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Fluid Mechanics

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CLASS TEST 2019-2020

CIVIL ENGINEERING

Date of Test : 27/08/2019

ANSWER KEY ➤ Fluid Mechanics

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

DETAILED EXPLANATIONS

1. (a)

Let, V = volume of water

$$\text{Change in volume} = dV = \frac{-1.5}{100}V = -0.015\,V$$

(–) sign indicate decrease in volume

$$\text{Increase in pressure } (\Delta p) = \left(-\frac{dV}{V}\right).k = 0.015 \times 2.2 \times 10^6 = 3.3 \times 10^4 \text{ kPa}$$

2. (b)

Height of columns of different liquid which produces the same pressure are called equivalent column.

$$P = \rho_\omega h_\omega = \rho_{ker} h_{ker}$$

$$h_{ker} = \left(\frac{\rho_\omega}{\rho_{ker}}\right)h_\omega = \left(\frac{1}{8}\times 4\right) = 5\text{ m}$$

4. (b)

In order to conserve mass, it must satisfy continuity equation

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

$$-2\rho_0 e^{-2t} + \frac{\partial\{\rho_0 e^{-2t}(8x+6y+8z)\}}{\partial x} + \frac{\partial\{\rho_0 e^{-2t}(7x+3y+4z)\}}{\partial y} + \frac{\partial\{\rho_0 e^{-2t}(8x+6y+\lambda z)\}}{\partial z} = 0$$

$$\Rightarrow \quad -2\rho_0 e^{-2t} + \rho_0 e^{-2t}(8) + \rho_0 e^{-2t}(3) + \rho_0 e^{-2t}\lambda = 0$$

$$\Rightarrow \quad -2 + 8 + 3 + \lambda = 0$$

$$\lambda = -9$$

6. (c)

Acceleration component of fluid particle are local tangential acceleration, Convective tangential acceleration, Convective normal acceleration.

7. (a)

Moment of momentum equation is also referred to as angular momentum equation and used to find torque.

8. (c)

In laminar below particle from one layer do not mix with other layer. These layer smoothly slides over each other.

9. (c)

Prandtl length (l) = ky

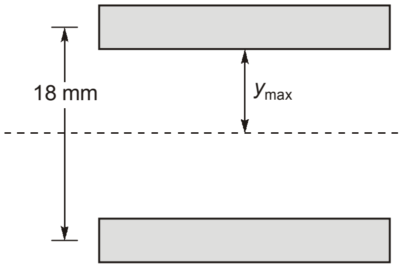
y = distance from wall

∴ mixing length will be zero at pipe wall.

11. (c)

Given data, $u = 1.5\,(1 - 10^3\,y^3)$, $\mu = 0.1$ N-s/m^2

$$\frac{du}{dy} = 1.5\,(-3000y^2)\ \text{sec}^{-1}$$



$$\therefore \quad \text{shear stress, } \tau = \mu\frac{du}{dy}$$

$$= (0.1)(-4500)\,y^2 = -450\,y^2$$

$\therefore$ shear stress at plate, when, $(y = y_{max}) \Rightarrow 2$

$$= (-450) \times (9 \times 10^{-3})\ \text{N/m}^2 = -0.036\ \text{N/m}^2$$

$$\text{shear force on each plate} = (-0.036 \times 4)\ \text{N} = -0.144\ \text{N}$$

12. (d)

Horizontal component of water pressure on the gate ,

$$(F_x) = (\gamma_\omega A\bar{x}) = [9.81 \times (5 \times 3) \times 1.5] = 220.725\ \text{kN}$$

Vertical component of pressure on gate

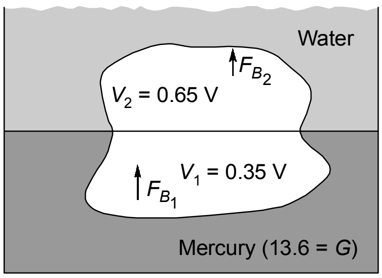
$$(F_y) = \gamma_\omega \times \text{volume of liquid supported by curved part } AB$$

$$= 9.81 \times \text{Area of AOB} \times 5 = 9.81 \times \frac{1}{4} \times \pi \times 3^2 \times 5$$

$$= 346.71\ \text{kN}$$

$$\text{Resultant force } (R) = \sqrt{F_x^2 + F_y^2} = \sqrt{(220.725)^2 + (346.71)^2} = 411\ \text{kN}$$

13. (c)



Buoyancy force due to mercury

$$F_{B1} = \rho_1 g V_1$$

$$= 13.6 \times 1000 \times 9.81 \times 0.35\ V = (46695.6\ V)\ \text{N}$$

$$\text{Buoyancy force due to water} = \gamma_\omega(0.65\ V)$$

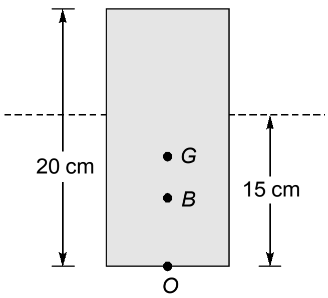
$$= (6376.5\ V)\ \text{N}$$

From Archimede's principle, $w = (f_{B1} + f_{B2})$

$$\rho.gV = (46695.6\ V + 6376.5\ V)$$

$$\rho = 5410\ \text{kg/m}^3$$

14. (c)



Elevation

$$\text{depth of immersion (d)} = 0.15 \text{ m}$$

$$OB = \left(\frac{0.15}{2}\right) = 0.075 \text{ m}$$

$$OG = \left(\frac{0.2}{2}\right) = 0.1 \text{ m}$$

$$BG = (0.1 - 0.075) = 0.025 \text{ m}$$

$$I = \frac{bh^3}{12} = \frac{0.65 \times (0.2)^3}{12} = 4.33 \times 10^{-4} \text{m}^4$$

$$BM = \frac{I}{V} = \frac{4.33 \times 10^{-4}}{(0.65 \times 0.2 \times 0.15)} = 0.022 \text{ m}$$

$$GM = BM - BG = 0.022 - 0.025$$

$$= -0.003$$

15. (a)

Given stream function,

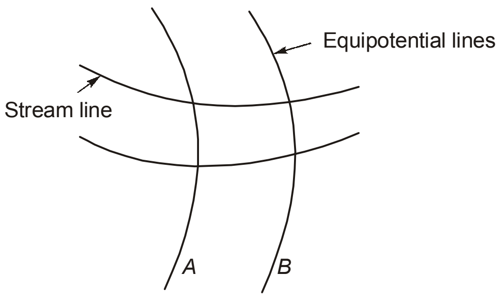
$$\Psi = 2x^2y + (x+1)y^2$$

$$\Psi_A = 0$$

$$\Psi_B = 4$$

$$\text{Flow rate} = \Psi_B - \Psi_A = (4 - 0) = 4 \text{ unit}$$

16. (d)



Applying continuity equation between streamlines

$$q = V_A \delta_{nA} = V_B \delta_B$$

$$V_B = V_A\left(\frac{\delta_A}{\delta_B}\right) = 7 \times \frac{20}{8} = 17.5 \text{ m/s}$$

Applying Bernoulli equation between A and B

$$Z_A + \frac{V_A^2}{2g} + \frac{P_A}{\gamma_\omega} = Z_B + \frac{V_B^2}{2g} + \frac{P_B}{\gamma_\omega}$$

$$Z_A = Z_B$$

$$\left(\frac{P_B}{\gamma_\omega}\right) = \left(\frac{P_A}{\gamma_\omega} + \frac{V_A^2}{2g} - \frac{V_B^2}{2g}\right) = \frac{300\times10^3}{900\times9.81} + \frac{49}{2\times9.81} - \frac{17.5^2}{2\times9.81}$$

$$= 184.25 \text{ kPa}$$

17. (a)

Continuity equation, $\dfrac{\partial u}{\partial x} + \dfrac{\partial v}{\partial y} = 0$ (for incompressible flow) ...(i)

$\omega_z = \dfrac{1}{2}\left(\dfrac{\partial v}{\partial x} - \dfrac{\partial u}{\partial y}\right) = 0$ (for irrotational flow) ...(ii)

From (i)

$$\frac{\partial}{\partial x}\left[\frac{y^3}{3} + 2x - x^2y\right] + \frac{\partial}{\partial y}\left[xy^2 - 2y - \frac{x^3}{3}\right] = 0$$

$$2 - 2xy + 2xy - 2 = 0$$

From (ii)

$$\frac{\partial}{\partial x}\left(xy^2 - 2y - \frac{x^3}{3}\right) - \frac{\partial}{\partial y}\left(\frac{y^3}{3} + 2x - 2x^2y\right) = 0$$

$$= y^2 - x^2 - y^2 + x^2 = 0$$

Hence flow is irrotational and fluid is incompressible.

18. (b)

Given data,

Diameter of pipe, $D = 61$ mm

Throat diameter, $d = 30$ mm

Pressure difference, $= 50$ kPa

a_1 = cross sectional area of pipe

a_2 = cross sectional area of throat

$\Rightarrow$ $h = \dfrac{50}{9.81} = 5.09$ m

$$Q = \frac{C_d \, . a_1 a_2}{\sqrt{a_1^2 - a_2^2}}\sqrt{2gh}$$

$$Q = \frac{(0.061)^2 \times (0.03)^2}{\sqrt{(0.061)^4 - (0.03)^4}} \times \sqrt{2\times9.81\times5.09} \times \frac{\pi}{4}$$

$$= 7.28 \times 10^{-3} \text{ m}^3/\text{s}$$

$$V = \frac{Q}{A_P} = 2.49 \text{ m/s}$$

19. (c)

Rankine half body is obtained by superposition of sink and uniform flow.
Stream function $\psi = uy + k\theta = ur\sin\theta + k\theta$
Velocity potential function $\phi = ur\cos\theta + k\ln r$
The distance of stagnation point from origin 0

$$x = \frac{k}{u}$$

where k is the strength of source.

20. (a)

Given data,
$$L_r = \left(\frac{1}{50}\right)$$
$$V_m = 2 \text{ m/s}$$
$$Q_m = 2\text{m}^3/\text{s}$$

In case of spillway model, gravity forces are predominate, therefore froude law will be applicable

$$F_M = \frac{V_m}{\sqrt{gL_m}} = \frac{V_p}{\sqrt{gL_P}}$$
$$V_r = \sqrt{L_r}$$
$$Q_r = A_r.\, V_n$$
$$Q_r = L_r^{2.5}$$
$$\frac{Q_P}{Q_m} = \left(\frac{50}{1}\right)^{2.5}$$
$$Q_P = 35355.3 \text{ m}^3/\text{sec}$$

21. (c)

$$\text{Reynold Number} = \frac{\text{Inertia force}}{\text{Viscous force}}$$
$$\text{Froude Number} = \sqrt{\frac{\text{Inertia force}}{\text{Gravity force}}}$$
$$\text{Mach Number} = \sqrt{\frac{\text{Inertia force}}{\text{Elastic force}}}$$
$$\text{Weber Number} = \sqrt{\frac{\text{Inertia force}}{\text{Surface force}}}$$
$$\text{Euler Number} = \sqrt{\frac{\text{Inertia force}}{\text{Pressure force}}}$$

22. (d)

Flow will take place due to total head of 20 m plus head of water equivalent to 80 kN/m^2

$$\therefore \quad 80 \text{ kN/m}^2 \text{ is equivalent to } \left(\frac{80}{9.81}\right) = 8.15 \text{ m of water}$$
$$\text{Total head causing flow} = (20 + 8.15) = 28.15 \text{ m}$$

$$\text{Neglecting minor loss, major friction loss} = \left(\frac{flQ^2}{12.1d^5}\right)$$

$$28.15 = \frac{0.04 \times 400 \times Q^2}{12.1 \times (0.25)^5} = 0.144 \text{ m}^3/\text{s}$$

$$Q = 144.19 \ l/s$$

23. (c)

Equivalent pipe must carry some discharge as that in compound pipe for same head loss as is compound pipe

$$\Rightarrow \quad \frac{f_e l_e Q_e^2}{12.1 d_e^5} = \sum \frac{f_i l_i Q_i^2}{12.1 d_i^2}$$

$$\Rightarrow \quad \frac{L_e}{D_e^5} = \frac{L_1}{D_1^5} + \frac{L_2}{D_2^5}$$

$$\Rightarrow \quad \frac{L_e}{(0.58)^5} = \frac{1900}{(0.6)^5} + \frac{600}{(0.8)^5}$$

$$L_e = 1723.93 \text{ m}$$

24. (d)

$n > 1$ for dilatant fluids

$n < 1$ for Pseudoplastic and thixotropic fluid.

25. (d)

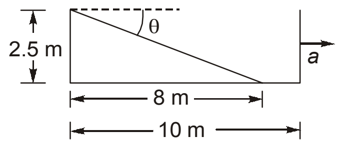
In the case of maximum acceleration, the free surface will be such that one end will have 2.5 m depth and the other will have zero depth. Equating volume contained by free surface to earlier volume.

$$\frac{l \times 2.5}{2} \times 3 = 3 \times 10 \times 1$$

$$l = l = \frac{20}{2.5} = 8 \text{ m}$$

$$\tan\theta = \frac{2.5}{8} = \frac{a}{g}$$

$$a = 0.31 \text{ g}$$



26. (d)

For isentropic process

$$\text{Compressibility,} \quad K = kp = \frac{dp}{(d\rho/\rho)}$$

$$\text{Speed of sound wave,} \quad C = \sqrt{\frac{K}{\rho}} = \sqrt{\frac{dp}{d\rho}} = \sqrt{\frac{kp}{\rho}} = \sqrt{kRT}$$

$$\text{For isothermal process } \frac{p}{\rho} = \text{constant } \frac{dp}{d\rho} = \frac{p}{\rho}$$

$$C = \sqrt{\frac{p}{\rho}} = \sqrt{RT}$$

27. (d)

For rotational flow

$$\omega_z = \frac{1}{2}\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right) \neq 0.$$

So $$\frac{\partial v}{\partial x} \neq \frac{\partial u}{\partial y}$$

	u	v	$\frac{\partial v}{\partial x}$	$\frac{\partial u}{\partial y}$
(a)	x	$-y$	0	0
(b)	$3x^2-3y^2$	$-6xy$	$-6y$	$-6y$
(c)	y	x	1	1
(d)	x^2y	$-xy^2$	$-y^2$	x^2

28. (b)

For laminar boundary layer

$$\delta = \frac{5x}{\sqrt{Re_x}} \quad \text{[Blasius solution]}$$

Thus $$\delta \propto \sqrt{x}$$

Turbulent boundary layer over flat plate

$$\delta = \frac{0.37x}{Re_x^{1/5}} \quad \text{for} \quad \frac{u}{V} = \left(\frac{y}{\delta}\right)^{1/7}$$

$$\delta \propto x^{4/5}$$

29. (d)

Velocity profile over a solid surface exhibits the following characteristics – for attached flow

For attached flow, $$\left(\frac{\partial u}{\partial y}\right)_{y_0} = +\text{ve}$$

At verge of separation, $$\left(\frac{\partial u}{\partial y}\right)_{y=0} = 0$$

Separated flow, $$\left(\frac{\partial u}{\partial y}\right)_{y=0} = -\text{ve}$$

30. (b)

As per Stokes law

Drag coefficient for sphere is

$$C_D = \frac{24}{R_e} \quad \text{(when Re < 0.2)}$$

$$\Rightarrow \quad 240 = \frac{24}{\left(\frac{VD}{\nu}\right)}$$

$$\Rightarrow \quad 240 = \frac{24\nu}{(40\times10^{-3})\times(5\times10^{-3})}$$

$$\Rightarrow \quad \nu = 2 \times 10^{-3}\ \text{m}^2/\text{s} = 20\ \text{cm}^2/\text{s}$$

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