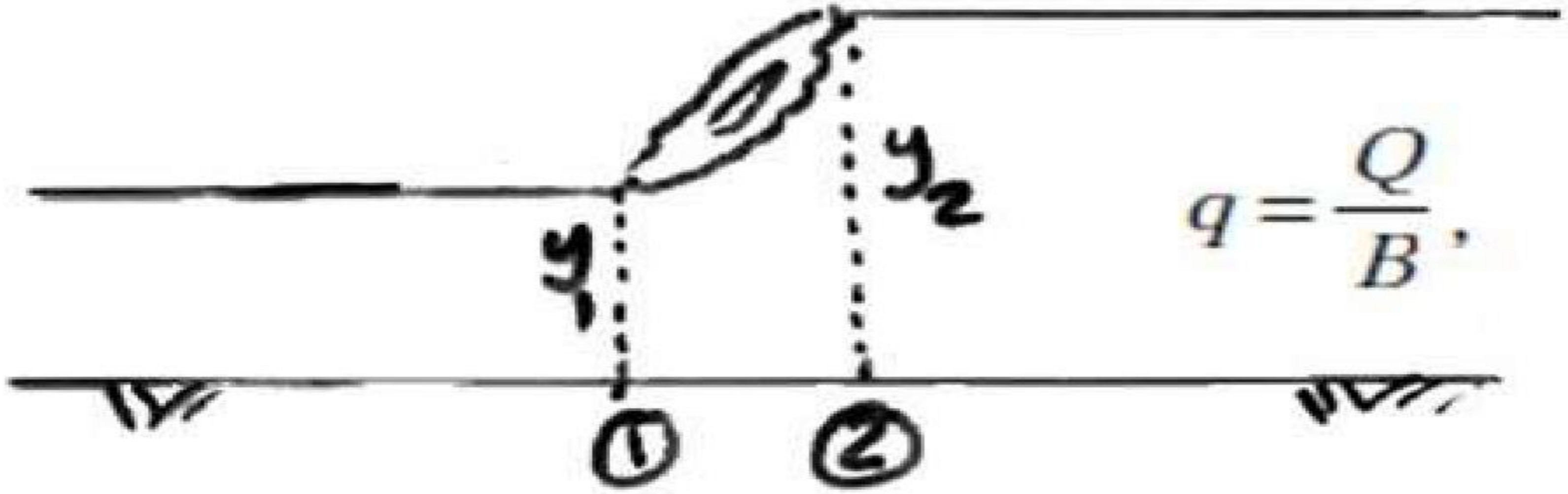
After simplifying, we obtain $$\Delta E = H_L = \frac{(y_2 - y_1)^3}{4y_1y_2}$$

Hydraulic Jump

Hydraulic Jump in Rectangular Channels

$$y_2 = -\frac{y_1}{2} + \sqrt{\left(\frac{y_1}{2}\right)^2 + \left(\frac{2q^2}{g\,y_1}\right)}$$

$$y_1 = -\frac{y_2}{2} + \sqrt{\left(\frac{y_2}{2}\right)^2 + \left(\frac{2q^2}{g\,y_2}\right)}$$



$$q = \frac{Q}{B}.$$

- **Ratio of conjugate depths:**

But for Rectangular section $$y_c^3 = \frac{q^2}{g}$$

$$\frac{y_2}{y_1} = \frac{1}{2}\left(-1 + \sqrt{1 + \frac{8q^2}{g\,y_1^3}}\right)$$

$$\frac{y_1}{y_2} = \frac{1}{2}\left(-1 + \sqrt{1 + \frac{8q^2}{g\,y_2^3}}\right)$$

$$\frac{y_2}{y_1} = \frac{1}{2}\left(-1 + \sqrt{1 + 8\left(\frac{y_c}{y_1}\right)^3}\right)$$

$$\frac{y_1}{y_2} = \frac{1}{2}\left(-1 + \sqrt{1 + 8\left(\frac{y_c}{y_2}\right)^3}\right)$$

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Thank you!

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