CLASS TEST

Sl. : 01SKME_ABCDEFGHI_16925

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HYDRAULIC MACHINE

MECHANICAL ENGINEERING

Date of Test : 16/09/2025

ANSWER KEY

1.	(d)	7.	(d)	13.	(a)	19.	()	25.	(a)
2.	(d)	8.	(c)	14.	(b)	20.	(c)	26.	(a)
3.	(c)	9.	(b)	15.	(d)	21.	(c)	27.	(a)
4.	(d)	10.	(c)	16.	(a)	22.	(d)	28.	(c)
5.	(b)	11.	(b)	17.	(c)	23.	(c)	29.	(a)
6.	(a)	12.	(b)	18.	(b)	24.	(d)	30.	(b)

DETAILED EXPLANATIONS

1. **(d)**

$$\text{Speed Ratio} = \frac{u}{\sqrt{2gH}}$$

$$\Rightarrow \quad \frac{u}{\sqrt{2\times 9.8\times 900}} = 0.45$$

$$\Rightarrow \quad u = 0.45\sqrt{2\times 9.8\times 900} = 59.8 \simeq 60 \text{ m/sec}$$

2. **(d)**

Given : $N_{s1} = N_{s2}$, $P_1 = P_2$, $\frac{N_1}{N_2} = 32$

Specific speed of turbine,

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

$$N_{s1} = N_{s2}$$

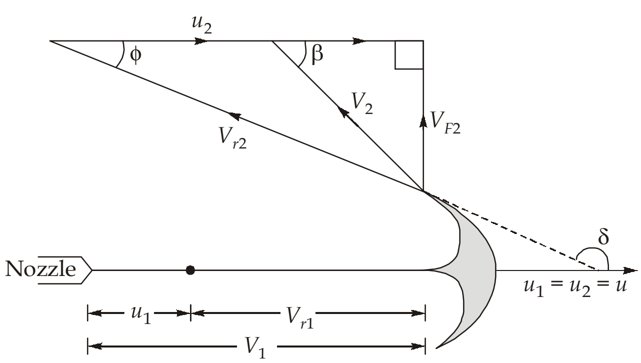
$$\frac{N_1\sqrt{P_1}}{H_1^{5/4}} = \frac{N_2\sqrt{P_2}}{H_2^{5/4}}$$

$$\Rightarrow \quad \left(\frac{H_1}{H_2}\right)^{5/4} = \frac{N_1}{N_2}\cdot\sqrt{\frac{P_1}{P_2}}$$

$$\Rightarrow \quad \frac{H_1}{H_2} = \left(\frac{N_1}{N_2}\right)^{4/5} \qquad [\because P_1 = P_2]$$

$$= (32)^{4/5} = 16$$

3. **(c)**



$$u_1 = u_2 = u = 10 \text{ m/s}$$

$$V_1 = 30 \text{ m/s}$$

$$Q = 0.2 \text{ m}^3/\text{s}$$

$$\delta = 120°$$

$$\phi = (180° - \delta)$$

$$= (180° - 120°) = 60°$$

Power developed by Pelton wheel:

$$P = \rho Q(V_1 - u)(1 + \cos\phi)u$$
$$= 1000 \times (0.2) \times (30 - 10) \times (1 + \cos 60°) \times 10$$
$$= 60000 \text{ W}$$
$$= 60 \text{ kW}$$

Note : By default consider blades to be smooth.

$\Rightarrow$ $$V_{r_1} = V_{r_2}$$

4. (d)

Governor of turbine, helps in starting and shutting down the turbo unit.

5. (b)

$$N_s = \frac{N\sqrt{Q}}{H_m^{3/4}} = \frac{T^{-1}L^{3/2}T^{-1/2}}{L^{3/4}}$$

$$\left[N = \left[M^0L^0T^{-1}\right]; Q = \left[M^0L^3T^{-1}\right]; H_m = \left[M^0LT^0\right]\right]$$

$$= \left[M^0L^{3/4}T^{-3/2}\right]$$

6. (a)

$$\text{Discharge, } Q = \frac{\pi}{4}\left(D^2 - D_b^2\right)V_f$$
$$= \frac{\pi}{4}\left(2^2 - 0.8^2\right) \times 0.65 \times \sqrt{2 \times 9.8 \times 30}$$
$$= 41.62 \text{ m}^3/\text{s}$$
$$\text{Power developed, } P = \rho g Q H \eta_0$$
$$= 9810 \times 41.62 \times 30 \times 0.9$$
$$= 11.02 \times 10^6 \text{ W}$$

7. (d)

Work done by ject on series of plates per second,

$$= F_x \times u$$
$$= \rho AV(V - u) \cdot u$$ [Where F_x = Force in x direction]

Kinetic energy of jet per second,

$$= \frac{1}{2}\text{mV}^2 = \frac{1}{2}\rho AV \cdot V^2 = \frac{1}{2}\rho AV^3$$

$$\text{Efficiency of jet} = \frac{\rho AV(V-u)\cdot u}{\frac{1}{2}\rho AV^3} = \frac{2(V-u)\cdot u}{V^2}$$

8. (c)

- Specific speed of pump, $N_s = \dfrac{N\sqrt{Q}}{H^{3/4}}$

S.No.	Turbine	Specific speed
1.	Pelton - Single jet - Multijet jet	Upto 30 30 - 60
2.	Francis	60 - 300
3.	Propellar	300 - 600
4.	Kaplan	600 - 1000

- Draft tube is required at the exit of reaction turbine.
- Screw pump is used for pumping viscous oil.

9. **(b)**

In this case, $D_1 = D_2$

$$\frac{Q_1}{D_1^3 N_1} = \frac{Q_2}{D_2^3 N_2}$$

$$\frac{0.5}{1200} = \frac{0.9}{N_2}$$

$$N_2 = 2160 \text{ rpm}$$

10. **(c)**

1. The specific speed for turbine is $\dfrac{NP^{1/2}}{H^{5/4}}$

2. The specific speed for pump is $\dfrac{NQ^{1/2}}{H^{3/4}}$

11. **(b)**

Applying energy equation,

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_j}{\rho g} + \frac{V_j^2}{2g} + Z_j + h_L$$

$$\Rightarrow \quad 0 + 0 + 1670 = 0 + \frac{V_j^2}{2g} + 1000 + h_L$$

$$A_{\text{penstock}} \times V_{\text{penstock}} = A_{\text{jet}} \times V_j$$

$$\Rightarrow \quad \frac{\pi}{4} D^2 \times V_P = \frac{\pi}{4} d_j^2 \times V_j$$

$$\Rightarrow \quad V_p = \left(\frac{d_j}{D}\right)^2 \times V_j = \left(\frac{0.18}{1}\right)^2 V_j = 0.0324 V_j$$

$$h_L = \frac{fLV_P^2}{D \times 2g}$$

$$= \frac{0.015 \times 6000 \times (0.0324)^2 \times V_j^2}{1 \times 2 \times 9.81}$$

$$= 4.815 \times 10^{-3} \; V_j^2$$

From energy equation,

$$1670 = \frac{V_j^2}{2g} + 1000 + 4.815 \times 10^{-3} V_j^2$$

$$670 = 0.0557 V_j^2$$

$$V_j = 109.675 \text{ m/s}$$

$$V_{\text{bucket}} = \frac{V_j}{2} = \frac{109.675}{2} = 54.8 \text{ m/s}$$

$$V_{\text{bucket}} = 54.8 = \frac{\pi DN}{60}$$

$$N = \frac{54.8 \times 60}{\pi \times 3}$$

$$= 348.86 \text{ rpm} \simeq 349 \text{ rpm}$$

12. (b)

$$\text{Mean bucket speed, } u = \phi\sqrt{2gH} = 0.47 \times \sqrt{2 \times 9.81 \times 60}$$

$$= 16.13 \text{ m/s}$$

$$\text{Velocity of jet, } V_1 = c_v\sqrt{2gH} = 0.97 \times \sqrt{2 \times 9.81 \times 60}$$

$$= 33.28 \text{ m/s}$$

$$\text{Power, } P = \rho Q(V_1 - u)(1 + k\cos\phi)u$$

$$= 1000 \times 0.8 \times (33.28 - 16.13) \times (1 + \cos 10) \times 16.13$$

$$= 439245.10 \text{ W}$$

$$\text{Shaft power, S.P.} = 439245.10 \times 0.96$$

$$= 421675.30 \text{ W}$$

$$\text{Overall efficiency, } \eta_0 = \frac{SP}{\rho gQH} = \frac{421675.3}{9810 \times 0.8 \times 60}$$

$$= 0.8955$$

13. (a)

$$\text{Peripheral velocity, } u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 1.5 \times 460}{60} = 36.13 \text{ m/s}$$

In inlet triangle,

$$\frac{V_1}{\sin 120°} = \frac{u_1}{\sin 38°} = \frac{36.13}{\sin 38°}$$

$$V_1 = 50.82 \text{ m/s}$$

$$\text{Velocity of flow, } V_{f_1} = V_1 \sin 22°$$

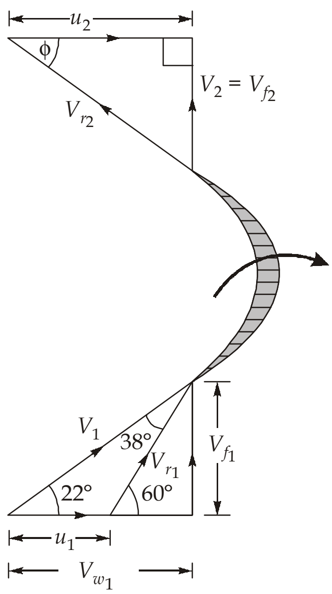
$$= 50.82 \sin 22°$$

$$= 19.04 \text{ m/s}$$

$$\text{Velocity of whirl, } V_{w_1} = V_1 \cos 22°$$

$$= 50.82 \times \cos 22°$$

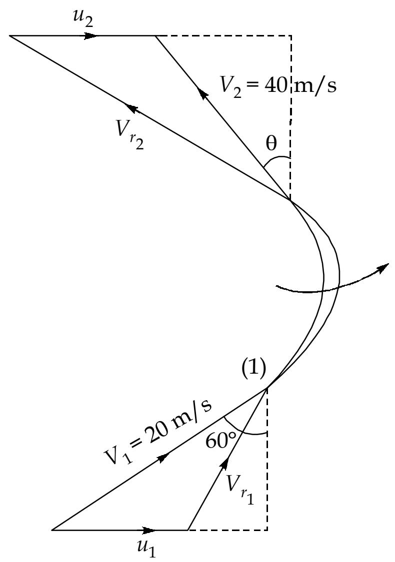
$$= 47.12 \text{ m/s}$$



$$\text{Discharge, } Q = \pi D_1 b_1 V_{f_1}$$
$$= \pi \times 1.5 \times 0.5 \times 19.04$$
$$= 44.86 \text{ m}^3/\text{s}$$

$$\text{Power developed, } P = \rho Q u_1 V_{w_1} \qquad (\text{as } V_{w_2} = 0)$$
$$= 1000 \times 44.86 \times 36.13 \times 47.12$$
$$= 76.38 \times 10^6 \text{ W}$$

14. (b)



$$R_1 = 2 \text{ m}, R_2 = 1 \text{ m}$$

$\because$ Torque = 0

$$\Rightarrow \quad T = \dot{m}\left(V_{w_2} R_2 - V_{w_1} R_1\right) = 0$$

$$\Rightarrow \quad V_{w_2} R_2 = V_{w_1} R_1 \qquad \ldots(i)$$

Now, from velocity triangles,

$$V_{w_1} = V_1 \sin 60° = 20\left(\frac{\sqrt{3}}{2}\right) = 10\sqrt{3}$$

and
$$V_{w_2} = V_2 \sin\theta = 40 \sin\theta$$

Putting values of V_{w_1} and V_{w_2} in equation (i), we get

$$(40 \sin\theta)(1) = 10\sqrt{3}(2)$$

$$\sin\theta = \frac{20\sqrt{3}}{40} = \frac{\sqrt{3}}{2}$$

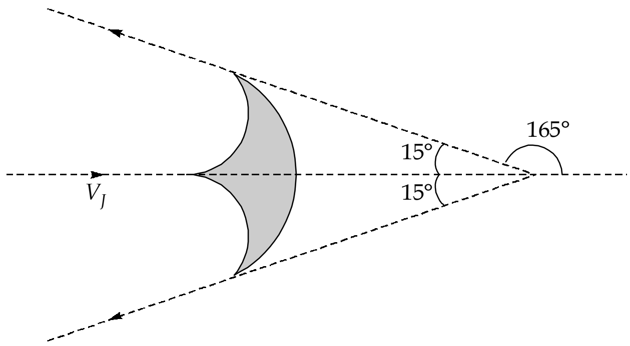
$$\theta = \sin^{-1}\left(\frac{\sqrt{3}}{2}\right) = 60°$$

15. (d)

$$\text{Discharge from jet } (Q) = \frac{6.116}{3600} = 1.6989 \times 10^{-3} \text{ m}^3/\text{s}$$

Now,
$$\text{velocity of jet} = \frac{Q}{\text{Area of jet}}$$

$$V_J = \frac{1.6989 \times 10^{-3}}{\frac{\pi}{4}(20 \times 10^{-3})^2} = 5.40 \text{ m/s}$$



For theoretical force it is assumed that velocity is not reduced as water passes around each cup,

$$\therefore \quad F_{\text{theoretical}} = \dot{m}(\Delta V)$$

$$= (\rho\dot{Q})(V_J(1 - \cos 165°))$$

$$= 1000 \times 1.6989 \times 10^{-3}(5.40(1 - \cos 165°))$$

$$= 18.035 \text{ N}$$

$$\therefore \quad \frac{\text{Actual force}}{\text{Theoretical force}} = \frac{15}{18.035} = 0.8316$$

If V_1 is the actual velocity at outlet,

Now, $\quad \text{Actual force} = \dot{m}(\Delta V_a)$

$$15 = \rho\dot{Q}(V_j - V_1 \cos(165°))$$

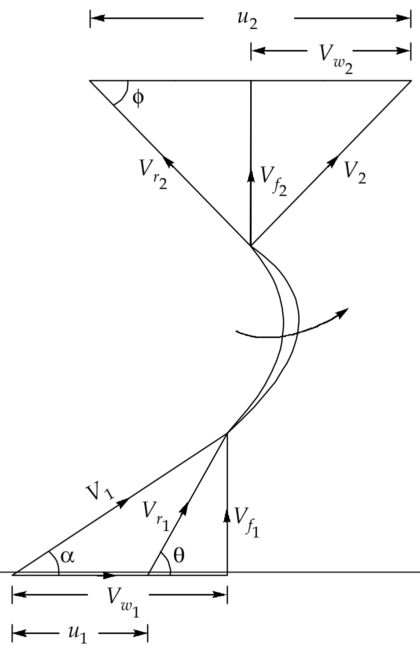
$$15 = 1000 \times 1.6989 \times 10^{-3}(5.40 - V_1(\cos 165°))$$

$$V_1 = 3.55 \text{ m/s}$$

$$\therefore \quad \frac{\text{Outlet velocity}}{\text{Inlet velocity}} = \frac{3.55}{5.40} = 0.6574$$

16. **(a)**

Velocity triangle for inward flow reaction turbine.



$$V_{w_1} = 4\sqrt{H} \text{ m/s}$$

$$V_{f_1} = 2\sqrt{H} \text{ m/s}$$

$$V_{w_2} = 0.25\sqrt{H} \text{ m/s}$$

$$V_{f_2} = 0.75\sqrt{H} \text{ m/s}$$

$$\frac{D_2}{D_1} = 0.5$$

$$\eta_H = 0.80$$

We know, hydraulic efficiency,

$$\eta_H = \frac{V_{w_1}u_1 - V_{w_2}u_2}{gH} \text{ and } \frac{u_1}{D_1} = \frac{u_2}{D_2} \Rightarrow \frac{u_2}{u_1} = \frac{D_2}{D_1} = 0.5$$

$$0.80 = \frac{4\sqrt{H}u_1 - 0.25\sqrt{H}u_2}{9.81(H)} = \frac{\left(4\sqrt{H} - 0.25\sqrt{H}(0.5)\right)u_1}{9.81H}$$

$\Rightarrow$ $$u_1 = 2.025\sqrt{H} \text{ and } u_2 = 1.0126\sqrt{H}$$

From outlet velocity triangle,
We have,

$\Rightarrow$ $$\tan\phi = \frac{V_{f_2}}{u_2 - V_{w_2}}$$

$\Rightarrow$ $$\tan\phi = \frac{0.75\sqrt{H}}{1.0126\sqrt{H} - 0.25\sqrt{H}}$$

$\Rightarrow$ $$\tan\phi = 0.9834$$

$\Rightarrow$ $$\phi = \tan^{-1}(0.9834) = 44.52°$$

17. (c)

Given : $H_1 = 25$, $N_1 = 200$ rpm, $Q_1 = 9 \text{ m}^3/\text{s}$, $\eta_0 = 0.9$

$\therefore$ $$\eta_0 = \frac{P_1}{\rho Q_1 g H_1}$$

or $$0.9 = \frac{P_1}{1000 \times 9 \times 9.81 \times 25}$$

$\Rightarrow$ $$P_1 = 1986525 \text{ W}$$

Now, $$H_2 = 20 \text{ m}, P_2 = ?, \text{ Unit power, } P_u = \frac{P}{H^{3/2}}$$

$\therefore$ For same turbine $$(P_u)_1 = (P_u)_2$$

$\Rightarrow$ $$\frac{P_1}{H_1^{3/2}} = \frac{P_2}{H_2^{3/2}}$$

$\Rightarrow$ $$\frac{1986525}{(25)^{3/2}} = \frac{P_2}{(20)^{3/2}}$$

$\Rightarrow$ $$P_2 = 1421441.58 \simeq 1.42 \text{ MW}$$

18. **(b)**

Given: Q = 400 m^3/s, H = 20 m, N = 100 rpm, η_o = 0.8, N_s = 450 rpm

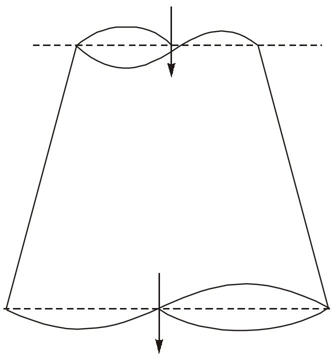
$$\therefore \quad \text{Specific speed, } N_s = \frac{N\sqrt{P}}{H^{5/4}} \qquad (P = \text{Power in kW})$$

$$\therefore \quad P = \left(\frac{450\times(20)^{5/4}}{100}\right)^2 = 36224.301 \text{ kW}$$

$$\text{Now, Total power output} = P_t = \rho g Q H \times \eta_o$$
$$= 1000 \times 9.81 \times 400 \times 20 \times 0.8$$
$$= 62784 \text{ kW}$$

$$\therefore \quad \text{Number of turbines} = \frac{\text{Total power output}}{\text{Power output from each turbine}}$$
$$= \frac{62784}{36224.301} = 1.73 \approx 2$$

19. **(a)**



$$\eta_{DT} = 0.85$$
$$A_1 = 1.5 \text{ m}^2$$
$$A_2 = 15 \text{ m}^2$$
$$Q = 15 \text{ m}^3/\text{s}$$
$$v_1 = \frac{Q}{A_1} = \frac{15}{1.5} = 10 \text{ m/s}$$
$$v_2 = \frac{Q}{A_2} = \frac{15}{15} = 1 \text{ m/s}$$
$$\eta_{DT} = \frac{\frac{v_1^2}{2g} - \frac{v_2^2}{2g} - h_f}{\frac{v_1^2}{2g}}$$
$$\Rightarrow \quad h_L = \frac{v_1^2}{2g} - \frac{v_2^2}{2g} - \eta_{DT} \times \frac{v_1^2}{2g}$$
$$= \frac{10^2 - 1^2 - (0.85)(10^2)}{2\times 9.81} = 0.713557 \text{ m}$$
$$\simeq 0.714 \text{ m}$$

20. **(c)**

Given: Q = 0.05 m^3/s, H = 30 m, d = 15 cm = 0.15 m, l = 150 m, f' = 0.014, η_o = 0.75.

$$\therefore \quad Q = A \times V$$
$$\Rightarrow \quad V = 2.83 \text{ m/s}$$

Manometric head,

$$H_m = H + \frac{4fLV^2}{2gD} + \frac{V^2}{2g}$$
$$= 30 + \frac{4\times 0.014\times 150\times (2.83)^2}{2\times 9.81\times 0.15} + \frac{(2.83)^2}{2\times 9.81}$$

$$= 53.267 \text{ m}$$

$$\therefore \quad \eta_o = \frac{\text{Water power}}{\text{Shaft power}}$$

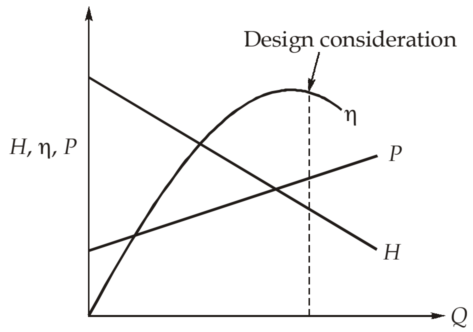
$$\text{or,} \quad 0.75 = \frac{\rho g Q H_m}{SP}$$

$$\text{SP} = \frac{1000 \times 9.81 \times 0.05 \times 53.267}{0.75} = 34.84 \text{ kW}$$

21. **(c)**

Governing mechanism in case of pelton wheel is carried out by jet deflector's and sprear rod, while in case of reaction turbine it is carried out by guide vanes.

22. **(d)**



23. **(c)**

$$\left(\frac{H}{D^2N^2}\right)_m = \left(\frac{H}{D^2N^2}\right)_p$$

$$\Rightarrow \quad \frac{30}{(1)^2 \times N^2} = \frac{20}{(3)^2 \times (600)^2}$$

$$N^2 = \frac{30 \times 3^2 \times 600^2}{20}$$

$$N = 2204.54 \text{ rpm} \approx 2205 \text{ rpm}$$

24. **(d)**

$$\sum F_x = -F = \dot{m}_{out} u_{out} - \dot{m}_{in} u_{in}$$

$$= \dot{m}(-V_j \cos\theta) - \dot{m} V_j = -\rho A_j V_j^2 (1 + \cos\theta)$$

$$F = \rho A_j V_j^2 (1 + \cos\theta)$$

$$\Rightarrow \quad \frac{3}{2} \rho A_j V_j^2 = \rho A_j V_j^2 (1 + \cos\theta)$$

$$\cos\theta = \frac{1}{2} \quad \Rightarrow \theta = 60°$$

25. (a)

Given, $H = 24.5$ m

$Q = 10.1\ m^3/s$

$N = 4$ rev/sec $= 4 \times 60 = 240$ rpm

$\eta_0 = 0.90$

Power generated

$$= \rho g H \times 0.9 \times Q$$

$$= 1000 \times 9.81 \times 10.1 \times 24.5 \times 0.9 = 2184.74 \text{ kW}$$

$$N_S = \frac{N\sqrt{P}}{H^{5/4}} = \frac{240\sqrt{2184.7}}{(24.5)^{5/4}} = 205.80$$

Types of turbine	Specific speed (S.I.)
Pelton wheel with single jet	8.5 to 30
Pelton wheel with two or more jets	30 to 51
Francis turbine	51 to 225
Kaplan or propeller turbine	255 to 860

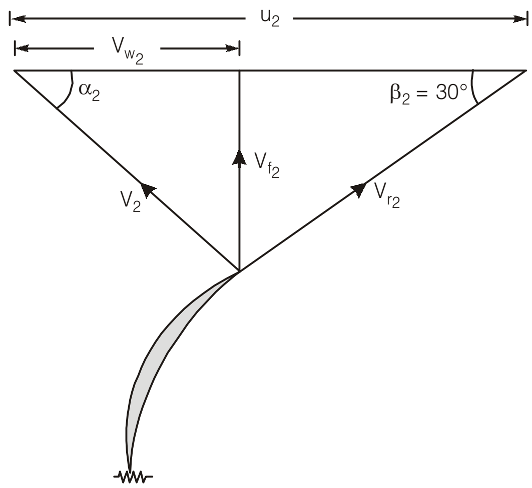
Hence, turbine is Francis.

26. (a)

At the outlet $$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.30 \times 1200}{60} = 18.85 \text{ m/s}$$

$$V_{f2} = 2.0 \text{ m/s and } \beta_2 = 30°$$

From the outlet velocity triangle,



$$\tan \beta_2 = \frac{V_{f_2}}{u_2 - V_{w_2}}$$

$$\tan 30° = \frac{2.0}{18.85 - V_{w_2}}$$

$$18.85 - V_{w_2} = 3.464; \text{ and hence } V_{w_2} = 15.386 \text{ m/s}$$

Manometric efficiency

$$\eta_m = \frac{gH}{u_2 V_{w_2}}$$

Head developed, $H = \eta_m \dfrac{u_2 V_{w_2}}{g} = \dfrac{0.85 \times 18.85 \times 15.386}{9.81} = 25.13$ m

27. (a)

$$\text{Power per wheel} = \frac{3000}{2} = 1500\,\text{kW}$$

$$\text{Power} = \eta_0\,\gamma QH$$

$$\Rightarrow \quad 1500 = 0.90 \times 9.79 \times Q \times 300$$

$$\Rightarrow \quad Q = 0.5674\ \text{m}^3/\text{s}$$

$$\text{Velocity of the jet} = V_1 = C_V\sqrt{2gH}$$

$$= 0.95\sqrt{2 \times 9.81 \times 300} = 72.88\,\text{m/s}$$

$$\text{For the nozzle: } Q = \frac{\pi}{4}d^2 V_1$$

$$\Rightarrow \quad 0.5674 = \frac{\pi}{4} \times d^2 \times 72.88$$

$$\Rightarrow \quad d = 9.95\ \text{cm}$$

28. (c)

$$\text{Net available head, } H = 500\,(1 - 0.05) = 475\ \text{m}$$

$$\text{Power per jet} = \frac{1500}{2} = 750\ \text{kW}$$

$$\text{Specific speed } (N_s) = \frac{N\sqrt{P}}{H^{5/4}}$$

$$\Rightarrow \quad 15 = \frac{N\sqrt{750}}{(475)^{5/4}}$$

$$\Rightarrow \quad N = 1214.58\ \text{rpm} \approx 1215\ \text{rpm}$$

29. (a)

$$\sigma_c = \frac{(\text{NPSH})_{\min}}{H}$$

$$0.12 = \frac{(\text{NPSH})_{\min}}{30}$$

$$\text{Minimum NPSH} = 3.6\ \text{m}$$

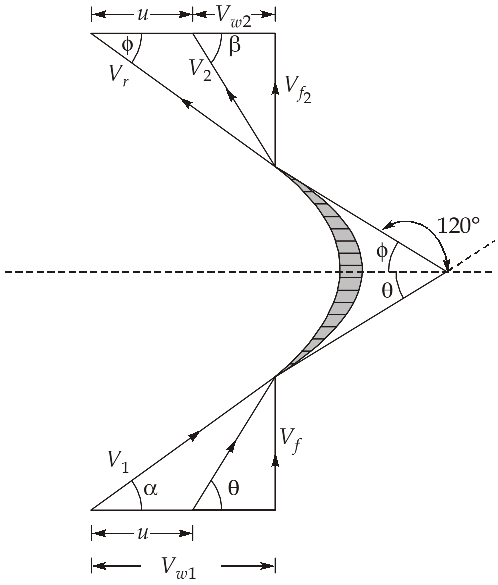
$$\text{NPSH} = \frac{(P_{atm})_{abs}}{\gamma} - \frac{P_v}{\gamma} - z_s - h_L$$

where, z_s = Elevation of the pump above the rump water surface, $(z_s)_{\max}$ corresponds to σ_c.

Hence, $$(z_s)_{\max} = \frac{(P_{atm})}{\gamma} - \frac{P_v}{\gamma} - h_L - (\text{NPSH})_{\min}$$

$$= \frac{96.0}{9.79} - \frac{3.0}{9.79} - 0.3 - 3.6 = 5.6\,\text{m}$$

30. **(b)**



$$\theta + \phi = 180° - 120° = 60°$$

So, $\theta = \phi = 30°$

Using sine rule in inlet velocity triangle

$$\frac{V_1}{\sin(180-\theta)} = \frac{u}{\sin(\theta-\alpha)} = \frac{V_r}{\sin\alpha}$$

$$\frac{15}{\sin 150} = \frac{6}{\sin(30-\alpha)}$$

$$\alpha = 18.46°$$

$$\frac{15}{\sin 150} = \frac{V_r}{\sin 18.46}$$

$$V_r = 9.5 \text{ m/s}$$

$$V_{w_1} = V_1 \cos\alpha$$

$$= 15 \times \cos 18.46 = 14.23 \text{ m/s}$$

In outlet velocity triangle,

$$V_{w_2} = V_r \cos\phi - u$$

$$= 9.5 \times \cos 30 - 6 = 2.23 \text{ m/s}$$

$$\text{W.D.} = \frac{1}{g}\left[V_{w_1} + V_{w_2}\right]u$$

$$= \frac{1}{9.81}[14.23 + 2.23] \times 6 = 10.07 \text{ Nm/N}$$

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