CBCS SCHEME

USN 18CV43

Fourth Semester B.E. Degree Examination, Jan./Feb. 2021
Applied Hydraulics

Time: 3 hrs. Max. Marks: 100

Note: ***Answer any FIVE full questions, choosing ONE full question from each module.***

Module-1

1 a. Explain the dimensional homogeneity of an equation with an example and state the uses of Dimensional analysis. **(06 Marks)**

b. Define the term Metacentre and Metacentric height. And A Rectangular pontoon 5m long, 3m wide and 1.2m height. The depth of immersion of pontoon is 0.8m in seawater. If the C.G is 0.6m above the bottom of the pontoon, determine the Metacentric height. Take density of seawater as 1025 kg/m^3. **(10 Marks)**

c. A Dam 15m long is to discharge water at the rate of 114m^3/s under a head of 3m. Design the model, if the supply available in the laboratory is 30 lps. **(04 Marks)**

OR

2 a. The Resisting torque 'T' against the motion of a shaft in a lubricated bearing depends on the viscosity 'μ', the rotational speed 'N' the diameter 'D' and the bearing pressure intensity 'ρ'. Show that $T = \mu ND^3 \phi\left(\frac{\rho}{\mu N}\right)$ Use Buckingham's π theorem method. **(10 Marks)**

b. Define the terms i) Geometric similarity ii) Kinematic similarity iii) Dynamic similarity. **(06 Marks)**

c. A model of spillway is made to test in the laboratory. The discharge and the velocity of flow over the model is measured as 2.5 m^3/s and 1.5m/s respectively. Find the discharge and the velocity over the prototype, which is 50 times larger than its model. **(04 Marks)**

Module-2

3 a. Distinguish between Open channel flow and Pipe flow. **(06 Marks)**

b. Show that the length of one sloping side of a most economical trapezoidal channel is equal to half of the Top width. Also determine the hydraulic mean depth for this condition. **(08 Marks)**

c. A Trapezoidal channel has side slope 2V:3H. It is discharging water at the rate of 20 cumecs, with a bed slope 1 in 2000. Design the channel for its bestform. Take Mannings n = 0.015. **(06 Marks)**

OR

4 a. Define Specific Energy and draw specific energy diagram. Obtain an expression for critical depth and critical velocity. **(10 Marks)**

b. A Rectangular channel 2.0m wide carries a discharge of 6m^3/s. Calculate the critical depth and specific energy at critical depth. **(04 Marks)**

c. Find the bed slope of Trapezoidal channel of bedwidth 6m, depth of water 3m and side slope of 3H:4V, when the discharge through the channel is 30m^3/s. Take C = 70. **(06 Marks)**

Module-3

5 a. Explain the classifications of surface profiles in an open channel with neat sketches. **(10 Marks)**

b. Define the terms i) Gradually Varied Flow (GVF) ii) Rapidly Varied Flow (RVF). **(04 Marks)**

Applied Hydraulics (18CV43)

1a. Dimensional Homogeneity :-

Dimensional homogeneity means the dimensions of each terms in an equation on both sides are equal. Thus if the dimensions of each terms on both sides of an equation are the Same the equation is Known as dimensionally homogeneous equation.

Example :- Let us consider the equation, $V = \sqrt{2gH}$

Dimension of L.H.S $= V = \frac{L}{T} = LT^{-1}$

Dimension of R.H.S $= \sqrt{2gH} = \sqrt{\frac{L}{T^2} \times L} = \sqrt{\frac{L^2}{T^2}} = \frac{L}{T} = LT^{-1}$ 06

Dimension of L.H.S = Dimension of R.H.S $= LT^{-1}$

$\therefore$ equation $V = \sqrt{2gH}$ is dimensionally homogeneous. So it can be used in any system of units.

Uses of dimensional analysis.

Dimensional analysis is a mathematical technique used to predict physical parameters that influence the flow in fluid mechanics, heat transfer in thermodynamics etc.

1b. Meta Centre

It is defined as the point about which a body starts oscillating when the body is tilted by a small angle.

Meta-Centric Height

The distance from Meta Centre and Centre of gravity of the body is called meta-Centric height.

Given :-

Dimension of Pontoon $= 5m \times 3m \times 1.20m$

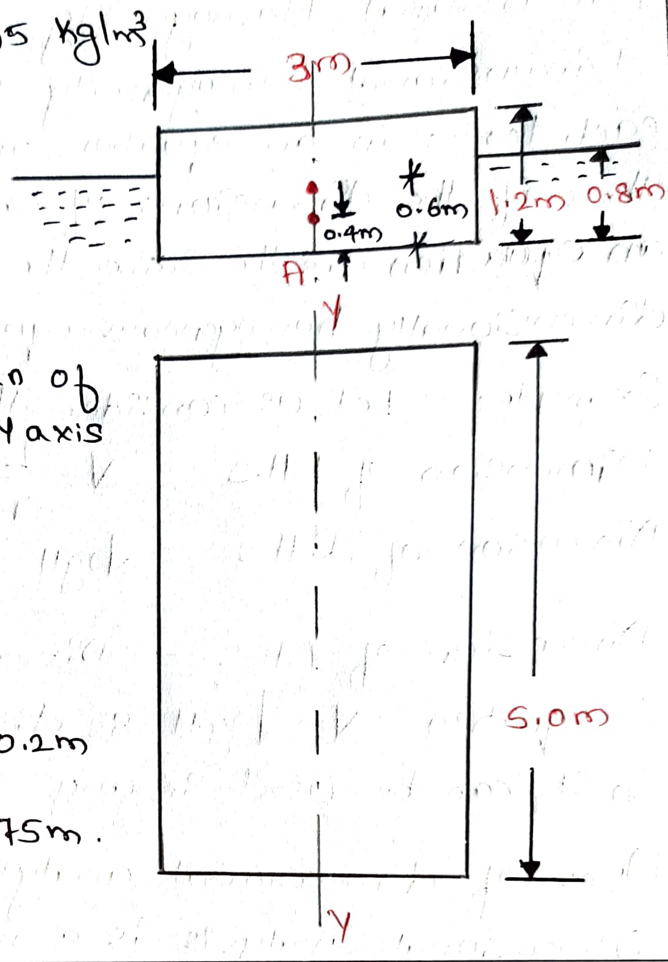
Depth of immersion $= 0.8m$

Distance $AG = 0.6m$

Distance $AB = \frac{1}{2} \times$ Depth of immersion

$= \frac{1}{2} \times 0.8 = 0.4m$

Density for sea water $= 1025\ kg/m^3$



Meta Centric height GM

$$GM = \frac{I}{\forall} - BG$$

I = M.O. Inertia of the plan of the Pontoon about Y-Y axis

$$= \frac{1}{12} \times 5 \times 3^3\ m^4 = \frac{45}{4}\ m^4$$

$\forall$ = Volume of the body

$$= 3 \times 0.8 \times 5.0 = 12.0\ m^3$$

$$\therefore BG = AG - AB = 0.6 - 0.4 = 0.2m$$

$$\therefore GM = \frac{45}{4} \times \frac{1}{12.0} - 0.2 = 0.7375m.$$

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1.c. The discharge ratio is $Q_r = \frac{Q_m}{Q_P}$

$1\ l/s = 0.001\ m^3/s.$

$30\ l/s = 30 \times 0.001\ m^3/s = 0.03\ m^3/s$

$$\therefore Q_r = \frac{0.03}{114}$$

$$\boxed{Q_r = 0.00026}$$

04

a. Given :- $T = f(\mu, N, D, \rho)$ or $f_1(T, D, N, \mu, \rho) = 0$ — (i)

$\therefore$ Total number of Variables, $n = 5$

Dimensions of each Variable are expressed as

$T = ML^2T^{-2}$, $D = L$, $N = T^{-1}$, $\mu = ML^{-1}T^{-1}$, $\rho = ML^{-3}$

$\therefore$ Number of fundamental dimensions, $m = 3$

Number of π-terms $= n - m = 5 - 3 = 2$

Hence equation (i) can be written as $f_1(\pi_1, \pi_2) = 0$.

$\pi_1 = D^{a_1} . N^{b_1} . \rho^{c_1} . T$

$\pi_2 = D^{a_2} . N^{b_2} . \rho^{c_2} . \mu$

Dimensional Analyses of π_1

$\pi_1 = D^{a_1} . N^{b_1} . \rho^{c_1} . T$

Substituting dimensions on both sides,

$M^0L^0T^0 = L^{a_1} . (T^{-1})^{b_1} . (ML^{-3})^{c_1} . ML^2T^{-2}$

Equating the powers of M, L, T on both sides,

Power of M, $0 = c_1 + 1$ $\therefore c_1 = -1$

Power of L, $0 = a_1 - 3c_1 + 2$ $\therefore a_1 = -5$

Power of T, $0 = -b_1 - 2$ $\therefore b_1 = -2$

Substituting the values of a_1, b_1 & c_1 in π_1

$\pi_1 = D^{-5} . N^{-2} . \rho^{-1} . T = \dfrac{T}{D^5 N^2 \rho}$

Dimensional analysis of π_2

$\pi_2 = D^{a_2} . N^{b_2} . \rho^{c_2} . \mu$

Substituting dimensions on both sides.

$M^0L^0T^0 = L^{a_2} . (T^{-1})^{b_2} . (ML^{-3})^{c_2} . ML^{-1}T^{-1}$

equating the powers of M, L, T on both sides.

Power of M, $0 = c_2 + 1$ $\therefore c_2 = -1$

Power of L, $0 = a_2 - 3c_2 - 1$ $\therefore a_2 = -2$ 10

Power of T, $0 = -b_2 - 1$ $\therefore b_2 = -1$

$$\pi_2 = D^{-2} N^{-1} \rho^{-1} \cdot \mu = \frac{\mu}{D^2 N \rho}$$

Substituting the values of π_1 and π_2

$$f_1\left(\frac{T}{D^5 N^2 \rho}, \frac{\mu}{D^2 N \rho}\right) \text{ or } \boxed{T = \mu N D^3 \phi\left(\frac{\rho}{\mu N}\right)}$$

2.b. i) 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.

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

ii) Kinematic Similarity – Kinematic similarity means the similarity of motion between model and prototype. Thus kinematic similarity is said to exist between the model and the prototype if the ratios of the velocity and acceleration at the corresponding points in the model and at the corresponding points in the prototype are the same. Since velocity and acceleration are vector quantities, hence not only the ratio of magnitude of velocity and acceleration at the corresponding points in model and prototype should be same. 06

iii) Dynamic Similarity – Dynamic similarity means the similarity of forces between the model and prototype. Thus dynamic similarity is said to exist between the model and the prototype if the ratios of the corresponding forces acting at the corresponding points are equal.

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

Given :

Discharge over model $Q_m = 2.5\ m^3/s$

Velocity over model $V_m = 1.5\ m/s$

Linear Scale ratio $L_r = 50$

For dynamic similarity, Froude model law is used.

$$\frac{V_p}{V_m} = \sqrt{L_r} = \sqrt{50} = \cancel{5.0}\ 7.07$$

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V_p : Velocity over prototype $= V_m \times 5 = 1.5 \times \cancel{5}\ 7.07 = \cancel{7.5}\ 10.60\ m/s$.

For discharge equatio, we get

$$\frac{Q_p}{Q_m} = L_r^{2.5} = (50)^{2.5}$$

$$\therefore\ Q_p = Q_m \times (50)^{2.5} = 2.5 \times (50)^{2.5} = 44194.17\ m^3/s.$$

3.a.

Open Channel flow	Pipe flow.
1. The pressure at the free sur-face remains constant	1. Pressure in the pipe is not constant.
2. Flow driven by gravity	2. Flow driven by pressure
3. Hydraulic gradient line coin-cides with the water surface line	3. Hydraulic gradient line do not Coincides top surface of water
4. Open Channel flow has a free surface	4. There is no free surface in pipe flow
5. Surface roughness varies with depth of flow	5. Surface roughness varies with the type of pipe material
6. The c/s of an open Channel can be trapezoidal, triangular, rectangular, circular etc.	6. The cross-section of a pipe generally circular

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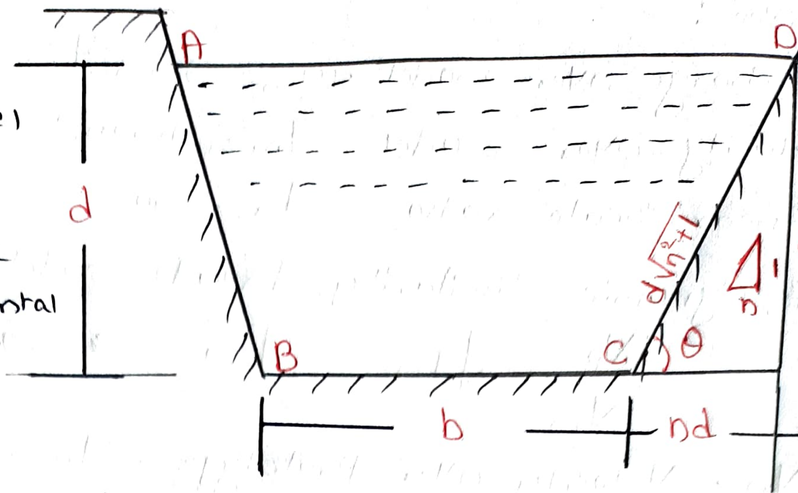
3b.

Let b = width of channel

d = depth of flow

θ = angle made by the sides with horizontal



i) The side slope is given as 1 Vertical to n horizontal

Area of flow $A = \frac{(BC+AD)}{2} \times d = \frac{b+(b+2nd)}{2} \times d$.

$= \frac{2b+2nd}{2} \times d = (b+nd) \times d$ ——— (i)

$\therefore \frac{A}{d} = b+nd$ (or) $b = \frac{A}{d} - nd$ ——— (ii)

Wetted Perimeter, $P = AB+BC+CD = BC+2CD$

$= b+2\sqrt{CE^2+DE^2} = b+2\sqrt{n^2d^2+d^2}$

$= b+2d\sqrt{n^2+1}$ ——— (iia)

For most economical Section, P should be minimum $\frac{dP}{d(d)} = 0$.

$P = \frac{A}{d} - nd + 2d\sqrt{n^2+1}$ ——— (iii)

Differentiating eqn (iii) w.r.t. d

$\frac{d}{d(d)}\left[\frac{A}{d} - nd + 2d\sqrt{n^2+1}\right] = 0$ (or) $-\frac{A}{d^2} - n + 2\sqrt{n^2+1} = 0$. (or)

$\frac{A}{d^2} + n = 2\sqrt{n^2+1}$

$\frac{(b+nd)d}{d^2} + n = 2\sqrt{n^2+1}$ (or) $\frac{b+nd}{d} + n = 2\sqrt{n^2+1}$

$\frac{b+2nd}{2} = d\sqrt{n^2+1}$ But from fig $\frac{b+2nd}{2}$ = Half of top width

and $d\sqrt{n^2+1}$ = CD = One of the sloping side.

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ii) Hydraulic mean depth

Hydraulic mean depth $m = \frac{A}{P}$

Value of $A = (b+nd) \times d$

Value of $P = b + 2d\sqrt{n^2+1} = b + (b + 2nd)$

$= 2b + 2nd = 2(b+nd)$

$\therefore$ Hydraulic mean depth, $m = \frac{A}{P} = \frac{(b+nd)d}{2(b+nd)} = \frac{d}{2}$

Hence for a trapezoidal section to be most economical hydraulic mean depth must be equal to half the depth of flow.

3.c Given:

Side Slopes $n = \frac{\text{Horizontal}}{\text{Vertical}} = \frac{3H}{2V}$

Slope of bed $= i = \frac{1}{2000}$

Discharge $= Q = 20\ m^3/sec$.

Manning's Constant $= N = 0.01$

For the most economical section, the condition is given by the equation

$\frac{b+2nd}{2} = d\sqrt{n^2+1}$ or $\frac{b + 2\,\frac{3}{2}\,d}{2} = d\sqrt{\left(\frac{3}{2}\right)^2+1} = 0.6d$. 06

$\therefore$ $\boxed{b = 0.6d}$

$C = \frac{1}{N} m^{1/6} = \frac{1}{0.01}(d/2)^{1/6}$ $(\because m = d/2)$

$Q = AC\sqrt{mi}$

$20 = A \times \frac{1}{0.01}(d/2)^{1/6} \times \sqrt{d/2 \times 1/2000}$

$A = (b+nd) \times d = (0.6d + \frac{3}{2}d) \times d = 2.1d \times d = 2.1d^2$

$20 = 2.1d^2 \times \frac{1}{0.01}\left(\frac{d}{2}\right)^{1/6} \times \sqrt{\frac{d}{2} \times \frac{1}{2000}} = 3.32d^2(0.5d)^{1/6} \times (d)^{1/2}$

$20 = 3.32\,d^{8/3}$

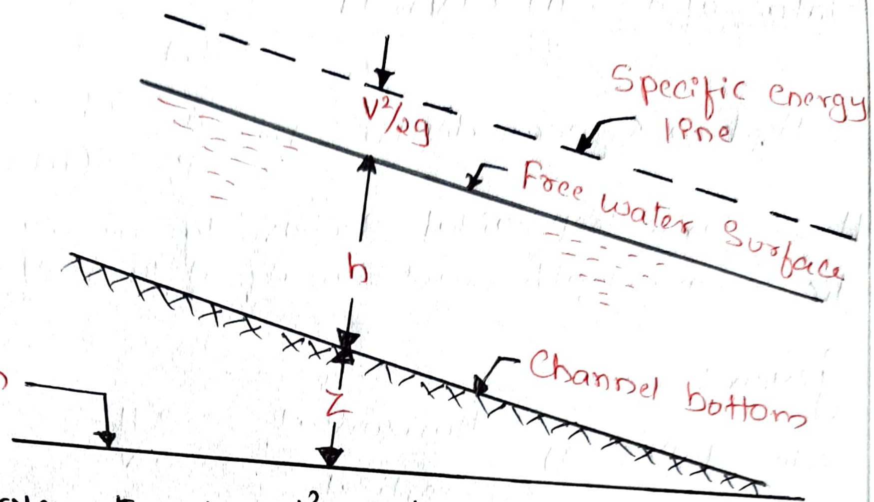
$d^{8/3} = 6.02$ $\therefore d = 1.95m$

$b = 0.6d = 0.6 \times 1.95 = 1.19\,m.$

4.a Specific energy – The total energy of a flowing liquid per unit weight is given by.

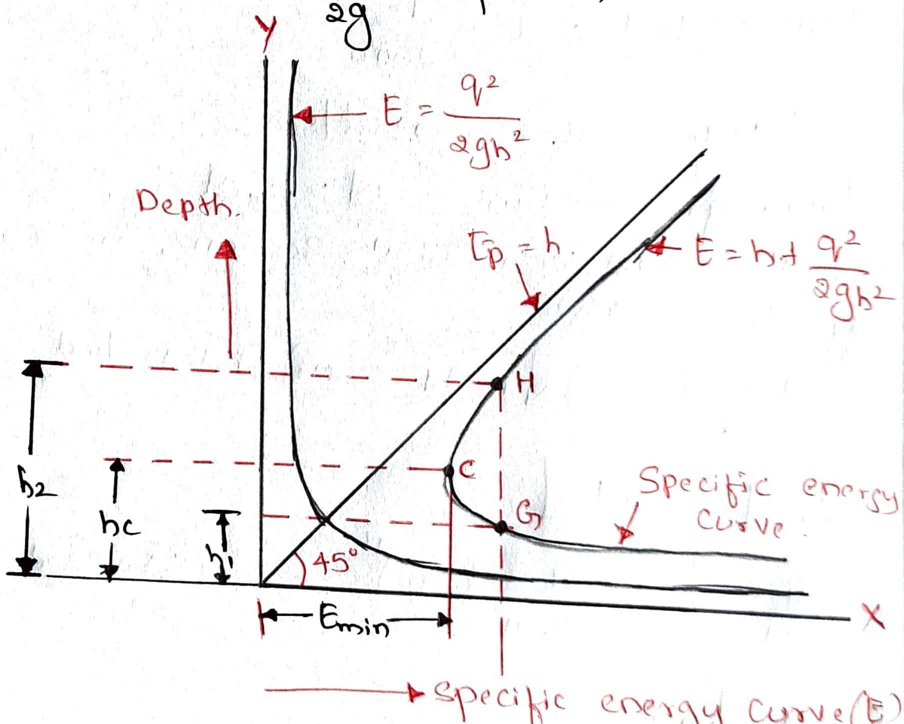
Total energy $= Z + h + \frac{V^2}{2g}$

$$E = h + \frac{V^2}{2g}$$



Specific energy curve $E = h + \frac{V^2}{2g} = E_p + E_k$

$E_k = \frac{q^2}{2gh^2}$.



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Critical depth – (h_c) Critical depth is defined as that depth of flow of water at which the specific energy is minimum. This is denoted by "h_c".

$\frac{dE}{dh} = 0$ where $E = h + \frac{q^2}{2gh^2}$

$\frac{d}{dh}\left[h + \frac{q^2}{2gh^2}\right] = 0$ or $1 + \frac{q^2}{2g}\left(\frac{-2}{h^3}\right) = 0$.

$1 - \frac{q^2}{gh^3} = 0$ or $1 = \frac{q^2}{gh^3}$ or $h^3 = \frac{q^2}{g}$

$\therefore\ h = \left(\frac{q^2}{g}\right)^{1/3}$ & $\boxed{h_c = \left(\frac{q^2}{g}\right)^{1/3}}$.

Critical Velocity (V_c) – The velocity of flow at the critical depth is known as critical velocity. It is denoted by V_c.

$$h_c = \left(\frac{q^2}{g}\right)^{1/3}$$

Taking cube to both sides, we get $h_c^3 = \frac{q^2}{g}$ or $g h_c^3 = q^2$

$$q = \frac{Area \times V}{b} = \frac{b \times h \times V}{b} = h \times V = h_c \times V_c$$

Substituting the value of q

$$g h_c^3 = (h_c \times V_c)^2 \quad \text{or} \quad g h_c^3 = h_c^2 \times V_c^2 \quad \text{or} \quad g h_c = V_c^2$$

$$\therefore\ \boxed{V_c = \sqrt{g \times h_c}}$$

4.b. Given:

Width of the channel $= b = 2.0\,m$

Discharge $Q = 6\,m^3/s$

$\therefore$ Discharge per unit width, $q = \frac{Q}{b} = \frac{6}{2} = 3\,m^2/s$.

Critical depth is given as $h_c = \left(\frac{q^2}{g}\right)^{1/3}$ 04

$$\therefore\ h_c = \left(\frac{3^2}{9.81}\right)^{1/3} = 0.972\,m.$$

Critical Velocity is given as $V_c = \sqrt{g_c \times h_c} = \sqrt{9.81 \times 0.972}$

$$\therefore\ \boxed{V_c = 3.088\ m/s.}$$

4.c. Given

$n = \frac{3}{4}$

$Q = 30\ m^3/s$

$C = 70$

$b = 6\,m$

$d = 3\,m$

$$A = (b + nd)d = \left(6 + \frac{3}{4}(3)\right)3 = 24.75\,m^2$$

$P = b + 2d\sqrt{n^2+1} = 6 + 2(3)\sqrt{(3/4)^2+1}$

$\boxed{P = 13.5\,m}$

$m = \dfrac{A}{P} = \dfrac{24.75}{13.5} = 1.83$ $\quad \boxed{m = 1.83}$

$Q = AC\sqrt{mi} \Rightarrow 30 = 24.75 \times 70\sqrt{1.83} \times \sqrt{i}$ 06

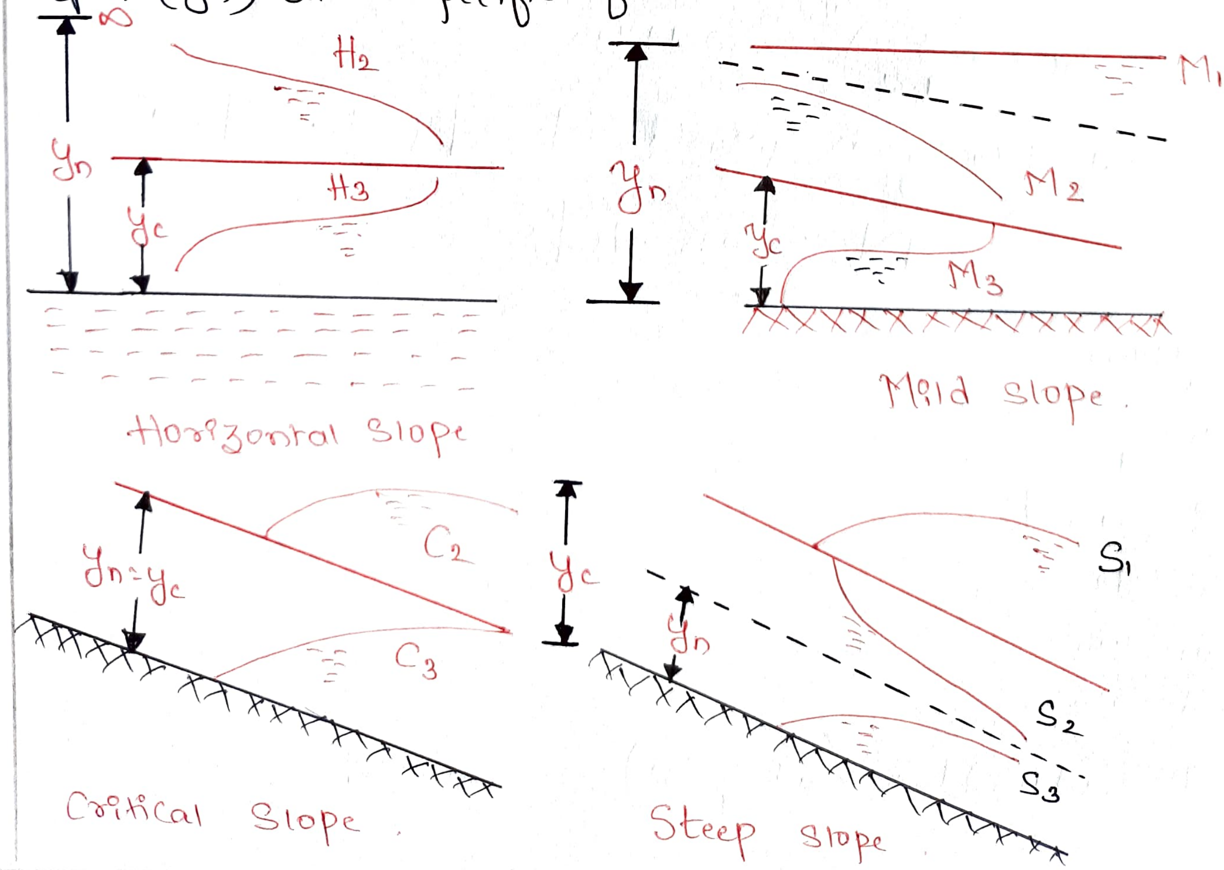
$\sqrt{i} = 0.0128.$ $\quad i = (0.0128)^2 = 1/6103.5$

$\boxed{i = 1/6103.5}$

5.a. Hydraulic Slope classification. - The hydraulic slope of a Culvert at a specific flow classifies the hydraulic regime and defines the type of solution generated from the gradually varied flow calculations.

Hydraulic slope is determined from

1. The Culvert bottom slope (S_o) and.
2. The relationship between critical depth (y_c) and normal depth (y_n) at a specific flow.



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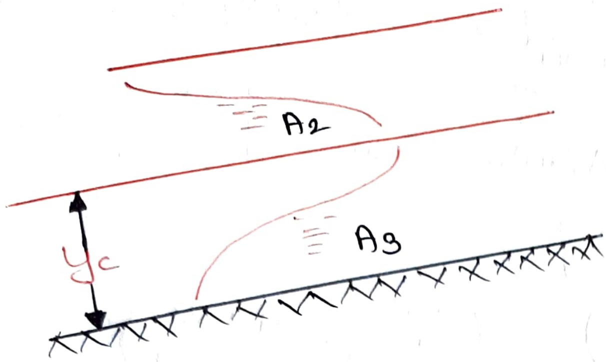


Adverse slope.

5.b. Gradually Varied Flow (G.V.F) – If the depth of flow in a channel changes gradually over a long length of the channel, the flow is said to be gradually varied flow and is denoted by G.V.F.

Rapidly Varied Flow (R.V.F) – Rapidly ~~flo~~ varied flow is defined as that flow in which depth of flow changes abruptly over a small length of the channel. When there is any obstruction in the path of flow of water, the level of water rises above the obstruction and then falls & again rises over a small length of channel, thus the depth of flow changes rapidly over a short length of the channel. For this short length of the channel the flow is called rapidly varied flow (R.V.F) 04

5.c. Given :-

$q = 2.5\ m^3/s$

$b = 1m$

$d_1 = 0.25\ m.$

$$d_2 = -\frac{d_1}{2} + \sqrt{\frac{d_1^2}{4} + \frac{2q^2}{gd_1}} = -\frac{0.25}{2} + \sqrt{\frac{0.25^2}{4} + \frac{2(2.5)^2}{9.81 \times 0.25}}$$ 06

$$= -0.125 + \sqrt{0.0156 + 5.0968}$$

$$= -0.125 + 5.1124 = 4.98\ m$$

$$h_L = \frac{(d_2 - d_1)^3}{4 d_1 d_2} = \frac{(4.98 - 1)^3}{4(4.98)(1)} = 3.1648\,m$$

6.a. Loss of energy due to hydraulic jump

$$h_L = E_1 - E_2$$

$$= \left(d_1 + \frac{V_1^2}{2g}\right) - \left(d_2 + \frac{V_2^2}{2g}\right) \quad \left(\because E_1 = d_1 + \frac{V_1^2}{2g}\right)$$

$$= \left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right) - (d_2 - d_1)$$

$$= \left(\frac{q^2}{2g d_1^2} - \frac{q^2}{2g d_2^2}\right) - (d_2 - d_1) \quad \left(\because V_1 = \frac{q}{d_1} \; \& \; V_2 = \frac{q}{d_2}\right)$$

$$= \frac{q^2}{2g}\left[\frac{1}{d_1^2} - \frac{1}{d_2^2}\right] - [d_2 - d_1] = \frac{q^2}{2g}\left[\frac{d_2^2 - d_1^2}{d_1^2 d_2^2}\right] - [d_2 - d_1]$$

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

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

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

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

$$= (d_2 - d_1)\left[\frac{(d_2 + d_1)^2}{4 d_1 d_2} - 1\right] = \frac{[d_2 - d_1]^3}{4 d_1 d_2}.$$

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

08

Froude Number $(F_e)_1$ on the upstream side of the jump.

$$(F_e)_1 = \frac{V_1}{\sqrt{g d_1}}$$

Depth of flow after the hydraulic jump is d_2 & it is given by equation.

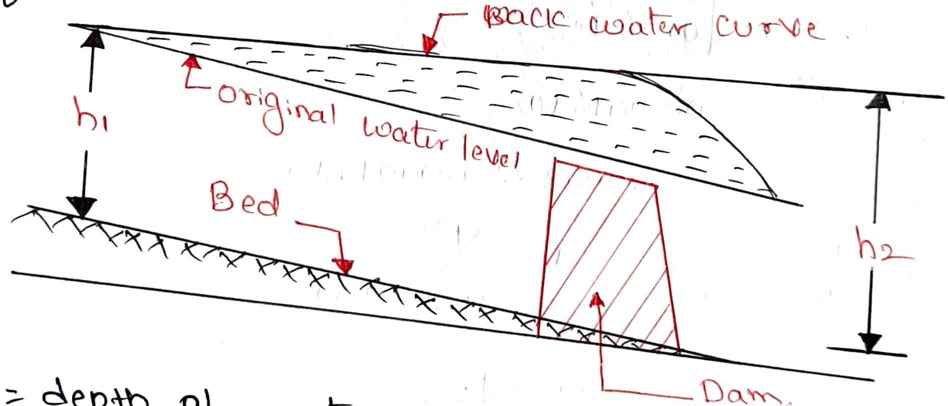
$$d_2 = -\frac{d_1}{2} + \sqrt{\frac{d_1^2}{4} + \frac{2V_1^2 d_1}{g}} = -\frac{d_1}{2} + \sqrt{\frac{d_1^2}{4}\left(1 + \frac{8V_1^2}{gd_1}\right)}$$

$$= -\frac{d_1}{2} + \frac{d_1}{2}\sqrt{1 + \frac{8V_1^2}{gd_1}}$$

But $(F_e)_1 = \frac{V_1}{\sqrt{gd_1}}$ or $(F_e)_1^2 = \frac{V_1^2}{gd_1}$

$$\therefore d_2 = -\frac{d_1}{2} + \frac{d_1}{2}\sqrt{1+8(F_e)_1^2} = \frac{d_1}{2}\left(\sqrt{1+8(F_e)_1^2} - 1\right)$$

6.b. i) Back water Curve & Afflux — Consider the flow over a dam. On the upstream side of the dam, the depth of water will be rising. If there had not been any obstruction in the path of flow of water in the channel, the depth of water would have been constant. Due to obstruction the water level rises and it has maximum depth from the bed at some section.



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Let h_1 = depth of water at the point, where the water starts rising up, and

h_2 = maximum height of rising water from bed.

Then $(h_2 - h_1)$ = afflux. Thus afflux is defined as the maximum increase in water level due to obstruction in the path of flow of water. The profile of the rising water on the upstream side of the dam is called back water curve.

The distance along the bed of the channel between the section where water starts rising to the section where water is having maximum height is known as length of back water curve.

6.c Given:-

$b = 4m$

$i_b = 0.0008$

$Q = 1.5\ m^3/s$

$h = 0.30m$

$N = 0.016$

$C = \frac{1}{N}(m)^{1/6}$

$A = b \times h = 4 \times 0.30 = 1.2m$, $P = (b+2h) = 4 + 2(0.3) = 4.6m$

$m = \frac{A}{P} = \frac{1.2}{4.6} = 0.26m$

$C = \frac{1}{0.016}(0.26)^{1/6} = 49.93$

$Q = AC\sqrt{m\, i_e}$ 06

$1.5 = 4.6(49.93)\sqrt{0.26\, i_e}$

$i_e = \left(\frac{1.5}{117.11}\right)^2 = 0.0001640$

$\frac{dh}{dx} = \frac{i_b - i_e}{1 - \frac{V^2}{gh}} = \frac{0.0008 - 0.0001640}{1 - \frac{V^2}{9.81 \times 0.30}}$

$V = \frac{Q}{Area} = \frac{1.5}{4 \times 0.3} = 1.25\ m/s$

$\frac{dh}{dx} = \frac{0.000636}{1 - \frac{(1.25)^2}{9.81 \times 0.30}} = 0.0001355$

$\frac{dh}{dh} > 0$ $\therefore$ The profile of the water so obtained is called ~~the~~ back water curve.

1\. Impulse Momentum principle - The momentum per second of a flowing fluid is equal to the product of mass per second and the velocity of the flow. Mathematically, the momentum per second of a flowing fluid is

$= \rho AV \times V$ where ρAV = mass per second. 04

Net force in the direction of flow = Rate of change of momentum in the direction of flow.

= Mass per second [change of velocity]

$= \rho AV [V_2 - V_1]$

V_2 = Final velocity in the direction of flow

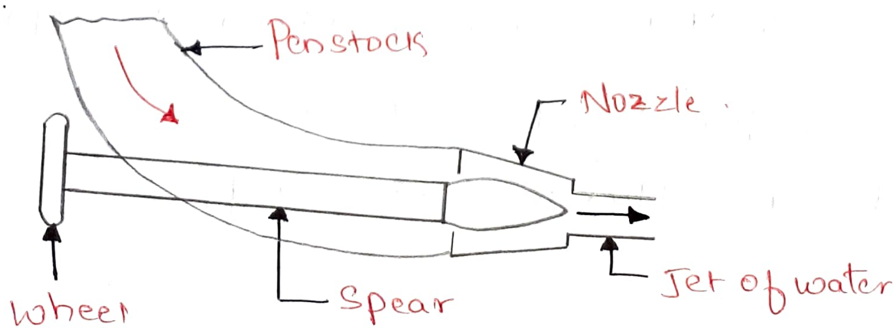
V_1 = Initial velocity in the direction of flow.

7.b. Pelton wheel (or turbine) -

The main parts of the pelton turbine are.

1. Nozzle and flow regulating arrangement.
2. Runner and buckets.
3. Casing and.
4. Breaking jet.

1\. Nozzle and flow regulating arrangement - The amount of water striking the buckets (vanes) of the runner is controlled by providing a spear in the nozzle. The spear is a conical needle which is operated either by a hand wheel or automatically in an axial direction depending upon the size of the unit. when the spear is pushed forward into the nozzle the amount of water striking the runner is reduced. On the other hand, if the spear is pushed back, the amount of water striking the runner increases. 10



2. Runner with Buckets - It consists of a circular disc on the periphery of which a number of buckets evenly spaced are fixed. The shape of the buckets is of a double hemispherical cup or bowl. Each bucket is divided into two symmetrical parts by a dividing wall which is known as splitter.

3. Casing - The function of the casing is to prevent the splashing of the water and to discharge water to tail race. It also acts as safegaurd against accidents. It is made of cast iron or fabricated steel plates. The casing of the pelton wheel does not perform any hydraulic function

4. Breaking Jet - when the nozzle is completely closed by moving the spear in the forward direction, the amount of water striking the runner reduces to zero. But the runner due to inertia goes on revolving for a long time. To stop the runner in a short time, a small ~~noz~~ nozzle is provided which directs the jet of water on the back of the vanes. This jet of water is called breaking jet.

7.C Given

$d = 7.5\,cm = 0.075\,m$

$a = \frac{\pi}{4}(0.075)^2 = 0.0044\,m^2$

$V = 20\,m/s$

$u = 5\,m/s$

i) Force exerted by the jet on a moving flat plate 06

$$F_x = \rho a (V-u)^2 = 1000 \times 0.0044 (20-5)^2 = 990\,N.$$

ii) Work done per second by the jet

$$= F_x \times u = 990 \times 5 = 4950\ Nm/s.$$

2. ## Layout of a Hydro Electric Power plant -

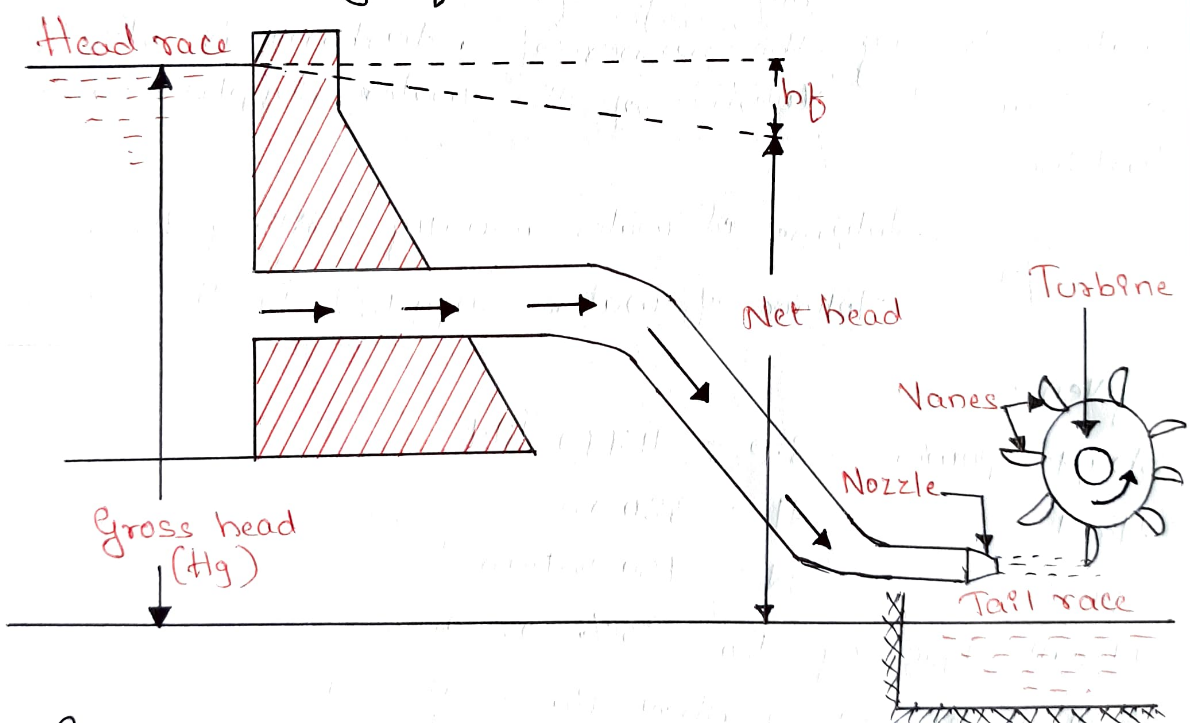
i) A dam constructed across a river to store water

ii) Pipes of large diameters called penstocks, which carry water under pressure from the storage reservoir to the turbines. these pipes are made of Steel or rein-forced Concrete.

iii) Turbines having different types of Vanes fitted to the wheels.

iv) Tail race, which is a channel which carries water away from the turbines after the water has worked on the turbine. The Surface of water in the tail race channel is also known as tail race.

$$H = H_g - h_f$$



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i) Gross head - The difference between the head race level and tail race level when no water is flowing is known as Gross Head. It is denoted by 'H_g'

ii) Net head - It is also called effective head and is defined as the head. and is defined as the head available at the inlet of the turbine.

3. Efficiencies of a Turbine.

a) Hydraulic Efficiency (η_h) : It is defined as the ratio of power given by water to the runner of a turbine to the power supplied by the water at the inlet of turbine

$$\eta_h = \frac{\text{Power delivered to runner}}{\text{Power supplied at inlet}} = \frac{R.P}{W.P.}$$

b) Mechanical Efficiency (η_m) - The power delivered by water to the runner of a turbine is transmitted to the shaft of the turbine.

$$\eta_m = \frac{\text{Power at the shaft of the turbine}}{\text{Power delivered by water to runner}} = \frac{S.P}{R.P}.$$

c) Volumetric Efficiency (η_v) : The volume of the water striking the runner of a turbine is slightly less than the volume of the water supplied to the turbine

$$\eta_v = \frac{\text{Volume of water actually striking the runner}}{\text{Volume of water supplied to the turbine}}.$$

But

8.b. Given -

Shaft power $S.P = 11772$ KW

Head $H = 380$ m

Speed $N = 750$ r.p.m

Overall efficiency $\eta_o = 86\%$ or 0.86.

Ratio of jet dia to wheel dia $= \frac{d}{D} = \frac{1}{6}$

Co. efficient of velocity $K_{v_1} = C_v = 0.985$

Speed ratio $K_{u_1} = 0.45$

Velocity of jet $V_1 = C_v\sqrt{2gH} = 0.985\sqrt{2\times9.81\times380} = 85.05$ m/s.

the Velocity of wheel $u = u_1 = u_2$

$= \text{Speed ratio} \times \sqrt{2gH} = 0.45\times\sqrt{2\times9.81\times380} = 38.85$ m/s.

But $u = \frac{\pi D N}{60} \Rightarrow 38.85 = \frac{\pi D N}{60}$.

$$D = \frac{60 \times 38.85}{\pi \times N} = \frac{60 \times 38.85}{\pi \times 750} = 0.989\,m$$

But $\frac{d}{D} = \frac{1}{6}$

$\therefore$ Dia of jet $d = \frac{1}{6} \times D = \frac{0.989}{6} = 0.165\,m$

Discharge of one jet q = Area of jet $\times$ Velocity of jet

$= \frac{\pi}{4} d^2 \times V_1 = \frac{\pi}{4} (0.165) \times 85.05\ m^3/s = 1.818\ m^3/s$ 10

now $\eta_o = \frac{S.P}{W.P} = \frac{11772}{\frac{\rho g \times Q \times H}{1000}}$

$$0.86 = \frac{11772 \times 1000}{1000 \times 9.81 \times Q \times 380}.$$

$\therefore$ Total discharge, $Q = \frac{11772 \times 1000}{1000 \times 9.81 \times 380 \times 0.86} = 3.672\ m^3/s$

$\therefore$ No. of jets $= \frac{\text{Total discharge}}{\text{Discharge of one jet}} = \frac{Q}{q} = \frac{3.672}{1.818} = 2$ jets

---

9.a Let N = Speed of the impeller in r.p.m

D_1 = Diameter of impeller at inlet

u_1 = Tangential Velocity of impeller at inlet.

$= \frac{\pi D_1 N}{60}$

D_2 = Diameter of impeller at outlet

u_2 = Tangential Velocity of impeller at outlet

$= \frac{\pi D_2 N}{60}$ 08

Water striking per second is given by

$= \frac{1}{g}\left[V_{w_1} u_1 - V_{w_2} u_2\right]$

$\therefore$ Work done by the impeller on the water per second per unit weight of water striking per second.

$= -$ [work done in case of turbine]

$= -\left[\frac{1}{g}(V_{w_1}u_1 - V_{w_2}u_2)\right] = 1/g\,[V_{w_2}u_2 - V_{w_1}u_1]$

$= \frac{1}{g} V_{w_2} u_2$

work done by impeller on water per second.

$= \frac{W}{g} \cdot V_{w_2} u_2$

q = Area × Velocity of flow $= \pi D_1 B_1 \times V_{f_1} = \pi D_2 B_2 \times V_{f_2}$

9.b Cavitation - Cavitation is defined as the phenomenon of formation of vapour bubbles of a flowing liquid in a region where the pressure of the liquid falls below its vapour pressure and the sudden collapsing of these vapour bubbles in a region of higher pressure.

Effects of Cavitation.

i) the mettalic surfaces are damaged and cavities are formed on the surface.

ii) Due to sudden collapse of vapour bubble, considerable noise & vibrations are produced. 04

iii) The efficiency of a turbine decreases due to cavitation. Due to pitting action, the surface of the turbine blades becomes rough and the force exerted by water on the turbines blades decreases. Hence, the work done by water or output horse power becomes less and thus efficiency decreases.

9.c. Given :-

S.P = 15000 KW

H = 30 m

Speed ratio, $u_1 \sqrt{2gH} = 2.0$

$\therefore u_1 = 2.0 \times \sqrt{2 \times 9.81 \times 30} = 24.26$ m/s

Flow ratio, $\frac{V_{f_1}}{\sqrt{2gH}} = 0.65$

$\therefore V_{f_1} = 0.65 \times \sqrt{2 \times 9.81 \times 30} = 15.76$ m/s.

Diameter of boss = 0.35 × Diameter of runner

$\therefore \quad D_b = 0.35 \times D_o$

Overall efficiency $\eta_o = 90\% = 0.90$

Using the relation $\eta_o = \frac{S.P}{W.P}$, where $W.P = \frac{\rho \times g \times Q \times H}{1000}$

$$0.90 = \frac{15000}{\frac{\rho \times g \times Q \times H}{1000}} = \frac{15000 \times 1000}{1000 \times 9.81 \times Q \times 30}$$

$$Q = \frac{15000 \times 1000}{0.9 \times 1000 \times 9.81 \times 30} = 56.63 \ m^3/s.$$

$$Q = \frac{\pi}{4}(D_o^2 - D_b^2) \times V_{f_1}$$

$$56.63 = \frac{\pi}{4}\left[D_o^2 - (0.35 D_o)^2\right] \times 15.76$$

$$= \frac{\pi}{4} \times 0.8775 D_o^2 \times 15.76 = 10.86 D_o^2$$

$$D_o = \sqrt{\frac{56.63}{10.86}} = 2.28 \ m$$

08

$$D_b = 0.35 \times D_o = 0.35 \times 2.28 = 0.798 \ m$$

ii) Speed of the turbine is given by $u_1 = \frac{\pi D_o N}{60}$

$$\therefore \quad 24.26 = \frac{\pi \times 2.28 \times N}{60}$$

$$\therefore \quad N = \frac{60 \times 24.26}{\pi \times 2.28} = 203.21 \ r.p.m$$

iii) Specific speed is given by $N_s = \frac{N\sqrt{P}}{H^{5/4}}$

$$N_s = \frac{203.21 \times \sqrt{15000}}{(30)^{5/4}} = \frac{203.21 \times 122.47}{70.21}$$

$$\boxed{N_s = 354.47 \ r.p.m}$$

10.a. Priming of a Centrifugal Pump - Priming of a centrifugal pump is defined as the operation in which the suction pipe, casing of the pump and a portion of the delivery pipe upto the delivery valve is completely filled up from outside source with the liquid to be raised by the pump before starting the pump. Thus the air from these parts of the pump is removed and these parts are filled with the liquid to be pumped. 04

The work done by the impeller per unit weight of liquid per sec is known as the head generated by the pump.

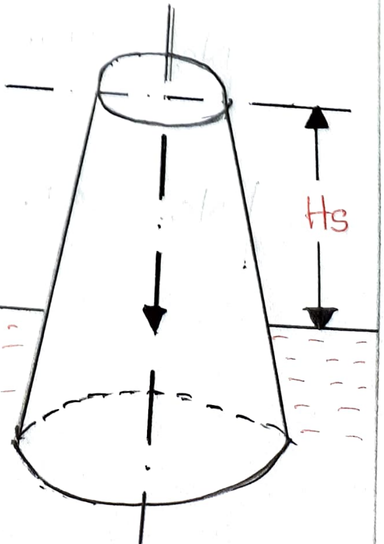
10.b. Uses of draft tube :-

1. It permits a negative head to be established at the outlet of the runner and thereby increase the net head on the turbine. The turbine may be placed above the tail race without any loss of net head and hence turbine may be inspected properly.

2. It converts a large proportion of the kinetic energy ($V_2^2/2g$) rejected at the outlet of the turbine into useful pressure energy. Without the draft tube, the K.E rejected at the outlet of the turbine will go waste to the tail race. 08

Hence by using draft-tube, the net head on the turbine increases. The turbine develops more power and also the efficiency of the turbine increases.

Types of Draft-Tubes



1. Conical draft-tube - The conical draft-tubes and Moody spreading draft-tubes are most efficient while simple elbow tubes and elbow draft tube with circular inlet and rectangular outlet

$D_1 = 300\,mm$, $D_2 = 600\,mm$, $\phi = 45°$, $N = 1000\,r.p.m$

$V_{f_1} = V_{f_2} = 3\,m/s$.

Tangential velocity of impeller at inlet and outlet are.

$$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 0.3 \times 1000}{60} = 15.70\ m/s$$

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.6 \times 1000}{60} = 31.41\ m/s.$$

i) Vane angle at inlet (θ)

$$\tan\theta = \frac{V_{f_1}}{u_1} = \frac{3}{15.70} = 0.191$$

$$\theta = \tan^{-1}(0.191) = 10.81° \text{ or } 10°48'$$

ii) Workdone by impeller on water per unit weight.

$$= \frac{W}{g} \times V_{w_2} u_2 = \frac{\rho \times g \times Q}{g} \times V_{w_2} \times u_2$$

$$= \frac{1000 \times 9.81 \times 0.191}{9.81} \times V_{w_2} \times 31.41$$

08

$\therefore$ ~~$V_{w_2} =$~~

$$\tan\phi = \frac{V_{f_2}}{u_2 - V_{w_2}} = \frac{3}{(31.41 - V_{w_2})}$$

$$31.41 - V_{w_2} = \frac{3}{\tan\phi} = \frac{3}{\tan(45°)} = 3$$

$$31.41 - V_{w_2} = 3$$

$$\therefore V_{w_2} = 31.41 - 3 = 28.41\ m/s$$

$$\therefore = \frac{1000 \times 9.81 \times 0.191}{9.81} \times 28.41 \times 31.41$$

$$= 170440.39\ Nm/s.$$

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