CLASS TEST

Sl. : 04DLSK_CE_ABC_07092026

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HYDRAULIC MACHINE

CIVIL ENGINEERING

Date of Test : 07/09/2026

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (a)

$$(F_r)_m = (F_r)_p$$

$$\left(\frac{V^2}{Lg}\right)_m = \left(\frac{V^2}{Lg}\right)_p$$

$$V_m = V_p\sqrt{\frac{L_m}{L_p}}$$

$$V_m = \frac{1}{\sqrt{36}} = \frac{1}{6} = 0.16 \text{ m/s}$$

2. (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,

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

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

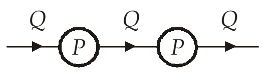
3. (c)

- Specific speed of turbine, $N_s = \dfrac{N\sqrt{P}}{H^{5/4}}$
- 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.

4. (c)



Pumps in series

$$Q = Q_1 = Q_2 ...$$
$$\text{and } H = H_1 + H_2 ...$$

5. (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 = $\sigma_c \times H$

6. (d)

N_s or specific speed is related to the rpm (N), net head H and power P as:

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

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

$$\Rightarrow \quad \sqrt{P} = \frac{N_s^2 \times H^{5/2}}{N^2} = \frac{32^2 \times 256^{5/2}}{420^2} = 6087.97 \text{ W} \approx 6 \text{ kW}$$

7. (b)

8. (a)

The specific speed for turbines is given by

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

The specific speed for pumps is given by

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

9. (a)

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

10. (d)

Vapour pressure always play very important role in cavitation.

11. (c)

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

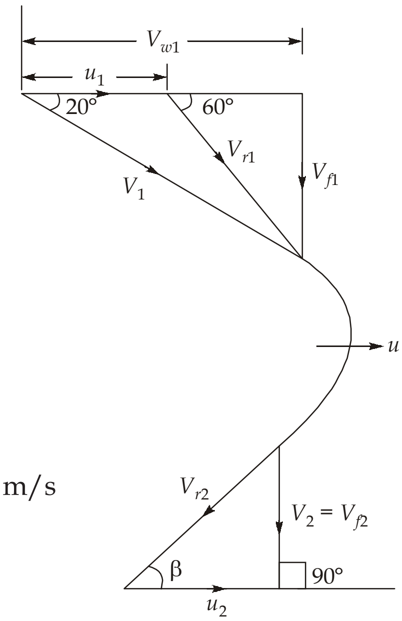
$$Q_1 = \frac{Q}{2}(1 + \cos\theta)$$

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

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

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

12. (b)



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

From inlet velocity triangle,

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

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

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

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

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

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

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

$= 5250$ kW

13. (c)

Given,

$$h_{f_s} = 0$$

$$h_{f_d} = 0.5 \text{ m}$$

$$H_1 = 4 \text{ m}$$

$$H_2 = 15.5 \text{ m}$$

$$Q_1 = 5 \text{ lps} = 0.005 \text{ m}^3/\text{s}$$

$$Q_2 = 75 \text{ lps} = 0.075 \text{ m}^3/\text{s}$$

Efficiency of ram,

$$\eta = \frac{Q_1\left(H_2 + h_{f_d}\right)}{\left(Q_1 + Q_2\right)\left(H_1 - h_{f_s}\right)} \times 100$$

$$= \frac{0.005 \times (15.5 + 0.5)}{0.08 \times (4 - 0)} \times 100$$

$$= \frac{5 \times 10^{-3} \times 16}{8 \times 10^{-2} \times 4} \times 100$$

$$\eta = 25\%$$

14. (a)

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,

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

$$= 30 + \frac{4 \times 0.014 \times 150 \times (2.83)^2}{2 \times 9.81 \times 0.15} + \frac{(2.83)^2}{2 \times 9.81}$$

$$= 53.267 \text{ m}$$

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

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

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

15. (a)

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

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

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

As we know,

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

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

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

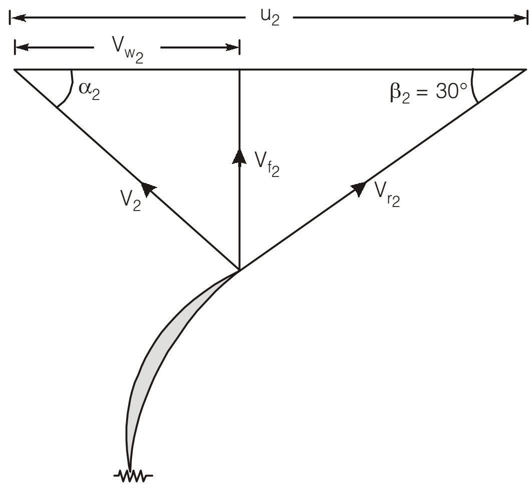
$$T_2 = 6820.926 \text{ Nm}$$

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

17. (d)

$$N_S = \frac{N\sqrt{P}}{(H)^{5/4}} = \frac{100\sqrt{6400}}{(10)^{5/4}} = 450$$

$$N_S(450) > 250$$

Turbine is Kaplan.

18. (b)

The force on the jet is upward and to the left. The leftward component is supplied by the compression spring.

$$F_x = \rho Q[(V_x)_2 - (V_x)_1]$$

$$= 1000 \times \left(\frac{\pi}{4} \times (0.035)^2 \times 20\right) \times (20 \cos 45° - 20)$$

$$= -112.7185 \text{ N}$$

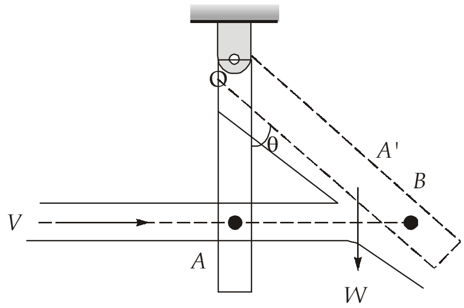
By Hooke's law, $F_x = -k\Delta x$

$$-112.7185 = -1.8 \times 1000 \, (\Delta x)$$

$$\Delta x = 62.62 \text{ mm} = 6.262 \text{ cm}$$

19. (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,

$$F_n = \rho a v^2 \cdot \sin\theta$$
$$\text{Here } \theta' = 90 - \theta$$
$$\text{So, } F_n = \rho a v^2 \cos\theta$$
$$\text{Moment of } F_n \text{ about } 0 = F_n \times OB$$
$$= \rho a v^2 \times \frac{OA}{\cos\theta}$$
$$= \rho a v^2\,(OA)$$

For equilibrium position, $\Sigma M_0 = 0$

$$W \times \sin\theta \times OA = \rho a v^2\,(OA)$$
$$\sin\theta = \frac{\rho a v^2}{W} \quad \text{(Since, } OA = OA'\text{)}$$
$$\sin\theta = \frac{10^3 \times 10^{-3} \times (50)^2}{5 \times 10^3}$$
$$\sin\theta = \frac{1}{2}$$
$$\theta = 30°$$

20. (d)

We know,
$$\frac{Q_1}{N_1 D_1^3} = \frac{Q_2}{N_2 D_2^3}$$
$$N_2 = \left(\frac{Q_2}{Q_1}\right) \cdot \left(\frac{D_1}{D_2}\right)^3 \cdot N_1$$

Here,
$$D_1 = D_2$$
$$N_1 = 900\text{ rpm}$$
$$Q_1 = 0.3\text{ m}^3/\text{s}$$
$$Q_2 = 0.4\text{ m}^3/\text{s}$$
$$N_2 = \left(\frac{0.4}{0.3}\right)(1)^3 \times 900$$
$$N_2 = 1200\text{ rpm}$$

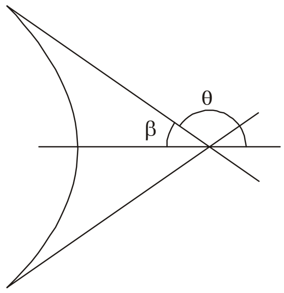
For corresponding head, $\dfrac{H_1}{D_1^2 N_1^2} = \dfrac{H_2}{D_2^2 N_2^2}$

$$H_2 = \left(\frac{N_2}{N_1}\right)^2 \left(\frac{D_2}{D_1}\right)^2 H_1$$

$$H_2 = \left(\frac{1200}{900}\right)^2 (1)^2 \times 15$$

$$H_2 = 26.67 \text{ m}$$

21. (b)



$$\frac{\text{Power}}{mg} = \frac{(V-u)(1+\cos\beta)u}{g} - \frac{k_1(V-u)^2}{2g}$$

β = blade angle

θ = 180 – β = bucket angle

θ = deflection angle

$$\Rightarrow \quad \eta = \frac{(V-u)(1-\cos\theta)u - \dfrac{k_1(V-u)^2}{2}}{\dfrac{V^2}{2}}$$

$$\Rightarrow \quad \eta = 2(1-\rho)\,\rho\,(1-\cos\theta) - k_1(1-\rho)^2$$

$$\frac{dn}{d\rho} = 2(1-\cos\theta)[1-2\rho] + 2k_1(1-\rho)$$

$$0 = (1-\cos\theta) + k_1 - \rho[k_1 + 2(1-\cos\theta)]$$

$$\rho = \frac{k_1 + (1-\cos\theta)}{k_1 + 2(1-\cos\theta)}$$

22. (d)

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

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

24. (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)

25. (b)

$$0.9 = \frac{72}{H}$$

$$\therefore \quad H = 80 \text{ m}$$

$$\therefore \quad \text{Pipe friction} = 100 - 80 = 20 \text{ m}$$

26. (c)

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

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

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

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

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

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

27. (d)

As flow rate increases frictional losses in the suction pipe increase, leading to higher NPSH requirement.

28. (b)

$$P = \eta_0 \rho Q g H$$

$$P \propto QH \quad \text{...(i)}$$

$$Q \propto D^2\sqrt{H} \quad \text{...(ii)}$$

$$u \propto \sqrt{H} \alpha DN \quad \text{...(iii)}$$

Putting (ii) and (iii) in equation (i),

$$P \propto \frac{H^{5/2}}{N^2}$$

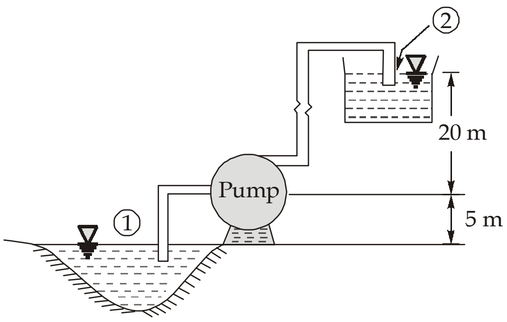
$$\Rightarrow \quad \frac{PN^2}{H^{5/2}} = \text{Constant}$$

$$\left.\frac{PN^2}{H^{5/2}}\right|_P = \left.\frac{PN^2}{H^{5/2}}\right|_M$$

$$\frac{30 \times 100^2}{20^{2.5}} = \frac{40 \times N_m^2}{20^{2.5}}$$

$$N_m = \sqrt{\frac{30}{40}} \times 100 = 86.6 \text{ rpm} \simeq 87 \text{ rpm}$$

29. (b)



Applying energy conservation between (1) and (2)

$$H_p = 5 + 20 = 25 \text{ m}$$

$$\text{Power} = \frac{\rho Q g H_p}{\eta} = \frac{10^3 \times 3 \times 20 \times 10^{-4} \times g \times 25}{0.75} \times 10^{-3} \text{kW}$$

$$= 2 \text{ kW}$$

30. (b)

$$N_s = \frac{N\sqrt{Q}}{H^{3/4}} = \frac{1500\sqrt{2.25}}{(16)^{3/4}} = 281.25$$

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