TED(10) 3027 HYDRAULICS.

Scheme of Valuation

PART – A

1. **Total pressure:** When a static mass of liquid comes in contact with a surface either plane or Curved a force is exerted by the liquid on the surface. This force is known as **Total pressure.** Total pressure is equal to the product of the pressure intensity and the area.

   Centre of pressure: The point of application of the total pressure on the surface is known as Centre of pressure.

2. **Vena contracta:** When water flows through an orifice the jet of water contracts from the mouth of orifice up to a distance of about one and half times the diameter of the orifice. This section of the jet beyond which no further contraction takes place and the stream lines first become parallel is known as vena contracta.

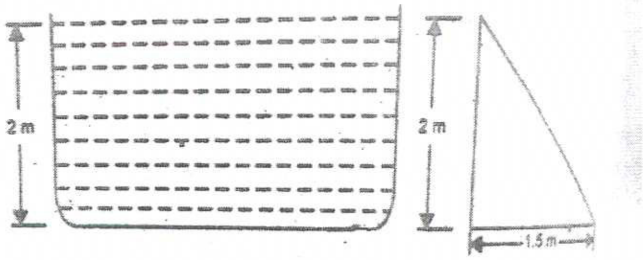
3. **Mouth piece:** It is a short length of tube or pipe which is not more than two to three times its diameter fitted to an orifice of same diameter provided in a tank.

4. **Notch:** It is an opening in the side of a tank or vessel such that the liquid level is below the top edge of the opening.

5. **Critical velocity:** The velocity of liquid at which the flow changes from laminar to turbulent is called critical velocity. (5 x 2 = 10)

PART-B

II 1. Solution:



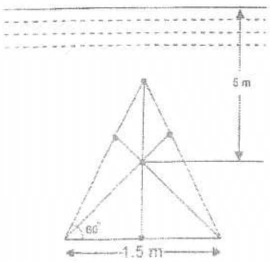
d = 2 m b = 1.5 m l = 14.2 m

Intensity of pressure on the base 'p' = wh = 9810 x 2 = 19620 N / m^2 = 19.62 KN/m^2

Average pressure on the end = wh/2 ,

Total pressure on the end = 19.62 x 2 x 1.5/2 = 58.86 KN. (3 + 3 = 6)

2. Solution



Height of the triangle = h = 0.75 tan 60^0 = 1.299m

Area = ½ b h = ½ x 1.5 x 1.299 = 0.974 m^2

$\overline{X}$ = 5m

Total pressure on the plate = w A $\overline{X}$ = 9.81 x 0.974 x 5 = 47.77 KN

(6)

3.

Solution. Given :

Dia. of tank, $D = 1.25$ m

$\therefore$ Area, $A = \frac{\pi}{4}(1.25)^2 = 1.227 \text{ m}^2$

Dia. of orifice, $d = 50$ mm $= .05$ m

$\therefore$ Area, $a = \frac{\pi}{4}(.05)^2 = .001963 \text{ m}^2$

$C_d = 0.62$

Initial height of water, $H_1 = 5$ m

Time in seconds, $T = 1.5 \times 60 = 90$ seconds

Let the height of water after 90 seconds = H_2

Using equation (7.11), we have $T = \dfrac{2A\left[\sqrt{H_1} - \sqrt{H_2}\right]}{C_d \cdot a \cdot \sqrt{2g}}$

or
$$90 = \frac{2 \times 1.227\left[\sqrt{5} - \sqrt{H_2}\right]}{0.62 \times 0.001963 \times \sqrt{2 \times 9.81}} = 455.215\left[2.236 - \sqrt{H_2}\right]$$

$\therefore$
$$\sqrt{H_2} = 2.236 - \frac{90}{455.215} = 236 - 0.1977 = 2.0383$$

$\therefore$
$$H_2 = 2.0383 \times 2.0383 = \mathbf{4.154 \text{ m. Ans.}}$$

(6)

Solution :

Given $Q = 21.5\ m^3/min = 0.358\ m^3/sec$

$H =$ depth of water

Length of the notch $L = 2H$

$C_d = 0.6$

using the relation $Q = \frac{2}{3} C_d . L \sqrt{2g}\ (H)^{3/2}$

$$0.358 = \frac{2}{3} \times 0.6 \times L \times \sqrt{2 \times 9.81} \left(\frac{L}{2}\right)^{3/2}$$

$$L^{5/2} = \frac{0.358 \times 3 \times 2\sqrt{2}}{2 \times 0.6 \times \sqrt{2 \times 9.81}} = 0.572$$

$$L = 0.80\ m \quad \text{or} \quad 80\ cm.$$

(6)

5. **Advantages of Triangular notch over rectangular notch:**

1. In case of a triangular notch the discharge can be measured more accurately than the rectangular notch.
2. For a right angled triangular notch or weir the expressions for the discharge is simplified ($Q= 1.417\ H^{5/2}$), only the head H is to be measured to calculate the discharge.
3. The co-efficient of discharge for a triangular notch is fairly constant for all the heads. Whereas in the case of rectangular notch the co-efficient of discharge varies with the head.
4. Ventilation for the triangular weir is not necessary.
5. In the case of triangular weir or notch the velocity of approach may be neglected without appreciable error.

(Any 4 x 1.5=6)

6.

Solution. Given :

Length of pipe, $L = 2000$ m

Discharge, $Q = 200$ litre/s $= 0.2$ m^3/s

Head lost due to friction, $h_f = 4$ m

Value of Chezy's constant, $C = 50$

Let the diameter of pipe $= d$

Velocity of flow, $V = \dfrac{\text{Discharge}}{\text{Area}} = \dfrac{Q}{\frac{\pi}{4}d^2} = \dfrac{0.2}{\frac{\pi}{4}d^2} = \dfrac{0.2 \times 4}{\pi d^2}$

Hydraulic mean depth, $m = \dfrac{d}{4}$

Loss of head per unit length, $i = \dfrac{h_f}{L} = \dfrac{4}{2000} = .002$

Chezy's formula is given by equation (11.4) as $V = C\sqrt{mi}$

Substituting the values of V, m, i and C, we get

$$\frac{0.2 \times 4}{\pi d^2} = 50\sqrt{\frac{d}{4} \times .002} \quad \text{or} \quad \sqrt{\frac{d}{4} \times .002} = \frac{0.2 \times 4}{\pi d^2 \times 50} = \frac{.00509}{d^2}$$

Squaring both sides, $\dfrac{d}{4} \times .002 = \dfrac{.00509^2}{d^4} = \dfrac{.0000259}{d^4}$ or $d^5 = \dfrac{4 \times .0000259}{.002} = 0.0518$

$\therefore$ $d = \sqrt[5]{0.0518} = (.0518)^{1/5} = 0.553$ m $=$ **553 mm. Ans.**

(6)

7. Solution:

$Q = 400$ l/sec $= 0.4$ m^3/sec , Bed slope, $i = 1/2000$, $C = 50$

For the rectangular channel to be most economical, Width, $b = 2d$, $m = d/2$

$A = b \times d = 2d \times d = 2d^2$, Discharge, $Q = AC\sqrt{mi}$,

$0.4 = 2d^2 \times 50 \times \sqrt{d/2 \times 1/2000}$

$= 2 \times 50 \times \sqrt{1/2 \times 2000}\; d^{5/2} = 1.581\, d^{5/2}$, $d^{5/2} = 0.4 / 1.581 = 0.253$,

d = 0.577m, **b** $= 2d = 2 \times 0.577 =$ **1.154m** **(6)**

PART – C

III (a)

$$Z_A = 0 \qquad Z_B = 5 \sin 30^0 = 5 \times \frac{1}{2} = 2.5 \text{ m.}$$

$$v_A = 1 \text{ m/sec.}$$

$$V_B = \left(\frac{0.08}{0.24}\right)^2 \times 1 = 0.111 \text{ m/sec.}$$

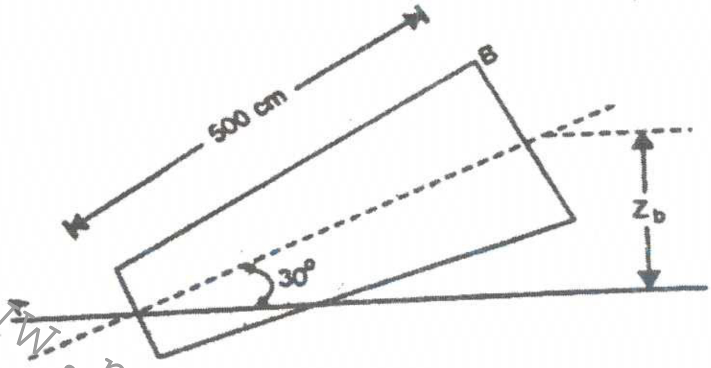


Fig. 4.9

$$\frac{v_A^{\ 2}}{2g} = \frac{1^2}{19.62} = 0.05097 \text{ m.}$$

$$\frac{v_B^{\ 2}}{2g} = \frac{0.111^2}{19.62} = 0.000629 \text{ m.}$$

$$Z_A + \frac{v_A^{\ 2}}{2g} + \frac{p_A}{w} = Z_B + \frac{v_B^{\ 2}}{2g} + \frac{p_B}{w} \quad \text{(neglecting losses)}$$

$$\frac{p_A}{w} - \frac{p_B}{w} = 2.5 + 0.000629 - 0.05$$

$$= 2.449659 \text{ m.} \quad \text{or} \quad \text{say } 2.5 \text{ m.}$$

(8)

(b)

Sp. gr. of fluid, $S_1 = 0.9$

$\therefore$ Density of fluid, $\rho_1 = S_1 \times 1000 = 0.9 \times 1000 = 900$ kg/m^3

Sp. gr. of mercury, $S_2 = 13.6$

$\therefore$ Density of mercury, $\rho_2 = 13.6 \times 1000$ kg/m^3

Difference of mercury level $h_2 = 20$ cm $= 0.2$ m

Height of fluid from A-A, $h_1 = 20 - 12 = 8$ cm $= 0.08$ m

Let p = Pressure of fluid in pipe

Equating the pressure above A-A, we get

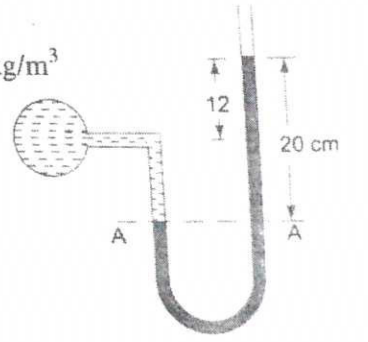


Fig. 2.10

$$p + \rho_1 g h_1 = \rho_2 g h_2$$

or $$p + 900 \times 9.81 \times 0.08 = 13.6 \times 1000 \times 9.81 \times .2$$

$$p = 13.6 \times 1000 \times 9.81 \times .2 - 900 \times 9.81 \times 0.08$$

$$= 26683 - 706 = 25977 \text{ N/m}^2 = \mathbf{2.597 \text{ N/cm}^2}. \textbf{ Ans.}$$

(7)

IV (a)

Solution. Given :

$b = 3$ m , $d = 4$ m, $\theta = 30°$

Distance of upper edge from free surface of water = 2 m

(*i*) **Total pressure force** is given by equation (3.6) as

$$F = \rho g A \bar{h}$$

where $\rho = 1000$ kg/m^3,

$A = b \times d = 3 \times 4 = 12$ m^2

and $\bar{h}$ = Depth of C.G. of plate from free water surface

$= 2 + BE = 2 + BC \sin\theta$

$= 2 + 2\sin 30° = 2 + 2 \times \frac{1}{2} = 3$ m

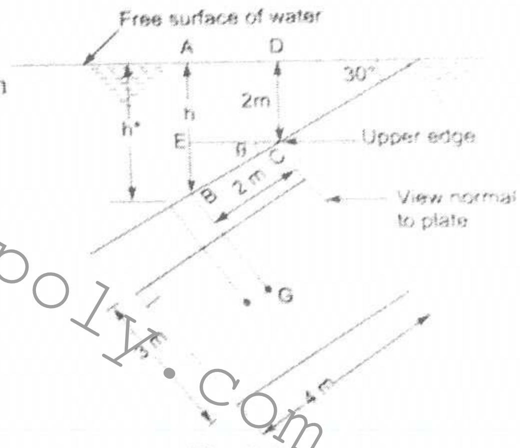


Fig. 3.19 (*a*)

$\therefore$ $F = 1000 \times 9.81 \times 12 \times 3 = 353167$ N $=$ **353.167 kN. Ans.**

(*ii*) **Centre of pressure (h*)**

Using equation (3.10), we have $h^* = \dfrac{I_G \sin^2\theta}{A\bar{h}} + \bar{h}$

where $I_G = \dfrac{bd^3}{12} = \dfrac{3 \times 4^3}{12} = 16$ m^4

$$\therefore \quad h^* = \frac{16 \times \sin^2 30°}{12 \times 3} + 3 = \frac{16 \times \frac{1}{4}}{36} + 3 = \mathbf{3.111 \text{ m. Ans.}}$$

(8)

(b)

Solution :

Let a_1 = area at inlet $= \pi \times \frac{0.25^2}{4} = 0.0490 m^2$

Pressure heat at inlet $= \frac{p_1}{W} = 7.6m$

Pressure head at throat $= \frac{p_2}{W} = 0$

Difference of pressure head = venturi head

$$= \frac{p_1}{W} - \frac{p_2}{W} = 7.6 - 0 = 7.6m$$

Discharge = φ = 8.1 m^3/minute

$$= \frac{8.1}{60} = 0.135 m^3/sec$$

K = 0.96

$$\varphi = k \cdot \frac{a_1 a_2}{a_1^2 - a_2^2} \times \sqrt{2gH}$$

$$0.135 = 0.96 \frac{0.0490 \times a_2}{\sqrt{0.0490^2 - a_2^2}} \times \sqrt{2 \times 9.81 \times 7.6}$$

$$0.135 = \frac{0.5744 \times a_2}{0.049^2 - a_2^2}$$

$$a_2^2 = 1.25679 \times 10^{-4}$$

$$a^2 = 0.01121 \ m^2$$

$$\frac{\pi d_2^2}{4} = 0.01121 \ m^2$$

$$d_2 = 0.11947 \ m$$

Dia. of throat, d_2 = 119.47 mm.

V (a)

Solution. Given :

Discharge, $Q = 98.2$ lit/s $= 0.0982$ m^3/s

Dia. of orifice, $d = 120$ mm $= 0.12$ m

$\therefore$ Area of orifice, $a = \frac{\pi}{4}(.12)^2 = 0.01131$ m^2

Head, $H = 10$ m

Horizontal distance of a point on the jet from vena-contracta, $x = 4.5$ m

and vertical distance, $y = 0.54$ m

Now theoretical velocity, $V_{th} = \sqrt{2g \times H} = \sqrt{2 \times 9.81 \times 10} = 14.0$ m/s

Theoretical discharge, $Q_{th} = V_{th} \times$ Area of orifice

$= 14.0 \times .01131 = 0.1583$ m^3/s

The value of C_d is given by $C_d = \frac{\text{Actual discharge}}{\text{The oretical discharge}} = \frac{Q}{Q_{th}} = \frac{0.0982}{0.1583} =$ **0.62. Ans.**

The value of C_c is given by equation (7.6),

$$C_v = \frac{x}{\sqrt{4yH}} = \frac{4.5}{\sqrt{4 \times 0.54 \times 10}} = \mathbf{0.968.\ Ans.}$$

The value of C_c is given by equation (7.7) as

$$C_c = \frac{C_d}{C_v} = \frac{0.62}{0.968} = \mathbf{0.64.\ Ans.}$$

(b)

Solution. Given : Width of orifice, $b = 2$ m

Depth of orifice, $d = 1.2$ m

Height of water from top edge of orifice, $H_1 = 3$ m

Difference of water level on both sides, $H = 3 + 0.5 = 3.5$ m

Height of water from the bottom edge of orifice, $H_2 = H_1 + d = 3 + 1.2 = 4.2$ m

The orifice is partially sub-merged. The discharge through sub-merged portion,

$$Q_1 = C_d \times b \times (H_2 - H) \times \sqrt{2gH}$$

$$= 0.64 \times 2.0 \times (4.2 - 3.5) \times \sqrt{2 \times 9.81 \times 3.5} = 7.4249 \text{ m}^3/\text{s}$$

The discharge through free portion is

$$Q_2 = \frac{2}{3} C_d \times b \times \sqrt{2g}\,[H^{3/2} - H_1^{3/2}]$$

$$= \frac{2}{3} \times 0.64 \times 2.0 \times \sqrt{2 \times 9.81}\ [3.5^{3/2} - 3.0^{3/2}]$$

$$= 3.779\ [6.5479 - 5.1961] = 5.108 \text{ m}^3/\text{s}$$

$\therefore$ Total discharge through the orifice is

$$Q = Q_1 + Q_2 = 7.4249 + 5.108 = \mathbf{12.5329\ m^3/s.\ Ans.}$$

VI (a) The following are the main parts of a centrifugal pump.

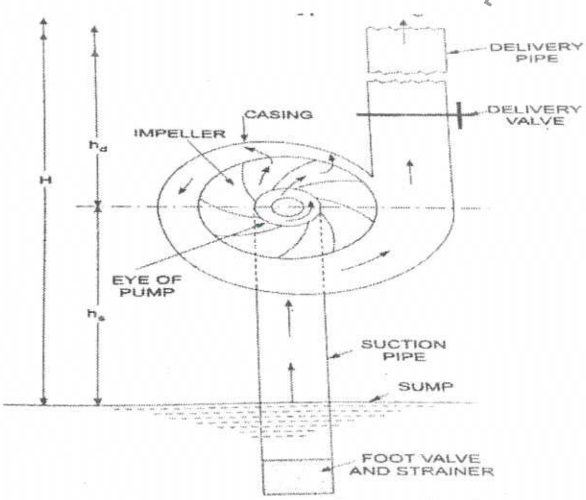
1. Impeller 2. Casing 3. Suction pipe with a foot valve and a strainer 4. Delivery pipe

1. Impeller: The rotating part of a centrifugal pump is called 'impeller'. It consists of a Series of backward curved vanes. The impeller is mounted on a shaft which is Connected to the shaft of an electric motor.

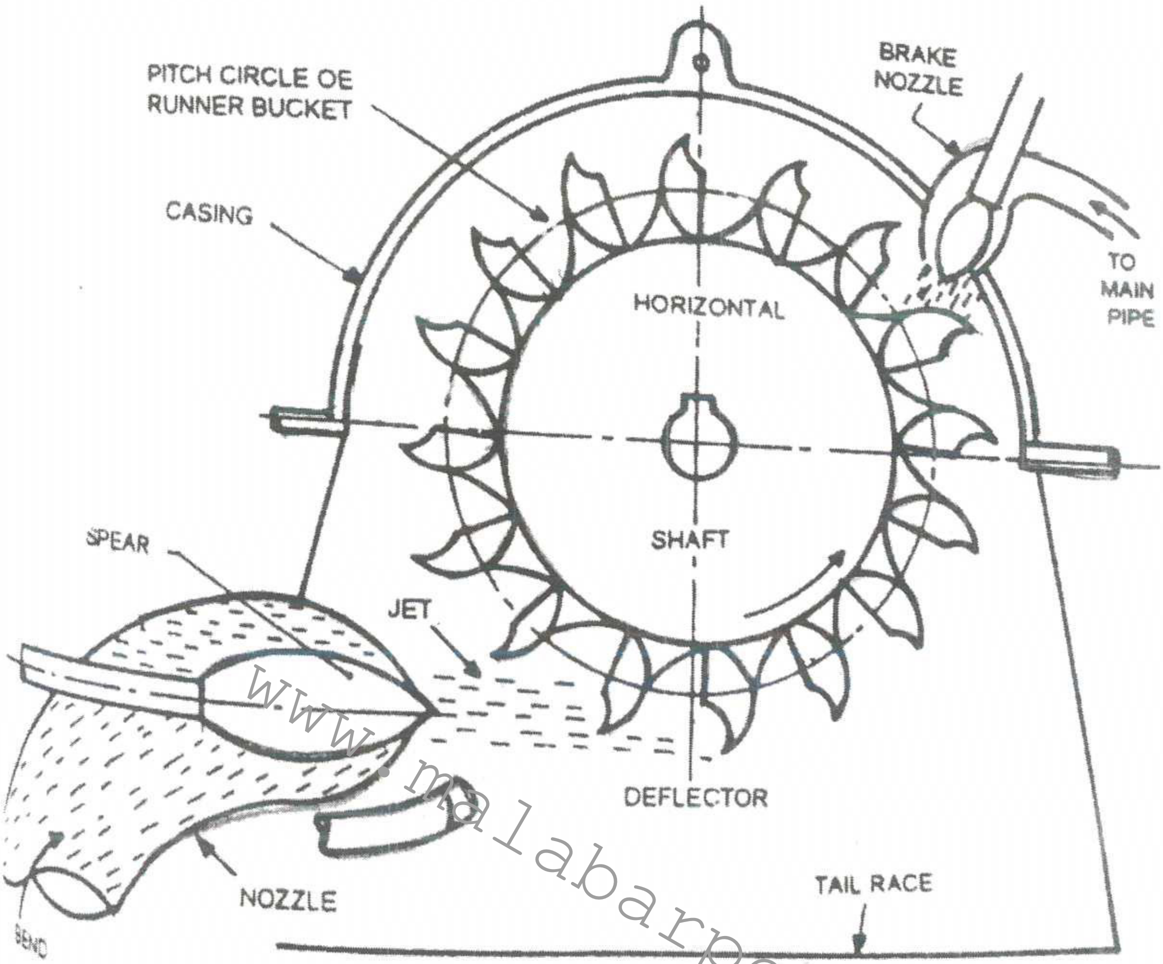
2. Casing: The casing of a centrifugal pump is similar to the casing of a reaction turbine. It is an air tight passage surrounding the impeller and is designed in such a way that the kinetic energy of the water discharged at the outlet of the impeller is converted into pressure energy before the water leaves the casing and enters the delivery pipes. Three types of the casings are commonly adopted. 1. Volute casing 2. Vortex casing 3. Casings with guide blades.

3. Suction pipe with a foot valve and a strainer. A pipe whose one end is connected to the inlet of the pump and other end dips into water in a sump is known as suction pipe. A foot valve which is a non-return valve or one way type of valve is fitted at the lower end of the suction pipe. The foot valve opens only in the upward direction. A strainer is also fitted at the lower end of the suction pipe.

4. Delivery pipe. A pipe whose one end is connected to the out let of the pump and other end delivers the water at a required height is known as delivery pipe. (4 x 2 = 8)



(b)



Main component parts of a pelton wheel:

1. Nozzle with flow regulating mechanism 2. Buckets and runner 3. Casing
4. Hydraulic brake 5. Deflector

VII (a)

Solution :

For rectangular weir L = 1 m, H = 200 mm = 0.2 m, $C_d = 0.62$

$$Q = \frac{2}{3} C_d . L . \sqrt{2g} . H^{3/2} = \frac{2}{3} \times 0.62 \times 1 \times \sqrt{2 \times 9.81 \times (0.2)^{3/2}}$$

$$= 0.16375 \text{ m}^3/\text{sec.}$$

For triangular weir.

Angle of the weir $\theta = 90^0$. $C_d = 0.6$

Let H = depth of water over triangular weir

$$0.16375 = \frac{8}{15} C_d . \sqrt{2g} . \tan \theta/2 . H^{5/2}$$

$$0.16375 = \frac{8}{15} \times 0.6 \times \sqrt{2 \times 9.81} \times \tan 45^0 \times H^{5/2}$$

$$H^{5/2} = 0.1155 \text{ m}$$

or $H = 0.422 \text{ m} = 42.2 \text{ cm.}$

(8)

(b)

Solution :

Length of weir = 50 m

Height of water = 0.7 m

Velocity of approach = 1.5 m/sec.

Head due to velocity of approach $h_a = \frac{v_a^2}{2g} = \frac{(1.5)^2}{2 \times 9.81}$

$$h_a = 0.115 \text{ m}$$

C_d = 0.62 (given)

Max. discharge over broad crested weir is

$$Q_{max} = 1.705 \, C_d . L. \left[(H + h_a)^{3/2} - (h_a)^{3/2}\right]$$

$$= 1.705 \times 0.62 \times 50 \left[(0.7 + 0.115)^{3/2} - (0.115)^{3/2}\right]$$

$$= 36.79 \text{ m}^3/\text{sec.}$$

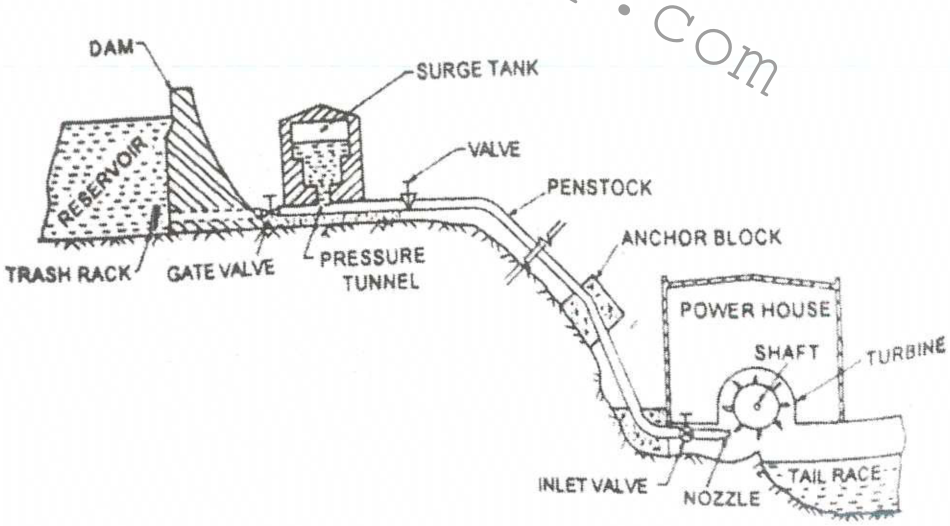
VIII (a) **Surge tank:** A surge tank is a small cylindrical storage tank with open top. It is connected to the pressure conduit carrying water to the turbines as close as possible. The surge tank reduces water hammer effects. It is placed as close to the turbine as possible.

Pen stock: These are pipes of large diameter carrying water under pressure. These are made of steel or reinforced concrete. The steel pipes are welded together to reduce the weight of the pipe line and also to reduce hydraulic losses. The thickness of steel pipe varies from 10 mm to 50 mm depending upon the pressure of water inside the pipe. In case of long pipes, surge tank is provided to reduce the water hammer. During steep changes in pen stocks air valves are provided to reduce the water hammer.

Anchor block: These are mass concrete blocks laid to support the penstocks at bends to resist its movement due to high inertia of the moving water through penstocks. Anchor blocks avoid the deviation of the pipe lines either in the horizontal plane or in the vertical plane. Anchorages are constructed with expansion joints. If the pipe line is buried no anchor blocks are necessary and the pipe line is free from landslides, falling rocks etc.

Tail Race: This is a channel through which water passed through the turbine is discharged to the downstream side of the parent river. (4 x 2 = 8)

(b)



(7)

IX (a)

Solution :

For most economical section $= \frac{b+2nd}{2} = d\sqrt{n^2+1}$

as $n = 2$

$$\frac{b+2\times 2d}{2} = d\sqrt{2^2+1}$$

$$\frac{d+4d}{2} = d\sqrt{5}$$

$$b + 4d = 2 \times \sqrt{5} \times d$$

$$\therefore \quad b = 4.472d - 4d = 0.472\ d.$$

$$\text{Area}\ A = (b + nd)d = (0.472d + 2d)\ d = 2.472\ d^2.$$

$$\text{H.M.D.}\quad m = \frac{d}{2}$$

$$v = C\sqrt{m\,i} = 30\sqrt{\frac{d}{2} \times \frac{1}{1200}}$$

$$Q = A \times v = 2.472\ d^2 \times 30 \times \sqrt{\frac{d}{2400}}$$

But Q is given as 10200 cubic metres/hour.

$$\therefore \frac{10200}{60\times 60} = \frac{2.472 \times 30 \times d^{5/2}}{\sqrt{2400}} \quad \text{or}\ d = 1.284\ m.$$

$$\text{Breadth} = 0.472\ d = 0.472 \times 1.284 = 0.606\ m.$$ (8)

(b) Solution: $d = 300$ mm $= 0.3$ m, $L = 600$ m, $hf = 50.4$ m, $f = 0.01$

$hf = f\,l\,Q^2 / 3\,d^5$, $50.4 = 0.01 \times 600 \times Q^2 / 3 \times (0.3)^5$, $Q^2 = 0.3674/6$

$Q = \sqrt{0.3674/6} = 0.25$ m^3/sec $= 250$ litres /sec.

X (a) Solution: $b = 9$ m, $d = 3$ m, $Q = 65$ m^3/sec, $C = 60$, $P = b + 2d = 9 + (2 \times 3) = 15$ m

$A = b \times d = 9 \times 3 = 27$ m^2, $m = A / P = 27/15 = 1.8$ m, $V = C\sqrt{mi}$

$V = 60 \times \sqrt{1.8 x\, i}$, Discharge, $Q = A \times V$, $V = Q/A = 65/27$

$65/27 = 60 \times \sqrt{1.8 \times i}$, $i = 8.94 \times 10^{-4}$, $i = 1/1118$, Bed slope = 1 in 1118.

(b) Solution: $A = (b + nd)\,d$, $b = 3$m, $d = 1.05$ m, $n = 1/2$, slope $= 1/625$

$A = 1.05\,(3 + 1/2 \times 1.05) = 3.7$ m^2

Length of sloping slide $= \sqrt{(1.0)^2 + (1.05/2)^2} = 1.17$, $P = b + 2 \times$ sloping side

$P = 3 + 2 \times 1.17 = 5.34$ m, $m = A/P = 0.7$

$m = A/P = 3.675/ 5.34 = 0.7$

using Mannings formula, $v = 1/N\, m^{2/3} . i^{1/2} = 1/0.03 \times 0.7^{2/3} (1/625)^{1/2} = 1.043$

Discharge, $Q = A \times V = 3.7 \times 1.043 = 3.862$ m^3/sec