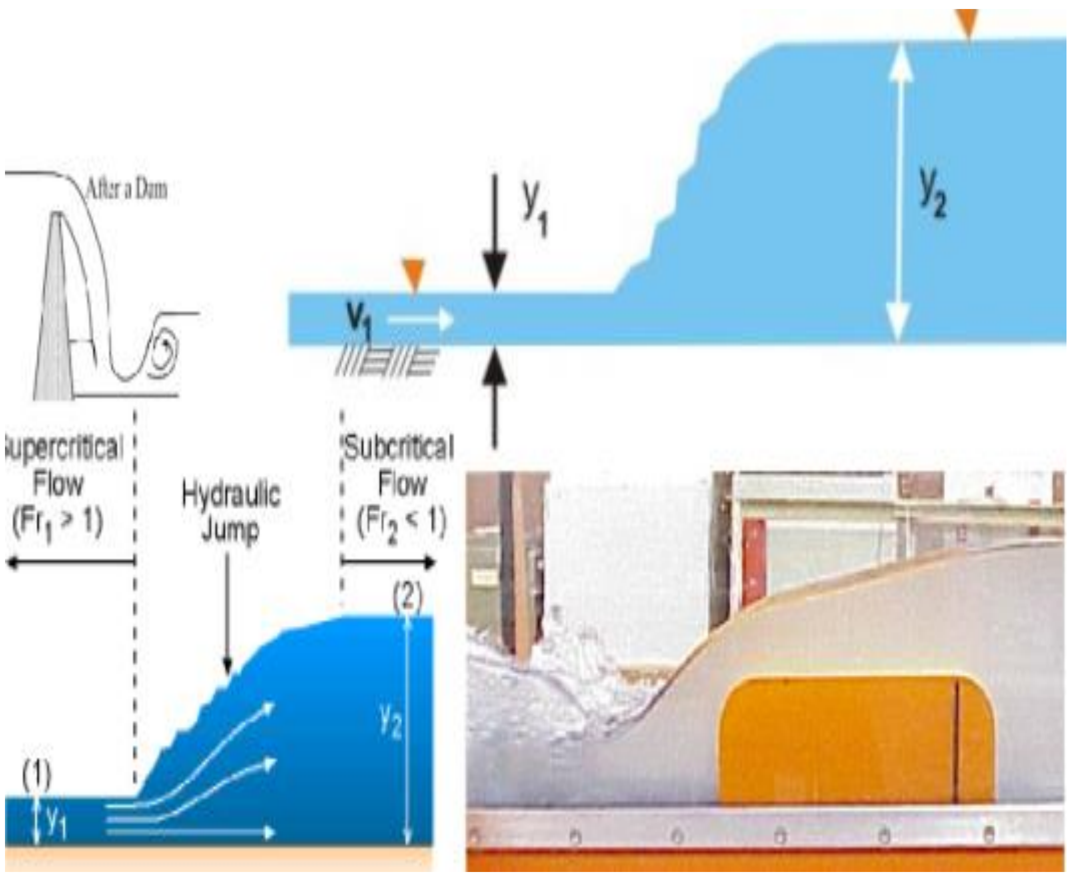
Aim: To observe the hydraulic jump phenomenon and to compare measured flow depths with theoretical results based on the application of continuity and momentum principles.

Apparatus Used: Tilting laboratory flume with manometer, slope adjusting scale and flow arrangement., Pump, Electric Motor, Sump, Volumetric Tank, Channel, Piping with necessary Valves and Fittings, Stopwatch

In the laboratory flume, the flow is regulated from the upstream end by a sluice gate so that a shallow and rapid "supercritical flow" develops. At the downstream end, an adjustable weir can be placed to form a barrier which forces the flow in front of the weir to pile up and becomes "subcritical". A hydraulic jump then forms at the transition from the upstream supercritical flow to the downstream subcritical flow. A hydraulic jump is analogous to the shock wave phenomenon observed in aerodynamics, where a supersonic flow meets a subsonic flow and a shock front develops at the transition between the two flow regimes.



Theory: The dynamics of hydraulic jump is governed by the flow continuity and the momentum equation. As we shall see, one of the major characteristic of a hydraulic jump is its large energy dissipation. Therefore, energy equation cannot be used at this point because the head loss is unknown (and not negligible). Using a control volume enclosing the jump as shown in Figure 1, the continuity equation is expressed as

$$Q = b\,V_1\,h_1 = b\,V_2\,h_2 \qquad (1)$$

Where, Q is the discharge, V represents the averaged velocity and h is the water depth. The subscript "1" and "2" represent flow information upstream and downstream of the hydraulic jump, respectively. The momentum equation which takes into account the hydrostatic forces and the momentum fluxes, but ignores the friction at the channel bottom and at the side walls, can be shown as

$$1/2\rho gbh1^2 - 1/2\,\rho gbh2^2 = \ \ (\mathrm{V2} - V1) \qquad (2)$$

in which ρ is the fluid density and g is the gravitational acceleration. If we define a momentum function as

$$\mathrm{M} = \mathrm{V}^2\mathrm{h}/2\mathrm{g}+\mathrm{h}^2/2 \qquad (3)$$

Then, using equation (1) we can show that equation (2) suggest

$$M1 = M2 \qquad (4)$$

From equation (1) and (2), it can be shown that the upstream and downstream flow depths are related by

$$\xi = h2/\,h1 = 0.5((1 + 8\mathrm{Fr}_1^{\,2})^{0.5} - 1)) \qquad (5)$$

Where, Fr_1 is the Froude number of the upstream flow and is defined as

$$\mathrm{Fr}_1 = V1/\,(gh_1)^{\,0.5} \qquad (6)$$

For a hydraulic jump, the upstream flow is supercritical and $\mathrm{Fr}_1>1$. On the other hand, the Froude number Fr2 of the downstream subcritical flow needs to satisfy

$$\mathrm{Fr}_2 = V2\,/(gh_2)^{0.5} < 1 \qquad (7)$$

You can further apply conservation of energy for this open channel flow problem as

$$h_1 + V_1^{\,2}/\,2g = \ \ h_2 + V_2^{\,2}/\,2g + h_\mathrm{L} \qquad (8)$$

And show that the head loss h_L for hydraulic jump is calculated as

$$h_\mathrm{L} = (h_2 - h_1)^3/\,4h_1\,h_2 \qquad (9)$$

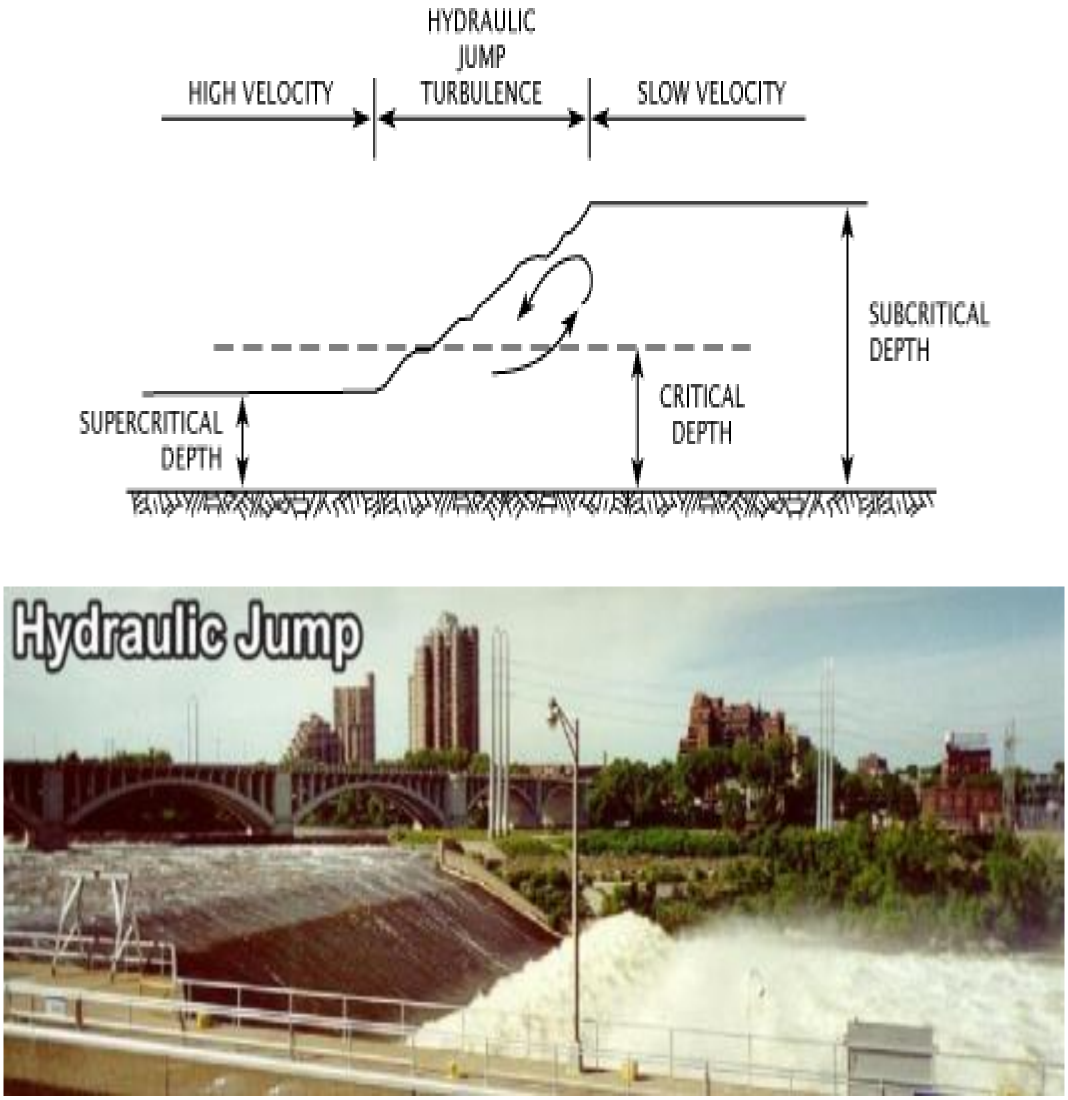


Fig.1 Hydraulic jump phenomenon

PROCEDURE:

1. Start the pump and turn the flow control valve open.

2. Allow the flow to become established and a jet to be developed under the sluice gate (the water level in the reservoir behind the gate should be steady at this point).

3. Place the weir at the downstream end and adjust the weir carefully to create a hydraulic jump which is fixed at about the midsection of the flume.

4. Measure water depths before and after the jump using a point gage.

5. Record the discharge Q (l/sec) from the flow meter reading.

6. Repeat steps 2 through 5 for a total of five different values of Q. The value of Q can be changed by adjusting the flow control valve. The downstream weir is used to position the jump in the midsection of the flume.

Observation Table:

S.No.	h_1	h_2	Time for 10 cm rise of water (t)	Q= AxR/t	$h_L = (h_2 - h_1)^3 / 4h_1 h_2$

Where,

A=Area of collecting tank in m^3

R = rise of water level taken in m

t = Time taken for rise of water level to rise R in t second.

Calculation:

Result:

Froude no at upstream ----------------

Froude no at downstream ---------------

Ratio of sequent depth -------------------

Energy Loss ---------------------------------

Precaution: