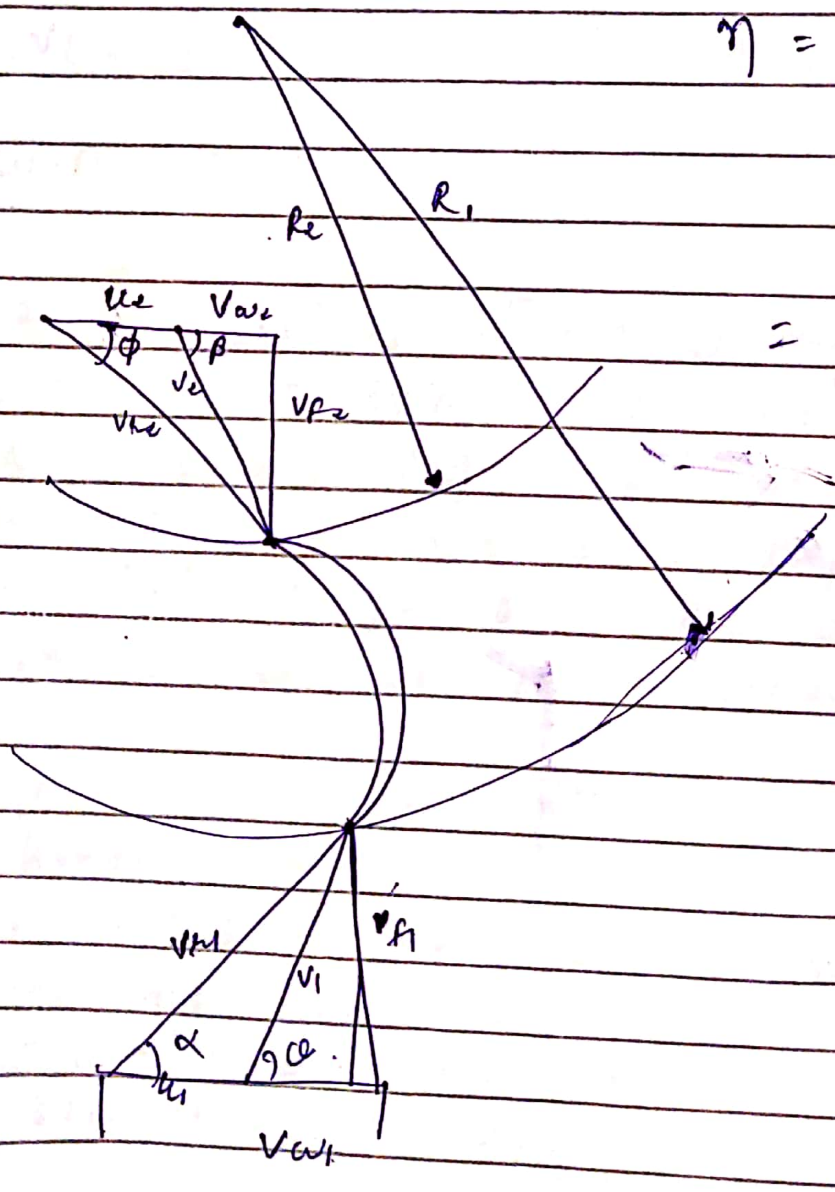
UNIT - 3

(1) Reaction turbine

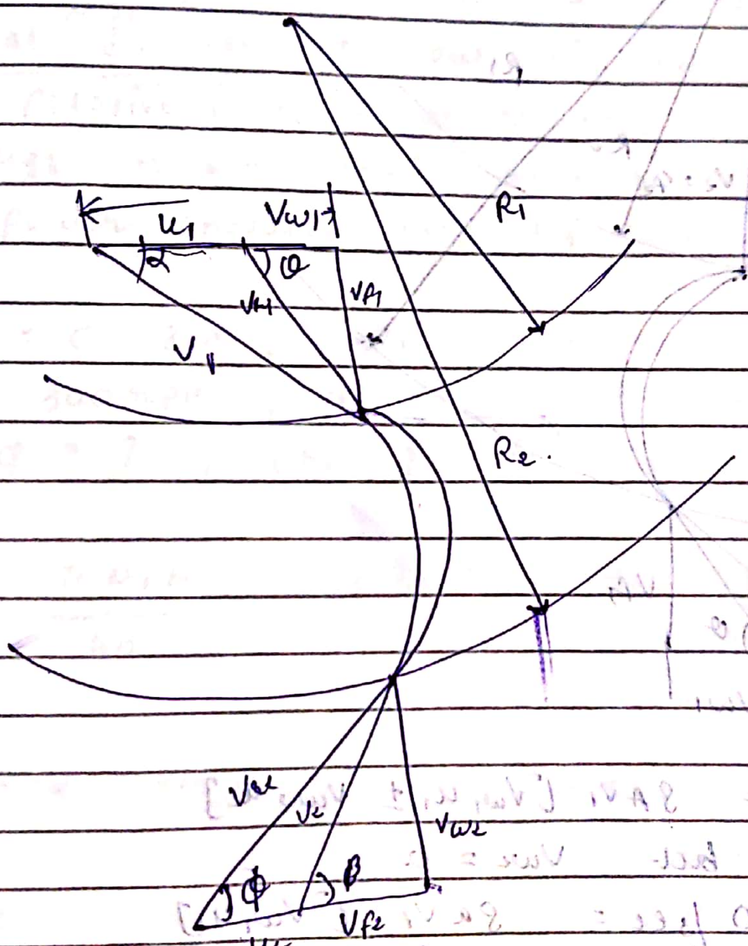
(i) Inwards flow Reaction turbine.



$$\eta = \frac{\rho a V_1 [V_{w_1} u_1 \pm V_{w_2} u_2]}{\rho Q g H}$$

$$= \frac{[V_{w_1} u_1 \pm V_{w_2} u_2]}{g H}$$

(2) Outward flow reaction turbine.



Date for radial flow reaction turbine

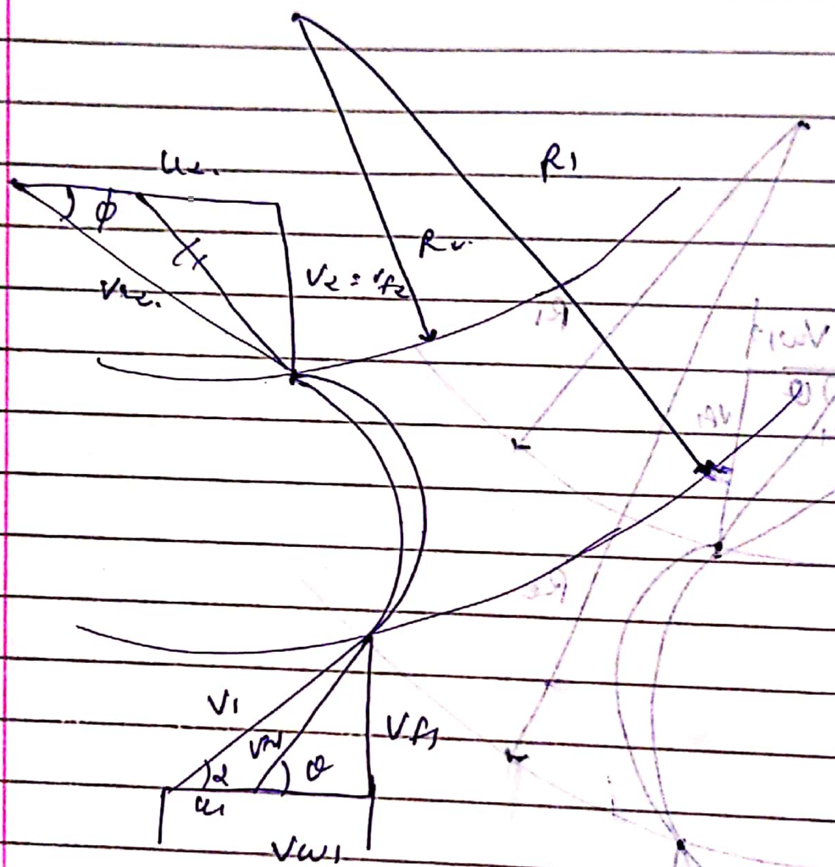
1 $K_u = \dfrac{u}{\sqrt{2gH}}$ $u_1 = \dfrac{\pi D_1 N}{60}$, $u_2 = \dfrac{\pi D_2 N}{60}$.

(3) flow ratio $K_f = \dfrac{V_{f1}}{\sqrt{2gH}}$

(4) $Q = \pi D_1 B_1 V_{f1} = \pi D_2 B_2 V_{f2}$

(5) $H = \dfrac{P_1}{\rho g} + \dfrac{V_1^2}{2g}$, $P_2/\rho g + V_2^2/2g$.

(7) Radial flow reaction turbine.



$$W.D/sec = \rho A V_1 [V_{w1} u_1 \pm V_{w2} u_2]$$

but $V_{w2} = 0$.

$$\therefore W.D/sec = \rho a V_1 [V_{w1} u_1]$$

$$\eta = \frac{W.D/sec}{W.P} = \frac{\rho a V_1 [V_{w1} u_1]}{\rho Q g H} = \frac{1}{gH}[V_{w1} u_1]$$

Head = $H = \frac{V_2^2}{2g} = \frac{1}{g}[V_{w1} u_1 \pm V_{w2} u_2]$

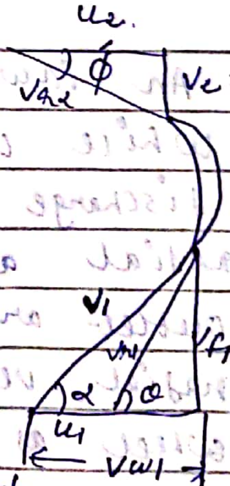
Flow ratio $= \frac{V_{f1}}{\sqrt{2gH}}$, Speed ratio $= \frac{u_1}{\sqrt{}}$

3.10 An inward flow reaction turbine has 0.4 m and 0.8 m internal and external diameters. Velocity of flow is constant and equal to 4 m/s. The turbine runner is having a speed of 300 rpm. The guide blade makes an angle of 15° with the wheel tangent, and breadth (width) of runner at inlet is 10 cm. Assume radial discharge. Find out (i) runner blade angle (ii) relative velocity at entrance (iii) Discharge through turbine (iv) Breadth of wheel at outlet (v) power produced (vi) Hydraulic efficiency.

$D_1 = 0.8 m$, $D_2 = 0.4 m$. $V_{f1} = V_{f2} = 4 m/s$.
$N = 300 rpm$, $\alpha = 15°$, $B_1 = 10 cm = 0.1 m$
θ & ϕ = ?, V_{r1} = ?, Q = ?, B_2 = ?, R.P = ?

⇒ $u_1 = \frac{\pi D_1 N}{60} = 12.56 m/s$ $u_2 = \frac{\pi D_2 N}{60} = 6.28 m/s$.

⇒



$\sin\alpha = \frac{V_{f1}}{V_{w1}}$ ∴ $V_{w1} = 14.93 m/s$

$\tan\theta = \frac{V_{f1}}{V_{w1} - u_1} = \frac{4}{14.93 - 12.56} = 1.688$

→ $\theta = 59.35°$

$\tan\phi = V_2/u_2 = V_{f2}/u_2 = 0.637$ ∴ $\phi = 32.5°$

⇒ $\sin\theta = \frac{V_{f1}}{V_{r1}}$ ∴ $V_{r1} = 4.65 m/s$.

→ $Q = \pi D_1 B_1 V_{f1} = \pi \times 0.8 \times 0.1 \times 4 = 1.005 m^3/s$

$Q = \pi D_1 B_1 V_{f1} = \pi D_2 B_2 V_{f2}$

$B_2 = 0.2\,m$

$\Rightarrow$ power developed $= \rho Q [V_{w1} u_1]$

$= 1000 \times 1.005 \times 14.93 \times 12.56$

$= 188.458$

$\Rightarrow H = \frac{V_{w1} u_1}{g} + \frac{V_2^2}{g} = \frac{V_{w1} u_1}{g} + \frac{V_{f2}^2}{2g}$

$= 19.93\,m$

$\eta = \frac{R.P}{\rho Q g H} = \frac{188.458 \times 10^3}{1000 \times 1.005 \times 9.81 \times 19.93}$

$= 95.91\%$

3.12 An inward flow reaction turbine produces 150 kW while working under a head of 25 m. The discharge through the turbine is 720 LPS and is radial at outlet. The diameter at the inlet and outlet are 60 cm and 45 cm respectively. Take radial velocity at outlet as 4.8 m/s, width of wheel as constant and speed of runner is 600 rpm. Calculate (i) overall and hydraulic eff. (ii) Inlet angle of guide and runner blade

$\rightarrow$ $S.P = 150 \times 10^3\,W$, $H = 25\,m$, $Q = 720 \times 10^{-3}\,m^3/s$

$D_1 = 0.6\,m$, $D_2 = 0.45\,m$, $\beta = 90°$, $V_{f2} = 4.8\,m/s$

$B_1 = B_2$, $N = 600\,rpm$, $\eta_o = ?$, $\eta_h = ?$, $\alpha, \theta = ?$

$$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 0.6 \times 600}{60} = 18.85 \, m/s$$

$$u_2 = \frac{\pi D_2 N}{60} = 14.14 \, m/s \qquad \eta_o = \frac{S.P}{\rho g Q H}$$

$$= \frac{150 \times 10^3}{1000 \times 720 \times 10^{-3} \times 9.81 \times 25} = 84.95\%$$

$$H = \frac{V_{w1} u_1}{g} + \frac{V_2^2}{2g} \quad \therefore V_{w1} = 12.4 \, m/s \quad [V_2 = V_{f2} = 4.8 \, m/s]$$

$$Q = \pi D_1 B_1 V_{f1} = \pi D_2 B_2 V_{f2}$$

$$\frac{D_1}{D_2} = \frac{V_{f2}}{V_{f1}} \quad \therefore \quad V_{f1} = 3.6 \, m/s.$$

$$\tan\alpha = \frac{V_{f1}}{V_{w1}} = 0.2903 \qquad \alpha = 16.19^\circ$$

$$\tan\theta = \frac{V_{f1}}{V_{w1} - u_1} = \frac{3.6}{V_{w1} - u_1} = -0.558.$$

$-ve$ sign $\theta > 90^\circ$ $\quad \therefore \theta = 150.83^\circ$

3.2 Francis turbine designed to develop 160 kW, working under a head of 10 m and running at 200 rpm. The hydraulic losses in turbine are 15% of available energy. The overall eff. of turbine is 80%. Assume flow ratio $K_f = 0.94$ and speed ratio $= 0.25$

(i) calculate. guide blade angle and runner vane angle at inlet.

Diameter and width at inlet.

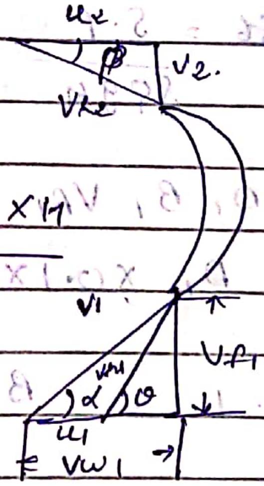
→ $S.P = 160 \times 10^3 W$, $H = 10 m$, $N = 200 rpm$, $\eta_h = 1 - 0.15 = 0.85$

$\eta_o = 0.8$, $K_f = 0.94$, $K_u = 0.25$, $\alpha_1 = ?$, $\beta_1 = ?$, $D_1 = ?$, $B_1 = ?$

$u_1 = K_u \sqrt{2gH} = 0.25 \times \sqrt{2 \times 9.81 \times 10} = 3.5 m/s.$

$V_{f1} = K_f \sqrt{2gH} = 0.94 \times \sqrt{2 \times 9.81 \times 10} = 13.16 m/s.$

$\beta = 90^\circ$, $V_{w2} = 0$, $V_2 = V_{f2}$



$\eta = \frac{V_{w1} u_1}{gH}$ $V_{w1} = \frac{\eta \times g \times H}{u_1}$

$V_{w1} = 23.82 m/s$

$\tan\alpha = \frac{V_{f1}}{V_{w1}} = \frac{13.16}{23.82}$ $\alpha = 28.92^\circ$

$\tan\theta = \frac{V_{f1}}{V_{w1} - u_1} = 0.6476$, $\theta = 32.92^\circ$

$u_1 = \frac{\pi D_1 N}{60}$ $\therefore D_1 = \frac{u \times 60}{\pi N} = 0.334 m.$

$\eta_o = \frac{S.P}{\rho Q g H} = \frac{160 \times 10^3}{1000 \times Q \times 9.81 \times 10}$ $B_1 = 0.147 m$

3.21 Estimate the main dimensions for a Francis turbine for the following conditions. Head = 100m. power 3 MW, speed 400 rpm, $\eta_h = 0.89$, $\eta_0 = 0.86$, $\frac{B_1}{D_1} = 0.1$, Flow ratio 0.2, $D_1 = 2D_2$, Velocity of flow is constant.

$\Rightarrow$ $H = 100m$, $S.P = 3 \times 10^6$ W, $N = 400$ rpm, $\eta_h = 0.89$,

$\eta_0 = 0.86$, $\frac{B_1}{D_1} = 0.1$, $K_f = 0.2$, $D_1 = 2D_2$, $V_{f1} = V_{f2}$

Find out, D_1, B_1, D_2, B_2, α, θ, β, ϕ = ?

$V_{f1} = K_f \sqrt{2gH} = 0.2 \sqrt{2 \times 9.81 \times 100} = 8.86$ m/s.

$V_{f2} = V_{f1} = 8.86$ m/s.

$\eta_0 = 0.86 = \frac{S.P}{\rho Q g H}$ $\therefore$ $Q = 3.556\ m^3/s$

$Q = \pi D_1 B_1 V_{f1}$

$3.556 = \pi D_1 \times 0.1 \times D_1 \times 8.86 = 1 - D_1 = 1.13$ m

$\frac{B_1}{D_1} = 0.1$ $\therefore$ $B_1 = 0.113$ m.

$D_2 = \frac{1}{2} D_1 = 0.565$ m.

$\therefore$ $Q = \pi D_2 B_2 V_{f2}$

$B_2 = 0.226$ m.

$u_1 = \frac{\pi D_1 N}{60} = 23.66$ m/s | $u_2 = \frac{\pi D_2 N}{60} = 11.83$ m/s

$\eta_h = \frac{V_{w1} u_1}{gH}$ $\therefore$ $V_{w1} = 36.9$ m/s.

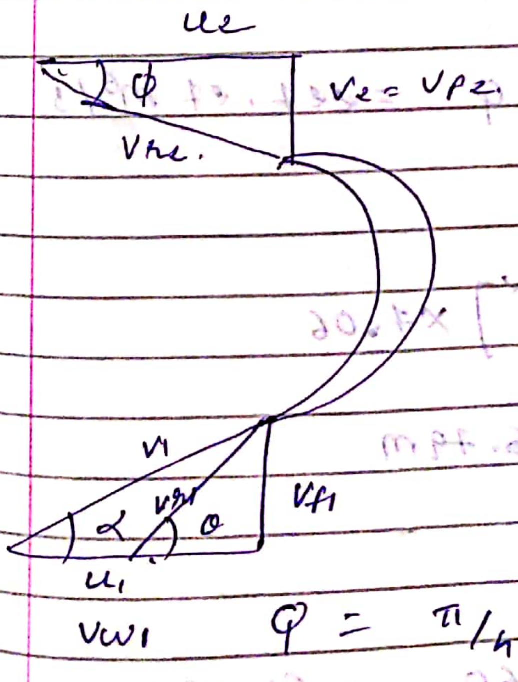
$\tan\alpha = \dfrac{V_{f1}}{V_{w1}}$ ∴ $\alpha = 13.5^\circ$

$\tan\theta = \dfrac{V_{f1}}{V_{w1} - u_1} =$ ∴ $\theta = 33.79^\circ$

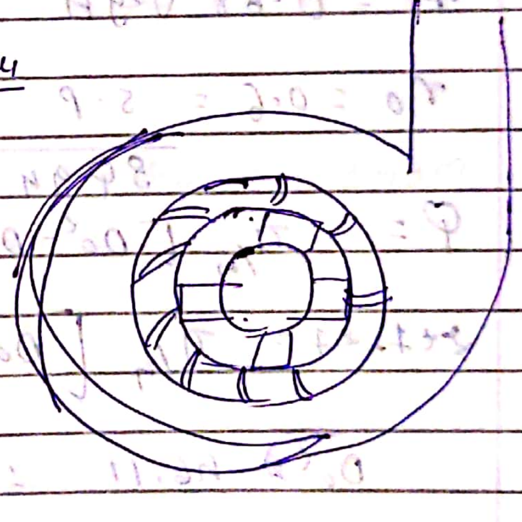
$\tan\phi = \dfrac{V_{f2}}{u_2} =$ ∴ $\phi = 36.83^\circ$

∴ $\beta = 90^\circ$ (radial discharge)

(7) kaplan turbine.



$\eta_h = \dfrac{V_{w1} u_1}{gH}$



$Q = \pi/4 \left[(D_o^2 - D_b^2) \right]$

$V_f = K_f \sqrt{2gH}$

$u_1 = u_2 = \dfrac{\pi D_o N}{60}$

$u = K_u \sqrt{2gH}$

3.26

(1) A kaplan turbine runner is to be designed to develop 7357.5 kW shaft power. The net available head is 5.5m. Assume that speed ratio is 2.09 and flow ratio is 0.68 and overall eff is 60%. The dia of boss is 1/3rd of the dia of runner, find dia of runner, its speed and specific speed.

S.P = 7357.5 kW, H = 5.5 m, K_u = 2.09, K_f = 0.68

$\eta_0 = 60\%$, $D_b = 1/3\ D_0$, $D_0 = ?$ $D_b = ?$, $N = ?$

$N_s = ?$

$u_1 = K_u \sqrt{2gH} = 21.71\ m/s.$

$V_{f1} = 0.68\sqrt{2gH} = 7.06\ m/s$

$\eta_0 = 0.6 = \dfrac{S.P}{\rho g Q H}$ $\therefore$ $Q = 227.27\ m^3/s.$

$Q = \frac{\pi}{4}\left[D_0^2 - D_b^2\right] \times V_{f1}$

$227.27 = \frac{\pi}{4}\left[D_0^2 - \left[\frac{D_0}{3}\right]^2\right] \times 7.06$

$D_0^2 = 46.11$ $\therefore$ $D_0 = 6.79\ m$

$D_b = 6.73/3 = 2.26\ m$

$u_1 = \dfrac{\pi D_0 N}{60}$ $\quad N = \dfrac{u_1 \times 60}{\pi \times D_0} = 61.06\ rpm.$

$N_s = \dfrac{N\sqrt{P}}{H^{5/4}} = 627.870\ rpm.$

Determine runner dia and rotational speed of kaplan turbine having following particulars:.

Net head = 5.5m

Speed ratio = 2.1 Power available = 8850kW

flow " = 0.67

η_0 = 0.85

Ratio of D_b/D_0 = 0.35

$H = 5.5\,m$, $K_u = 2.1$, $K_f = 0.67$, $\eta_0 = 0.85$, $D_b/D_0 = 0.35$

$P = 8850\ kW$

$u = K_u\sqrt{2gH} = 21.81\ m/s.$

$V_f = K_f\sqrt{2gH} = 6.96\ m/s.$

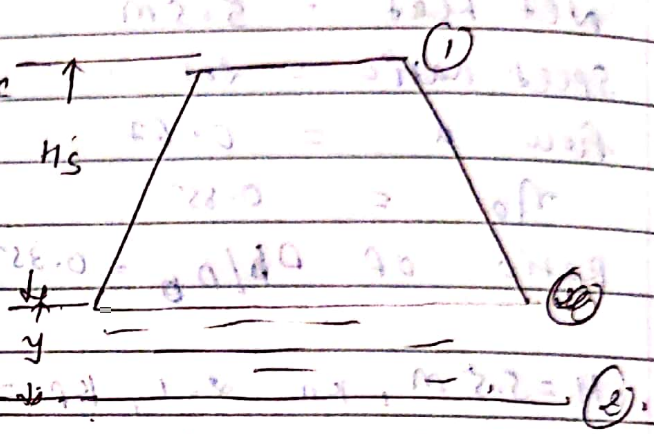
$\eta_0 = 0.85 = \dfrac{P}{\rho Q g H}$ $\therefore Q = 192.97\ m^3/s.$

$Q = \pi/4\,[D_0^2 - D_b^2] \times V_f$ $\therefore D_0 = 6.343\,m.$

$N = 65.67\ rpm$

Draft tube

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + H_s + y = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + 0 + h_f \quad \text{--- (i)}$$



$$\frac{P_2}{\rho g} = \frac{P_a}{\rho g} + y \quad = \text{atm pr. head} + y$$

Substituting $\frac{P_2}{\rho g}$ in eqn (i)

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + H_s + y = \frac{P_a}{\rho g} + y + 0 + h_f + \frac{V_2^2}{2g}$$

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + H_s = \frac{P_a}{\rho g} + h_f + V_2^2/2g$$

$$\frac{P_1}{\rho g} = \frac{P_a}{\rho g} + \frac{V_2^2}{2g} + h_f - \frac{V_1^2}{2g} - H_s$$

$$= \frac{P_a}{\rho g} - H_s - \left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g} - h_f\right)$$

η of draft tube

$$\eta_d = \frac{\text{Actual conversion of kinetic head into pr. head}}{\text{Kinetic head at inlet of draft tube}}$$

Theoritical conversion of kinetic head into pr head in draft tube $= \frac{V_1^2}{2g} - V_2^2/2g$

Actual conversion of kinetic head into pr. head

$$= \frac{V_1^2}{2g} - \frac{V_2^2}{2g} - h_f$$

$$\eta_d = \frac{V_1^2/2g - V_2^2/2g - h_f}{V_1^2/2g}$$

Scanned with CamScanner

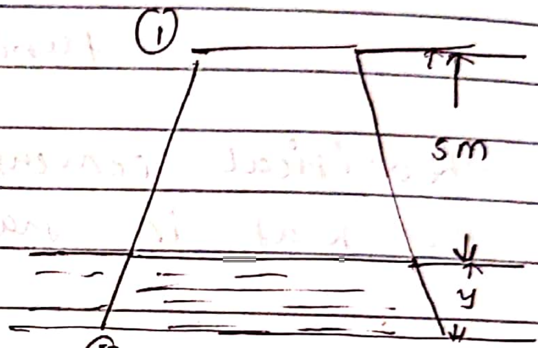
18.33

A water turbine has a velocity of 6 m/s at the entrance of draft tube and a velocity of 1.2 m/s at the exit. For friction losses of 0.1 m and a tail water 5 m below the entrance of draft tube, find the pr. head at the entrance.

$V_1 = 6$ m/s.

$V_2 = 1.2$ m/s

$h_f = 0.1$ m



$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + h_f$$

$z_1 = 5 + y$, $z_2 = 0$, $V_1 = 6$ m/s, $V_2 = 1.2$ m/s

$$\frac{P_1}{\rho g} + \frac{6^2}{2 \times 9.81} + (5 + y) = \frac{P_a}{\rho g} + y + \frac{1.2^2}{2 \times 9.81} + 0 + 0.1$$

$$\frac{P_1}{\rho g} + 1.835 + 5 + y = \frac{P_a}{\rho g} + y + 0.0734 + 0.1$$

$$\frac{P_1}{\rho g} + 6.835 = \frac{P_a}{\rho g} + 0.1734$$

Taking $P_a/\rho g = 0$. (atm. pr.)

$$\frac{P_1}{\rho g} + 6.835 = 0 + 0.1734$$

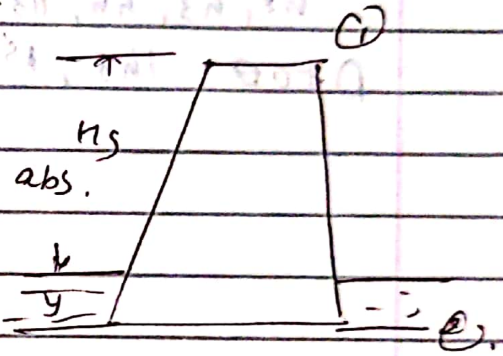
$$P_1/\rho g = -6.6616 \text{ m}$$

A conical draft tube having dia at top is 2 m and pr. head at 7 m of water (vaccum), discharges water at the outlet with a velocity of 1.2 m/s at the rate of 25 m^3/s. If atm. pr. head is 10.3 m of water and losses betn the inlet and outlet of the draft tubes are negligible, find length of draft tube immersed in water. Total length of tube is 5 m.

$D_1 = 2$ m

$P_1/\rho g$ = 7 m vaccum

$= 10.3 - 7.0 = 3.3$ m abs.



$V_e = 1.2$ m/s

$Q = 25\ m^3/s$

h_f = negligible

$$V_1 = Q/\tfrac{\pi}{4}d_1^2 = \frac{25}{\pi/4\,(2.0)^2} = 7.957\ m/s.$$

$$P_1/\rho g = P_a/\rho g - H_s - \left[V_1^2/2g - V_e^2/2g - h_f \right]$$

$$3.3 = 10.3 - H_s - \left[\frac{7.957^2}{2\times 9.81} - \frac{1.2^2}{2\times9.81} - 0\right]$$

$h_f = 0$, $P_a/\rho g = 10.3$

$H_s = 3.8464$ m

y = Total length $- H_s$

$= 5 - 3.8464$

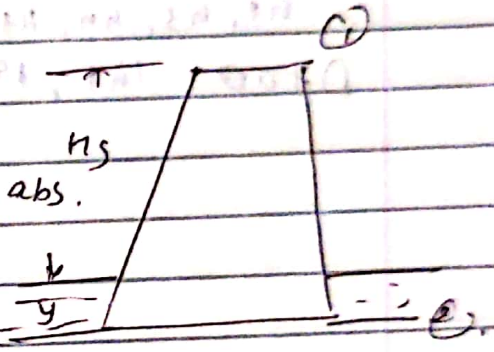
$= 1.1536$ m

A conical draft tube having dia at top is 2 m and pr. head at 7 m of water. (vaccum), discharges water at the outlet with a velocity of 1.2 m/s at the rate of 25 m^3/s. If atm. pr. head is 10.3 m of water and losses betn the inlet and outlet of the draft tubes are negligible, find length of draft tube immersed in water. Total length of tube is 5 m.

$D_1 = 2$ m

$P_1/\rho g = 7$ m vaccum

$= 10.3 - 7.0 = 3.3$ m abs.



$V_2 = 1.2$ m/s

$Q = 25\ m^3/s$

h_f = negligible

$$V_1 = Q/\frac{\pi}{4} d_1^2 = \frac{25}{\pi/4 (2.0)^2} = 7.957 \text{ m/s}$$

$$P_1/\rho g = Pa/\rho g - H_s - \left[V_1^2/2g - V_2^2/2g - h_f \right)$$

$$3.3 = 10.3 - H_s - \left(\frac{7.957^2}{2\times 9.81} - \frac{1.2^2}{2\times 9.81} - 0 \right]$$

$h_f = 0$, $Pa/\rho g = 10.3$

$H_s = 3.8464$ m

y = Total length $- H_s$

$= 5 - 3.8464$

$= 1.1536$ m