CLASS TEST

S.No. 01SPME-ABCD-05082023

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HYDRAULIC MACHINE

MECHANICAL ENGINEERING

Date of Test : 05/08/2023

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (b)

For maximum energy transfer $\frac{dE}{du} = 0$

where $$E = \frac{u(v_1 - u)}{g}(1 + k\cos\theta)$$

$$\therefore \quad \frac{d}{du}\left(v_1 u - u^2\right) = 0$$

$$\Rightarrow \quad v_1 - 2u = 0$$

$$\Rightarrow \quad \frac{u}{v_1} = 0.5$$

2. (c)

Given data :

$$P = 3\text{ MW} = 3000\text{ kW}$$
$$N = 140\text{ rpm}$$
$$H = 10\text{ m}$$

Specific speed : $$N_s = \frac{N\sqrt{P}}{H^{5/4}} \quad \text{(S.I. unit)}$$

where N is in rpm

P is in kW

and H is in m

$$\therefore \quad N_s = \frac{140 \times \sqrt{3000}}{(10)^{5/4}} = 431.20 \quad \text{(S.I. unit)}$$

3. (d)

As we know,

$$P \propto Q \propto d^2$$

$$\Rightarrow \quad \frac{P_2}{P_1} = \left(\frac{d_2}{d_1}\right)^2$$

$$\Rightarrow \quad \frac{1 - 0.64}{1} = \left(\frac{d_2}{150}\right)^2$$

$$\Rightarrow \quad d_2 = 0.6 \times 150\text{ mm}$$

$$d_2 = 90\text{ mm}$$

4. (d)

5. (c)

Unit power

$$\Rightarrow \quad P_u = \frac{P}{H^{\frac{3}{2}}}$$

Unit discharge,

$$Q_u = \frac{Q}{\sqrt{H}}$$

$$\Rightarrow \quad \frac{P_u}{Q_u} = \frac{P.H^{\frac{1}{2}}}{Q.H^{\frac{3}{2}}} = \frac{100(200)^{\frac{1}{2}}}{0.125(200)^{\frac{3}{2}}} \times 10^3 = 4000$$

6. **(a)**

$$d = 50 \text{ mm}$$
$$\theta = 30°$$
$$F_x = 1471.5 \text{ N}$$
$$F_x = \rho A V^2 \sin^2\theta$$
$$A = \frac{\pi}{4} \times 0.05^2 = 0.001963 \text{ m}^2$$
$$1471.5 = 1000 \times 0.001963 \times V^2 \times \sin^2(30)$$
$$V = 54.7583 \text{ m/s}$$
$$Q = AV = 0.001963 \times 54.7583 = 0.1075 \text{ m}^3\text{/s} = 107.5 \text{ liter/s}$$

7. **(a)**

$$H \propto D^2 N^2$$
$$Q \propto D^3 N$$
$$P \propto D^5 N^3$$

8. **(a)**

9. **(b)**

$$F = \rho a (v - u)^2$$
$$150 = 1000 \times 0.0015 \times (15 - u)^2$$
$$\Rightarrow \quad u = 5 \text{ m/s}$$

10. **(b)**

$$\text{Speed } (V) = \sqrt{2gH}$$
$$\therefore \quad V \propto H^{1/2}$$
$$\text{Discharge } (Q) = AV$$
$$\therefore \quad Q \propto D^2\sqrt{H}$$
$$\therefore \quad Q \propto H^{1/2}$$

Now,

$$\text{Power } (P) = \rho Q g H$$
$$P \propto \sqrt{H} \times H$$
$$P \propto H^{3/2}$$

11. **(b)**

Since
$$\frac{P_1}{D_1^2 H_1^{3/2}} = \frac{P_2}{D_2^2 H_2^{3/2}}$$
$$\Rightarrow \quad \frac{150}{D_1^2(16)^{3/2}} = \frac{750}{D_2^2(25)^{3/2}}$$
$$\Rightarrow \quad D_r = 1.6$$

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12. **(d)**

Discharge is radial

$$\therefore \quad V_{w_2} = 0$$

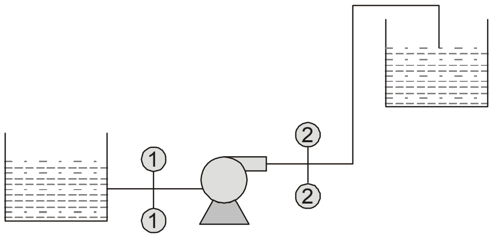
$$u = 0.96\sqrt{2g8} = 12.03 \text{ m/s}$$

$$\eta_h = \frac{\rho Q V_{w_1} u}{\rho g Q H}$$

$$V_{w_1} u = \eta_h g H$$

$$V_{w_1} = \frac{0.85 \times 9.81 \times 8}{12.03} = 5.54 \text{ m/s}$$

13. **(b)**



$$S = 0.8$$

$$\therefore \quad \rho = 0.8 \times 1000 = 800 \text{ kg/m}^3$$

$$W_p = 50 \text{ J/kg}$$

$$V_1 = 1 \text{ m/s}$$

$$V_2 = 7 \text{ m/s}$$

Applying Bernoulli's equation between sections (1)–(1) and (2)–(2)

$$\frac{p_1}{\rho} + \frac{V_1^2}{2} + gz_1 + W_P = \frac{p_2}{\rho} + \frac{V_2^2}{2} + gz_2$$

where $z_1 = z_2$

$$\frac{p_1}{\rho} + \frac{V_1^2}{2} + W_P = \frac{p_2}{\rho} + \frac{V_2^2}{2}$$

$$\frac{p_2 - p_1}{\rho} = \frac{V_1^2 - V_2^2}{2} + W_P$$

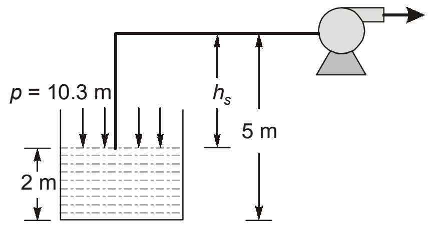
$$p_2 - p_1 = \rho\left[\frac{V_1^2 - V_2^2}{2} + W_P\right]$$

$$= 800\left[\frac{(1)^2 - (7)^2}{2} + 50\right] = 20800 \text{ N/m}^2 = 20.8 \text{ kN/m}^2$$

14. **(d)**

15. (a)

Given data:



$$H_{atm} = 10.3 \text{ m}$$
$$h_s = 5 - 2 = 3 \text{ m}$$
$$h_{fs} = 2 \text{ m}$$
$$H_v = 3 \text{ m}$$
$$NPSH = H_{atm} - H_v - h_s - h_{fs}$$
$$= 10.3 - 3 - 3 - 2 = \mathbf{2.3\ m}$$

16. (a)

Given data:

Condition-1

$$H_1 = 25 \text{ m}$$
$$N_1 = 200 \text{ rpm}$$
$$Q_1 = 9 \text{ m}^3/\text{s}$$
$$\eta_0 = 90\% = 0.90$$

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

∴ $$0.90 = \frac{P_1}{1000 \times 9 \times 9.81 \times 25}$$

or $$P_1 = 1986525 \text{ W}$$
$$= 198 \text{ MW}$$

Condition-2

$$H_2 = 20 \text{ m}$$
$$P_2 = ?$$

$$\text{Unit power} : P_u = \frac{P}{H^{3/2}}$$

$$(P_u)_1 = (P_u)_2$$

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

or $$P_2 = P_1 \times \left(\frac{H_2}{H_1}\right)^{3/2} = 1.98 \times \left(\frac{20}{25}\right)^{3/2} = 1.42 \text{ MW}$$

17. (d)

$$\text{Power} = T_1 \omega_1$$

$$75000 = T_1 \times \frac{2\pi \times 210}{60}$$

$$T_1 = 3410.463 \text{ Nm}$$

As we know,

$$\text{Unit torque, } T_u = \frac{T}{H}$$

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$$\Rightarrow \qquad \frac{T_2}{T_1} = \frac{H_2}{H_1}$$

$$\frac{T_2}{3410.463} = \frac{10}{5}$$

$$T_2 = 6820.926 \text{ Nm}$$

18. (a)

Given,
$$H = 24.5 \text{ m}$$
$$Q = 10.1 \text{ m}^3/\text{s}$$
$$N = 4 \text{ rev/sec} = 4 \times 60 = 240 \text{ rpm}$$
$$\eta_0 = 0.90$$

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

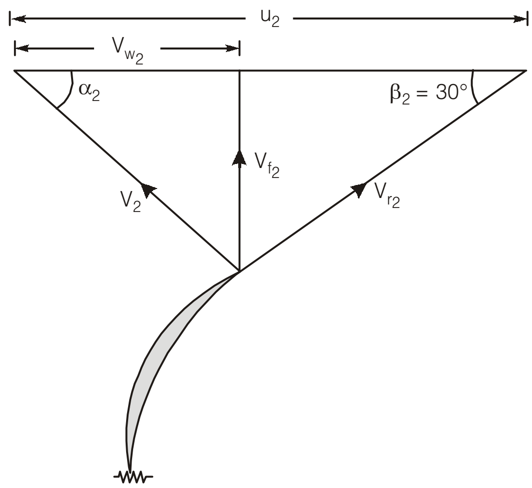
Hence, turbine is Francis.

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

20. (b)

Linear scale ratio = 36

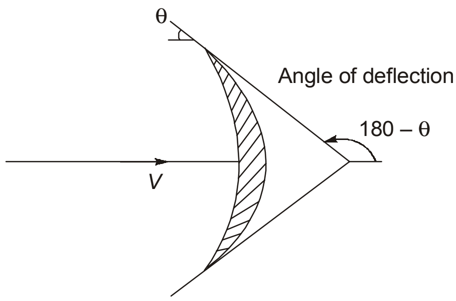
$$\Rightarrow \quad \frac{Q_p}{Q_m} = L_r^{2.5}$$

$$\Rightarrow \quad \frac{Q_p}{Q_m} = (36)^{2.5}$$

$$\Rightarrow \quad Q_p = Q_m \times (36)^{2.5} = 2 \times 36^{2.5}$$

$$\Rightarrow \quad Q_p = 15552 \text{ m}^3/\text{s}$$

21. (d)



Diameter of Jet = 60 mm

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

Velocity of Jet = 50 m/s

Angle of deflection = 120°

$$\therefore \quad \theta = 180° - 120° = 60°$$

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

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

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

22. (a)

The specific speed for turbines is given by

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

The specific speed for pumps is given by

$$N_s = \frac{N\sqrt{Q}}{H^{3/4}}$$

23. (a)

$$\text{NPSH} = \frac{P_a}{\rho g} - \frac{P_v}{\rho g} - h_s - h_f$$

NPSH = Net positive suction head

$$\frac{P_a}{\rho g} = \text{Atmospheric pressure head}$$

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$$\frac{P_v}{\rho g} = \text{Vapour pressure head}$$

$$h_s = \text{Suction head}$$

$$h_f = \text{head loss}$$

$$\frac{P_a}{\rho g} = \frac{100\times10^3}{1000\times9.81} = 10.1936 \text{ m}$$

$$\frac{P_v}{\rho g} = 0.40 \text{ m}$$

$$h_f = 0.5 \text{ m}$$

$$\text{NPSH} = 3.3 \text{ m}$$

$$h_s = 10.1936 - 3.3 - 0.40 - 0.5$$

$$= 5.9936 = 5.99 \text{ m}$$

24. (d)

Equating the head coefficients, we get

$$\frac{N_1 D_1}{\sqrt{H_1}} = \frac{N_2 D_2}{\sqrt{H_2}}$$

$$\therefore \quad D_1 = \left(\frac{N_2}{N_1}\right)\cdot\sqrt{\frac{H_1}{H_2}}\times D_2$$

$$= \left(\frac{1200}{1200}\right)\sqrt{\frac{25}{9}}\times300 = 500 \text{ mm}$$

25. (c)

On splitting of jet into two stream, the larger discharge would be

$$Q_1 = \frac{Q}{2}(1+\cos\theta)$$

and smaller discharge would be, $Q_2 = \frac{Q}{2}(1-\cos\theta)$

$$\text{So,} \quad \frac{\text{Smaller discharge}}{\text{Larger discharge}} = \frac{\frac{Q}{2}(1-\cos\theta)}{\frac{Q}{2}(1+\cos\theta)} = \frac{1-\cos\theta}{1+\cos\theta}$$

$$= \frac{1-\cos(90-30°)}{1+\cos(90-30°)} = \frac{1-\frac{1}{2}}{1+\frac{1}{2}} = \frac{1}{3}$$

26. (a)

$$\text{B.P.} = \frac{\dot{m}gh}{\eta_m} = \frac{80\times9.81\times30}{0.8} = 29.4 \text{ kW}$$

27. (d)

When diameter constant

(i) $$U_1 = \frac{\pi DN}{60} \propto \sqrt{H}$$

$\therefore$ $$H \propto N^2$$

(ii) $$Q = \pi D_1 b_1 \times V_f$$

$$Q \propto V_f \,\alpha\, N$$

$\therefore$ $$Q \propto N$$

(iii) $$\text{Power } P = \rho g Q H$$

$$P \propto N \times N^2$$

$$P \propto N^3$$

Now, $$\frac{H_2}{H_1} = \left(\frac{N_2}{N_1}\right)^2$$

$$H_2 = 10 \times \left(\frac{2000}{1000}\right)^2 = 40 \text{ m}$$

$$\frac{P_2}{P_1} = \left(\frac{N_2}{N_1}\right)^3 ; P_2 = 1 \times \left(\frac{2000}{1000}\right)^3 = 8 \text{ kW}$$

28. (b)

$$V_1 = C_V \sqrt{2gH}$$

$\Rightarrow$ $$V_1 = 0.985\sqrt{2 \times 9.81 \times 45}$$

$$= 29.27 \text{ m/s}$$

$$\beta = 165°, \quad \beta' = 180 - 165 = 15°, \quad k = 1 \text{ (assumed)}$$

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

$$= 1000 \times 0.8 \times 14 \times (29.27 - 14) \times (1 + \cos 15) = 336.22 \text{ kW}$$

$\therefore$ Power delivered to shaft $= 336.22 \times 0.95$

$$= 319.411 \text{ kW}$$

29. (d)

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

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

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

$$\cos\theta = 0.5$$

$$\theta = 60°$$

30. (c)

Specific speed is independent of dimensions, size of both actual and specific turbine.

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