CLASS TEST

Sl. : 01SKCE_ABCD_10092025

MADE EASY
Leading Institute for IES, GATE & PSUs
Delhi | Bhopal | Hyderabad | Jaipur | Pune | Kolkata
Web: www.madeeasy.in | **E-mail:** info@madeeasy.in | **Ph:** 011-45124612

HYDRAULIC MACHINE

CIVIL ENGINEERING

Date of Test : 10/09/2025

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (b)

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

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

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

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

2. (a)

$$\text{Maximum height attained} = \frac{u^2 \sin^2 \alpha}{2g} = \frac{18^2 \times (\sin 60)^2}{2 \times 9.81} = 12.38 \text{ m}$$

3. (a)

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

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

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

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

4. (d)

Work done by ject on series of plates per second,

$$= F_x \times u$$

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

Kinetic energy of jet per second,

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

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

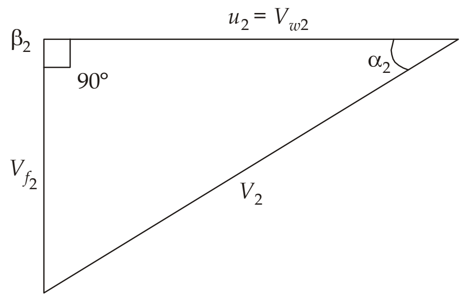
5. (c)

- 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.

6. (a)



From the outlet velocity triangle

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

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

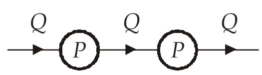
Manometric efficiency,

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

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

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

7. (c)



Pumps in series

$$Q = Q_1 = Q_2 ...$$

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

8. (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 $= \sigma_c \times H$

9. (b)

Power required to run the pump = $P = \rho Q g h$

$$= 1000 \times (20 \times 10^{-3}) \times 9.81 \times 35 = 6.867 \text{ kW}$$

10. (b)

- Rotodynamics machines are those whose functioning depends on the principle of fluid dynamics.
- Positive displacement machines are those whose functioning depends on the change of volume of certain amount of fluid within the machine.

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, $Q_2 = \frac{Q}{2}(1-\cos\theta)$

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. (a)

Given: Weight flow rate = 230 N/s

Mass flow rate, $$\dot{m} = \frac{w}{g} = \frac{230}{9.81} = 23.445 \text{ kg/s}$$

So, discharge, $$\dot{Q} = \frac{w}{\rho g} = \frac{230}{10^3 \times 9.81} = 0.02345 \text{ m}^3/\text{s}$$

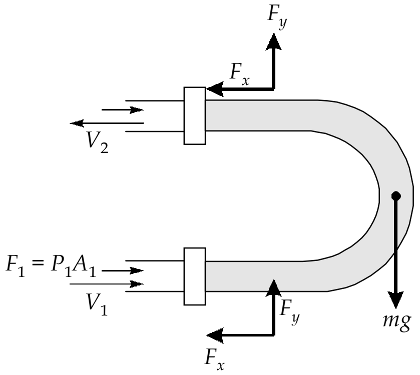
So, average velocity through pipe of water,

$$\Rightarrow \quad V = \frac{Q}{A} = \frac{0.02345}{\frac{\pi}{4}(0.05)^2} = 11.94 \text{ m/s}$$

As per second law of motion

$$\Rightarrow \quad \Sigma F_{ext} = \dot{m}\left(V_f - V_i\right)$$

Along x-direction:



$$-F_x + (P_1 - P_a)\times A_1 + (P_2 - P_a)\times A_2 = m_2V_2 - m_1V_1$$

$$-F_x = 23.44\times(-11.94 - 11.94) - \left[(165-101)\times 10^3 + (134-101)\times 10^3\right]\times\frac{\pi}{4}\times 0.05^2$$

$F_x = 750.206$ N (←)

Along y-direction

$$\Sigma F_y = \dot{m}\left(V_{2y} - V_{1y}\right)$$

$$\Rightarrow \quad F_y - m_{\text{fluid}} \times g = 0$$

$$F_y = m_{\text{fluid}} \times g$$

$$= \frac{\pi}{4}\times(0.05)^2\times(7.5)\times 1000\times 9.81$$

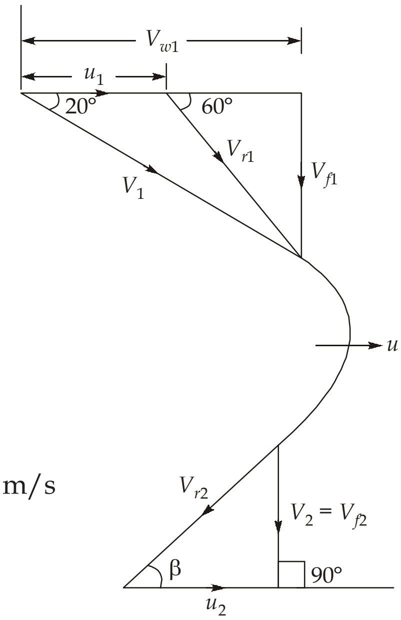
$$F_y = 144.46 \text{ N } (\uparrow)$$

So, total force that flange has to withstand is

$$F = \sqrt{F_x^2 + F_y^2} = \sqrt{(750)^2 + (144.46)^2}$$

$$= 763.78 \text{ N} \simeq 764 \text{ N}$$

13. (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 $= \rho Q(u_1V_{w1} - u_2V_{w2})$

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

$$= 5250 \text{ kW}$$

14. (c)

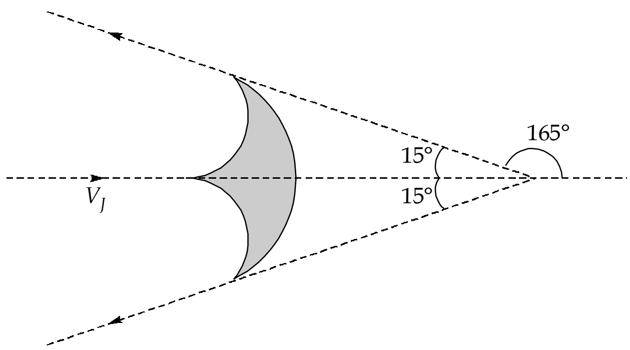
Given,
$$h_{f_s} = 0$$
$$h_{f_d} = 0.5 \text{ m}$$
$$H_1 = 4 \text{ m}$$
$$H_2 = 15.5 \text{ m}$$
$$Q_1 = 5 \text{ lps} = 0.005 \text{ m}^3/\text{s}$$
$$Q_2 = 75 \text{ lps} = 0.075 \text{ m}^3/\text{s}$$

Efficiency of ram,
$$\eta = \frac{Q_1\left(H_2 + h_{f_d}\right)}{(Q_1+Q_2)\left(H_1 - h_{f_s}\right)} \times 100$$
$$= \frac{0.005 \times (15.5 + 0.5)}{0.08 \times (4-0)} \times 100$$
$$= \frac{5 \times 10^{-3} \times 16}{8 \times 10^{-2} \times 4} \times 100$$
$$\eta = 25\%$$

15. (d)

$$\text{Discharge from jet } (Q) = \frac{6.116}{3600} = 1.6989 \times 10^{-3} \text{m}^3/\text{s}$$

Now, $$\text{velocity of jet} = \frac{Q}{\text{Area of jet}}$$
$$V_J = \frac{1.6989 \times 10^{-3}}{\frac{\pi}{4}(20 \times 10^{-3})^2} = 5.40 \text{ m/s}$$



For theoretical force it is assumed that velocity is not reduced as water passes around each cup,

$$\therefore \quad F_{\text{theoretical}} = \dot{m}(\Delta V) = (\rho\dot{Q})(V_J(1-\cos 165°))$$
$$= 1000 \times 1.6989 \times 10^{-3}(5.40(1-\cos 165°)) = 18.035 \text{ N}$$

$$\therefore \quad \frac{\text{Actual force}}{\text{Theoretical force}} = \frac{15}{18.035} = 0.8316$$

If V_1 is the actual velocity at outlet,

Now, $$\text{Actual force} = \dot{m}(\Delta V_a)$$

$$15 = \rho\dot{Q}\left(V_j - V_1\cos(165°)\right)$$

$$15 = 1000 \times 1.6989 \times 10^{-3}\left(5.40 - V_1\left(\cos 165°\right)\right)$$

$$V_1 = 3.55 \text{ m/s}$$

$$\therefore \quad \frac{\text{Outlet velocity}}{\text{Inlet velocity}} = \frac{3.55}{5.40} = 0.6574$$

16. (d)

Discharge is radial

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

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

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

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

$$V_{w1} = \frac{0.85 \times 9.81 \times 8}{12.03} = 5.54 \text{ m/s}$$

17. (a)

Given: $Q = 0.05$ m^3/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,

$$H_m = H + \frac{4fLV^2}{2gD} + \frac{V^2}{2g} = 30 + \frac{4 \times 0.014 \times 150 \times (2.83)^2}{2 \times 9.81 \times 0.15} + \frac{(2.83)^2}{2 \times 9.81}$$

$$= 53.267 \text{ m}$$

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

or,

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

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

18. (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,

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

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

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

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

19. (c)

Manometric efficiency, $\eta_m = \dfrac{gH_m}{V_{w2}u_2}$

$$\Rightarrow \quad 0.75 = \frac{g \times 30}{V_{w2}u_2}$$

$$\text{Total head, } \frac{V_{w2}u_2}{g} = \frac{30}{0.75} = 40 \text{ m}$$

Pressure rise through the impeller $\left(\dfrac{p_2 - p_1}{\rho g}\right)$ is 65% of the total head developed by the pump.

$$\text{Thus, } \frac{p_2 - p_1}{\rho g} = 0.65 \times \frac{V_{w2}u_2}{g} = 0.65 \times 40 = 26 \text{ m}$$

Energy equation between the inlet and outlet tip of the impeller,

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + \frac{V_{w2}u_2}{g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2$$

$$\Rightarrow \quad \frac{p_2 - p_1}{\rho g} = \frac{V_f^2}{2g} + \frac{V_{w2}u_2}{g} - \frac{V_2^2}{2g} \qquad (\because z_1 = z_2; V_1 = V_f)$$

$$\Rightarrow \quad 26 = \frac{3^2}{2 \times 9.81} + 40 - \frac{V_2^2}{2g}$$

$$\Rightarrow \quad \frac{V_2^2}{2g} = \frac{3^2}{2 \times 9.81} + 40 - 26$$

$$V_2 = 16.8428 \text{ m/s} = \sqrt{V_{f2}^2 + V_{w2}^2} = \sqrt{3^2 + V_{w2}^2}$$

$$V_{\omega 2} = 16.5735 \text{ m/s}$$

20. (a)

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

Power generated

$= \rho g H \times 0.9 \times Q$
$= 1000 \times 9.81 \times 10.1 \times 24.5 \times 0.9 = 2184.74$ 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

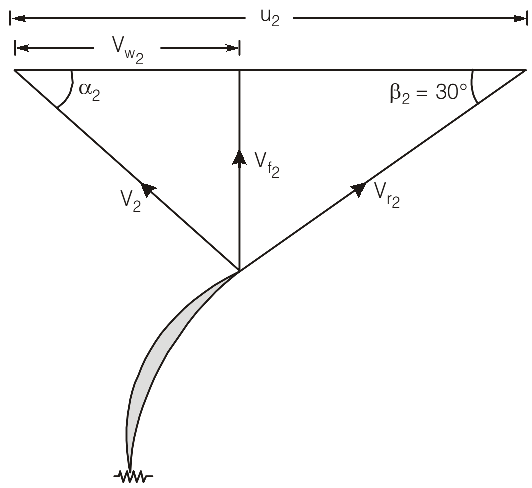
Hence, turbine is Francis.

21. (a)

At the outlet $\quad u_2 = \dfrac{\pi D_2 N}{60} = \dfrac{\pi \times 0.30 \times 1200}{60} = 18.85$ 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, $H = \eta_m \dfrac{u_2 V_{w_2}}{g} = \dfrac{0.85 \times 18.85 \times 15.386}{9.81} = 25.13 \text{ m}$

22. (d)

Net available head, $H = 500\ (1 - 0.05) = 475$ m

$$\text{Power per jet} = \frac{1500}{2} = 750 \text{ kW}$$

$$\text{Specific speed } (N_s) = \frac{N\sqrt{P}}{H^{5/4}}$$

$$\Rightarrow \quad 15 = \frac{N\sqrt{750}}{(475)^{5/4}}$$

$$\Rightarrow \quad N = 1214.58 \text{ rpm}$$

23. **(a)**

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

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

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

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

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

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

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

24. **(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.

25. **(a)**

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 + h_L + h_T$$

$$0 + 0 + 95 = 0 + \frac{(1.5)^2}{2 \times 10} + 0 + 20 + h_T$$

$$h_T = 95 - 0.1125 - 20 = 74.8875 \text{ m}$$

The work done by the fluid on a turbine is positive. The power extracted is

$$P = \rho g Q h_T = 1000 \times 10 \times 25 \times 74.8875$$
$$= 18.72185 \text{ MW}$$

26. **(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,
$$F_x = -k\Delta x$$

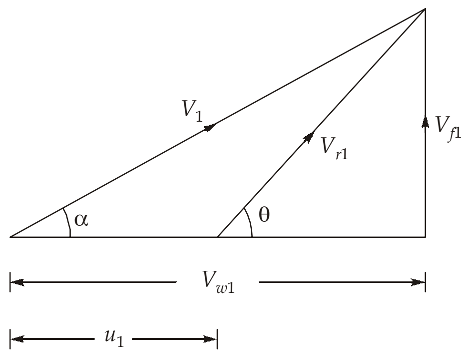
$$-112.7185 = -1.8 \times 1000\ (\Delta x)$$

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

27. (b)

Hydraulic efficiency, $\eta_h = \dfrac{v_{\omega 1}u_1 - v_{\omega 2}u_2}{gH}$ [1, 2 → Inlet and outlet respectively]

$$0.83 = \frac{4.25\sqrt{H}u_1 - 0.35\sqrt{H}u_2}{9.81H}$$



$$u_1 = u$$

$$\Rightarrow \quad u_2 = 0.7u$$

$$0.83 = \frac{4.25\sqrt{H}u - 0.35\sqrt{H}(0.7)u}{9.81H}$$

$$u = \frac{0.83 \times 9.81\sqrt{H}}{4.25 - 0.35 \times 0.7} = 2.03\sqrt{H} = u_1$$

$$u_2 = 1.423\sqrt{H}$$

From inlet velocity triangle, we have

$$\tan\theta = \frac{V_{f1}}{(V_{w1} - u_1)} = \frac{1.05\sqrt{H}}{4.25\sqrt{H} - 2.03\sqrt{H}} = 0.47297$$

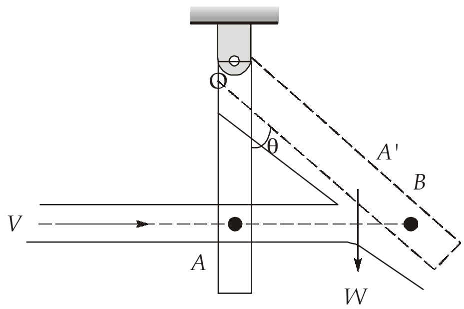
$$\theta = 25.31°$$

28. (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, $\Sigma M_0 = 0$

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

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

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

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

$$\theta = 30°$$

29. (b)

Power developed $P \propto Q \propto d^2$ where, d = diameter of the jet

Required jet diameter,

$$\frac{P_1}{P_2} = \frac{d_1^2}{d_2^2}$$

$$\frac{P}{(1-0.64)P} = \frac{(150)^2}{d_2^2}$$

$$\frac{1}{0.36} = \left(\frac{150}{d_2}\right)^2$$

$$d_2 = 150\sqrt{0.36}$$

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

30. (d)

We know, $$\frac{Q_1}{N_1 D_1^3} = \frac{Q_2}{N_2 D_2^3}$$

$$N_2 = \left(\frac{Q_2}{Q_1}\right)\cdot\left(\frac{D_1}{D_2}\right)^3 \cdot \text{N}_1$$

Here, $D_1 = D_2$

N_1 = 900 rpm

Q_1 = 0.3 m^3/s

Q_2 = 0.4 m^3/s

$$N_2 = \left(\frac{0.4}{0.3}\right)(1)^3 \times 900$$

$$N_2 = 1200 \text{ rpm}$$

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

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

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

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

■■■■