CLASS TEST

Sl. : 01IGCE_ABC_13082024

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HYDRAULIC MACHINE

CIVIL ENGINEERING

Date of Test : 13/08/2024

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (d)

$$\text{force} = \dot{m}[V\cos\theta - (-V\cos\theta)]$$

$$200 = \dot{m} \times 2V \times \cos\theta$$

$$200 = 20 \times 2 \times 10 \times \cos\theta$$

$$\cos\theta = 0.5$$

$$\theta = 60°$$

3. (a)

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

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

$$\%\ \text{Change} = \frac{N_{S2} - N_{S1}}{N_{S1}} \times 100 = \frac{2N_{S2} - N_{S1}}{N_{S1}} \times 100 = 100\ \%$$

4. (b)

For geometrically similar model and prototype

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

Given, $$N_m = 2N_p$$

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

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

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

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

5. (a)

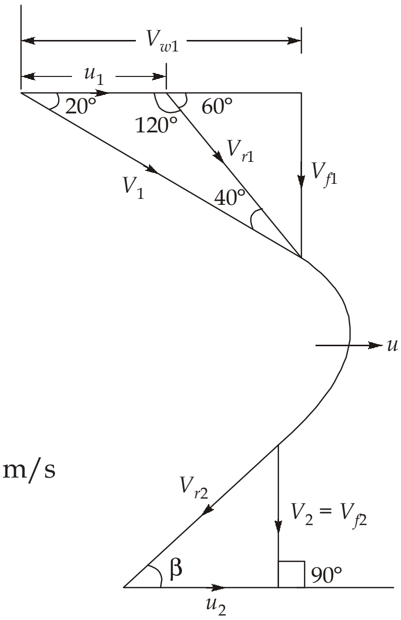
$$\left(\frac{H}{D^2N^2}\right)_m = \left(\frac{H}{D^2N^2}\right)_p$$

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

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

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

6. (b)



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

From inlet velocity triangle,

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

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

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

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

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

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

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

$\simeq 5250$ kW

7. (c)

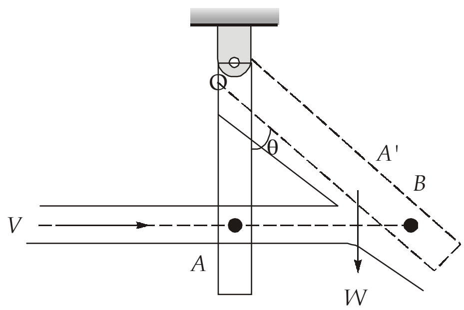
Pelton turbine — Specific speed from 10 to 50 + tangential flow.
Francis turbine — Specific speed from 60 to 300 + mixed flow.
Propeller turbine — Specific speed from 300 to 1000 + axial flow with fixed runner vanes.
Kaplan turbine — Specific speed from 300 to 1000 + axial flow with adjustable runner vanes.

8. (a)

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

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

Velocity of jet $= 50$ m/s



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

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

Here $\theta' = 90 - \theta$

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

Moment of F_n about 0 $= F_n \times OB$

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

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

For equilibrium position, $\Sigma M_0 = 0$

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

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

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

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

$$\theta = 30°$$

9. (c)

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

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

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

$$U = \frac{\pi D N}{60}$$

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

10. (d)

Vapour pressure always play very important role in cavitation.

11. (d)

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

12. (a)

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

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

$$\therefore \quad N_2 = 200 \sqrt{\frac{81}{100}}$$

$$N_2 = 200 \times \frac{9}{10} = 180 \text{ rpm}$$

Also
$$P_2 = \left(\frac{H_2}{H_1}\right)^{3/2} \times P_1 = \left(\frac{81}{100}\right)^{3/2} \times 500 = 364.5 \text{ kW}$$

13. (a)

$$H \propto D^2 N^2$$

$$Q \propto D^3 N$$

$$P \propto D^5 N^3$$

14. (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,

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

$$670 = 0.0557 V_j^2$$

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

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

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

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

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

15. (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

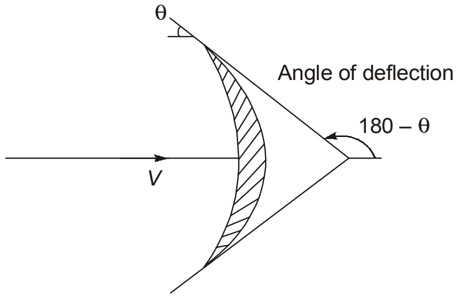
(i) Reaction turbine
(ii) Low head turbine (2 m-70 m)
(iii) High specific discharge
(iv) Axial flow
(v) High specific speed (300 –1100 rpm)

16. (d)

Force on spring will be the force in horizontal direction.

$$\therefore \quad F_H = \rho Q V \cos\theta = 1000 \times 0.1 \times 4 \cos 30° = 400 \times \frac{\sqrt{3}}{2} = 200\sqrt{3} \text{ N}$$

17. (d)



$$\text{Diameter of Jet} = 60 \text{ mm}$$
$$\therefore \quad \text{Area} = \frac{\pi}{4} \times (0.06)^2 = 2.827 \times 10^{-3} \text{ m}^2$$
$$\text{Velocity of Jet} = 50 \text{ m/s}$$
$$\text{Angle of deflection} = 120°$$
$$\therefore \quad \theta = 180° - 120° = 60°$$
$$F = \rho a v^2 [1 + \cos\theta]$$
$$F = 1000 \times 2.827 \times 10^{-3} \times 50^2 [1 + \cos 60°]$$
$$F = 10601.25 \text{ N} = 10.601 \text{ kN}$$

18. (c)

$$Q = \frac{2ALN}{60} = \frac{2 \times 0.075 \times 0.40 \times 80}{60}$$
$$Q = 0.08 \text{ m}^3/\text{sec}$$
$$Q = 80 \ lps$$

19. (c)

$$\therefore \quad \sigma = \frac{H_a - H_v - H_s}{H}$$
$$0.12 = \frac{10.2 - 1.2 - H_s}{50}$$
$$H_s = 3 \text{ m}$$

20. (b)

$$N_S = \frac{N\sqrt{P}}{H^{5/4}} = \frac{180\sqrt{6400}}{(81)^{5/4}}$$
$$N_S = 59.26 \text{ (SI)}$$
$$N_S(\text{Mks}) = 1.166 \, N_S \text{ (SI)}$$
$$N_S(\text{Mks}) = 69.096 > 60$$

For this range of specific speed Francis turbine should be preferred to use.

21. (c)

$$N_{turbine} = \frac{N\sqrt{P}}{H^{5/4}} = \frac{T^{-1}\sqrt{\frac{F \times L}{T}}}{L^{5/4}}$$

$$= F^{1/2}\, L^{[(1/2)-(5/4)]}\, T^{-1-(1/2)}$$

$$= F^{1/2}\, L^{-3/4}\, T^{-3/2}$$

22. (c)

$$\sigma_c = NPSH/H$$

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

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

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

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

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

23. (c)

Reverse jet is used to stop the Pelton turbine, not to protect it from over-speeding.

24. (b)

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

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

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

25. (b)

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

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

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

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

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

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