S.No. : 04 GH1_ME_F_250919

Fluid Mechanics & Machinery

MADE EASY
India's Best Institute for IES, GATE & PSUs

Delhi | Noida | Bhopal | Hyderabad | Jaipur | Lucknow | Indore | Pune | Bhubaneswar | Kolkata | Patna

Web: www.madeeasy.in | **E-mail:** info@madeeasy.in | **Ph:** 011-45124612

CLASS TEST 2019-2020

MECHANICAL ENGINEERING

Date of Test : 25/09/2019

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, $\Delta P = \frac{8\sigma}{d}$

where, ΔP is pressure difference,

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

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,

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

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

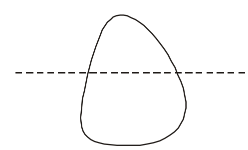
As it passing through 1, 1

$\therefore \quad c = 1$

$\therefore$ 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)

$d = 50 \text{ mm}$

$\theta = 30°$

$F_x = 1471.5 \text{ N}$

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

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

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

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

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

6. (b)

Force on piston = Shear force due to oil viscosity

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

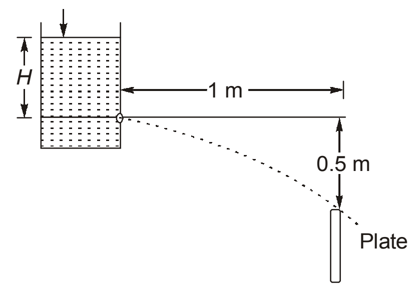
$$18 = \frac{\mu V}{h} \times \pi \times d \times L$$

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

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

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

7. (b)



For a point on the trajectory.

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

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

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)

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

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

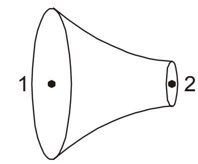
$$= 4 + 5t^2 + 15y$$

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)

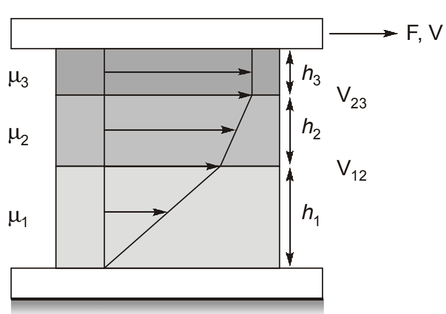
The specific speed for turbines is given by

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

The specific speed for pumps is given by

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

17. (c)



$$\text{Area of each plate} = 1 \text{ m}^2$$

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

$$\Rightarrow \quad 100 = \frac{0.15\times V_{12}}{0.5\times10^{-3}} \quad \Rightarrow V_{12} = 0.333$$

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

$$\therefore \qquad 100 = \frac{0.5 \times (V_{23} - 0.333)}{0.25 \times 10^{-3}} \Rightarrow V_{23} = 0.383$$

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

$$\therefore \qquad 100 = \frac{0.2 \times (V - 0.383)}{0.2 \times 10^{-3}} \Rightarrow V = 0.483 \text{ m/s}$$

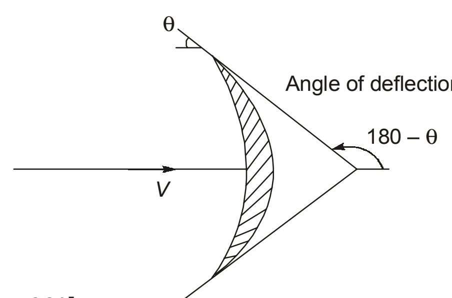
18. (b)

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

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

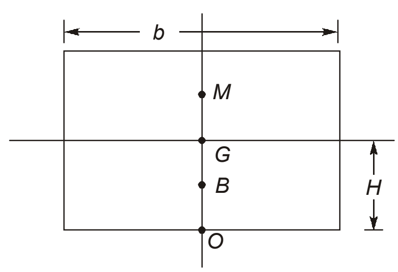
19. (b)

$$\text{Diameter of Jet} = 60 \text{ mm}$$
$$\therefore \qquad \text{Area} = \frac{\pi}{4} \times (0.06)^2 = 2.827 \times 10^{-3} \text{ m}^2$$
$$\text{Velocity of Jet} = 50 \text{ m/s}$$
$$\text{Angle of direction} = 120°$$
$$\therefore \qquad \theta = 180° - 120° = 60°$$
$$F = \rho a v^2 [1 + \cos\theta]$$
$$F = 1000 \times 2.827 \times 10^{-3} \times 50^2 [1 + \cos 60°]$$
$$F = 10601.25 \text{ N} \quad \text{or} \quad 10.6 \text{ kN}$$



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.

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

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

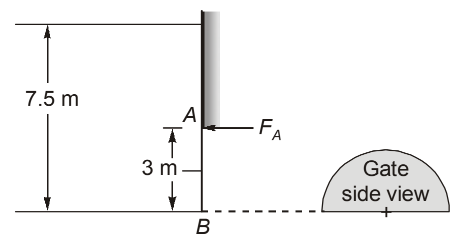
$$\therefore \quad \frac{b^2}{12H} - \frac{H}{2} \geq 0$$

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

$$H = \sqrt{6}$$

$$\Rightarrow \quad b \geq 6$$

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

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

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

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

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

22. (a)

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

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

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

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

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

Where, K is a constant

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

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

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

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

23. (d)

$\because$ 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.

$\therefore$ 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 $\Sigma F_y = 0$

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

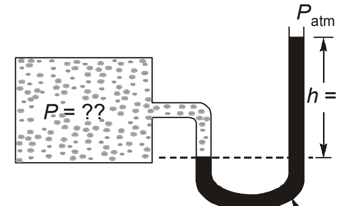
$\therefore$ It is towards vertically upward direction.

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

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

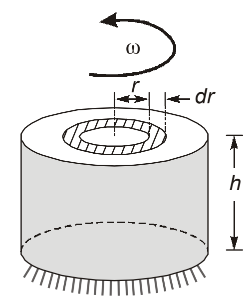
Here
$$C_D = 0.30,$$
$$A = 2.6 \text{ m}^2$$
$$\rho = 1.2 \text{ kg/m}^3$$
$$V = 120 \text{ kmph}$$

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

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

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

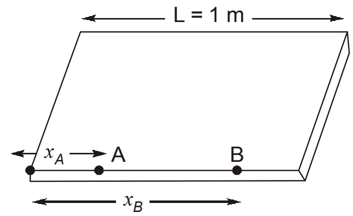
$$\Rightarrow \quad T = \frac{1.6 \times \pi \times 0.1^4 \times 2\pi \times 600}{2 \times 0.001 \times 60} = 15.79 \text{ m}$$

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

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

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

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)

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

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

■■■■