CLASS TEST

Sl. : 02SK_CE_JKL_03102025

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HYDRAULIC MACHINE

CIVIL ENGINEERING

Date of Test : 03/10/2025

ANSWER KEY

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

We know that, $N_u = \dfrac{N}{\sqrt{H}} = \text{Constant}$

$$\Rightarrow \quad \frac{N_1}{\sqrt{H_1}} = \frac{N_2}{\sqrt{H_2}}$$

$$\Rightarrow \quad N_2 = N_1\sqrt{\frac{H_2}{H_1}} = 300\sqrt{\frac{60}{45}} = 346.41 \text{ rpm} \approx 347 \text{ rpm}$$

3. (b)

$$P = T\times\omega$$

$$= 13900\times\left(\frac{2\pi\times 600}{60}\right) = 873.632 \text{ kW}$$

4. (d)

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

5. (b)

Given: d = 10 cm = 0.1 m, δ = 120°, θ = 180° – 120° = 60°, V = 30 m/s

$\therefore$ Force exerted by jet $= \rho A V^2 (1 + \cos\theta)$

$$= 1000\times\frac{\pi}{4}\times(0.1)^2\times(30)^2\times(1+\cos 60°)$$

$$= 10.6 \text{ kN}$$

6. (b)

Given : P_1 = 7000 kW; N_1 = 200 rpm; H_1 = 30 m; H_2 = 15 m

We know, Unit power, $P_u = \dfrac{P}{H^{3/2}}$

$\therefore$ For the same turbine:

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

$$\therefore \quad \frac{7000}{(30)^{3/2}} = \frac{P_2}{(15)^{3/2}}$$

$$\Rightarrow \quad P_2 = 2474.87 \text{ kW} = 2.47 \text{ MW}$$

7. (d)

Work done by ject on series of plates per second,

$$= F_x \times u$$

$$= \rho A V (V - u) \cdot u \qquad \text{[Where } F_x = \text{Force in } x \text{ direction]}$$

Kinetic energy of jet per second,

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

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

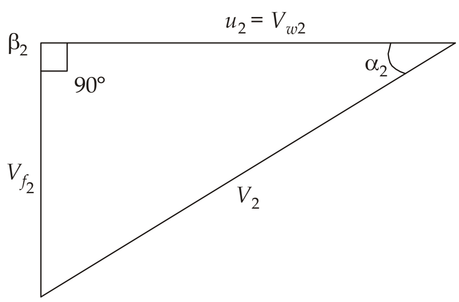
8. (c)

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

S.No.	Turbine	Specific speed
1.	Pelton - Single jet	Upto 30
	- Multijet jet	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. (a)



From the outlet velocity triangle

$$V_{w_2} = V_2 \cos \alpha_2 = u_2$$

$$u_2 = \pi D_2 N/60 = \pi \times 0.3 \times 1450/60 = 22.78 \text{ m/s}$$

Manometric efficiency,

$$\eta_H = \frac{gH}{u_2 V_{w_2}} = \frac{gH}{u_2^2} \qquad [H = \text{net head developed}]$$

$$0.82 = \frac{9.81 \times H}{(22.78)^2}$$

$$H = 43.36 \text{ m}$$

10. (d)

Depending upon the pump, a critical cavitation number of $\sigma < \sigma_c$ will result in cavitation and cause severe reduction in pump efficiency. Hence for operational purpose it should be seen that $\sigma \geq \sigma_c$

i.e NPSH $\geq \sigma_c H$

Hence minimum NPSH $= \sigma_c \times H$

11. (c)

12. (c)

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

$$\Rightarrow \quad u_1 = 2\times\sqrt{2\times 9.81\times 40} = 56 \text{ m/s}$$

$$\text{Flow ratio} = \frac{V_{f1}}{\sqrt{2gH}} = 0.65$$

$$\Rightarrow \quad V_{f1} = 0.65\times\sqrt{2\times 9.81\times 40} = 18.2 \text{ m/s}$$

Given: Power, $P = (\rho g Q H) \times \eta_{overall}$

$$10\times 10^6 = 10^3 \times 9.81 \times (Q) \times 40 \times 0.90$$

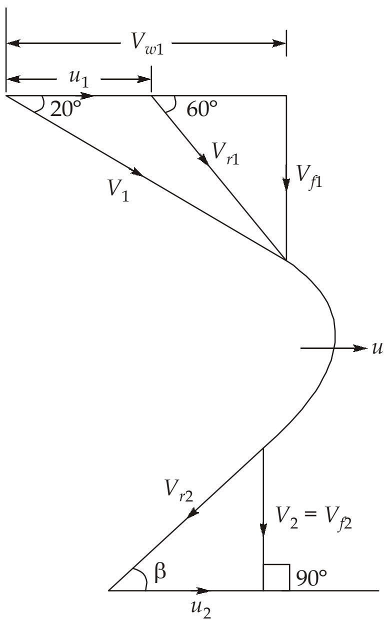
$$Q = 28.31 \text{ m}^3/\text{s}$$

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

$$28.31 = \frac{\pi}{4}D^2 \times \left[1 - 0.35^2\right]\times 18.2$$

$$D = 1.5 \text{ m}$$

13. (a)



$$u_1 = \frac{\pi DN}{60} = \frac{\pi\times 1.2\times 450}{60} = 9\pi \text{ m/s}$$

From inlet velocity triangle,

$$\frac{V_1}{\sin 120°} = \frac{u_1}{\sin 40°}$$

$$V_1 = 9\pi \times \frac{\sin 120°}{\sin 40°} = 38 \text{ m/s}$$

$$V_u = V_1 \cos 20° = 35.7 \text{ m/s};$$

$$V_{w2} = 0 \text{ (Radial exit)}$$

$$V_{f1} = V_1 \sin 20° = 38 \times \sin 20° = 12.99 \approx 13 \text{ m/s}$$

So, Power developed $= \rho Q(u_1 V_{w1} - u_2 V_{w2})$

$$= 10^3 \times (0.4 \times 13) \times (9\pi) \times 35.7$$

$$= 5250 \text{ kW}$$

14. (b)

$$\because \quad \frac{N_1}{\sqrt{H_1}} = \frac{N_2}{\sqrt{H_2}}$$

$$\Rightarrow \quad N_2 = N_1\sqrt{\frac{H_2}{H_1}}$$

$\because$ Head is reduced by 11 m

So, $H_2 = 36 - 11 = 25$ m

$$N_2 = 100 \times \sqrt{\frac{25}{36}} = 83.33 \text{ rpm}$$

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

$$P_2 = P_1\left(\frac{H_2}{H_1}\right)^{3/2}$$

$$= 8000\left(\frac{25}{36}\right)^{3/2} = 4629.6 \text{ kW}$$

15. (b)

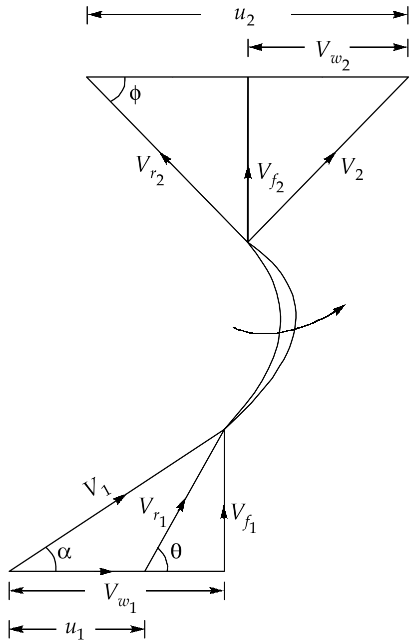
$\because$ Shape number is also known as non-dimensional specific speed

For pumps,
$$S_q = \frac{N\sqrt{Q}}{(gH)^{3/4}}$$

$$= \frac{1200 \times \sqrt{\frac{1.8 \times 10^3}{60}}}{\left(\sqrt{\sqrt{9.81}}\right)^3 \times \left(6^2\right)^{3/4}} = 80.67 \simeq 80$$

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,

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

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

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

From outlet velocity triangle,

We have,

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

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

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

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

17. (c)

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

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

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

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

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

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

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

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

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

18. (b)

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

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

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

Now, Total power output $= P_t = \rho g Q H \times \eta_o$

$= 1000 \times 9.81 \times 400 \times 20 \times 0.8$

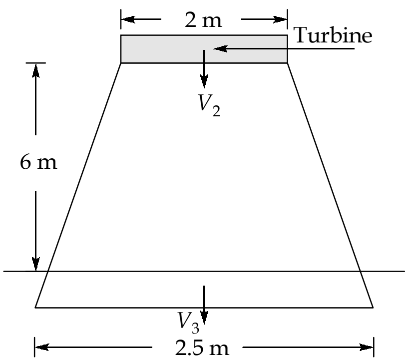
$= 62784$ kW

$$\therefore \quad \text{Number of turbines} = \frac{\text{Total power output}}{\text{Power output from each turbine}}$$

$$= \frac{62784}{36224.301} = 1.73 \approx 2$$

19. (a)

Given: $d_2 = 2$ m, $d_3 = 2.5$, $Q = 15$ m^3/s



$$\therefore \quad V_2 = \frac{Q}{A_2} = \frac{15}{\frac{\pi}{4}\times(2)^2} = 4.7746\,\text{m}; \quad \frac{V_2^2}{2g} = 1.162 \text{ m}$$

$$V_3 = \frac{Q}{A_3} = \frac{15}{\frac{\pi}{4}\times(2.5)^2} = 3.0558\,\text{m}; \quad \frac{V_3^2}{2g} = 0.4759 \text{ m}$$

$$h_L = 0.3\times\frac{V_2^2}{2g} = 0.14278\,\text{m}$$

$$\therefore \text{Efficiency of draft tube, } \eta_d = \frac{\frac{V_2^2}{2g}-\frac{V_3^2}{2g}-h_L}{\frac{V_2^2}{2g}} = \frac{1.162-0.4759-0.14278}{1.162}$$

$$= 0.4675 \approx 46.75\%$$

20. (c)

Given: $Q = 0.05\text{ m}^3/\text{s}$, $H = 30$ m, $d = 15$ cm $= 0.15$ m, $l = 150$ m, $f' = 0.014$, $\eta_o = 0.75$.

$$\therefore \quad Q = A \times V$$

$$\Rightarrow \quad V = 2.83 \text{ m/s}$$

Manometric head,

$$H_m = H + \frac{4fLV^2}{2gD} + \frac{V^2}{2g}$$

$$= 30 + \frac{4\times0.014\times150\times(2.83)^2}{2\times9.81\times0.15} + \frac{(2.83)^2}{2\times9.81}$$

$$= 53.267 \text{ m}$$

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

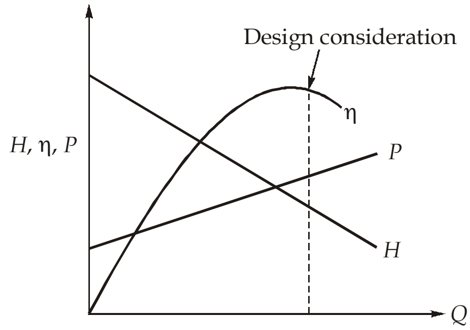
$$\text{or,} \quad 0.75 = \frac{\rho g Q H_m}{SP}$$

$$\text{SP} = \frac{1000\times9.81\times0.05\times53.267}{0.75} = 34.84\,\text{kW}$$

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)**

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

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

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

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

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

25. **(a)**

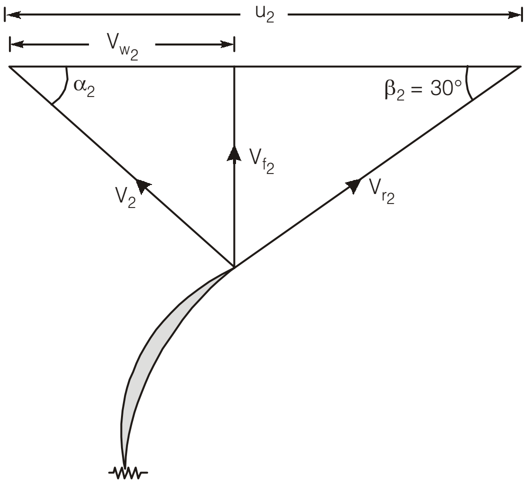
For delivering constant discharge, air vessels are provided on delivery side of the pump.

26. **(a)**

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

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

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

27. (a)

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

$$\text{Power} = \eta_0 \gamma Q H$$

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

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

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

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

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

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

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

28. (c)

Net available head, H = 500 (1 – 0.05) = 475 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)

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

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

Minimum NPSH = 3.6 m

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

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

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

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

30. (b)

Area of jet, $$a = \frac{\pi}{4}\left(\frac{75}{1000}\right)^2 = 0.00442 \text{ m}^2$$

The normal thrust on a moving flat plate is given as

$$F = \rho a(v - u)^2$$

$$= 1000 \times (0.00442)(20 - 5)^2 = 994.5 \text{ N}$$

Work done per second by the jet on the plate

$$= F \times u = (994.5 \times 5) = 4972.5 \text{ N.m}$$

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