S.No. : 02 GH1_ME_B_280819
Fluid Mechanics & Machinery

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# CLASS TEST 2019-2020

## MECHANICAL ENGINEERING

**Date of Test : 28/08/2019**

## ANSWER KEY ➤ Fluid Mechanics & Machinery

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

## Detailed Explanations

1. (b)

For soap bubble, $\Delta P = \dfrac{8\sigma}{d}$

where, $\Delta P$ is pressure difference,

$\sigma$ is surface tension, $\Delta P = \dfrac{8 \times 0.072}{0.001} = 576 \text{ N/m}^2$

3. (a)

We know, equation of an stream-line is

$$\frac{dx}{u} = \frac{dy}{v} = \frac{dz}{\omega}$$

$\because$ The flow is 2-dimensional,

$$\therefore \quad \frac{dx}{u} = \frac{dy}{v}, \quad \frac{dx}{x} = \frac{dy}{-y}$$

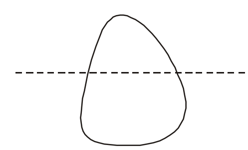
On integrating, $\ln x = \ln\left(\dfrac{c}{y}\right), \; x = \dfrac{c}{y} \Rightarrow xy = c$

As it passing through 1, 1

$\therefore \quad c = 1$

$\therefore$ Equation of stream-line is $xy - 1 = 0$

4. (b)



Let $V$ is total volume of Iceberg and let $x$ is the volume of Iceberg inside water.

According to floatation principle,

Weight of body = Weight of liquid displaced

$\therefore \quad 8 \text{ kN} \times V = x \times 10.05 \text{ kN}$

$x = 0.796\, V$

$\therefore$ Percentage of total volume of Icerberg above water surface will be

$$= \frac{(V - x)}{V} \times 100 = \frac{(0.2039\, V)}{V} \times 100 = 20.39\%$$

5. (a)

$d = 50 \text{ mm}$

$\theta = 30°$

$F_x = 1471.5 \text{ N}$

$F_x = \rho A V^2 \sin^2\theta$

$A = \dfrac{\pi}{4} \times 0.05^2 = 0.001963 \text{ m}^2$

$1471.5 = 1000 \times 0.001963 \times V^2 \times \sin^2(30°)$

$V = 54.7583 \text{ m/s}$

$Q = AV = 0.001963 \times 54.7583 = 0.1075 \text{ m}^3\text{/s} = 107.5 \text{ liters/s}$

6. (b)

Force on piston = Shear force due to oil viscosity

$18 = \tau \,.\, A$

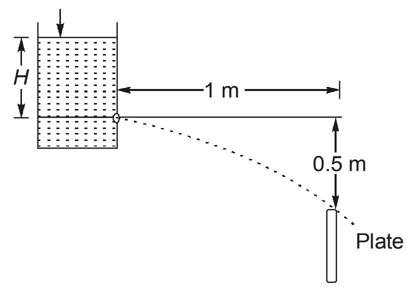
$$18 = \frac{\mu V}{h} \times \pi \times d \times L$$

$$\Rightarrow \quad 18 = \frac{3 \times 0.1 \times V \times \pi \times 0.0795 \times 0.3}{0.025 \times 10^{-2}}$$

$$\Rightarrow \quad V = 0.2001 \text{ m/s}$$

$$\Rightarrow \quad V = 20 \text{ cm/s}$$

7. (b)




For a point on the trajectory.

$$\therefore \quad x = u_1 t \quad \text{...(i)}$$

$$z = \frac{1}{2} g t^2 \quad \text{...(ii)}$$

For, $C_V = 1, \quad u_1 = \sqrt{2gH}$

From Eq. (i) and (ii)

$$\therefore \quad z = \frac{x^2}{4H} \Rightarrow H = \frac{x^2}{4z} \Rightarrow \frac{(1)^2}{4 \times 0.5} = 0.5\text{m}$$

8. (c)

During cavitation, the vapour bubbles starts forming where the pressure of the liquid falls below the vapour pressure and sudden collapsing of these vapour bubbles in a region of higher pressure. When they collapse, a very high pressure is created. This causes pitting action on the surfaces over which they collapse. Hence during, cavitation and subsequent, pitting, pre-dominant forces are compressive forces.

9. (a)

Power available at the nozzle is

$$P = \frac{\rho g Q H}{1000} \text{ kW} = \frac{1000 \times 9.81 \times 0.1 \times 700}{1000} = 686.7 \text{ kW}$$

11. (a)

$$a_x = \frac{du}{dt} + u\frac{\partial u}{dx} + v\frac{\partial u}{\partial y} \Rightarrow 2t + (t^2 + 3y)0 + (4t + 5x)(3)$$

$$a_y = \frac{dv}{dt} + u\frac{\partial v}{dx} + v\frac{\partial v}{\partial y} \Rightarrow 4t + (t^2 + 3y)5 + (4t + 5x)0$$

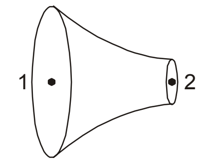
$$= 4 + 5t^2 + 15y$$

At point (5, 3), $a_x = (14 \times 2) + (15 \times 5) = 103$

$$a_y = 4 + (5 \times 2^2) + (15 \times 3) = 69$$

$$a = \sqrt{103^2 + 69^2} = 123.97 \text{units}$$

12. (b)




$$Q = A_1V_1 = A_2V_2$$

$$\Rightarrow \quad \frac{\pi}{4}\times 0.3 \times V_1 = \frac{\pi}{4}\times 0.15^2 \times V_2$$

$$\Rightarrow \quad V_2 = 4V_1$$

Applying Bernoulli equation at point 1 and 2,

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

But $Z_1 = Z_2$ for the same horizontal level

$$\frac{P_1-P_2}{\rho g}+\frac{V_1^2}{2g} = \frac{V_2^2}{2g}$$

$$\frac{0.05\times 13.6\times 1000\times g}{1000\times g} = \frac{V_2^2}{2g}-\frac{V_1^2}{2g}$$

$$0.68 = \frac{16V_1^2-V_1^2}{2g}$$

$$\Rightarrow \quad V_1 = 0.943 \text{ m/s}$$

$$\Rightarrow \quad Q = A_1V_1 = \pi\times 0.25\times 0.3^2\times 0.943 = 0.06666 \text{ m}^3\text{/s}$$

$$\Rightarrow \quad Q = 66.66 \approx 67 \ l\text{/s}$$

13. (c)

At stagnation point, $u = 0, \quad v = 0$

$$\Rightarrow \quad x + 2y + 2 = 0,\ 2x - y = 3.5$$

On solving above equations,

$$x = 1, \quad y = -1.5$$

$$D = \sqrt{(x-0)^2+(y-0)^2} = 1.8027\text{m}$$

$$D = \sqrt{(1-0)^2+(-1.5-0)^2} = 1.8027\,m$$

14. (b)

For similar turbines, specific power will be same

$$H_m : H_p = 1:4$$

$$P_p = 300 \text{ kW}$$

$$\frac{N_mD_m}{\sqrt{H_m}} = \frac{N_pD_p}{\sqrt{H_p}}$$

$$\frac{N_mD_m}{\sqrt{10}} = \frac{N_pD_p}{\sqrt{40}}$$

$$\frac{1000\times D_p}{\sqrt{40}} = \frac{N_mD_m}{\sqrt{10}}$$

$$\therefore \quad N_m = \frac{1000\times 4\times\sqrt{10}}{\sqrt{40}}$$

$$\Rightarrow \quad N_m = 2000$$

Now, for the same specific speeds

$$\frac{N_m\sqrt{P_m}}{H_m^{\frac{5}{4}}} = \frac{N_p\sqrt{P_p}}{H_p^{\frac{5}{4}}}$$

$$\Rightarrow \quad P_m = 2.34 \text{ kW}$$

15. (a)

For the condition of verge of tipping, the centre of pressure must be at C.

$$\therefore \quad \text{Height of C above B} = \frac{H}{3} = \frac{9.5}{3} = 3.16 \text{ m}$$

[$\because$ for a rectangular plane surface of height H, just completely inside fluid, the centre of pressure is at $\frac{H}{3}$ from base.]

16. (a)

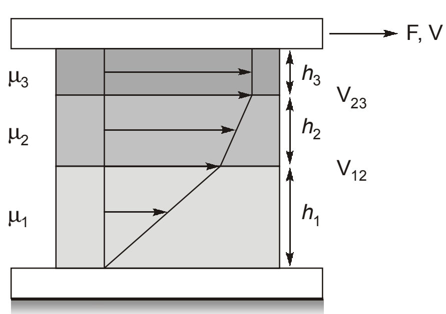
The specific speed for turbines is given by

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

The specific speed for pumps is given by

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

17. (c)




Area of each plate = 1 m$^2$

$\therefore$ Shear stress on each plate and layer will be,

$$\tau = F/A = \frac{100}{1} = 100 \text{ N/m}^2$$

$\therefore$ Let $V_{12}$ be the velocity of intermediate layer between fluid 1 and 2 and $V_{23}$ be the corresponding velocity for layer between 2 and 3.

Then, $$\tau = \frac{\mu_1 V_{12}}{h_1}$$

$$\Rightarrow \quad 100 = \frac{0.15 \times V_{12}}{0.5 \times 10^{-3}} \quad \Rightarrow V_{12} = 0.333$$

Also, $$\tau = \mu_2 \times \frac{(V_{23} - V_{12})}{h_2}$$

$$\therefore \quad 100 = \frac{0.5\times(V_{23}-0.333)}{0.25\times10^{-3}} \Rightarrow V_{23} = 0.383$$

Also,
$$\tau = \mu_2 \times \frac{(V_{23}-V_{12})}{h_2}$$

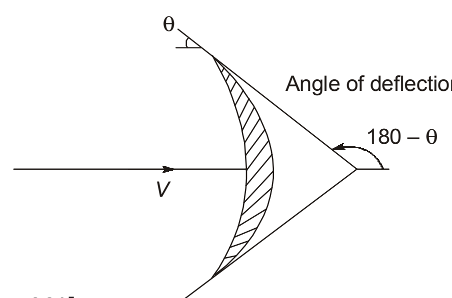
$$\therefore \quad 100 = \frac{0.2\times(V-0.383)}{0.2\times10^{-3}} \Rightarrow V = 0.483 \text{ m/s}$$

18. (b)

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

Now,
$$\text{Power}\,(P) = \rho QgH$$
$$P \propto \sqrt{H}\times H$$
$$P \propto H^{3/2}$$

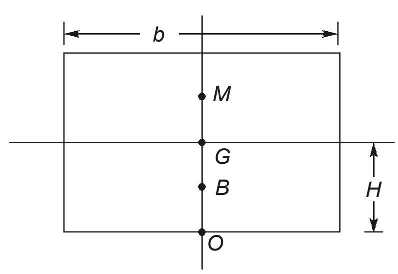
19. (b)




$$\text{Diameter of Jet} = 60 \text{ mm}$$
$$\therefore \quad \text{Area} = \frac{\pi}{4}\times(0.06)^2 = 2.827\times10^{-3}\text{ m}^2$$
$$\text{Velocity of Jet} = 50 \text{ m/s}$$
$$\text{Angle of direction} = 120^\circ$$
$$\therefore \quad \theta = 180^\circ - 120^\circ = 60^\circ$$
$$F = \rho a v^2 [1+\cos\theta]$$
$$F = 1000\times2.827\times10^{-3}\times50^2[1+\cos 60^\circ]$$
$$F = 10601.25 \text{ N} \quad \text{or} \quad 10.6 \text{ kN}$$

20. (a)

Let $B$, $G$ and $M$ be the centre of buoyancy, centre of gravity and meta-centre of the plate.




$$OB = \frac{H}{2}, \quad OG = H$$
$$BG = OG - OB = \frac{H}{2}$$
$$BM = \frac{I}{V} = \frac{Lb^3}{12\times L\times b\times H} = \frac{b^2}{12H}$$

where, $L$ = Length of the plate in a direction perpendicular to the plane of the figure.

$$\therefore \qquad GM = BM - BG = \frac{b^2}{12H} - \frac{H}{2}$$

For stable equilibrium of plate, $MG \geq 0$.

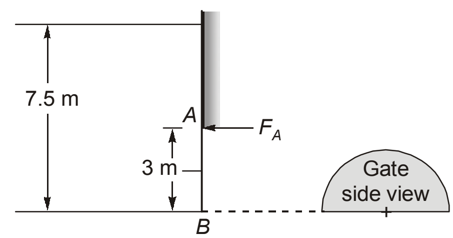
$$\therefore \qquad \frac{b^2}{12H} - \frac{H}{2} \geq 0$$

$$\Rightarrow \qquad \frac{b}{H} \geq \sqrt{6}$$

$$H = \sqrt{6}$$

$$\Rightarrow \qquad b \geq 6$$

21. (b)




$$F = \rho g A\bar{h}$$

$$\bar{h} = 7.5 - \frac{4R}{3\pi} \Rightarrow 6.226 \text{ m}$$

$$h^* = \frac{I_g}{A\bar{h}} + \bar{h}$$

$$I_g = \frac{\pi}{128}D^4 - \frac{\pi D^2}{8} \times \left(\frac{2D}{3\pi}\right)^2 \Rightarrow 8.8912$$

$$h^* = \frac{8.8912 \times 8}{\pi \times 6^2 \times 6.226} + 6.226 \Rightarrow 6.327$$

Taking moments from point B, we have

$$F_A \times 3 = F \times (7.5 - h^*)$$

$$F_A \times 3 = 1000 \times 9.81 \times \frac{\pi}{2} \times (3)^2 \times 6.226 \times (7.5 - 6.327)$$

$$\Rightarrow \qquad F_A = 337611.52 \text{ N}$$

$$F_A = 337.611 \text{ kN} \simeq 337.61 \text{ kN}$$

22. (a)

As the Reynods number, Re > $10^5$ (turbulent flow)

$$C_d = \frac{0.074}{(\text{Re}_L)^{1/5}}$$

$$F_D = C_d \times \frac{1}{2}\rho V^2 \times A$$

$$\therefore \qquad F_D = \frac{0.074}{\text{Re}_L^{1/5}} \times \frac{1}{2}\rho V^2 \times L \times b$$

$$F_D = KL^{4/5}$$

Where, $K$ is a constant

$$\therefore \qquad F_{D_1} = KL^{4/5}$$

$$F_{D_2} = K(L + 0.1L)^{4/5}$$

$$\therefore \qquad \frac{F_{D_2} - F_{D_1}}{F_{D_1}} = \frac{K(1.1)^{4/5} L^{4/5} - KL^{4/5}}{KL^{4/5}}$$

$$\% \text{ change in drag force} = (1.1)^{4/5} - 1$$
$$\% \text{ change in drag force} = 0.07923 \times 100$$
$$= 7.923\ \% \simeq 8\%$$

23. (d)

∵ Continuity equation holds,

$$\therefore \quad \frac{\pi}{4} \times (5)^2 \times 2 = \frac{\pi}{4} \times 3^2 \times x$$
$$x = 5.55 \text{ m/s}$$

Mars flow rate

$$\Rightarrow \quad \dot{m} = \int_{\dot{m}} A_1 V_1 = 100 \times \frac{\pi}{4} \times 0.05^2 \times 2 = 3.9269 \text{ kg/s}$$

Let $F_x$ and $F_y$ be the force in Right and vertically upward diversion respectively to hold the box in position.

∴ Now, $\Sigma F_x = 0$ [Box is stationary after applying force]

$$-\dot{m} \times V_1 \cos 65° + F_x = -\dot{m} \times V_2 \cos 0°$$
$$-3.9269 \times 2 \times \cos 65° + F_x = -3.9269 \times 5.55 \times 1$$
$$F_x = -18.475 \text{ N.}$$

$F_x$ must be in left as $F_x$ comes out to be negative.

Similarly for vertical direction $\Sigma F_y = 0$

$$F_y - 3.9269 \times 2 \times \sin 65° = 0$$
$$F_y = 7.11 \text{ N}$$

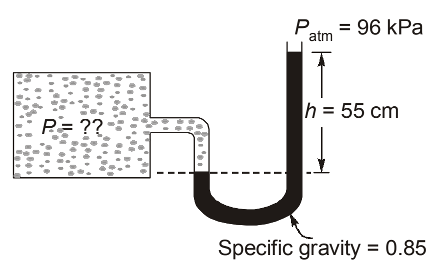
∴ It is towards vertically upward direction.

24. (a)

Break power, $$\text{B.P.} = \frac{mgh}{\eta_m} = \frac{80 \times 9.81 \times 30}{0.8} = 29.4 \text{ kW}$$

25. (b)

$$P = P_{atm} + \rho g h$$
$$P = 96 \text{ kPa} + \frac{(850 \times 9.81 \times 0.55)}{1000} \text{kPa}$$
$$= 96 + 4.586$$
$$= 100.5861 \simeq 100.6 \text{ kPa}$$




26. (c)

The continuity equation is given by

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial y} + \frac{\partial(\rho w)}{\partial z} = 0$$

Now, $$\rho = \rho_0 e^{-2t}$$
$$\frac{\partial \rho}{\partial t} = -2\rho_0 e^{-2t} = -2\rho$$
$$\frac{\partial(\rho u)}{\partial x} = 5\rho$$
$$\frac{\partial(\rho v)}{\partial y} = 5\rho$$

$$\frac{\partial(\rho w)}{\partial z} = \lambda\rho$$

$$\therefore \quad -2\rho + 5\rho + 5\rho + \lambda\rho = 0$$

$$8 + \lambda = 0$$

$$\lambda = -8$$

27. (d)

The drag force on the automobile may be given as

$$F_D = C_D A \times \frac{\rho V^2}{2}$$

Here $C_D = 0.30,$

$$A = 2.6 \text{ m}^2$$

$$\rho = 1.2 \text{ kg/m}^3$$

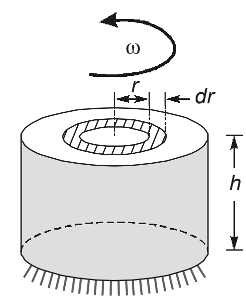
$$V = 120 \text{ kmph}$$

$$\therefore \quad F_D = \frac{0.30 \times 2.6 \times 1.2 \times (120 \times 10^3)^2}{2 \times (60 \times 60)^2}$$

$$F_D = 520 \text{ N}$$

28. (a)

Consider a strip of thickness $dr$ at a distance $r$ from centre




$$\therefore \quad \tau = \mu \frac{du}{dy}$$

$$\Rightarrow \quad \tau = \frac{\mu \times r\omega}{h}$$

$$\therefore \quad dF = \tau.dA = \frac{\mu r\omega}{h} \times 2\pi r.dr$$

$$\therefore \quad dT = dF.r \Rightarrow \frac{\mu r\omega}{h} \times 2\pi r.dr.r$$

∴ On integrating from 0 to $R$

$$T = \int_0^R dT = \frac{2\mu\pi\omega}{h} \times \int_0^R r^3.dr$$

$$\Rightarrow \quad = \frac{2\mu\pi\omega \times R^4}{24h} \Rightarrow T = \frac{\mu\pi R^4\omega}{2h}$$

Substituting value

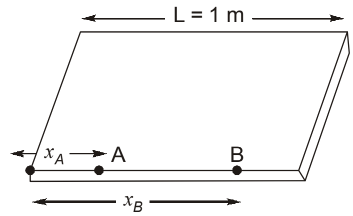
$$\Rightarrow \quad T = \frac{1.6 \times \pi \times 0.1^4 \times 2\pi \times 600}{2 \times 0.001 \times 60} = 15.79 \text{ m}$$

$$P = \frac{2\pi NT}{60}$$

$$\Rightarrow \quad P = \frac{2\pi \times 600 \times 15.79}{60}$$

$$P = 992.114 \text{ W} \simeq 992.11 \text{ W}$$

29. (d)




$$\delta \alpha \sqrt{x}$$

$$\frac{\delta_B}{\delta_A} = \sqrt{3}$$

Moreover, $$\frac{\delta_B}{\delta_A} = \sqrt{\frac{x_B}{x_A}} = \sqrt{3}$$

$\Rightarrow$ $$x_B = 3x_A$$

Also, $$x_B + x_A = 1$$

$\Rightarrow$ $$3x_A + x_A = 1$$

$\Rightarrow$ $$x_A = 0.25$$

$\Rightarrow$ $$x_B = 0.75$$

30. (b)

$$\eta_{\text{Overall}} = \frac{\text{Shaft power}}{gQH}$$

$$Q = \frac{500}{0.53} \times \frac{1}{9.81} \times \frac{1}{30} = 2.0469 \text{ m}^3/\text{s}$$

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