CLASS TEST

S.No. : 03 GH1_ME_C_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.	(c)	7.	(a)	13.	(d)	19.	(a)	25.	(a)
2.	(b)	8.	(a)	14.	(a)	20.	(d)	26.	(b)
3.	(c)	9.	(c)	15.	(c)	21.	(d)	27.	(c)
4.	(d)	10.	(c)	16.	(c)	22.	(a)	28.	(b)
5.	(b)	11.	(a)	17.	(b)	23.	(d)	29.	(d)
6.	(b)	12.	(c)	18.	(c)	24.	(b)	30.	(b)

Detailed Explanations

1. (c)

$\therefore$ Acceleration for flow with only a local acceleration is given by

$$a_x = \frac{\partial u}{\partial t}$$

$\therefore$ Uniform unsteady will be the answer.

3. (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.

4. (d)

$$\text{Power, } P = \rho g Q H$$

$$Q \propto A \times V$$

$$V \propto \sqrt{H}$$

$$\therefore \quad \frac{P}{H^{3/2}} = \text{constant}$$

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

$$\therefore \quad P_2 = 10000\left(\frac{4}{5}\right)^{1.5} = 7.15 \text{ MW}$$

5. (b)

$$F = \rho a\,(v - u)^2$$

$$150 = 1000 \times 0.0015 \times (15 - u)^2$$

$$\Rightarrow \quad u = 5 \text{ m/s}$$

6. (b)

$$\Omega_x = \frac{\partial w}{\partial y} - \frac{\partial v}{\partial z}$$

$$\Rightarrow \quad \Omega_x = -18yz - 3y$$

$$\Rightarrow \quad \Omega_{x(1,1,1)} = -21 \text{ units}$$

7. (a)

The hydraulic ram or (hydram) is a type of pump in which the energy of large quanity of water falling through a small height is utilised to lift a small quantity of this water to great height.

8. (a)

For laminar flow through pipe, the entrance length, L_e, can be estimated from the equation. $\frac{L_e}{D} = 0.06\text{ Re}$

9. (c)

Newton's law of viscosity

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

Where τ = shear stress

$\frac{du}{dy}$ = Rate of strain or rate of angular deformation

10. (c)

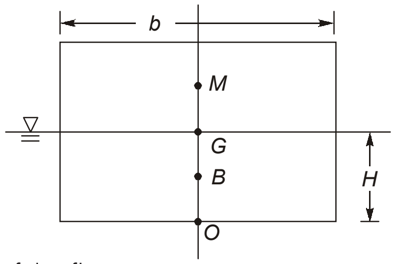
$$\tau A = mg\sin\theta$$

$$\mu\left(\frac{v}{t}\right)A = mg\sin\theta$$

$$v = \frac{mgt\sin\theta}{\mu A} = \frac{15\times 9.81\times 0.1\times 10^{-3}\times \sin 30^\circ}{8.14\times 10^{-2}\times 0.25} = 0.36 \text{ m/s}$$

11. (a)

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



$$OB = \frac{H}{2},\ OG = H$$

$$BG = OG - OB = \frac{H}{2}$$

$$BM = \frac{I}{V} = \frac{Lb^3}{12\times L\times b\times H} = \frac{b^2}{12H}$$

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

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

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

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

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

$$H = \sqrt{6}$$

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

12. (c)

The prototype operates in water and the model test is to be performed in air. For the similarity,

$$Re_{model} = Re_{prototype}$$

$$\frac{V_m D_m}{\nu_m} = \frac{V_P D_P}{\nu_P}$$

$$\frac{V_m \times 0.152}{1.46\times 10^{-5}} = \frac{2.57\times 0.3}{1.57\times 10^{-6}}$$

$$\Rightarrow \quad V_m = 47.169 \text{ m/s}$$

14. (a)

$$\psi = 2\sqrt{3}\,xy$$

$$u = \frac{\partial\psi}{\partial y} = 2\sqrt{3}\,x$$

$$\Rightarrow \quad v = -\frac{\partial\psi}{\partial x} = -2\sqrt{3}\,y$$

$$\Rightarrow \qquad V = \sqrt{u^2 + v^2}$$

$$\Rightarrow \qquad 4 = \sqrt{4(3)\left[x^2 + y^2\right]} \qquad \text{...(1)}$$

$$\tan\theta = \frac{v}{u}$$

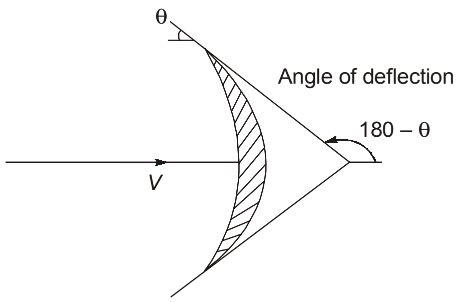
$$\Rightarrow \qquad \tan 150° = -\frac{2\sqrt{3}\,y}{2\sqrt{3}\,x}$$

$$\Rightarrow \qquad y = 0.5774\,x \qquad \text{...(2)}$$

from (2) substitute y is 1 and solving

$$x = 0.999,\ y = 0.5774$$

15. (c)



$$\text{Diameter of Jet} = 60 \text{ mm}$$

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

$$\text{Velocity of Jet} = 50 \text{ m/s}$$

$$\text{Angle of direction} = 120°$$

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

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

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

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

16. (c)

Given data:

$$V = 3.2 \text{ m}^3$$

$$w = 27.5 \text{ kN} = 27500 \text{ N}$$

$$\nu = 7 \times 10^{-3} \text{ stoke} = 7 \times 10^{-3} \text{ cm}^2\text{/s} = 7 \times 10^{-7} \text{ m}^2\text{/s}$$

$$\text{Specific weight : w} = \frac{W}{V} = \frac{27.5}{3.2} = 8.593 \text{ kN/m}^3$$

$$\text{Mass density : } \rho_{oil} = \frac{M}{V} = \frac{W}{gV} = \frac{27500}{9.81 \times 3.2} = 876.02 \text{ kg/m}^3$$

$$\text{Specific volume : } v = \frac{1}{\rho_{oil}} = \frac{1}{876.02} = 1.14 \times 10^{-3} \text{ m}^3\text{/kg}$$

$$\text{Specific gravity: } S = \frac{\rho_{oil}}{\rho_{water}} = \frac{876.02}{1000} = 0.876$$

$$\text{Dynamic viscosity: } \mu = \rho\nu = 876.02 \times 7 \times 10^{-7} = 6132.14 \times 10^{-7} \text{ Ns/m}^2$$

$$= 6132.14 \times 10^{-7} \times 10 \text{ poise}$$

$$= 6132.14 \times 10^{-6} \text{ poise} = 6132.14 \times 10^{-6} \times 100 \text{ centipoise}$$

$$= 0.613 \text{ cP}$$

17. (b)

$$\eta_{overall} = \frac{SP}{gQH\rho}$$

or

$$Q = \frac{500}{0.83} \times \frac{1000}{9.81} \times \frac{1}{30 \times 1000} = 2.0469$$

18. (c)

$$p_A + \rho_w g z_1 = p_{atm} + \rho_{Hg} g z_2$$

or $$\rho_w g z_1 = \rho_{Hg} g z_2 \qquad \because p_A = p_{atm}$$

or $$\rho_w z_1 = \rho_{Hg} z_2$$

$$1000 \times 0.11 = 13600 \times z_2$$

or $$z_2 = 0.00809 \text{ m} = 0.809 \text{ cm}$$

19. (a)

Applying Bernoulli's is equation between points 1 and 2

$$\frac{p_2}{\rho g} + z_2 = \frac{p_1}{\rho g} + z_1$$

$$\frac{p_2}{\rho g} = \frac{p_1}{\rho g} + z_1 - z_2 = \frac{h_m \rho_m g}{\rho g} + z_1 - z_2 = \frac{0.212 \times 10^3 \times 13.6 \times 9.81}{9.81 \times 10^3} + 0 - 2.4$$

$$= 0.4832$$

$$p_2 = 0.4832 \times 9.81 \times 10^3 \text{ Pa} = 4.74 \text{ kPa}$$

21. (d)

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(0.075)^3 = 0.00176625 \text{ m}^3$$

$$\text{Upthrust} = V\rho_w g = 0.00176625 \times 10^3 \times 9.81 = 17.327 \text{ N}$$

$$\text{Weight} = 0.5 \times 9.81 = 4.905 \text{ N}$$

$\therefore$ $$\text{Tension in string} = 17.327 - 4.905 = 12.422 \text{ N}$$

22. (a)

$$\rho = \frac{m}{V} = \frac{\rho_o L_o A}{A[L_o - vt]}$$

$$\rho = \frac{\rho_o L_o}{L_o - vt} = \frac{1.2 \times 20}{20 - 2 \times 5} = \frac{1.2 \times 20}{10} = 2.4 \text{ kg/m}^3$$

23. (d)

Let the parabolic velocity distribution is

$$V = A + By + Cy^2$$

where, constants, A, B and C are to be determined from boundary conditions.

$$V = 0, \quad \text{at } y = 0 \text{ (No slip at the plate surface)}$$

$$V = 1.125 \text{ m/s at } y = 0.075 \text{ m}$$

$$\frac{dV}{dy} = 0, \text{ at } y = 0.075 \text{ (condition of vertex of parabola)}$$

Substituting the boundary conditions, we have

$$A = 0$$

$$1.125 = 0.075\,B + (0.075)^2 C$$

$$\frac{dV}{dy} = B + 2Cy$$

$$0 = B + 2C \times 0.075$$

$\Rightarrow$ $$B = 30, \quad C = -200$$

$\therefore$ $$V = 30\,y - 200\,y^2$$

$\therefore \quad \frac{dV}{dy} = 30 - 400y$

at $y = 0.05$ m, $\quad \frac{dV}{dy} = 30 - 400 \times 0.05, \quad \frac{dV}{dy} = 10$

$\therefore \quad \tau = \frac{\mu dV}{dy} = 0.05 \times 10 = 0.5 \text{ N/m}^2$

24. (b)

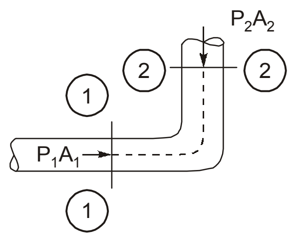
Given,

$$\mu = 0.05$$
$$d = 0.2 \text{ m}$$
$$U_{max} = 1.5 \text{ m/s}$$

$\Rightarrow \quad \bar{U} = \frac{U_{max}}{2} = 0.75 \text{ m/s}$ [laminar flow through pipe]

$$\Delta P = \frac{32\mu \bar{U} L}{D^2} = \frac{32 \times 0.05 \times 0.75 \times 2}{0.2^2} = 60 \text{ N/m}^2$$

25. (a)



$$D = 0.3 \text{ m}$$
$$A_1 = A_2 = \frac{\pi}{4} D^2 = 0.07068 \text{ m}^2$$
$$V = V_1 = V_2 = \frac{Q}{A} = \frac{0.3}{0.07068} = 4.244 \text{ m/s}$$

Now, $\quad \theta = 90°,$

$$P_1 = 24.525 \text{ N/cm}^2 = 24.525 \times 10^4 \text{ N/m}^2$$
$$P_2 = 23.544 \times 10^4 \text{ N/m}^2$$

Force along x-axis on bend,

$$F_x = \rho Q [V_{1x} - V_{2x}] + P_{1x} A_1$$
$$F_x = 1000 \times 0.3 [4.244 - 0] + 24.525 \times 10^4 \times 0.07068$$
$$F_x = 18.607 \text{ kN}$$

Similarly, force along y-axis on bend,

$$F_y = \rho Q [V_{1y} - V_{2y}] - P_{2y} A_2$$
$$F_y = 1000 \times 0.3 [0 - 4.244] - 235440 \times 0.07068$$
$$F_y = -17.91 \text{ kN}$$
$$F_R = \sqrt{F_x^2 + F_y^2} = 25.826 \text{ kN}$$

26. (b)

Hagen–Poiseuille's equation,

$$\Delta p = \frac{32\mu VL}{d^2}$$

where $\quad V = \frac{Q}{A} = \frac{Q}{\frac{\pi}{4}d^2} = \frac{4Q}{\pi d^2}$

$$\therefore \quad \Delta p = \frac{128\mu QL}{\pi d^4}$$

$$\Delta p \propto \frac{1}{d^4}$$

$$\Delta p \times d^4 = C$$

$$\Delta p_1 d_1^4 = \Delta p_2 d_2^4$$

$$\Delta p_1 \times d_1^4 = \Delta p_2 \times (2d_1)^4$$

or $$\Delta p_2 = \frac{\Delta p_1}{16}$$

27. (c)

$$\Delta p_2 = \Delta p_1 + 0.05\,\Delta p_1 = 1.05\Delta p_1$$

$$Q = \frac{C_d Aa}{\sqrt{A^2 - a^2}}\sqrt{2gh}$$

where $$h = \frac{\Delta p}{\rho g}$$

$$\therefore \quad Q = \frac{C_d Aa}{\sqrt{A^2 - a^2}}\sqrt{\frac{2\Delta p}{\rho}}$$

$$Q \propto \sqrt{\Delta p}$$

$$\frac{Q}{\sqrt{\Delta p}} = \text{C}$$

$$\frac{Q_1}{\sqrt{\Delta p_1}} = \frac{Q_2}{\sqrt{\Delta p_2}}$$

or $$\frac{Q_2}{Q_1} = \sqrt{\frac{\Delta p_2}{\Delta p_1}} = \sqrt{1.05} = 1.0246$$

$$\%\text{ error in flow rate} = \left(\frac{Q_2 - Q_1}{Q_1}\right) \times 100$$

$$= \left(\frac{Q_2}{Q_1} - 1\right) \times 100 = (1.024 - 1) \times 100 = 2.46\%$$

29. (d)

Given, $$N_1 = 200 \text{ rpm}, \quad P_1 = 5200 \text{ kW}, \quad H_1 = 250, \quad \eta_0 = 82\% = 0.82$$

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

$$\Rightarrow \quad 0.82 = \frac{5200 \times 1000}{1000 \times 9.81 \times Q_1 \times 250}$$

$$Q_1 = 2.5857$$

Now, $$\frac{Q_1}{\sqrt{H_1}} = \frac{Q_2}{\sqrt{H_2}}$$ [By definition of unit speed]

$$\frac{2.5857}{\sqrt{250}} = \frac{Q_2}{\sqrt{150}}$$

$\Rightarrow$ $$Q_2 = 2 \text{ m}^3/\text{s}$$

30. (b)

$$u = 2y^2$$
$$v = 3x$$
$$w = 0$$

$$\frac{du}{dt} = \frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}$$

$$= 0 + 0 + 3x \times 4y + 0 = 12\,xy$$

$$\frac{dv}{dt} = \frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z}$$

$$= 0 + 2y^2 \times 3 + 0 + 0 = 6y^2$$

$\therefore$ $$a = 12xyi + 6y^2j$$

$$a(1, 2, 0) = 24i + 24j$$

$$|\vec{a}|_{(1,2,0)} = 24\sqrt{2} = 33.94 \text{ units}$$

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