# UNIT - IV -

## APPLICATION OF SPECIFIC ENERGY

[14 MARKS]

THEORIES :- 06 MARKS

NUMERICALS :- 08 MARKS

### THEORY :-

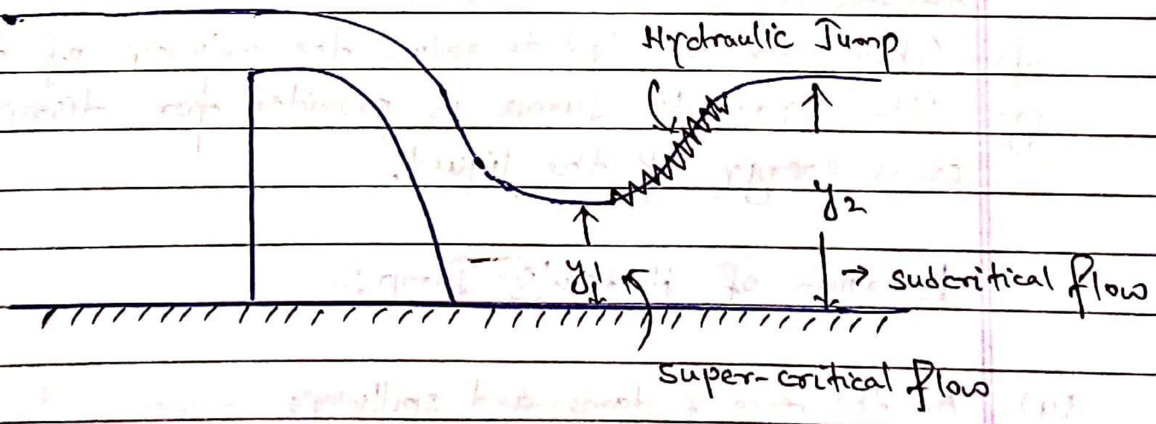
01. Explain hydraulic Jump.

[Compulsary]

ANS→ Hydraulic Jump :-

The hydraulic jump is defined as the sudden and turbulent passage of water from a supercritical state to subcritical state.

(Fig. Hydraulic Jump)




Types of hydraulic Jump :-

Based on froude number.

(a) Undular Jump
(b) Weak Jump
(c) Oscillating Jump
(d) Steady Jump
(e) Strong Jump

## Application of Hydraulic Jump :-

(a) It is a useful means of dissipating excess energy of water flowing over spillways and other hydraulic structures or through sluices and thus preventing possible erosion on the downstream side of these structures.

(b) It raises the water level in the channels for irrigation etc.

(c) It increases the weight on an apron of a hydraulic structure due to increased depth of flow and hence the uplift pressure acting on the apron is considerably counterbalanced.

(d) It increases the discharge through a sluice by holding back the tail water.

(e) It may be used for mixing chemicals in water and other liquids; since it facilitates thorough mixing due to turbulence created in it.

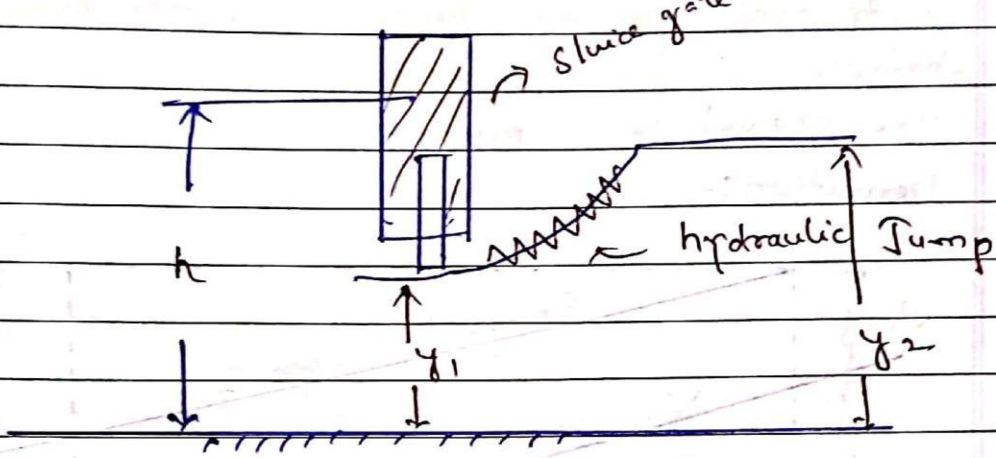
(f) They are provided to reduce the velocity of the flow.

(g) The hydraulic Jump is provided for dissipating the excess energy of the liquid.

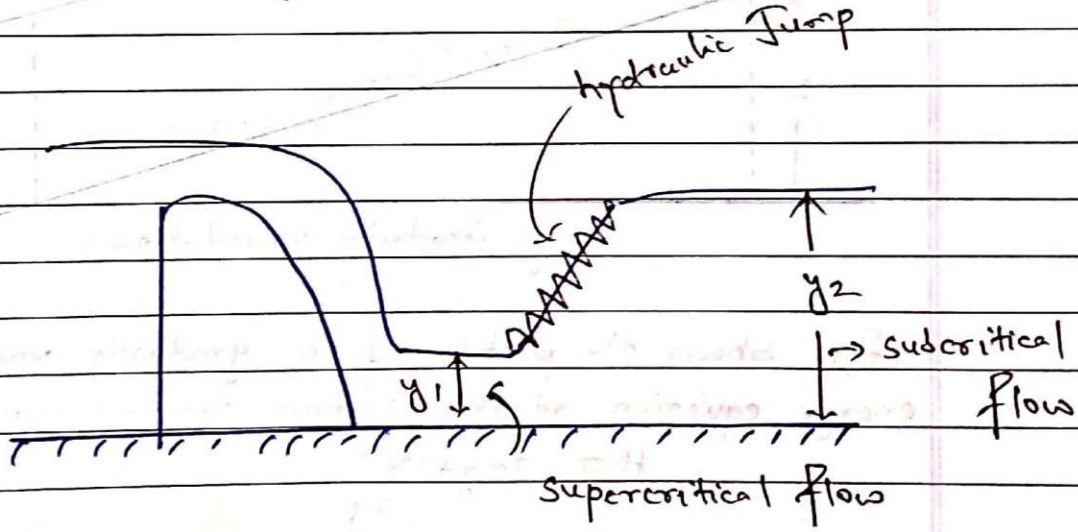
## Location of Hydraulic Jump :-

(a) At the foot of dams and spillways

(b) In the sluice gates




(c) when the slope of channel changes




02. State the assumptions and derive dynamic equation for gradually varied flow. (GVF)

(Compulsory)

ANS:- Assumptions :-

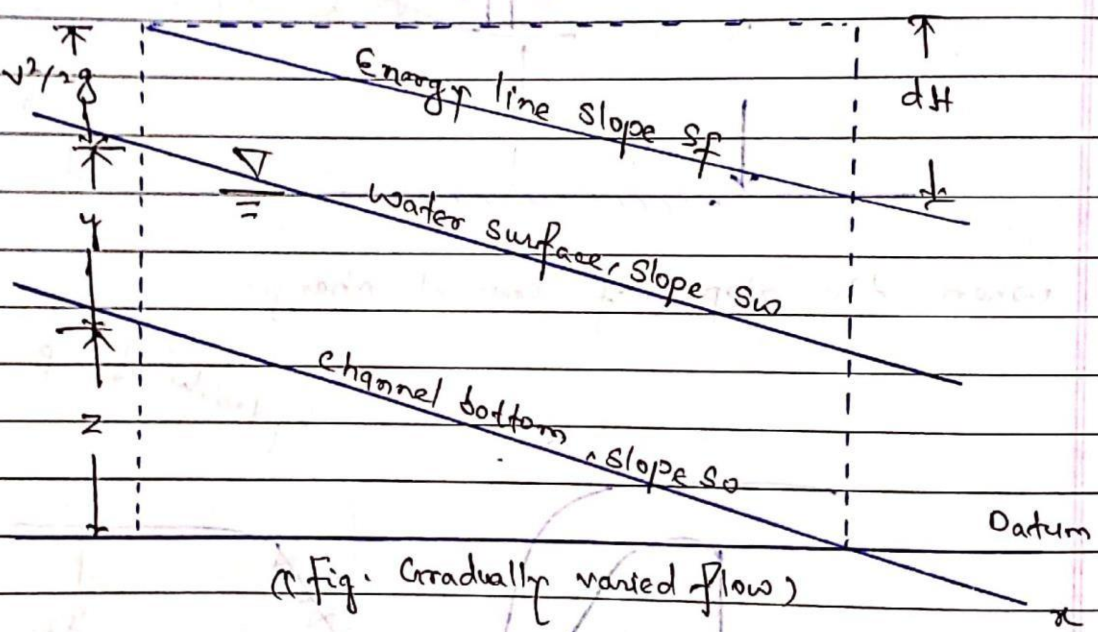
(a) The bed slope is very small.
(b) The flow is steady ; therefore discharge is continuous.
(c) Energy correction factor $\alpha$ is unity.

(d) Roughness coefficient is constant.

(e) Hydrostatic pressure prevails over the cross section of channel.

(f) The channel is prismatic.

Derivation :-




(Fig. Gradually varied flow)

Fig. shows the profile of a gradually varied flow. The energy equation at any section can be written as

$$H = z + y + \frac{V^2}{2g}$$

$$H = z + y + \frac{Q^2}{2gA^2} \quad \left(\because V = \frac{Q}{A}\right) \quad \text{----(iii)}$$

Now, taking the bed of the channel as x-axis and differentiation eqn (3) w.r.t x,

$$\frac{dH}{dx} = \frac{dz}{dx} + \frac{dy}{dx} + \frac{d}{dx}\left(\frac{Q^2}{2gA^2}\right) \quad \text{----(iv)}$$

but $\frac{dH}{dx}$ = slope of the channel bed $= -S_f$

$\frac{dz}{dx}$ = slope of the channel bed $= -S_o$

[Dynamic Eq$^n$ = $\frac{S_0 - S_f}{1 - Fr^2}$]

(The -ve sign for $S_f$ and $S_0$ indicates that both H and z decreases as x increases.)

and

$$\frac{d}{dx}\left(\frac{Q^2}{2gA^2}\right) = \frac{-Q^2}{gA^3}\left(\frac{dA}{dx}\right) = \frac{-Q^2}{gA^3}\left\{\frac{dA}{dy} \times \frac{dy}{dx}\right\}$$

But

$$\frac{dA}{dy} = T \text{ (top width)}$$

$$\therefore \frac{d}{dx}\left(\frac{Q^2}{2gA^2}\right) = \frac{-Q^2}{gA^3}(T)\frac{dy}{dx}$$

Substituting in eq$^n$ (iv)

$$-S_f = -S_0 + \left(\frac{dy}{dx}\right) - \frac{Q^2T}{gA^3}\left(\frac{dy}{dx}\right)$$

or $$\frac{dy}{dx} = \frac{S_0 - S_f}{1 - \frac{Q^2T}{gA^3}} \quad \text{------ (v)}$$

Also

$$\frac{Q^2T}{gA^3} = \frac{Q^2}{gA^2} \times \frac{1}{(A/T)} = \frac{v^2}{gD} = Fr^2$$

where, D = hydraulic depth

Hence, $$\frac{dy}{dx} = \frac{S_0 - S_f}{1 - Fr^2} \quad \text{------ (vi)}$$

Eq$^n$ (vi) and (v) is the differential equation for gradually varied flow. It is also known as dynamic equation for gradually varied flow or simply gradually varied flow (GVF) equations.

The equation 6 and 5 represents the slope of water surface with respect to the channel bottom as x-axis.

03. Explain the following GVF profiles :-
(a) M Slope (b) S slope (c) C Slope

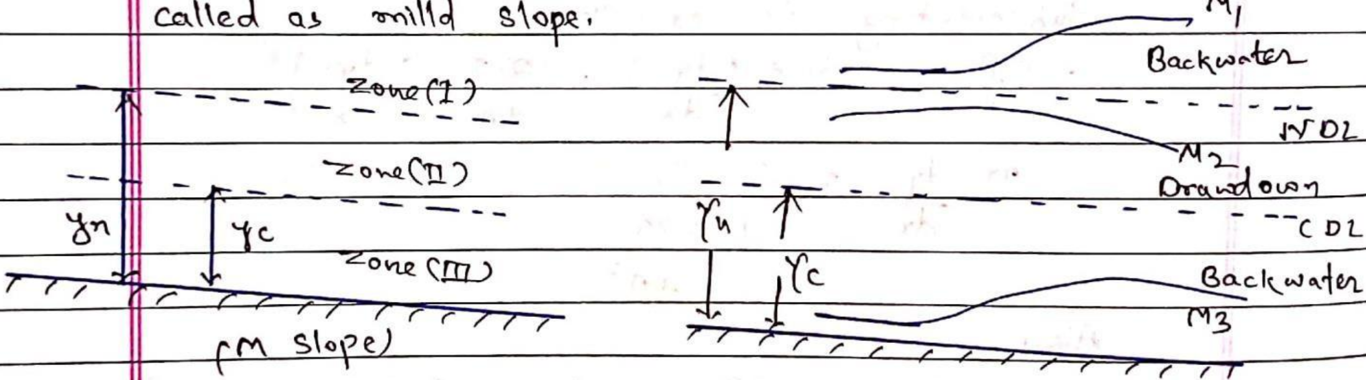
[ FUTURE ]

ANS→ (a) M Slope :- (Mild Slope)

The basic equation is

$$\frac{dy}{dx} = S_0 \frac{1 - \left(\frac{y_n}{y}\right)^N}{1 - \left(\frac{y_c}{y}\right)^M}$$

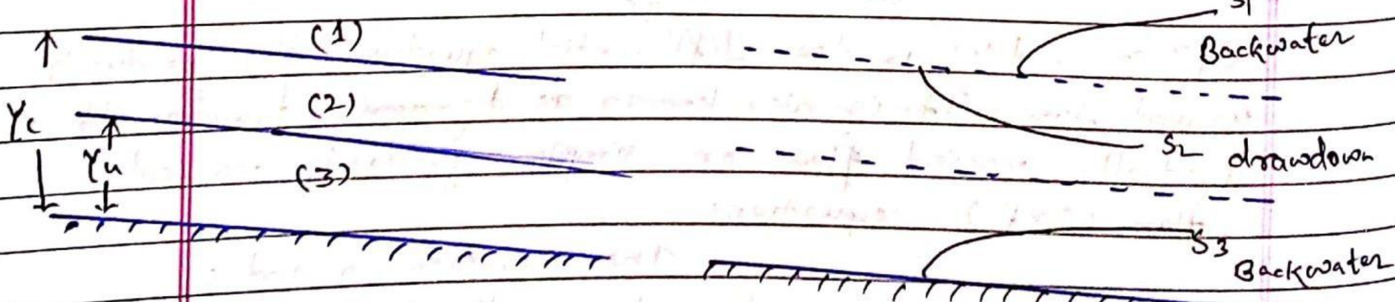
when normal depth ($y_n$) is more than critical depth ($y_c$) i.e $y_n > y_c$ subcritical flow then the slope is called as milld slope.




(M slope)

(b) S slope :- (Steep slope)

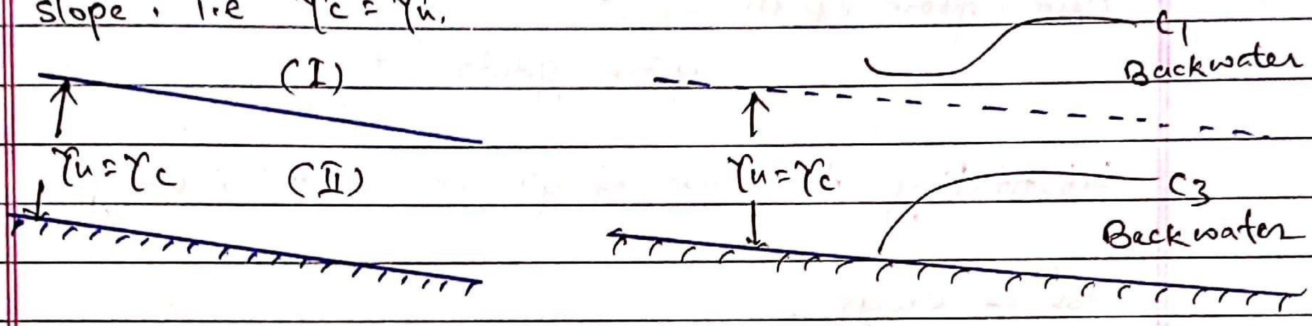
when $y_c > y_n$ → super critical flow condition then the slope is called steep slope. i.e $y_c > y_n$




(S slope)

(C) C Slope :- (Critical Slope)

when $y_c = y_n$ then the flow becomes critical flow and then the corresponding slope if called as critical slope. i.e $y_c = y_n$.




(C slope)

Q4. Derive the expression for energy loss in hydraulic jump in terms of sequent depth.

(Compulsary)

ANS→ Derivation :-

when hydraulic jump takes place, a loss of energy due to eddies formation and turbulence occurs. This loss of energy is equal to the difference of specific energies at sections 1-1 and 2-2

or loss of energy due to hydraulic jump

$$h_L = E_1 - E_2$$

$$= \left(d_1 + \frac{v_1^2}{2g}\right) - \left(d_2 + \frac{v_2^2}{2g}\right) \quad \left(\because E_1 = d_1 + \frac{v_1^2}{2g} \text{ and so } E_2\right)$$

$$= \left(\frac{v_1^2}{2g} - \frac{v_2^2}{2g}\right) - (d_2 - d_1)$$

$$= \left(\frac{q^2}{2gd_1^2} - \frac{q^2}{2gd_2^2}\right) - (d_2 - d_1)$$

$$\left(\because v_1 = \frac{q}{d_1} \text{ and } v_2 = \frac{q}{d_2}\right)$$

$$= \frac{q^2}{2g}\left[\frac{1}{d_1^2} - \frac{1}{d_2^2}\right] - [d_2 - d_1] = \frac{q^2}{2g}\left[\frac{d_2^2 - d_1^2}{d_1^2 d_2^2}\right] - [d_2 - d_1] \quad \text{---(i)}$$

But from eqn (i)

$$q^2 = g d_1 d_2 \frac{(d_2 + d_1)}{2}$$

Substituting the value of $q^2$ in eqn (i), we get

Loss of energy :

$$h_L = g d_1 d_2 \frac{(d_2+d_1)}{2} \times \frac{d_2^2 - d_1^2}{2g d_1^2 d_2^2} - (d_2 - d_1)$$

$$= \frac{(d_2+d_1)(d_2^2 - d_1^2)}{4 d_1 d_2} - (d_2 - d_1)$$

$$= \frac{(d_2+d_1)(d_2+d_1)(d_2-d_1)}{4 d_1 d_2} - (d_2 - d_1)$$

$$= (d_2 - d_1)\left[\frac{(d_2+d_1)^2}{4 d_1 d_2} - 1\right] \text{minus}$$

$$= (d_2 - d_1)\left[\frac{d_2^2 + d_1^2 + 2d_1 d_2 - 4 d_1 d_2}{4 d_1 d_2}\right]$$

$$= (d_2 - d_1)\frac{[d_2 - d_1]^3}{4 d_1 d_2}$$

$$\boxed{\therefore h_L = \frac{[d_2 - d_1]^3}{4 d_1 d_2}}$$

# NUMERICALS :-

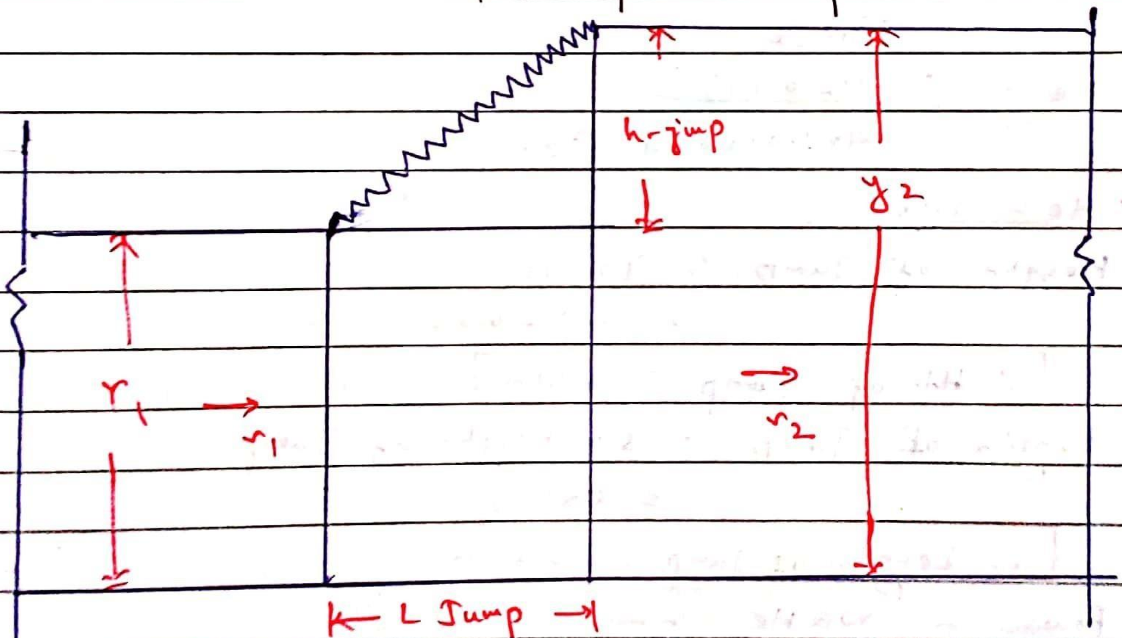
## TYPE - I - [Compulsory]

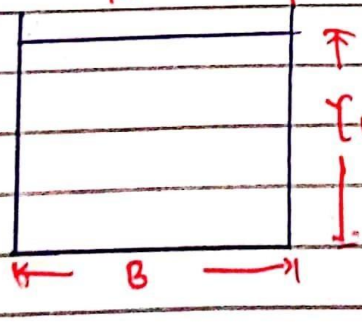
[Based on Hydraulic Jump] [7 MARKS]

Q1. A rectangular channel has to carry discharge of $12\ m^3/sec$ at velocity of $7\ m/sec$. Determine :

1. whether hydraulic jump will occur or not
2. Depth before and after jump
3. Head loss in jump
4. Height of Jump
5. Length of Jump
6. Power loss in Jump, if width of channel is 7m.

Sol$^n$ →




Given data

$B_{Jump} = 7m$

$Q = 12\ m^3/sec$

$V_1 = 7\ m/sec$

⟨1⟩ $Q = A_1 v_1$

$12 = B \times Y_1 \times v_1$

$12 = 7 \times Y_1 \times 7$

$\boxed{\therefore Y_1 = 0.24\ m}$

<2> $Fr_1 = \frac{V_1}{\sqrt{g y_1}} = \frac{7}{\sqrt{9.81 \times 0.24}}$

$\boxed{\therefore Fr_1 = 4.516 > 1}$

$\therefore$ Jump will occur

$\therefore$ flow is supercritical.

<3> $\frac{y_2}{y_1} = \frac{1}{2}\left[-1 + \sqrt{1 + 8 Fr_1^2}\right]$

$\frac{y_2}{0.24} = 0.5\left[-1 + \sqrt{1 + 8 \times (4.516)^2}\right]$

$\boxed{\therefore y_2 = 1.41 m}$

<4> $He = \frac{(y_2 - y_1)^3}{4 y_1 \times y_2}$

$He = \frac{(1.41 - 0.24)^3}{4 \times 1.41 \times 0.24}$

$\boxed{\therefore He = 1.18 m}$

<5> Height of Jump $= y_2 - y_1$

$= 1.41 - 0.24$

$\boxed{\therefore \text{Ht of Jump} = 1.17 m}$

<6> Length of Jump $= 5 \times$ height of Jump

$= 5 \times 1.17$

$\boxed{\therefore \text{Length of Jump} = 5.85 m}$

(7) Power $= \frac{wQHe}{1000}$ ... $w = \rho$

$P = \frac{9810 \times 12 \times 1.18}{1000}$

$\boxed{\therefore P = 138.90 kW}$

[He = head loss]



Q2. A rectangular channel 7m wide carries discharge of 14 m3/sec at velocity of 7m/sec. Determine whether jump will occur or not. Also find sequent depth and power loss in jump.

Soln → Given data,

$B = 7m$

$Q = 14\ m^3/sec$

$V_1 = 7\ m/sec$

(1) $Q = A_1 \times V_1$

$Q = B \times Y_1 \times V_1$

$14 = 7 \times Y_1 \times 7$

$\boxed{\therefore Y_1 = 0.285m}$

(2) $Fr_1 = \frac{V_1}{\sqrt{g Y_1}}$

$\Rightarrow Fr_1 = \frac{7}{\sqrt{9.81 \times 0.285}}$

$\boxed{\therefore Fr_1 = 4.186 > 1}$

Jump will occur

$\therefore$ Flow is supercritical.

(3) $\frac{Y_2}{Y_1} = \frac{1}{2}\left[-1 + \sqrt{1+8 Fr_1^2}\right]$

$\frac{Y_2}{0.285} = \frac{1}{2}\left[-1 + \sqrt{1+8 \times (4.186)^2}\right]$

$\boxed{\therefore Y_2 = 1.55m}$

(4) Height of Jump $= Y_2 - Y_1$

$= 1.55 - 0.285$

$\boxed{\therefore \text{Ht. of Jump} = 1.265m}$

(5) $He = \frac{(Y_2 - Y_1)^3}{4 \times Y_1 \times Y_2} = \frac{(1.55 - 0.285)^3}{4 \times 1.55 \times 0.285}$

$\therefore \boxed{He = 1.145 m}$

(6) Power, $P = \frac{wQHe}{1000}$ --- $w = \rho$

$P = \frac{9810 \times 14 \times 1.145}{1000}$

$\therefore \boxed{P = 156.56 KW}$

(7) Length of Pump = 4.5 × Height of Jump

= $4.5 \times 1.265$

$\boxed{\therefore \text{Length of Jump} = 5.69 m}$

Q3. A rectangular channel carrying super-critical flow is to be provided with hydraulic Jump. It is desired to have head loss = 4m. If the inlet Frouder's No. 8. Determine the sequent depth.

Soln→ Given data; $He = 4m$

$Fr_1 = 8$

To find : (a) $Y_2 = ?$

$he = \frac{(Y_2 - Y_1)^3}{4 \times Y_1 \times Y_2}$ ..... (i)

$\Rightarrow 4 = \frac{(Y_2 - Y_1)^3}{4 \times Y_1 \times Y_2}$

Now;

$\frac{Y_2}{Y_1} = \frac{1}{2}[-1 + \sqrt{1 + 8 \times Fr_1{}^2}]$

$\frac{Y_2}{Y_1} = \frac{1}{2}[-1 + \sqrt{1 + 8 \times 8^2}]$

$\frac{Y_2}{Y_1} = 10.824$

$Y_2 = 10.824 \times Y_1$ ..... (ii)

from eqⁿ (i), put $y_2 = 10.824 \times y_1$

$$He = \frac{(y_2 - y_1)^3}{4 \times y_1 \times y_2}$$

$$\Rightarrow 4 = \frac{(10.824 \times y_1 - y_1)^3}{4 \times y_1 \times 10.824 \times y_1}$$

$$\boxed{\therefore y_1 = 0.18\ m}$$

From eqⁿ (ii) put $y_1 = 0.18\ m$

$$y_2 = 10.824 \times y_1$$

$$\Rightarrow y_2 = 10.824 \times 0.18$$

$$\boxed{\therefore y_2 = 1.977\ m}$$

04. A hydraulic jump occurs in a rectangular channel with depth and after jump as 0.6 and 3.1 m. Det.

(a) Critical depth

(b) Head loss in Jump

(c) Power loss in Jump

Solⁿ → Given data, $y_1 = 0.6\ m$

$y_2 = 3.1\ m$

$$D_c \text{ or } y_c = \left[\frac{q^2}{g}\right]^{1/3}$$

(1) $$\frac{2q^2}{g} = y_1 \times y_2 (y_1 + y_2)$$

$$\frac{2 \times q^2}{9.81} = 0.6 \times 3.1 (0.6 + 3.1)$$

$$\boxed{\therefore q = 5.81\ m^3/sec/m}$$

(2) $$y_c = \left[\frac{q^2}{g}\right]^{1/3} = \left[\frac{5.81^2}{9.81}\right]^{\frac{1}{3}}$$

$$\boxed{\therefore y_c = 1.50\ m}$$

(3) $He = \frac{(y_2 - y_1)^3}{4 \times y_1 \times y_2}$

$He = \frac{(3.1 - 0.6)^3}{4 \times 3.1 \times 0.6}$

$\boxed{\therefore He = 2.1 m}$

(4) $P = \frac{w Q He}{1000}$ -- If Q is not given, then calculate power loss per m width

$P = \frac{9810 \times 5.81 \times 2.1}{1000}$

$\boxed{\therefore P = 119.69 \ kw/m.}$

05. A rectangular channel 5m wide carries discharge of 15 m³/sec at velocity of 10m/sec. If hydraulic Jump occurs determine,

(a) Sequent depth

(b) Energy loss in Jump

(c) Power loss in Jump

Solⁿ→ Given data, $B = 5m$

$Q = 15 m^3/sec$

$v_1 = 10 m/sec$

(a) $Q = A_1 \times v_1$

$Q = B \times y_1 \times v_1$

$\Rightarrow 15 = 5 \times y_1 \times 10$

$\boxed{\therefore y_1 = 0.3 m}$

(b) $fr_1 = \frac{v_1}{\sqrt{g y_1}}$

$= \frac{10}{\sqrt{9.81 \times 0.3}}$

$\boxed{\therefore fr_1 = 5.8371}$

Jump will occur.

∴ Flow is supercritical flow.

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

$\frac{y_2}{0.3} = \frac{1}{2}\left[-1 + \sqrt{1+8 \times 5.83^2}\right]$

$\boxed{\therefore y_2 = 2.32\,m}$

(d) $H_e = \frac{(y_2 - y_1)^3}{4 \times y_1 \times y_2}$

$\therefore H_e = \frac{(2.32 - 0.3)^3}{4 \times 2.32 \times 0.3}$

$\boxed{\therefore H_e = 2.96\,m}$

(e) Power, $P = \frac{w Q H_e}{1000}$

$P = \frac{9810 \times 15 \times 2.96}{1000}$

$\boxed{\therefore P = 435.65\,KW}$

S/2016

06. A hydraulic jump takes place in a rectangular channel with of initial and sequent depths of 0.6m and 2.4m respectively. Determine

(i) The discharge per meter width

(ii) The possible critical depth for this discharge

(iii) Energy loss in the jump.

Solⁿ, Given data,

$y_1 = 0.6\,m$

$y_2 = 2.4\,m$

$y_c = \left[\frac{q^2}{g}\right]^{1/3}$

(i) $\frac{2q^2}{g} = y_1 \times y_2 (y_1 + y_2)$

$\frac{2 \times q^2}{9.81} = 0.6 \times 3.1 (0.6 + 3.1)$

$\boxed{\therefore q = \cancel{4.800}\ m^3/sec/m}$ $\therefore q = 4.603\ m^3/sec/m$

(ii) $y_c = \left[\frac{q^2}{g}\right]^{1/3}$

$y_c = \left[\frac{\cancel{5.810}\ 4.603^2}{9.81}\right]^{1/3}$

$\boxed{\therefore y_c = \cancel{0.839\,m}}$ $1.292\ m$

(iii) $H_e = \frac{(y_2 - y_1)^3}{4 \times y_1 \times y_2}$

$H_e = \frac{(2.4 - 0.6)^3}{4 \times 2.4 \times 0.6}$

$\boxed{\therefore H_e = 1.0125\ m}$

W 2016 07. A hydraulic jump is formed in rectangular channel with super critical flow velocity 12 m/sec and ratio of sequent depth is 11.5. Determine

(a) Depth of Jump
(b) Intial froude number
(c) Head loss
(d) Energy loss as % of initial.

Sol$^n$ → Given data ; $\frac{y_2}{y_1} = 11.5$

$V_1 = 12\ m/s$

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

$\Rightarrow 11.5 = \frac{1}{2}\left[-1 + \sqrt{1 + 8 Fr_1^2}\right]$

$$\boxed{\therefore Fr_1 = 8.477 > 1}$$

$\therefore$ Jump will occur.

Therefore flow is supercritical flow.

(b) $Fr_1 = \dfrac{v_1}{\sqrt{g y_1}}$

$\Rightarrow 8.477 = \dfrac{12}{\sqrt{9.81 \times y_1}}$

$$\boxed{\therefore y_1 = 0.205 m}$$

(c) $\dfrac{y_2}{y_1} = 11.5$

$y_2 = 11.5 \times y_1$

$y_2 = 11.5 \times 0.205$

$$\boxed{\therefore y_2 = 2.35 m}$$

(d) $He = \dfrac{(y_2 - y_1)^3}{4 \times y_1 \times y_2}$

$He = \dfrac{(2.35 - 0.205)^3}{4 \times 2.35 \times 0.205}$

$$\boxed{\therefore He = 5.121 m}$$

(e) Energy loss as % of initial.

$E = y_1 + \dfrac{v^2}{2g}$

$E = 0.205 + \dfrac{12^2}{2 \times 9.81}$

$\therefore E = 7.54 m$

$$\boxed{\therefore \frac{5.121}{7.54} \times 100 = 67.91\%}$$

$\therefore$ Energy loss as (%) of initial energy = 67.91%

W 2015 08. In a rectangular channel of 0.8m width, a hydraulic Jump occur at a point where the depth of water flow is 0.18 m and froude number is 2.5. Calculate

(i) Specific energy
(ii) The critical and subsequent depths
(iii) Loss of head
(iv) Energy dissipated.

Soln Given data:

$$F_{R1} = 2.5$$

$$Y_1 = 0.18 \text{ m}$$

$$B = 0.8 \text{ m}$$

(i) $E = Y_1 + \frac{v_1^2}{2g}$

But $\cancel{v_1 = \frac{Q}{A g}}$ ..... $Q = Av$

$\cancel{v_1 = \frac{Q}{2\times 9.81}}$ ..... (i)

(ii) $F_{r1} = \frac{v_1}{\sqrt{g \times Y_1}}$

$\Rightarrow 2.5 = \frac{v_1}{\sqrt{9.81 \times 0.18}}$

$$\boxed{\therefore v_1 = 3.32 \text{ m/sec}}$$

(iii) $E = Y_1 + \frac{v_1^2}{2g}$

$E = 0.18 + \frac{(3.32)^2}{2\times 9.81}$

$$\boxed{\therefore E = 0.741 \text{ m}}$$

$Q = Av$

$Q = B \times Y_1 \times v_1$

$$\boxed{Q = 0.8 \times 0.18 \times 3.32}$$

$\therefore Q = 0.478 \ m^3/sec$

(iv) $\dfrac{y_2}{y_1} = \dfrac{1}{2}\left[-1+\sqrt{1+8 Fr_1^2}\right]$

$\Rightarrow \dfrac{y_2}{0.18} = \dfrac{1}{2}\left[-1+\sqrt{1+8\times(2.5)^2}\right]$

$\boxed{\therefore y_2 = 0.552 \ m}$

(v) $\dfrac{2q^2}{g} = y_1 \times y_2 (y_1+y_2)$

$\dfrac{2\times q^2}{9.81} = 0.552\times 0.18 \,(0.18+0.552)$

$\boxed{\therefore q = 0.597 \ m^3/sec/m}$

(vi) $y_c = \left[\dfrac{q^2}{g}\right]^{1/3}$

$y_c = \left[\dfrac{0.597^2}{9.81}\right]^{1/3}$

$\boxed{\therefore y_c = 0.331 \ m}$

(vii) $H_e = \dfrac{(y_2-y_1)^3}{4\times y_1 \times y_2}$

$H_e = \dfrac{(0.552-0.18)^3}{4\times 0.552\times 0.18}$

$\boxed{\therefore H_e = 0.1295 \ m}$

S 2015 Q9. A rectangular channel carrying a supercritical flow is to be provided with a hydraulic jump type of energy dissipater. It is desired to have an energy loss of 4m in jump. What should be the sequent depths, if the inlet Froude Number is 7?

Sol$^n$ Given data,

$$H_e = 4m$$

$$F_{r_1} = 7$$

To find :- Sequent Depth ($y_1$ & $y_2$) = ?

$$H_e = \frac{(y_2 - y_1)^3}{4 \times y_1 \times y_2} \quad \text{---} \quad (i)$$

$$\Rightarrow 4 = \frac{(y_2 - y_1)^3}{4 \times y_1 \times y_2}$$

Now;

$$\frac{y_2}{y_1} = \frac{1}{2}\left[-1 + \sqrt{1 + 8 \times F_{r_1}^2}\right]$$

$$\frac{y_2}{y_1} = \frac{1}{2}\left[-1 + \sqrt{1 + 8 \times 7^2}\right]$$

$$\frac{y_2}{y_1} = 9.412$$

$$\therefore y_2 = 9.412 \times y_1 \quad \text{---} \quad (ii)$$

Put $y_2 = 9.412 \times y_1$ in eq$^n$ (i),

$$\Rightarrow 4 = \frac{(9.412 \times y_1 - y_1)^3}{4 \times y_1 \times 9.412 \times y_1}$$

$$\boxed{\therefore y_1 = 0.252 \ m}$$

Put $y_1 = 0.252$ in eq$^n$ (ii), we get

$$y_2 = 9.412 \times y_1$$

$$y_2 = 9.412 \times 0.252$$

$$\boxed{\therefore y_2 = 2.38 \ m}$$

Hence,

Sequent depths are $y_1 = 0.252 \ m$

and $y_2 = 2.38 \ m$.

2014 10. In a horizontal rectangular channel a hydraulic jump occurs and the depth of flow before and after the jump is observed to be 0.5 m and 2 m respectively. Determine the intensity of discharge and critical depth of flow.

Soln→ Given data; $y_1 = 0.5 m$

$y_2 = 2 m$

To find :- (a) $q = ?$

(b) $y_c = ?$

$$y_c = \left[\frac{q^2}{g}\right]^{1/3}$$

$$\frac{2q^2}{g} = y_1 \times y_2 \times (y_1 + y_2)$$

$$\frac{2 \times q^2}{9.81} = 0.5 \times 2 \times (0.5 + 2)$$

$$\boxed{\therefore q = 3.501 \ m^3/sec/m}$$

Now;

$$y_c = \left[\frac{q^2}{g}\right]^{1/3}$$

$$y_c = \left[\frac{3.501^2}{9.81}\right]^{1/3}$$

$$\boxed{\therefore y_c = 1.0770 m}$$

11. A hydraulic Jump occuring in a rectangular channel if the frouder's number before Jump was 10.2. Determine frouders number after Jump and sequent depth also.

Soln→ Given data;

$Fr_1 = 10.2$

To find: (a) $Fr_2 = ?$

(b) $y_1, y_2 = ?$

$$\frac{Y_1}{Y_2} = \frac{1}{2}\left[-1+\sqrt{1+8\,Fr_2^2}\right]$$

$$\frac{Y_2}{Y_1} = \frac{1}{2}\left[-1+\sqrt{1+8\,Fr_1^2}\right]$$

Multiplying Both equations;

$$1 = \frac{1}{4}\left[-1+\sqrt{1+8\,Fr_2^2}\right]\left[-1+\sqrt{1+8\,FR_1^2}\right]$$

$$4 = \frac{1}{4}\left[-1+\sqrt{1+8\,Fr_2^2}\right]\left[-1+\sqrt{1+8\times10.2^2}\right]$$

$$1.1435 = \sqrt{1+8\,Fr_2^2}$$

$$\boxed{\therefore Fr_2 = 0.196}$$

$$\frac{Y_2}{Y_1} = \frac{1}{2}\left[-1+\sqrt{8\,Fr_1^2}\right]$$

$$\boxed{\therefore \frac{Y_2}{Y_1} = 13.93}$$

# UNIT-V-

## HYDRAULIC MODELS

[13 MARKS]

THEORIES :- 06 Marks
NUMERICALS :- 07 Marks

THEORY →

01. Explain.
(a) froude model law.
(b) Reynold's model law.
} model laws or similarity laws

[Compulsary]

ANS→ (a) froude model law:-

Froude model law is the law in which the models are based on froude number which means for dynamic similarity between the model and prototype, the froude number for both of them should be equal.

Froude model law is applied in the following fluid flow problems:-

(a) free surface flows such as flow over spillways, weirs, sluices, channels etc.
(b) flow of jet from an orifice or nozzle.
(c) where waves are likely to be formed on surface.
(d) where fluids of different densities flow over one another.

Let $V_m$ = velocity of fluid in model
$L_m$ = Linear dimension or Length of model
$g_m$ = Acceleration due to gravity
and $V_p$, $L_p$ and $g_p$ are the corresponding values of the velocity, Length and acceleration due to gravity

for the prototype.
According to froude model law,

$$\therefore (\frac{v}{\sqrt{gL}})_{model} = (\frac{v}{\sqrt{gL}})_{prototype} \text{ or } \frac{V_m}{\sqrt{g_m L_m}} = \frac{V_p}{\sqrt{g_p L_p}}$$

(b) Reynold's law :-

Reynold's model law is the law in which models are based on Reynold's number. Models based on Reynold's number includes!

(i) pipe flow

(ii) Resistance experienced by sub-marines, airplanes, fully immersed bodies etc.

the models are designed for dynamic similarity on Reynolds law, which states that the Reynold number for the model must be equal to the Reynold number for the prototype.

Let $V_m$ = velocity of fluid in model,
$\rho_m$ = Density of fluid in model,
$L_m$ = Length or Linear dimension of the model
$\mu_m$ = Viscosity or fluid in model.

and $V_p$, $\rho_p$, $L_p$ and $\mu_p$ are the corresponding values of velocity, density, Linear dimension and viscosity of fluid in prototype.

According to Reynold's model law,

$$\therefore [Re]_m = [Re]_p \text{ or } \frac{\rho_m V_m L_m}{\mu_m} = \frac{\rho_p V_p L_p}{\mu_p}$$

Q2. What do you mean by similitude and what are the different types of similarities that must exist between a model and a prototype?

[Semi-compulsary]

ANS-> Similitude :-

Similitude is defined as the similarity between the model and its prototype in every respect which means that the model and prototype have similar properties or model and prototype are completely similar.

Types of Similarities :-

Three types of similarities must exist between the model and prototype.

They are

(a) Geometric Similarity
(b) Kinematic Similarity and
(c) Dynamic Similarity

(a) Geometric Similarity :-

The geometric similarity is said to exist between the model and the prototype. The ratio of all corresponding linear dimension in the model and prototype are equal.

Let $L_m$ = Length of model
$b_m$ = breadth of model
$D_m$ = diameter of model
$A_m$ = area of model
$V_m$ = volume of model

and $L_p, B_p, D_p, A_p, V_p$ = corresponding values of the prototype.

For geometric similarity,

$$\boxed{\therefore \frac{L_p}{L_m} = \frac{b_p}{b_m} = \frac{D_p}{D_m} = L_r}$$

Where; $L_r$ = scale ratio

(b) Kinematic Similarity :-

Kinematic similarity means the similarity of motion between model and prototype.

Let

$V_{p_1}$ = Velocity of fluid at point 1 in prototype

$V_{p_2}$ = Velocity of fluid at point 2 in prototype

$a_{p_1}$ = Acceleration of fluid at 1 in prototype

$a_{p_2}$ = Acceleration of fluid at 2 in prototype

and $V_{m_1}$, $V_{m_2}$, $a_{m_1}$, $a_{m_2}$ = corresponding values at the corresponding points of fluid velocity and acceleration in the model.

For kinematic Similarity,

$$\boxed{\therefore \frac{V_{p_1}}{V_{m_1}} = \frac{V_{p_2}}{V_{m_2}} = V_r}$$

Where; $V_r$ = velocity ratio

(c) Dynamic Similarity :-

Dynamic similarity means the similarity of forces between the model and prototype.

Let $(F_i)_p$ = Intertia force at a point in prototype

$(F_v)_p$ = Viscous force at the point in prototype

$(F_g)_p$ = Gravity force at the point in prototype

and $(F_i)_m$, $(F_v)_m$, $(F_g)_m$ = Corresponding values of forces at the corresponding point in model.

For dynamic Similarity,

$$\boxed{\therefore \frac{(F_i)_p}{(F_i)_m} = \frac{(F_v)_p}{(F_v)_m} = \frac{(F_g)_p}{(F_g)_m} = F_r}$$

where $F_r$ = force ratio

Q3. What do you mean by undistorted models and distorted models? OR Classification of models.
[Semi-compulsory]

Ans→ (a) Undistorted models :-

Undistorted models are those models which are geometrically similar to their prototypes or in other words if the scale ratio for the linear dimensions of the model and its prototype is same ; the model is called undistorted model.

(b) Distorted models :-

A model is said to be distorted if it is not geometrically similar to its prototype.

The following are some of the reasons for adopting distorted models:-

(a) To maintain accuracy in vertical measurements.
(b) To maintain turbulent flow.
(c) To obtain suitable roughness condition.
(d) To obtain suitable bed material.

For a distored model different scale ratios for the linear dimension are adopted.

## NUMERICALS:-

TYPE-I- [Compulsary]

[Based on prototype, Drain] [7 Marks]

or

[Based on velocity and discharge in the Prototype]

S/2005 Q1. The velocity and discharge in 1:40 model of a spillway are 2.8 m/sec and 3.2 m³/sec. Find the corresponding velocity and discharge in the prototype.

Soln→ Given data,

$V_m = 2.8$ m/sec

$Q_m = 3.2$ m³/sec

$L_r = 40$

To find:- (a) velocity of prototype ($V_p$) = ?

(b) Discharge of prototype ($Q_p$) = ?

velocity of prototype,

$$\frac{V_p}{V_m} = \sqrt{L_r}$$

$$\frac{V_p}{2.8} = \sqrt{40}$$

$$\boxed{\therefore V_p = 17.70 \text{ m/sec}}$$

Discharge of prototype

$$\frac{Q_p}{Q_m} = L_r^{2.5}$$

$$\frac{Q_p}{3.2} = 40^{2.5}$$

$$Q_p = 32.38 \times 10^3 \text{ m}^3\text{/sec}$$

$$\boxed{\therefore Q_p = 32.38 \times 10^3 \text{ m}^3\text{/sec}}$$

S/2004 02. In 1:30 model of spillway, the velocity and discharge are 1.5 m/sec and 20 m3/sec. find the corresponding velocity and discharge in the prototype.

Soln Given data,

$V_m = 1.5$ m/sec

$Q_m = 20 \, m^3/sec$

$L_r = 30$

To find:- (a) $V_p = ?$

(b) $Q_p = ?$

$$\frac{V_p}{V_m} = \sqrt{L_r}$$

$$\frac{V_p}{1.5} = \sqrt{30}$$

$$\boxed{\therefore V_p = 8.215 \text{ m/sec}}$$

$$\frac{Q_p}{Q_m} = L_r^{2.5}$$

$$\frac{Q_p}{20} = 30^{2.5}$$

$$\boxed{\therefore Q_p = 98.590 \times 10^3 \; m^3/sec}$$

S/2006 03. A 1:50 spillway model has a discharge of 125 m3/s. What is the corresponding prototype discharge? If a flood phenomenon takes 12 hours to occurs in the prototype how long should it take in the model?

Soln→ Given data,

$L_r = 50$ $\quad t_p = 12$ hours

$Q_m = 125 \, m^3/sec$

To find :- (a) $Q_p = ?$

(b) $t_m = ?$

$$\frac{Q_{p}}{Q_{pm}} = L_r^{2.5}$$

$$\frac{Q_{p}}{Q_{p}\,125} = 50^{2.5}$$

$$\boxed{\therefore Q_p = 2.209 \times 10^6 \ m^3/sec}$$

$$\cancel{\frac{t_p}{t_m} = \sqrt{L_r}}$$

$$\cancel{\frac{12 \text{ hours}}{t_m} = \sqrt{50}}$$

$$\boxed{\therefore t_m = 1.656 \times 10^{-4} \ Sec}$$

$$\frac{t_m}{t_p} = \sqrt{L_r}$$

$$\Rightarrow \frac{t_m}{12} = \sqrt{50}$$

$$\therefore t_m = 305.470 \times 10^3 \ sec$$

W/2007, S/2009, S/2013 04. In 1:40 model of spillway, the velocity and discharge are 1.6 m/sec and 22 m3/sec. Find the corresponding velocity and discharge in the prototype.

Sol^n → Given data :

$L_r = 40$

$v_m = 1.6$ m/sec

$Q_m = 22$ m3/sec

To find :- (a) $v_p = ?$

(b) $Q_p = ?$

$$\frac{v_p}{v_m} = \sqrt{L_r}$$

$$\frac{v_p}{1.6} = \sqrt{40}$$

$$\boxed{\therefore v_p = 10.119 \ m/sec}$$

$$\frac{Q_p}{Q_m} = L_r^{2.5}$$

$$\frac{Q_p}{22} = 40^{2.5}$$

$$\boxed{\therefore Q_p = 222.624 \times 10^3 \ m^3/sec}$$

05. In the model test of a spillway the discharge and velocity of flow over the model were 2 m3/s and 1.5 m/s respectively. Calculate the velocity and discharge over the prototype which is 36 times the model size.

Soln → Given data, : $Q_m = 2 \ m^3/sec$

$Q_m = 2 \ m^3/sec$

$V_m = 1.5 \ m/sec$

$L_r = 36$

To find :- (a) $V_p = ?$

(b) $Q_p = ?$

$$\frac{V_p}{V_m} = \sqrt{L_r}$$

$$\frac{V_p}{1.5} = \sqrt{36}$$

$$\boxed{\therefore V_p = 9 \ m/sec}$$

$$\frac{Q_p}{Q_m} = L_r^{2.5}$$

$$\frac{Q_p}{2} = 36^{2.5}$$

$$\boxed{\therefore Q_p = 15552 \ m^3/sec}$$

# TYPE-II [Compulsary]

## [Based on Model Dimension of Spillway] [6 MARKS]

W 2008

01. A 7.2 m high and 15 m long spillway discharge 94 m³/sec under a head at 2 m. It 1:9 scale model of the spillway is to be constructed. Find the model dimension head over the model and model discharge. If model experiences a force of 7500 N (764.53 kgf); deto force on the prototype.

Sol$^n$ → Given data,

$L_r = 9$ , $Q_p = 94\ m^3/sec$

$L_p = 15\ m$

$H_p = 7.2\ m$

$h_p = 2\ m$

To find :- (a) $h_m$ and $L_m = ?$ (c) $F_p = ?$

(b) $Q_m = ?$

(i)
$$\frac{H_p}{H_m} = \frac{L_p}{L_m} = L_r$$

$$\frac{H_p}{H_m} = L_r$$

$$\frac{7.2}{H_m} = 9$$

$$\boxed{\therefore H_m = 0.8\ m}$$

$$\frac{L_p}{L_m} = L_r$$

$$\frac{15}{L_m} = 9$$

$$\boxed{\therefore L_m = 1.67\ m}$$

(ii) Head over the model ($h_m$)

$$\frac{h_p}{h_m} = L_r$$

$$\frac{2}{h_m} = 9$$

$\boxed{\therefore h_m = 0.22 m}$

(iii) $\frac{Q_p}{Q_m} = L_r^{2.5}$

$\frac{Q_p}{Q_m} = 9^{2.5}$

$\frac{94}{Q_m} = 9^{2.5}$

$\boxed{\therefore Q_m = 0.387 \, m^3/sec}$

(iv) force on the prototype

$F_R = \frac{F_p}{F_m} = L_r^3$

$\frac{F_p}{F_m} = L_r^3$

$\frac{F_p}{7500} = 9^3$

$\boxed{\therefore F_p = 5467500 \, N.}$

W 2016

02. A spillway 8m high and 14m long discharges 90m3/sec, water under a head of 3.0m. If a 1:20 scale model of thin spillway is constructed. Find the model dimensions, head over the model and the model discharge.

Soln → Given data, $H_p = 8m$

$L_p = 14m$

$Q_p = 90 m^3/sec$

$h_p = 3.0 m$

$L_r = 20$

To Find :- (a) $H_m, L_m = ?$

(b) $h_m = ?$

(c) $Q_m = ?$

$$\frac{H_p}{H_m} = \frac{L_p}{L_m} = L_r$$

$$\frac{H_p}{H_m} = L_r$$

$$\Rightarrow \frac{8}{H_m} = 20$$

$$\boxed{\therefore H_m = 0.4 m}$$

$$\frac{L_p}{L_m} = 20$$

$$\frac{14}{L_m} = 20$$

$$\boxed{\therefore L_m = 0.7 m}$$

$$\frac{h_p}{h_m} = L_r$$

$$\frac{3.0}{h_m} = 20$$

$$\boxed{\therefore h_m = 0.15}$$

$$\frac{Q_p}{Q_m} = L_R^{2.5}$$

$$\frac{Q_p}{90} = 20^{2.5}$$

$$\cancel{\therefore Q_p = 19.876\ m^3/sec}$$

$$\Rightarrow \frac{90}{Q_m} = 20^{2.5}$$

$$\boxed{\therefore Q_m = 0.050\ m^3/sec}$$

S/2011 03. A spillway 7m high and 15m long discharge 90 m³/sec water under a head of 2.5m. If a 1:10 scale model of this spillway is constructed, find the model dimensions, head over the model and the model discharge.

Sol$^n$ → Given data: $H_p = 7m$

$L_p = 15m$

$Q_p = 90\ m^3/sec$

$h_p = 2.5m$

$L_r = 10$

To find :- (a) $H_m, L_m = ?$

(b) $h_m = ?$

(c) $Q_m = ?$

$$\frac{H_p}{H_m} = \frac{L_p}{L_m} = L_r$$

$$\frac{H_p}{H_m} = L_r$$

$$\Rightarrow \frac{7}{H_m} = 10$$

$$\boxed{\therefore H_m = 0.7m}$$

$$\frac{L_p}{L_m} = L_r$$

$$\frac{15}{L_m} = 10$$

$$\boxed{\therefore L_m = 1.5m}$$

$$\frac{h_p}{h_m} = L_r$$

$$\Rightarrow \frac{2.5}{h_m} = 10$$

$$\boxed{\therefore h_m = 0.25m}$$

$$\frac{Q_p}{Q_m} = L_r^{2.5}$$

$$\frac{90}{Q_m} = 10^{2.5}$$

$$\boxed{\therefore Q_m = 0.284\ m^3/sec}$$

## TYPE-III (Compulsory)

[Based on Prototype roughness coefficient] [7 MARKS]

W/2014 Q1. A model of an open channel to the scale of 1/100, If the model has mannings $n = 0.013$, to what value of prototype roughess coefficient would these corresponds.

Solⁿ→ Given data:

$L_r = 100$

$n_m = 0.013$

To find:- (a) $n_p = ?$

$$\frac{n_m}{n_p} = L_r^{1/6}$$

$$\Rightarrow \frac{0.013}{n_p} = 100^{1/6}$$

$$\boxed{\therefore n_p = 6.0340 \times 10^{-3}}$$

W/2015 Q2. A model of an open channel is built to a scale of 1/100 If the model considering roughness coefficient 0.015, to what valve of prototype roughness coefficient would this corresponds?

Solⁿ→ Given data:

$L_r = 100$

$n_m = 0.015$

To find (a) $n_p = ?$

$$\frac{n_m}{n_p} = L_r^{1/6}$$

$$\frac{0.015}{n_p} = 100^{1/6}$$

$$\boxed{\therefore n_p = 6.9623 \times 10^{-3}}$$

# TYPE - IV [Compulsary]

[Based on wave resistance of Prototype] [7 MARKS]

Q1. A ship model of scale $\frac{1}{50}$ is towed through sea water at a speed of 1 m/sec, a force of 2N is subjected to the model. Determine the speed of the ship and propolsive force on the ship. if prototype is subjected to wave resistance only.

Sol$^n$ Given data,

$L_r = 50$

$V_m = 1 m/sec$

$F_m = 2N$

To find :- (a) $V_p = ?$

(b) $F_p = ?$

(i) $\frac{V_p}{V_m} = \sqrt{L_r}$

$\frac{V_p}{1} = \sqrt{50}$

$\boxed{\therefore V_p = 7.07 \ m/sec}$

(ii) $\frac{F_p}{F_m} = L_r^3$

$\frac{F_p}{2} = 50^3$

$\boxed{\therefore F_p = 250000 N.}$

# TYPE-V (Compulsary)

[Based on time will be required to drain the prototype]

[7 MARKS]

S/2016 01. A model of reservoir is completely drained in 5 minutes by mean of a sluice gate. If the model is built to a scale of 1:400, what time will be required to drain the prototype.

Soln → Given data; $L_r = 400$

$t_m = 5\,min$

To find :- (a) $t_p$

$\frac{t_p}{t_m} = \sqrt{L_r}$ ~~$\frac{t_m}{t_p}$~~

$\Rightarrow \frac{t_p}{5\times 60} = \sqrt{400}$ $\Rightarrow$ ~~$t_p = \frac{5\times 60}{\sqrt{400}}$~~

$\boxed{\therefore t_p = \cancel{6000\,sec}}$ 6000 sec

W/2011 02. A 1:1000 model is experimented satisfying froude's law. what internal of time in the model represents on day in the prototyp?

Soln → Given data; $L_r = 1000$

$t_p = 1\,day$

To find :- $t_m = ?$

~~$\frac{t_m}{t_p} = \sqrt{L_r}$~~ $\frac{t_p}{t_m} = \sqrt{L_r} \Rightarrow \frac{1\times 24\times 60\times 60}{t_m} = \sqrt{1000}$

~~$\Rightarrow \frac{t_m}{1\,day} = \sqrt{1000}$ $\therefore t_m = \sqrt{1000}\times 1\times 24\times 60\times 60$~~

$t_m = 2.732\times 10^{6}$ Sec

$\boxed{\therefore t_m = \cancel{2.732\times 10^{6}\,Sec}}$

# PRACTICES :-

01. In 1 in 40 models of a spillway, the velocity and discharge are 2 m/s and 2.5 m3/sec. find the corresponding velocity and discharge in the prototype.

Sol^n → Given data,

$$L_r = 40$$

$$V_m = 2 m/s$$

$$Q_m = 2.5 m^3/sec$$

To find :- (a) $V_p = ?$

(b) $Q_p = ?$

$$\frac{V_p}{V_m} = \sqrt{L_r}$$

$$\Rightarrow \frac{V_p}{2} = \sqrt{40}$$

$$\boxed{\therefore V_p = 12.649 \ m/sec}$$

$$\frac{Q_p}{Q_m} = L_r^{2.5}$$

$$\Rightarrow \frac{Q_p}{2.5} = 40^{2.5}$$

$$\boxed{\therefore Q_p = 25298.221 \ m^3/sec}$$

02. In the model test of a spillway the discharge and velocity of flow over the model were 2 m3/sec and 1.5 m/s respectively. Calculate the velocity and discharge over the prototype which is 36 times the model size.

Sol^n → Given data, $V_m = 1.5 m/s$

$$Q_m = 2 m^3/s$$

$$L_r = 36$$

To find :- (a) $V_p = ?$

(b) $Q_p = ?$

$$\frac{V_p}{V_m} = \sqrt{L_r}$$

$$\Rightarrow \frac{V_p}{1.5} = \sqrt{36}$$

$$\boxed{\therefore V_p = 9 \text{ m/s}}$$

$$\frac{Q_p}{Q_m} = L_r^{2.5}$$

$$\frac{Q_p}{2} = 36^{2.5}$$

$$\boxed{\therefore Q_p = 15552 \text{ m}^3/\text{s}}$$

03. In a geometrically similar model of spillway the discharge per meter length is $\frac{1}{6}$ m3/s. If the scale of the model is $1/36$. Find the discharge per metre run of the prototype.

Soln → Given data, $Q_m = \frac{1}{6}$ m3/s

$L_r = 36$ , $L_m = 1m$

To find:- $Q_p = ?$

$$\frac{Q_p}{Q_m} = L_r^{2.5}$$

$$\Rightarrow \frac{Q_p}{1/6} = 36^{2.5}$$

$$\therefore Q_p = 1296 \text{ m}^3/\text{sec}$$

$$\frac{L_p}{L_m} = L_r$$

$$\Rightarrow \frac{L_p}{1} = 36$$

$$\therefore L_p = 36 \text{ m}$$

$\therefore Q_p = 36\ m^3/sec$ per m.

Q4. A 1:64 model is constructed of an open channel in concrete which has Manning's N = 0.014. Find the value of N for the model.

Soln Given data: $L_r = 64$

$N_p = 0.014$

To find:- $N_m = ?$

$$\frac{N_p}{N_m} = L_r^{1/6}$$

$$\Rightarrow \frac{0.014}{N_m} = 64^{1/6}$$

$$\boxed{\therefore N_m = 7 \times 10^{-3}}$$

Q5. A spillway 7.2m high and 150m long discharges 2150 m³/s under a head of 4m. If a 1:16 model of the spillway is to be constructed, find the model dimensions, head over the model and the model discharge.

Soln Given data: $H_p = 7.2\ m$

$L_p = 15\ m$

$Q_p = 2150\ m^3/s$

$h_p = 4\ m$

$L_r = 16$

To Find:- (a) $H_m, L_m = ?$

(b) $h_m = ?$

(c) $Q_m = ?$

$$\frac{Hp}{Hm} = \frac{Lp}{Lm} = Lr$$

$$\frac{Hp}{Hm} = Lr$$

$$\Rightarrow \frac{7.2}{Hm} = 16$$

$$\boxed{\therefore Hm = 0.45m}$$

$$\frac{Lp}{Lm} = Lr$$

$$\Rightarrow \frac{15}{Lm} = 16$$

$$\boxed{\therefore Lm = 0.9375\ m}$$

$$hp \frac{\cancel{Lm}}{hm} = Lr$$

$$\Rightarrow \frac{4}{hm} = 16$$

$$\boxed{\therefore hm = 0.25m}$$

$$\frac{Qp}{Qm} = Lr^{2.5}$$

$$\Rightarrow \frac{2150}{Qm} = 16^{2.5}$$

$$\boxed{\therefore Qm = 2.099\ m^3/s}$$

06. In 1:30 model of a spillway ; the velocity and discharge are 1.5 m/sec and 2.0 $m^3/s$. Find the corresponding velocity and discharge in the prototype.

Sol$^n$ → Given data, $Lr = 30$

$Vm = 1.5\ m/s$

$Qm = 2.0\ m^3/s$

To find :- (a) $V_p = ?$
(b) $Q_p = ?$

$$\frac{V_p}{V_m} = \sqrt{L_r}$$

$$\Rightarrow \frac{V_p}{1.5} = \sqrt{30}$$

$$\boxed{\therefore V_p = 8.215 \text{ m/sec}}$$

$$\frac{Q_p}{Q_m} = L_r^{2.5}$$

$$\frac{Q_p}{2.0} = 30^{2.5}$$

$$\boxed{\therefore Q_p = 9859.006 \text{ m}^3\text{/sec}}$$

Q7. A ship-model of scale $\frac{1}{60}$ is towed through sea-water at a speed of 0.5 m/sec. A force of 1.5 N is required to tow the model. Determine the speed of the ship and propulsive force on the ship; if prototype is subjected to wave resistance only.

Soln → Given data,
$L_r = 60$
$V_m = 0.5$ m/sec
$F_m = 1.5$ N

To find :- (a) $V_p = ?$
(b) $F_p = ?$

$$\frac{V_p}{V_m} = \sqrt{L_r}$$

$$\Rightarrow \frac{V_p}{0.5} = \sqrt{60}$$

$$\boxed{\therefore V_p = 3.872 \text{ m/sec}}$$

$$\frac{F_p}{F_m} = L_r^3$$

$$\Rightarrow \frac{F_p}{1.5} = 60^3$$

$$\boxed{\therefore F_p = 324 \times 10^3 N}$$