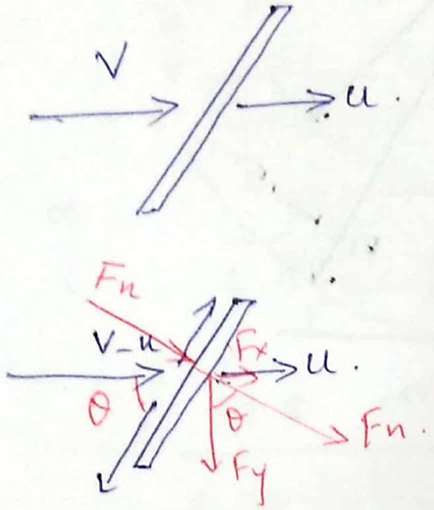
IAT 2 – Scheme & Solution

Part – A

1a)



— (1)

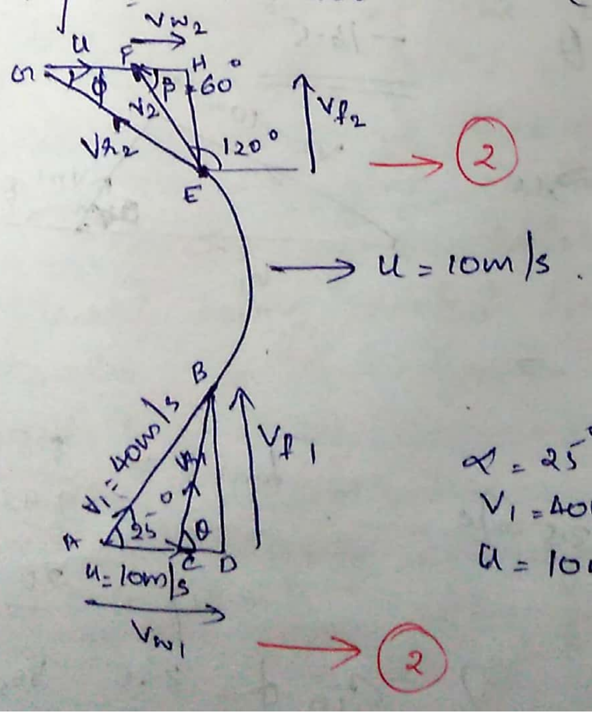
Net force in normal direction = $\frac{\text{Mass striking}}{\text{time}} \times$ [Velocity of jet before striking – velocity of jet after striking] — (1)

$= \rho a (V-u) \times [(V-u) \sin\theta]$

$= \rho a (V-u)^2 \sin\theta$ — (2)

$F_x = F_n \sin\theta = \rho a (V-u)^2 \sin^2\theta$
$F_y = F_n \cos\theta = \rho a (V-u)^2 \sin\theta \cos\theta$ } — (1)

b.)



→ (2)

→ (2)

$\alpha = 25°$
$V_1 = 40 m/s$.
$u = 10 m/s$.

Assuming no shock

Let $u_1 = u_2 = u = 10 m/s$

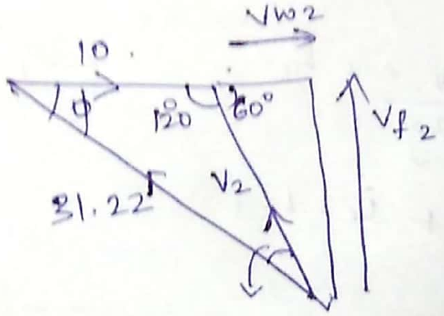
$V_{r_1} = V_{r_2}$.

$\tan\theta = \dfrac{V_{f_1}}{V_{w_1} - u} = \dfrac{40\sin 25}{40\cos 25 - 10}$

$\theta = 32.78^\circ$ → (1)

$\sin\theta = \dfrac{V_{f1}}{V_{r_1}}$ $V_{r_1} = \dfrac{V_{f1}}{\sin\theta} = 31.22\,m/s$ → (1)

$V_{r_1} = V_{r_2} = 31.22\,m/s$.



$\dfrac{31.22}{\sin 120} = \dfrac{10}{\sin(60-\phi)}$

$\phi = 43.9^\circ$ — (1)

$180 - (120+\phi)$

$= 60 - \phi$

i) Vane angles are $\theta = 32.78^\circ$ & $\phi = 43.9^\circ$.

ii) Work done $= \dfrac{\rho a v}{Wt/s}\left[V_{w_1} + V_{w_2}\right]u$

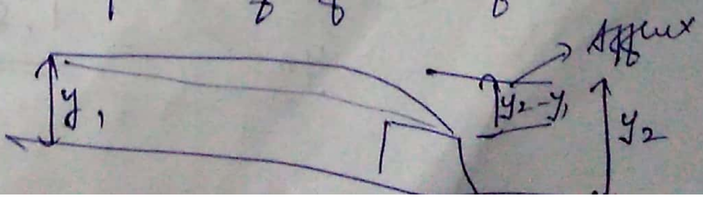
$= \dfrac{1}{g}\left[V_{w_1} + V_{w_2}\right]u$

$= \dfrac{1}{g}\left[40\cos 25 + 31.22\cos 43.9 - 10\right] 10$

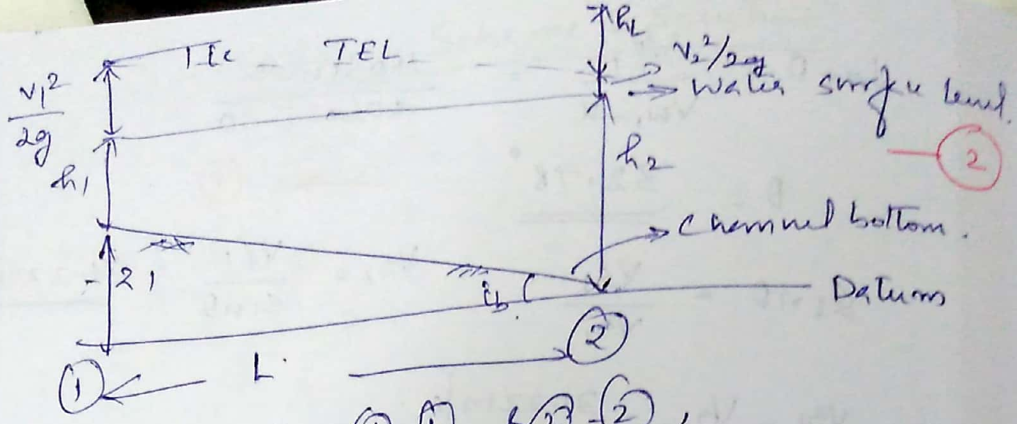
$= 49.69\,Nm/N$ — (2)

iii) $\eta = \dfrac{49.69}{\dfrac{\frac{1}{2}\rho a v\, v^2}{W/s}} = \dfrac{49.69}{\frac{1}{2}\times\frac{1}{g}\cdot v^2} = 80.9\%$ — (1)

2a.) The max. increase in water level due to obstruction in path of flow of water.



— (2)



Bernoulli's @ (1)-(1) & (2)-(2),

$$z_1 + h_1 + \frac{v_1^2}{2g} = h_2 + \frac{v_2^2}{2g} + h_L$$ — (2)

$$i_b \cdot L + E_1 = E_2 + i_e \cdot L$$

$$L = \frac{E_2 - E_1}{i_b - i_e}$$ — (1)

b.) $B = 3m$ $i_b = 0.0001$ $Q = 3 m^3/s$.

$y = 0.5m$, $N = 0.016$.

$$y_c = \left(\frac{(Q/B)^2}{g}\right)^{1/3} = \underline{0.467m}$$ — (2)

$y_n = ?$

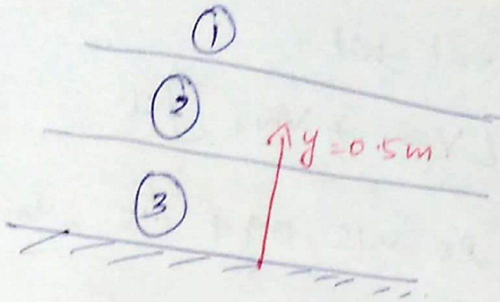
$$Q = By \cdot \frac{1}{N} \cdot R^{2/3} S^{1/2}.$$ — (1)

$$3 = 3 \times y_n \times \frac{1}{0.016} \times \left(\frac{By_n}{B+2y_n}\right)^{2/3} \times .0001^{1/2}$$

$$3 = \frac{3}{0.016} \times y_n \times 3^{2/3} \left[\frac{y_n}{3+2y_n}\right]^{2/3} \times 0.0001^{1/2}.$$

$$\frac{0.016}{3^{2/3} \times 0.0001^{1/2}} = \frac{y_n^{5/3}}{(3+2y_n)^{2/3}} = 0.769.$$

$$y_n = \underline{1.82m}$$ — (2)



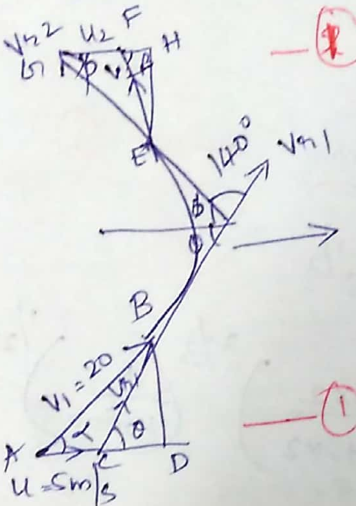
$y_n > y_c$

∴ Mild slope channel & M profile. — (2)

y = 0.5m, lies in zone 2.

∴ M_2 profile — (1)

3a.)



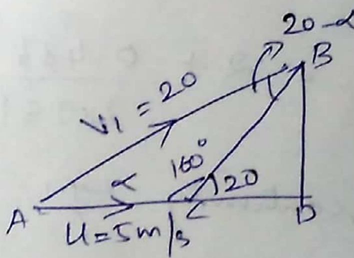
— (1)

— (1)

Since a symmetrical vane, $\theta + \phi + 140 = 180$

$\theta = \phi = \frac{40}{2} = 20°$ — (1)

Inlet Δ^{le}.



180 − (160 + α)

20 − α

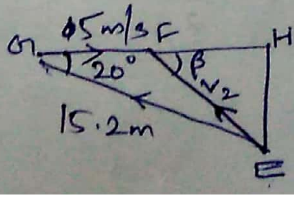
$\frac{20}{\sin 160} = \frac{5}{\sin(20-\alpha)}$ $\alpha = 15.09°$ (1)

$V_{r_1} = \sqrt{20^2 + 5^2 - 2 \times 20 \times 5 \cos 15.09}$

$= 15.23 m/s$ (1)

$V_{r_2} = V_{r_1} = 15.23 m/s$

Outlet Δ^{le}.



$\tan \beta = \frac{15.2 \sin 20}{15.2 \cos 20 - 5}$

$\beta = 29.25°$ (1)

Work done /unit wt

$= \frac{1}{g} [V_{w1} + V_{w2}] u$

$= \frac{1}{g} [20 \cos 15.09 + (15.2 \cos 20 - 5)]$

$= 14.57 Nm/N$ — (2)

3.b.) $y_2 - y_1 = 1m$. $S = 1/10000$

$N = 0.03$

$B = 30m$.

$y_1 = 2m$

$y_2 = y_1 + 1 = 3m$ — (1)

$V_1 = \frac{1}{N} R^{2/3} S^{1/2}$

$= \frac{1}{0.03} \times \left(\frac{30 \times 2}{30 + 2 \times 2}\right)^{2/3} \left(\frac{1}{10000}\right)^{1/2}$

$= 0.486 m/s$ — (1)

$E_1 = y_1 + \frac{V_1^2}{2g} = 2 + \frac{0.486^2}{2 \times 9.81} = 2.012m$ — (1)

$V_2 \Rightarrow$ from continuity eqn.

$A_1 V_1 = A_2 V_2$

$3 \times 2 \times .486 = 3 \times 3 \times V_2$

$V_2 = 0.324 m/s$ — (1)

$E_2 = y_2 + \frac{V_2^2}{2g}$

$= 3 + \frac{0.324^2}{2g} = 3.005m$ (1)

$i_B = ?$

$$V_{avg} = \frac{1}{N} R_{avg}^{2/3} \, i_c^{1/2}.$$

$$V_1 A_1 = V_2 A_2 = V_{avg} A_{avg}.$$

$$V_{avg} = \frac{V_1 A_1}{A_{avg}} = \frac{.486 \times 30 \times 2.}{30\,(2+3)/2}.$$

$$= \underline{\underline{0.389 \, m/s}}.$$

$$R_{avg} = \frac{R_1 + R_2}{2} = \left(\frac{1.765 + 2.5}{2}\right)$$

$$= \underline{\underline{2.13 \, m}}$$

$$0.389 = \frac{1}{0.03} \times 2.13^{2/3} \, i_c^{1/2}. \quad — (1).$$

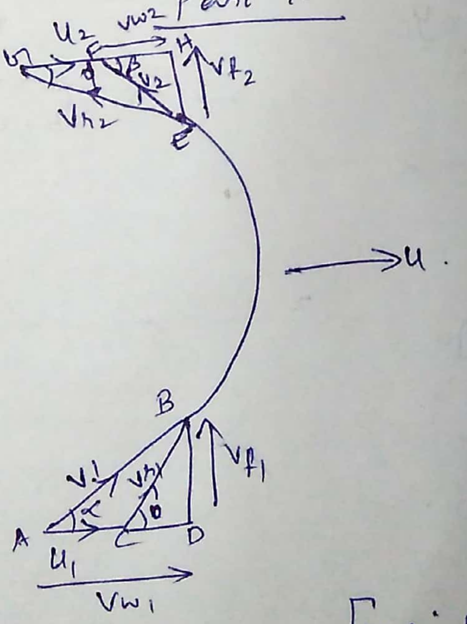
$$i_c = \underline{\underline{4.97 \times 10^{-5}}} \qquad \frac{E_2 - E_1}{4.97 \times 10^{-5}}$$

$$L = \frac{1}{10000} — .$$

$$= \underline{\underline{19739.12 \, m}}. \quad — (1)$$

Part B.

4.a)



Listing of components. — (2)

— (2)

$$F_x = \frac{\text{Mass}}{\text{unit time}} \left[\text{velocity before striking} - \text{velocity of jet after striking}\right]$$

$$= \rho a V_{r_1} \left[V_1 \cos\alpha - - V_2 \cos\beta \right] — (2)$$

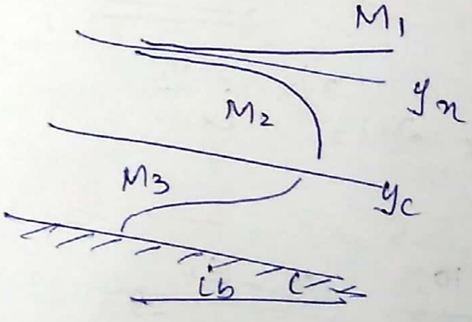
$$= \rho a V_{r_1} \left[V_1 \cos\alpha + V_2 \cos\beta \right]$$

$$F_x = \rho a V_{r_1} \left[V_{w_1} \pm V_{w_2} \right]$$

$$\text{Work done} = \rho a V_{r_1} \left[V_{w_1} \pm V_{w_2} \right] u \quad \text{— (2)}$$

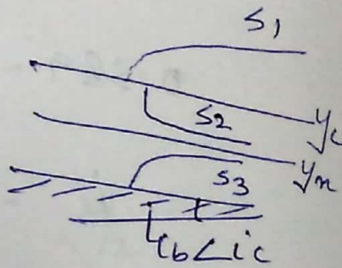
$$\text{Efficiency} = \frac{\rho a V_{r_1} \left[V_{w_1} \pm V_{w_2} \right] u}{\frac{1}{2} \rho a v_1^3} \quad \text{— (2)}$$

5a.) M curves.



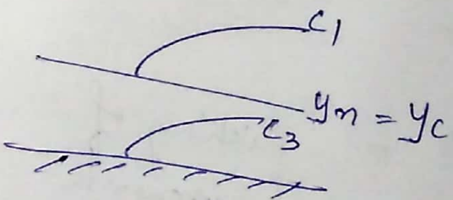
$i_b > i_c$. —2

S curves



—2

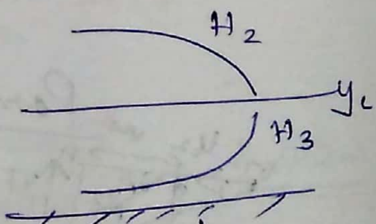
C curves.



$i_b = i_c$.

—2

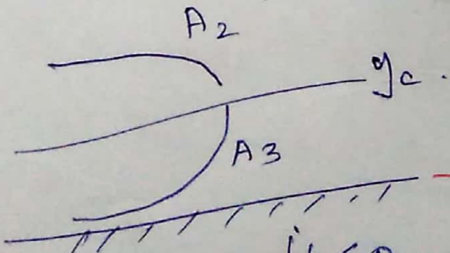
H curves.



$i_b = 0$

—2

Adverse slopes.



—2

$i_b < 0$.