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HYDRAULIC MACHINE

MECHANICAL ENGINEERING

Date of Test : 18/10/2026

ANSWER KEY >

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

DETAILED EXPLANATIONS

1. (c)

As per given data,

$$\begin{aligned}\text{Dynamic head, } h &= h_{\text{stag}} - h_{\text{static}} \\ h &= 10 - 5 = 5 \text{ m}\end{aligned}$$

$$\begin{aligned}\therefore \text{Velocity of flow} &= 0.95\sqrt{2 \times 9.81 \times 5} \\ &= 9.4 \text{ m/sec}\end{aligned}$$

2. (c)

3. (a)

$$\frac{N_{S_1}}{N_{S_2}} = \sqrt{\frac{n_1}{n_2}} = \sqrt{\frac{25}{100}} = \frac{1}{2}$$

$$\Rightarrow N_{S_2} = 2 N_{S_1}$$

$$\% \text{ Change} = \frac{N_{S_2} - N_{S_1}}{N_{S_1}} \times 100 = \frac{2N_{S_2} - N_{S_1}}{N_{S_1}} \times 100 = 100 \%$$

4. (b)

For geometrically similar model and prototype

$$\left(\frac{P}{N^3 D^5} \right)_{\text{model}} = \left(\frac{P}{N^3 D^5} \right)_{\text{prototype}}$$

$$\text{Given, } N_m = 2N_p$$

$$\Rightarrow \frac{P_m}{N_m^3 D_m^5} = \frac{P_p}{N_p^3 D_p^5}$$

$$\frac{P_m}{P_p} = \frac{N_m^3 D_m^5}{N_p^3 D_p^5}$$

$$\frac{P_m}{P_p} = \frac{2^3 N_p^3}{N_p^3} \times \frac{D_m^5}{16^5 D_p^5}$$

$$P_m = \frac{10 \times 10^6 \times 2^3}{16^5} \text{ W} = 76.29 \text{ W}$$

5. (a)

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

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

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

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

6. (c)

$$\text{Speed ratio} = \frac{U}{\sqrt{2gH}}$$

$$U = 0.45 \times \sqrt{2 \times 9.81 \times 200}$$

$$U = 28.19 \text{ m/sec}$$

$$U = \frac{\pi DN}{60}$$

$$\Rightarrow D = 1.077 \text{ m}$$

7. (d)

$$\text{B.P.} = \frac{mgh}{\eta_m} = \frac{80 \times 9.81 \times 30}{0.8} = 29.430 \text{ kW}$$

8. (d)

Characteristics of Pelton wheel

- (i) Impulse turbine
- (ii) High head turbine (300 – 2000 m)
- (iii) Low specific discharge turbine
- (iv) Axial flow turbine
- (v) Low specific speed turbine (4 – 70 rpm)

Characteristics of Francis turbine

- (i) Reaction turbine
- (ii) Medium head turbine (30 – 500 m)
- (iii) Medium specific discharge
- (iv) Radial flow turbine, but modern Francis turbine are mixed flow turbine
- (v) Medium specific speed turbine (60 m-400 rpm)

Characteristics of Kaplan turbine

- (i) Reaction turbine
- (ii) Low head turbine (2 m-70 m)
- (iii) High specific discharge
- (iv) Axial flow
- (v) High specific speed (300 – 1100 rpm)

9. (c)

$$\sigma_c = \text{NPSH}/H$$

$$\therefore 0.144 = \frac{\text{NPSH}}{25}$$

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

$$\text{NPSH} = H_{\text{atm}} - H_v - h_s - h_L$$

$$3.6 = 9.8 - 0.3 - h_s - 0.4$$

$$\therefore h_s = 5.5 \text{ m}$$

10. (b)

$$N_s = \frac{N_1 Q_1^{1/2}}{(gH_1)^{3/4}}$$

$$N_1 = \frac{N_s (gH_1)^{3/4}}{Q_1^{1/2}}$$

$$= \frac{0.183 \times (9.81 \times 15)^{3/4}}{\sqrt{2}} = 5.467 \text{ rev/s}$$

11. (b)

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

From inlet velocity triangle,

$$\frac{V_1}{\sin 120^\circ} = \frac{u_1}{\sin 40^\circ}$$

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

$$V_{w1} = V_1 \cos 20^\circ = 35.7 \text{ m/s};$$

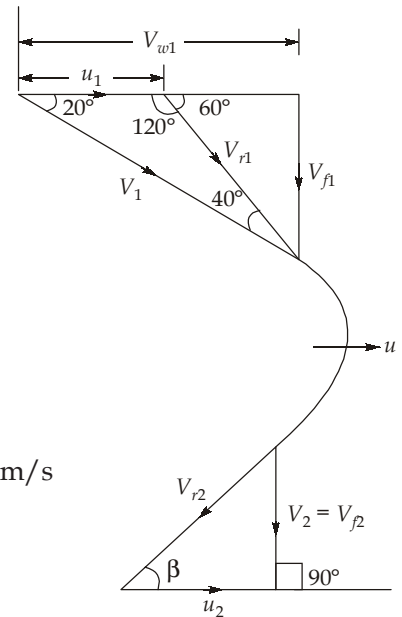
$$V_{w2} = 0 \text{ (Radial exit)}$$

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

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

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

$$\simeq 5250 \text{ kW}$$



12. (c)

Pelton turbine – Specific speed from 10 to 50 + tangential flow.

Francis turbine – Specific speed from 60 to 300 + mixed flow.

Propeller turbine – Specific speed from 300 to 1000 + axial flow with fixed runner vanes.

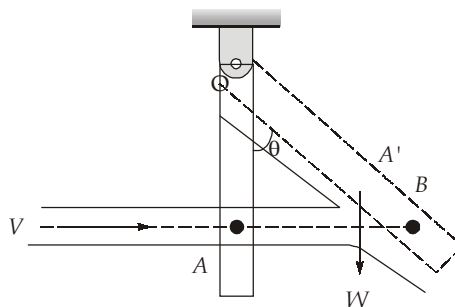
Kaplan turbine – Specific speed from 300 to 1000 + axial flow with adjustable runner vanes.

13. (a)

$$\text{Area} = 10 \text{ cm}^2$$

$$= 10^{-3} \text{ m}^2$$

$$\text{Velocity of jet} = 50 \text{ m/s}$$



Force on an inclined stationary plate in normal direction to the plate,

$$F_n = \rho a v^2 \cdot \sin \theta$$

$$\text{Here } \theta' = 90 - \theta$$

$$\text{So, } F_n = \rho a v^2 \cos \theta$$

$$\text{Moment of } F_n \text{ about } O = F_n \times OB$$

$$= \rho a v^2 \times \frac{OA}{\cos \theta}$$

$$= \rho a v^2 (OA)$$

$$\text{For equilibrium position, } \Sigma M_0 = 0$$

$$W \times \sin \theta \times OA = \rho a v^2 (OA)$$

$$\sin \theta = \frac{\rho a v^2}{W} \quad (\text{Since, } OA = OA')$$

$$\sin \theta = \frac{10^3 \times 10^{-3} \times (50)^2}{5 \times 10^3}$$

$$\sin \theta = \frac{1}{2}$$

$$\theta = 30^\circ$$

14. (d)

$$\text{Diameter of Jet} = 60 \text{ mm}$$

$$\therefore \text{Area} = \frac{\pi}{4} \times (0.06)^2 = 2.827 \times 10^{-3} \text{ m}^2$$

$$\text{Velocity of Jet} = 50 \text{ m/s}$$

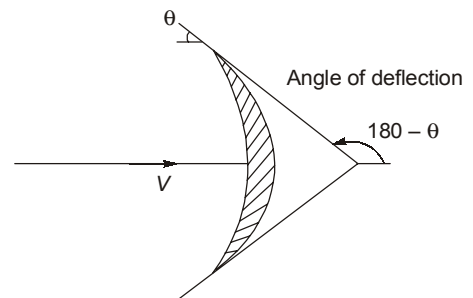
$$\text{Angle of deflection} = 120^\circ$$

$$\therefore \theta = 180^\circ - 120^\circ = 60^\circ$$

$$F = \rho a v^2 [1 + \cos \theta]$$

$$F = 1000 \times 2.827 \times 10^{-3} \times 50^2 [1 + \cos 60^\circ]$$

$$F = 10601.25 \text{ N} = 10.601 \text{ kN}$$



15. (b)

$$\text{Power at head of 25 m} = \rho g Q H \eta$$

$$= 1000 \times 9.81 \times 9 \times 25 \times 0.9 = 2 \times 10^6 \text{ W}$$

$$= 2 \text{ MW}$$

The power parameter remains constant

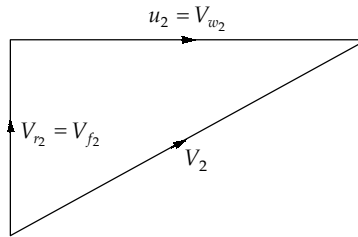
$$\frac{P}{\rho D^2 H^{3/2}} = \text{constant}$$

$$P \propto H^{3/2}$$

$$\therefore \text{Power generated} = 2 \times 10^6 \times \left(\frac{20}{25} \right)^{3/2}$$

$$= 1.43 \times 10^6 \text{ W} = 1.43 \text{ MW}$$

16. (d)



$$D_2 = 24 \text{ cm}, \eta_m = 0.85$$

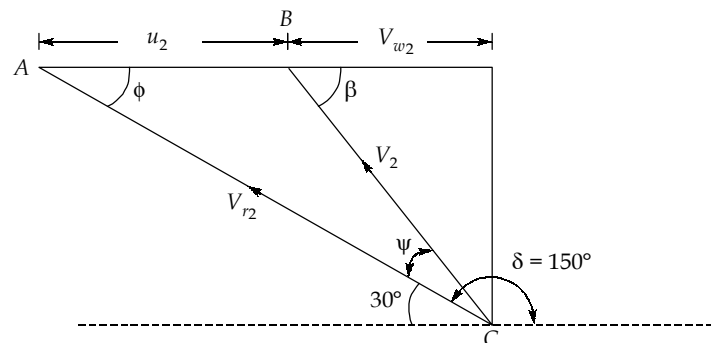
$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.24 \times 1400}{60} = \frac{88}{5} \text{ m/s}$$

$$\eta_m = \frac{g H_m}{V_{w2} u_2} = \frac{g H_m}{u_2^2}$$

$$0.75 = \frac{9.81 \times H_m}{\left(\frac{88}{5}\right)^2}$$

$$H_m = 23.68 \text{ m}$$

17. (a)



$$u_1 = u_2 = 9 \text{ m/sec}$$

$$\delta = 150^\circ; \phi = 30^\circ$$

$$V_2 = 6 \text{ m/s}$$

In $\triangle ABC$,

By sine rule,
$$\frac{u_2}{\sin \psi} = \frac{V_2}{\sin 30^\circ}$$

$$\Rightarrow \sin \psi = \frac{u_2}{V_2} \sin 30^\circ$$

$$= \frac{9}{6} \times \frac{1}{2}$$

$$\psi = 48.59^\circ$$

18. (a)

For pump,

$$\begin{aligned}\frac{P_s}{\rho g} &= \frac{P_d}{\rho g} + (h_L)_{\text{pump}} - H_{\text{mano}} \\ &= \frac{120 \times 10^3}{1000 \times 9.81} + 3 - 10 \\ P_s &= (12.23 + 3 - 10) \times \rho g \\ P_s &= 5.234 (1000 \times 9.81) \\ P_s &= 51.33 \text{ kPa}\end{aligned}$$

19. (c)

Given : $D_2 = 0.3 \text{ m}$, $N = 1800 \text{ rpm}$, $\eta_{\text{mano}} = 0.9$

Now,
$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.3 \times 1800}{60} = 9\pi \text{ m/s}$$

$\therefore$ Manometric efficiency,

$$\eta_{\text{mano}} = \frac{gH_m}{V_{w_2} u_2}$$

For radial blades, $u_2 = V_{w_2}$

$$\therefore 0.9 = \frac{9.81 \times H}{(9\pi)^2}$$

$$\therefore H = 73.34 \text{ m}$$

20. (d)

Given : $A_s = 20 \text{ cm}^2$, $A_p = 60 \text{ cm}^2$, $\omega = 40 \text{ rad/s}$, $r = 15 \text{ cm}$

Maximum velocity,
$$V_{\text{max}} = \frac{A_p}{A_s} \times \omega r$$

$$V_{\text{max}} = \frac{60}{20} \times 40 \times 0.15 = 18 \text{ m/s}$$

For double acting pump, average velocity

$$\bar{V}_s = \frac{2V_{\text{max}}}{\pi} = \frac{2 \times 18}{3.14} = 11.45 \text{ m/s}$$

21. (d)

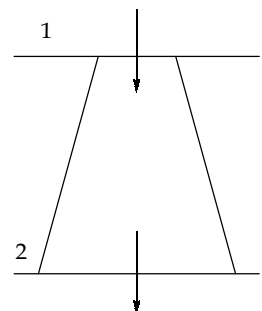
Here, $\frac{V_1^2}{2g} = 3.0 \text{ m}$, $\frac{V_2^2}{2g} = 0.2 \text{ m}$, $H_L = 0.4 \text{ m}$

Efficiency of draft tube is given by,

$$\eta_{\text{DT}} = 1 - \frac{H_L}{\frac{V_1^2}{2g} - \frac{V_2^2}{2g}}$$

$$\eta_{\text{DT}} = 1 - \frac{0.4}{3 - 0.2}$$

$$\eta_{\text{DT}} = 0.857 \text{ or } 85.7\%$$



22. (c)

Here, $D_1 = 4$ m, $H = 10$ m, $B_1 = B_2 = 0.8$ m, $V_f = 3$ m/s, $\eta_0 = 0.8$

Now, discharge, $Q = \pi D_1 B_1 \times V_f$
 $= \pi \times 4 \times 0.8 \times 3$
 $= 30.16 \text{ m}^3/\text{s}$

Overall efficiency is given by,

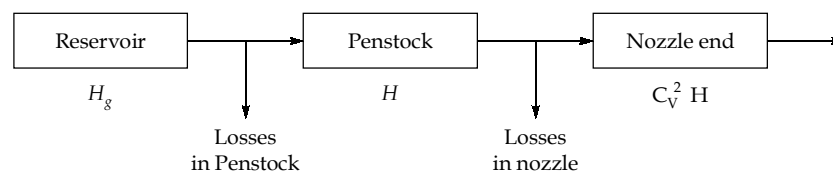
$$\eta_0 = \frac{P}{\rho g Q H}$$

$\therefore$

$$\begin{aligned} P &= \eta_0 \times \rho g Q H \\ &= 0.8 \times 10^3 \times 9.81 \times 30.16 \times 10 \\ &\simeq 2367 \text{ kW} \end{aligned}$$

23. (b)

$$\begin{aligned} H_g &= 400 \text{ m} \\ C_u &= 0.97 \end{aligned}$$



$$\text{Loss in nozzle} = (1 - C_v^2) H$$

$\therefore$

$$H = 0.9 \times H_g = 0.9 \times 400 = 360 \text{ m}$$

$$\begin{aligned} \text{Head loss in nozzle} &= (1 - 0.97^2) \times 360 \\ &= 1.97 \times 0.3 \times 360 = 10.8 \times 1.97 \\ &= 21.27 \text{ m} = 21.3 \text{ m} \end{aligned}$$

24. (b)

$$\dot{m} = \rho a v_1 = 30 \text{ kg/s}$$

$$v_1 = 20 \text{ m/s}$$

$$w = 1800 \text{ N}$$

$$x = 3 \text{ m}$$

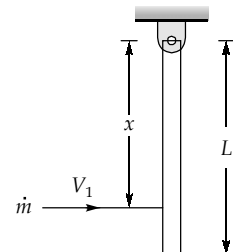
$$l = 4 \text{ m}$$

$$\sin \theta = \frac{2 \rho a v_1^2 x}{w l}$$

$$= \frac{2 \dot{m} v_1 x}{w l} = \frac{2 \times 30 \times 20 \times 3}{1800 \times 4}$$

$$\sin \theta = 0.5$$

$$\theta = 30^\circ$$



25. (b)

$$\delta = 150^\circ$$

$$\beta_2 = 180^\circ - \delta = 30^\circ$$

$$K = 0.9$$

$$\eta_n = 0.9$$

Hydraulic efficiency, $\eta_H = \eta_w \times \eta_n$

$$(\eta_H)_{\max} = (\eta_w)_{\max} \times \eta_n$$

$$= \left(\frac{1 + K \cos \beta_2}{2} \right) \times \eta_n$$

$$= \left(\frac{1 + 0.9 \times \cos 30^\circ}{2} \right) \times 0.9 = 80\%$$

26. (c)

$$\dot{m} = 5 \text{ kg/s} = \rho \cdot Q$$

$$Q = \frac{5}{10^3} = 5 \times 10^{-3} \text{ m}^3/\text{s}$$

Discharge in two directions will be

$$\begin{aligned} Q_1 &= \frac{Q}{2}(1 + \cos \theta) = \frac{5 \times 10^{-3}}{2}(1 + \cos 60^\circ) \\ &= 3.75 \times 10^{-3} \text{ m}^3/\text{s} \end{aligned}$$

$$\begin{aligned} Q_2 &= \frac{Q}{2}(1 - \cos \theta) = \frac{5 \times 10^{-3}}{2}(1 - \cos 60^\circ) \\ &= 1.25 \times 10^{-3} \text{ m}^3/\text{s} \end{aligned}$$

27. (b)

$$\sin \theta = \frac{2\rho A V^2 x}{Wl} = \frac{2 \times 1000 \times 10^{-3} \times (10)^2}{1000 \times l} \frac{2l}{3}$$

$$\sin \theta = 0.133$$

$$\theta = \sin^{-1} 0.133$$

28. (c)

$$\frac{D}{D_p} = 4$$

$$\frac{H}{H_p} = 5$$

for pump, $\frac{H}{D^2 N^2} = \text{constant}$

and $\frac{P}{N^3 D^5} = \text{constant}$

$$\Rightarrow \frac{H^3}{D^6 N^6} \times \frac{N^6 \cdot D^{10}}{P^2} = \text{constant}$$

$$\Rightarrow \frac{H^3 \cdot D^4}{P^2} = \frac{H_m^3 \cdot D_m^4}{P_m^2}$$

$$\Rightarrow \frac{P}{P_m} = \sqrt{\left(\frac{H}{H_m}\right)^3 \left(\frac{D}{D_m}\right)^4} = \sqrt{5^3 \times 4^4}$$

$$= 16 \times 5\sqrt{5} = 80\sqrt{5} \approx 179$$

29. (a)

$$\eta = 0.80$$

$$u_1 = 11 \text{ m/s}$$

$$D_2 = 2D_1$$

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi D_1 N}{60} \times 2 = 2u_1 = 2 \times 11 = 22 \text{ m/s}$$

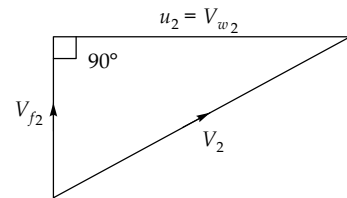
 $\therefore$ Radial vane at outlet so

$$u_2 = V_{w2}$$

$$\eta_m = \frac{gH_m}{V_{w2} \cdot u_2}$$

$$\Rightarrow 0.8 = \frac{9.81 \times H_m}{22 \times 22}$$

$$H_m = \frac{22^2 \times 0.80}{9.81} = 39.47 \text{ m}$$



30. (b)

$$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 1.4 \times 300}{60}$$

$$u_1 = 22 \text{ m/s}$$

$$Q = A_f V_{f1} = 8 \text{ m}^3/\text{s}$$

$$\Rightarrow \pi D_1 B \times V_{f1} = 8$$

$$\frac{22}{7} \times 1.4 \times 0.25 V_{f1} = 8$$

$$V_{f1} = \frac{80}{11} \text{ m/s}$$

$$\tan \alpha = \frac{80}{11 \times 22} = 0.3306$$

$$\alpha = 18.29^\circ$$

