CLASS TEST

S.No. : 01JP-CE-03072023

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CIVIL ENGINEERING

Fluid Mechanics

Duration : 1:00 hr. **Maximum Marks : 50**

Read the following instructions carefully

1. This question paper contains **30** objective questions. **Q.1-10** carry one mark each and **Q.11-30** carry two marks each.
2. Answer all the questions.
3. Questions must be answered on Objective Response Sheet (**ORS**) by darkening the appropriate bubble (marked **A**, **B**, **C**, **D**) using HB pencil against the question number. Each question has only one correct answer. In case you wish to change an answer, erase the old answer completely using a good soft eraser.
4. There will be **NEGATIVE** marking. For each wrong answer **1/3rd** of the full marks of the question will be deducted. More than one answer marked against a question will be deemed as an incorrect response and will be negatively marked.
5. Write your name & Roll No. at the specified locations on the right half of the **ORS**.
6. No charts or tables will be provided in the examination hall.
7. Choose the **Closest** numerical answer among the choices given.
8. If a candidate gives more than one answer, it will be treated as a **wrong answer** even if one of the given answers happens to be correct and there will be same penalty as above to that questions.
9. If a question is left blank, i.e., no answer is given by the candidate, there will be **no penalty** for that question.

DO NOT OPEN THIS TEST BOOKLET UNTIL YOU ARE ASKED TO DO SO

Q.No. 1 to Q.No. 10 carry 1 mark each

Q.1 The velocity components in the x and y directions are given by $u = \lambda xy^3 - x^2 y$ & $v = xy^2 - \frac{3}{4}y^4$.
The value of λ for a possible flow field involving an incompressible fluid is

(a) $-\frac{3}{4}$ (b) $-\frac{4}{3}$
(c) $\frac{4}{3}$ (d) 3

Q.2 In laminar boundary layer over flat plate the ratio of shear stresses τ_1 and τ_2 at two sections 1 and 2 at distance from leading edge such that $x_2 = 15\,x_1$, is given by

(a) $\sqrt{5}$ (b) $\sqrt{15}$
(c) $\frac{1}{\sqrt{15}}$ (d) 15

Q.3 Match the dimensionless numbers given in column A to their expressions indicated in column B. (Using usual notations)

Column A	Column B
A. Froude's Number	1. $\frac{V}{\sqrt{\frac{K}{\rho}}}$
B. Mach Number	2. $\frac{V}{\sqrt{\frac{P}{\rho}}}$
C. Euler Number	3. $\frac{V}{\sqrt{gl}}$
D. Weber Number	4. $\frac{V}{\sqrt{\frac{\sigma}{L\rho}}}$

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	4	2	1	3
(c)	3	1	2	4
(d)	2	1	4	3

Q.4 Which one of the following statements relating to vortex flow is INCORRECT?

(a) In the formation of free vortex flow, streamlines are asymmetric and irrotational.
(b) In a forced vortex flow, work transfer between the fluid and the surrounding takes place and the flow is rotational.
(c) In a free vortex flow, radial motion towards the core takes place due to variation of depth of water in the whirlpool or due to the difference of pressure resulting from higher velocity near the core.
(d) In a free vortex flow, there is no variation of energy from streamline to streamline and irrotationality is not deviated from near the core.

Q.5 Uniform flow of a real fluid takes place in a horizontal pipe of diameter *D*. If p_1 and p_2 are the pressures at the upstream and downstream sections of a stretch of length *L* of the pipe, the boundary shear stress τ_0 could be expressed by the momentum equation as τ_0 =

(a) $(p_1 - p_2)\pi\frac{D^2}{4L}$ (b) $(p_1 - p_2)\frac{D}{4L}$
(c) $(p_1 - p_2)\frac{4L}{D}$ (d) $(p_1 - p_2)\frac{D}{\rho g L}$

Q.6 If $\psi = 2xy$, the magnitude of the velocity vector at (2, –2) is

(a) $4\sqrt{2}$ (b) 4
(c) –8 (d) $\sqrt{2}$

Q.7 A model of a weir made with horizontal scale of 1/40 and vertical scale of 1/9 passes a discharge of 1 lps. The corresponding discharge in the prototype would be

(a) 10.8 lps (b) 108 lps
(c) 1080 lps (d) 10800 lps

Q.8 In a triangular notch, there is an error of 4% in observing the head. The error in the computed discharge is

(a) 4% (b) 10%
(c) 6% (d) 2.5%

Q.9 In limiting condition of laminar flow in a pipe, the minimum friction factor will be

(a) 0.036 (b) 0.032
(c) 0.045 (d) 0.022

Q.10 Displacement thickness for velocity profile $\frac{u}{U} = \left(\frac{y}{\delta}\right)^2$ is ____. (Where δ is nominal boundary layer thickness.)

(a) δ
(b) $\frac{3}{2}\delta$
(c) $\frac{\delta}{3}$
(d) $\frac{2}{3}\delta$

Q. No. 11 to Q. No. 30 carry 2 marks each

Q.11 Three pipes of lengths 1000 m, 2000 m and 3000 m and diameters 200 mm, 400 mm and 600 mm respectively are connected in series. These pipes are to be replaced by a single pipe of 6000 m. The diameter of this single pipe is

(a) 282 mm
(b) 301 mm
(c) 196 mm
(d) 252 mm

Q.12 A 400 m long horizontal pipe is to deliver 900 kg/min of oil (specific gravity = 0.9, kinematic viscosity = 0.0002 m^2/s). If the head loss is not to exceed 8 m of oil, the diameter (in metre) of the pipe is

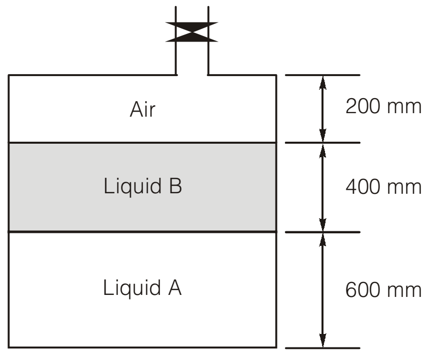
$$\left[\text{Take friction factor for laminar flow, } f = \frac{64}{R_e}\right]$$

(a) 0.1782
(b) 0.4368
(c) 0.3280
(d) 0.1622

Q.13 A pipe of diameter 400 mm and length 4000 m is used for transmission of power by water. The total head at inlet of pipe is 400 m. The discharge through the pipe is 0.2 m^3/s. The maximum power available is

(a) 523.2 kW
(b) 632.6 kW
(c) 261.6 kW
(d) 309.6 kW

Q.14 A cylindrical process reactor is made of heavy construction and contains two liquids A and B as shown in figure below. There is an air space of 200 mm above the top free surface of liquid B. In a certain process, the air pressure changes from 5 atm to 45 atm. Assume that there are no changes in the temperature and in the dimensions of the tank. Given, the bulk modulus of elasticity of liquid A is 2.2×10^9 Pa and of liquid B is 1.44×10^9 Pa. The drop (in mm) in the top free surface of liquid B is

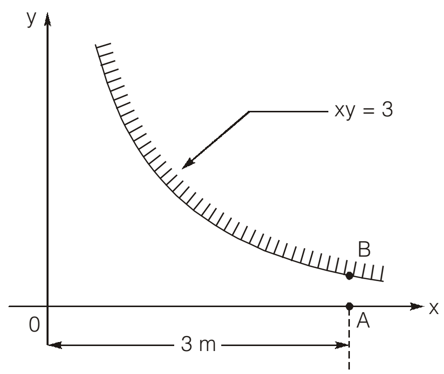


(a) 2.231 mm
(b) 1.672 mm
(c) 2.462 mm
(d) 1.478 mm

Q.15 The mass density at a certain great depth from the surface of ocean where the pressure is stated to be 80MPa. Consider density at surface, ρ = 1250 kg/m^3 and bulk modulus of of elasticity = 2500 MPa.

(a) 1332 kg/m^2
(b) 1500 kg/m^2
(c) 1290 kg/m^2
(d) 992 kg/m^2

Q.16 The stream function ψ = 4xy in which ψ is in cm^2/sec and x, y are in meters, describes the incompressible flow between the boundary as shown in figure below.

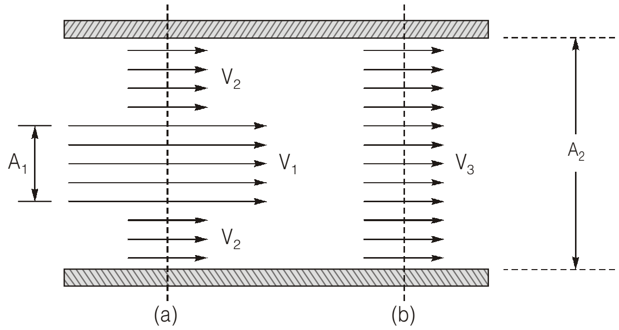


The convective acceleration at B is ________ $\times 10^{-6}$ cm/s^2.

(a) 42.91
(b) 48.41
(c) 56.24
(d) 50.59

Linked Answer Q.17 and Q.18

A jet of water with velocity V_1 as shown in figure and area of cross-section A_1 enters a stream of slow moving water in a pipe of area A_2 and velocity V_2. The two streams enter with the same pressure P_1. After thoroughly mixing in the pipe, the stream emerges as a single stream with velocity V_3 and pressure P_2. Assume there are no losses in the flow. [Take V_1 = 20 m/s, V_2 = 10 m/s, A_1 = 0.01 m², A_2 = 0.02 m², density of water ρ_w = 1000 kg/m³]



Q.17 Value of kinetic energy correction factor is

(a) 1.13 (b) 1.33
(c) 1.73 (d) 1.83

Q.18 The pressure difference $(P_2 - P_1)$ is

(a) 37.125 kPa (b) 43.315 kPa
(c) 47.235 kPa (d) 53.165 kPa

Q.19 A rigid pipe conveying water is 3000 m long. The velocity of flow is 1.2 m/s. The rise of pressure caused within the pipe due to valve closer in 2.5 seconds nearly is
[Given $K = 20 \times 10^8$ N/m²]

(a) 1500 kPa (b) 1600 kPa
(c) 1700 kPa (d) 1800 kPa

Q.20 Total acceleration in fluid flow consists of local and convective parts. Column A of the following table shows few situations of pipe flows. Identify the type of acceleration associated with each, choosing it from Column B.

Column A

A. Flow at constant rate passing through a bend.
B. Gradually changing flow through a straight pipe.
C. Gradually changing flow through a bend
D. Flow at a constant rate passing through a straight uniform diameter pipe.

Column B

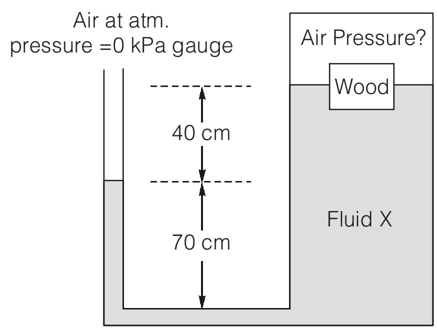
(i) Zero acceleration
(ii) Local and convective acceleration both.
(iii) Convective acceleration
(iv) Local acceleration

(a) A – (iii), B – (iv), C – (ii) and D – (i)
(b) A – (iv), B – (iii), C – (i) and D – (ii)
(c) A – (ii), B – (iv), C – (iii) and D – (i)
(d) A – (iii), B – (i), C – (iv) and D – (ii)

Q.21 A 30 cm × 15 cm venturimeter is inserted in a vertical pipe carrying oil of specific gravity 0.9 in upward direction. The difference of levels between the throat and inlet section is 50 cm. The oil-mercury differential manometer gives a reading of 30 cm of mercury. Neglect losses. The discharge of oil is

(a) 146.8 *l*/s (b) 155.9 *l*/s
(c) 166.3 *l*/s (d) 173.2 *l*/s

Q.22 A block of wood (specific gravity = 0.6) floats in fluid X as shown in the figure such that 75% of its volume is submerged in fluid X. The gauge pressure (in Pa) of the air in the tank is _____ Pa.
[Take g = 9.81 m/s², density of water = 1000 kg/m³ and neglect the buoyancy of air on the upper part of block]



(a) –2012.8 (b) –3139.2
(c) –4262.9 (d) None of these

Q.23 A rectangular tank of length 5 m, width 2.5 m and height 2 m is completely filled with water and is at rest. The tank is open at top. The tank is subjected to a horizontal constant linear acceleration of 3 m/s² in the direction of its length. The volume of water spilled from the tank is

(a) 9.56 m³ (b) 13.61 m³
(c) 10.21 m³ (d) 15.42 m³

Q.24 A horizontal pipe of diameter d_1 is contracted to a diameter d_2. The pressure intensities in the large and smaller pipe is 14 N/cm^2 and 12 N/cm^2 respectively. Velocity changes from 1.6 m/s to 6.4 m/s. The rate of flow is 300 litres/s. The value of coefficient of contraction C_c is

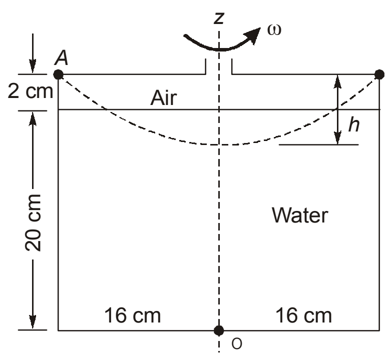
(a) 0.84 (b) 0.98
(c) 0.90 (d) 0.88

Q.25 A smooth two dimensional flat plate is exposed to a wind velocity of 100 km per hour. If laminar boundary layer exists upto a value of Reynolds number equal to 3×10^5, then the maximum thickness of laminar boundary layer will be

[Take kinematic viscosity of air as 1.49×10^{-5} m^2/s]

(a) 1.95 mm (b) 1.21 mm
(c) 2.02 mm (d) 1.47 mm

Q.26 The cylinder is rotated about the central axis as shown in figure. The force (in N) on the bottom of the cylinder, when the rotation speed is such that the water just touches the point A will be



(a) 157.8 (b) 187.5
(c) 142.1 (d) 117.5

Q.27 An oil of viscosity 9 poise is flowing through a pipe of 30 cm diameter. If the flow is laminar, shear stress at the wall is 0.3kPa. The mean velocity of the flow is m/s is

(a) 12.5 (b) 25
(c) 37.5 (d) 75

Q.28 An air bubble of 1 mm diameter rises in an oil medium with a uniform velocity of 8 mm/s. The kinematic viscosity of oil is

[Assume Stokes law is valid]

(a) 6.813×10^{-5} m^2/s
(b) 7.334×10^{-5} m^2/s
(c) 8.125×10^{-5} m^2/s
(d) 9.912×10^{-5} m^2/s

Q.29 Consider the following statements:

1. The buoyant force is equal to the weight of the fluid displaced by the solid body and always acts upwards through center of gravity of submerged portion of solid body.
2. A submerged body is stable if the center of gravity of the body lies below the center of buoyancy.
3. A large metacentric height in a vessel weakens stability and makes time period of oscillation shorter.

Which of the above statements is(are) CORRECT?

(a) 1 only (b) 2 only
(c) 1 and 2 (d) 2 and 3

Q.30 A pipe of diameter 150 mm is suddenly enlarged to a diameter of 300 mm. The rate of flow of water through the pipe is 250 litres/s. The head loss is ________ m of water.

(a) 5.742 (b) 4.643
(c) 2.312 (d) 6.217

■■■■

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FLUID MECHANICS

CIVIL ENGINEERING

Date of Test : 03/07/2023

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (d)

$$u = \lambda xy^3 - x^2y$$

$$v = xy^2 - \frac{3}{4}y^4$$

For incompressible flow,

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

$$\frac{\partial u}{\partial x} = \lambda y^3 - 2xy$$

$$\frac{\partial v}{\partial y} = 2xy - 3y^3$$

$$\lambda y^3 - 2xy + 2xy - 3y^3 = 0$$

$$\Rightarrow \qquad \lambda = 3$$

2. (b)

For laminar boundary layer over a flat plate

$$\tau = C_f \frac{\rho v^2}{2}$$

where

$$C_f = \frac{0.664}{\sqrt{Re_x}}$$

$$\Rightarrow \qquad \tau \propto \frac{1}{\sqrt{x}} \qquad \left[\because Re_x = \frac{Vx}{\nu}\right]$$

$$\Rightarrow \qquad \frac{\tau_1}{\tau_2} = \sqrt{\frac{x_2}{x_1}} = \sqrt{15}$$

3. (d)

We know that

$$V_{air} = C\sqrt{2gx\left(\frac{S_m}{S} - 1\right)}$$

where,

$$x = 12 \times 10^{-3}\text{ m}$$

$$g = 9.81\text{ m/s}^2$$

$$S_m = 1$$

$$S = \frac{1.2}{1000} = 1.2 \times 10^{-3}$$

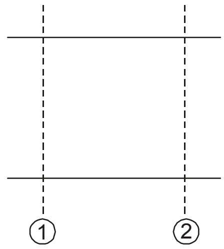
$$C = 1$$

$$V_{air} = \sqrt{2 \times 9.81 \times 12 \times 10^{-3}\left(\frac{1}{1.2 \times 10^{-3}} - 1\right)} = 13.998 \approx 14\text{ m/s}$$

4. (c)

In the central region of free vortex motion the viscous effects become quite predominant, due to which the fluid tends to rotate like a solid body with velocity proportional to the radius. The motion of particles is circular i.e. tangential.

5. (b)



$$\tau_0 L\pi D = (p_1 - p_2)\frac{\pi}{4}D^2$$

$$\Rightarrow \quad \tau_0 = (p_1 - p_2)\frac{D}{4L}$$

6. (a)

$$\psi = 2xy$$

$$\because \quad u = -\frac{\partial\psi}{\partial y} = -2x$$

$$v = \frac{\partial\psi}{\partial x} = 2y$$

At (2, –2), $u = 4$, $v = 4$

$$\therefore \quad |\vec{V}| = \sqrt{u^2 + v^2} = 4\sqrt{2}$$

7. (c)

$$\frac{q}{Q} = \frac{1}{40} \times \frac{1}{9}\sqrt{\frac{1}{9}}$$

$$\Rightarrow \quad Q = 1080 \text{ lps}$$

8. (b)

$$Q = C_d \frac{8}{15}\sqrt{2g}\tan\left(\frac{\theta}{2}\right)H^{5/2}$$

$$\therefore \quad \frac{\partial Q}{Q} = \frac{5}{2}\frac{\partial H}{H} = \frac{5}{2} \times 4 = 10\,\%$$

9. (b)

In pipe, limiting Reynolds is 2000. (Re $\leq$ 2000) In general.

$$f = \frac{64}{Re}$$

$$f = \frac{64}{2000} = 0.032$$

10. (d)

Displacement thickness, $\delta^* = \int_0^\delta \left(1 - \frac{u}{U}\right)dy = \int_0^\delta \left(1 - \frac{y^2}{\delta^2}\right)dy = \left[y - \frac{y^3}{3\delta^2}\right]_0^\delta = \delta - \frac{\delta}{3} = \frac{2\delta}{3}$

11. (a)

For pipes in series

$$\frac{L}{d^5} = \frac{L_1}{d_1^5} + \frac{L_2}{d_2^5} + \frac{L_3}{d_3^5}$$

$$\Rightarrow \quad \frac{6000}{d^5} = \frac{1000}{(0.2)^5} + \frac{2000}{(0.4)^5} + \frac{3000}{(0.6)^5}$$

$$\Rightarrow \quad d = 0.282 \text{ m} \quad \text{or} \quad d = 282 \text{ mm}$$

12. (d)

$$h_L = \frac{fIQ^2}{12.1D^5}$$

Mass flow rate, $\dot{m} = \rho Q$

$$\frac{900}{60} = 0.9 \times 10^3 \times Q$$

$$\therefore \quad Q = 0.0167 \text{ m}^3/\text{sec}$$

$$Re = \frac{\rho VD}{\mu} = \frac{VD}{\nu}$$

$$V = \frac{Q}{A} = \frac{4Q}{\pi D^2}$$

$$h_L = \frac{64}{Re} \times \frac{LQ^2}{12.1D^5} = \frac{64LQ^2}{12.1D^5} \times \frac{\nu}{VD} = \frac{64LQ^2}{12.1D^5} \times \frac{\nu}{D} \times \frac{\pi D^2}{4Q}$$

$$h_L = 4.15\frac{LD\nu}{D^4}$$

$$8 = \frac{4\pi}{3} \times \frac{400 \times 0.0167 \times 0.0002}{D^4}$$

$$D = 0.1622 \text{ m}$$

13. (a)

Maximum head available at the outlet of the pipe $= H - h_f$

$$= H - \frac{H}{3} = \frac{2H}{3} = \frac{2 \times 400}{3} = 266.67 \text{ m}$$

$\therefore$ Maximum power available $= \rho Qg(H - h_f)$

$$= \frac{1000 \times 9.81 \times 0.2 \times 266.67}{1000} \text{ kW} = 523.2 \text{ kW}$$

14. (a)

Here,
$$\Delta p = 45 - 5 = 40 \text{ atm} = 40 \times 101.325 \text{ kPa}$$
$$= 4053 \text{ kPa}$$

For liquid A: Since the vessel is cylindrical

$$-\frac{\Delta\forall}{\forall} = \frac{\Delta h_A}{h_A} = -\frac{\Delta p}{K_A} = \frac{4053\times10^3}{2.2\times10^9} = 0.0018423$$
$$-\Delta h_A = 0.0018423 \times 600 = 1.105 \text{ mm}$$

Similarly, for liquid B: Since the vessel is cylindrical

$$-\frac{\Delta\forall}{\forall} = \frac{\Delta h_B}{h_B} = -\frac{\Delta p}{K_B} = \frac{4053\times10^3}{1.44\times10^9} = 0.002815$$
$$-\Delta h_B = 0.002815 \times 400 = 1.126 \text{ mm}$$

Total decrease in the top free surface of liquid B

$$= (-\Delta h_A - \Delta h_B)$$
$$= 1.105 + 1.126 = 2.231 \text{ mm}$$

15. (c)

Given,
$$K = 2500 \text{MPa}$$
$$\rho_{surface} = 1250 \text{ kg/m}^3$$

We know that,
$$K = \frac{-dP}{\frac{dV}{V}} = \frac{dP}{\frac{d\rho}{\rho_{surface}}}$$

Here,
$$dP = 80 - 0 = 80 \text{MPa}$$
$$d\rho = \rho_{surface} \cdot \frac{dP}{K}$$
$$d\rho = 1250 \times \frac{80}{2500}$$
$$d\rho = \frac{80}{2} = 40 \text{MPa}$$
$$\rho_{final} - \rho_{surface} = 40$$
$$\rho_{final} = (40 + 1250) \text{ kg/m}^3 = 1290 \text{ kg/m}^3$$

16. (d)

The convective acceleration,

$$a_x = u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} \quad .....(i)$$
$$a_y = u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} \quad .....(ii)$$
$$u = -\frac{\partial \psi}{\partial y} = -4x$$
$$v = \frac{\partial \psi}{\partial x} = 4y$$

For point B,

$x = 3$ m $\qquad y = 1$ m

$u = -0.12$ cm/s $\qquad v = 0.04$ cm/s

$$\frac{\partial u}{\partial x} = -4 \qquad \frac{\partial u}{\partial y} = 0$$

$$\frac{\partial v}{\partial x} = 0 \qquad \frac{\partial v}{\partial y} = 4$$

Substituting in equation (i) and (ii), we get

$$a_x = (-0.12) \times (-4) \times 10^{-4} = 48 \times 10^{-6}\ \text{cm/s}^2$$
$$a_y = (0.04) \times (4) \times 10^{-4} = 16 \times 10^{-6}\ \text{cm/s}^2$$

$$a = \sqrt{a_x^2 + a_y^2} = \sqrt{\left(48 \times 10^{-6}\right)^2 + \left(16 \times 10^{-6}\right)^2}$$
$$= 50.59 \times 10^{-6}\ \text{cm/s}^2$$

17. (b)

By continuity equation

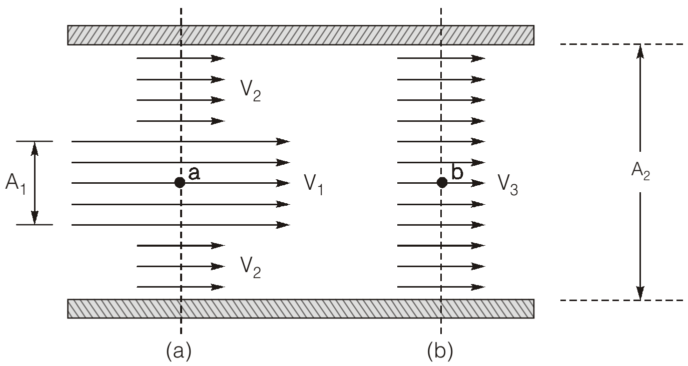
$$A_1V_1 + (A_2 - A_1)\,V_2 = A_2V_3$$
$$0.01 \times 20 + (0.02 - 0.01) \times 10 = 0.02 \times V_3$$
$$V_3 = 15\ \text{m/sec}$$

Kinetic energy correction factor (α)

$$= \frac{\frac{1}{2}(\rho A_1V_1).V_1^2 + \frac{1}{2}\left[\rho(A_2 - A_1)V_2\right]V_2^2}{\frac{1}{2}(\rho A_2V_3)V_3^2}$$

$$= \frac{0.01 \times 20^3 + 0.01 \times (10)^3}{0.02 \times (15)^3} = 1.33$$

18. (a)



Applying Bernoulli's equation at section a and b,

$$\frac{P_a}{\rho_g} + \alpha\left(\frac{V_3^2}{2g}\right) = \frac{P_b}{\rho_g} + \frac{V_b^2}{2g}$$

$P_a = P_1$, $\quad P_b = P_2$, $\quad V_b = V_3$

$$\left(\frac{P_2 - P_1}{\rho g}\right) = 0.33\left(\frac{V_3^2}{2g}\right)$$

$$\Rightarrow \qquad (P_2 - P_1) = \frac{0.33(15)^2 \times 10^3}{2} = 37.125\text{kPa}$$

19. (c)

$$\text{Velocity of wave in pipe} = \sqrt{\frac{K}{\rho}} = \sqrt{\frac{20\times10^8}{10^3}} = 1414.21 \text{ m/s}$$

So, $$t = \frac{2L}{c} = \frac{2\times3000}{1414.21} = 4.24s$$

$\because$ $$t_c < t$$

So, it is a sudden closer

$$\text{Increase in pressure will be} = \rho.c.v$$
$$= 1000 \times 1414.21 \times 1.2 = 1697 \text{ kPa} \simeq 1700 \text{ kPa}$$

21. (c)

$$d_1 = 30 \text{ cm}$$

$\therefore$ $$a_1 = \frac{\pi}{4}\times30^2 = 706.86 \text{ cm}^2 = 0.070686 \text{ m}^2$$

$$d_2 = 15 \text{ cm}$$

$\therefore$ $$a_2 = \frac{\pi}{4}\times15^2 = 176.71 \text{ cm}^2 = 0.017671 \text{ m}^2$$

Specific gravity of oil, $S_o = 0.9$

Specific gravity of mercury,

$$S_g = 13.6$$

Differential manometer reading,

$$x = 30 \text{ cm}$$

$\therefore$ $$h = \left(\frac{p_1}{\rho g}+Z_1\right)-\left(\frac{p_2}{\rho g}+Z_2\right) = x\left(\frac{S_g}{S_o}-1\right)$$

$$= 30\left(\frac{13.6}{0.9}-1\right) = 30(15.11-1)$$

$$= 30 \times 14.11$$

$$= 423.33 \text{ cm of oil} = 4.23 \text{ m of soil}$$

$$C_d = 1.0 \text{ (since losses are zero)}$$

$\therefore$ $$\text{Discharge, } Q = \frac{C_d a_1 a_2}{\sqrt{a_1^2 - a_2^2}}\times\sqrt{2gh}$$

$\Rightarrow$ $$Q = \frac{(1)\times(0.070686)\times(0.017671\times\sqrt{2\times9.81\times4.23}}{\sqrt{0.070686^2-0.017671^2}}$$

$\Rightarrow$ $$Q = 0.1663 \text{ m}^3/\text{s} = 166.3 \text{ } l/\text{s}$$

22. (b)

In order to apply the hydrostatic relation for the air pressure calculation, the density of fluid X must be found. Neglecting the buoyancy of the air on the upper part of the block, then

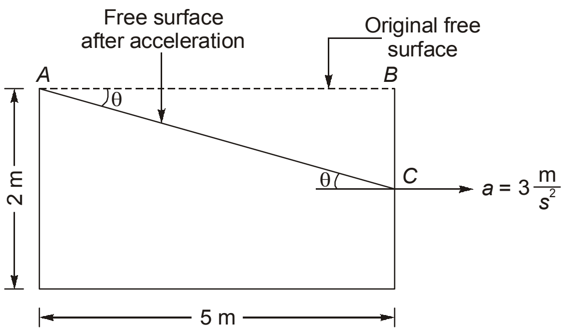
$$0.6\,\gamma_{\text{water}} V = \gamma_x (0.75 V)$$

$$\gamma_x = 0.8\,\gamma_{water}$$
$$= 0.8\,\rho_{water}\,g$$
$$= 0.8 \times 1000 \times 9.81$$
$$= 7848\text{ N/m}^3.$$

The air gauge pressure may then be calculated as

$$0 - \gamma_x\,(0.4) = P_{air}$$
$$P_{air} = -7848 \times 0.4 = -3139.2\text{ Pa}$$

23. (a)



L = 5 m, b = 2.5 , H = 2 m and a = 3 m/s^2

The slope of the free surface of water after the tank is subjected to a linear constant acceleration is

$$\tan\theta = \frac{a}{g} = \frac{3}{9.81} = 0.306$$

Now, $$\tan\theta = \frac{BC}{AB}$$

$$\Rightarrow \quad 0.306 = \frac{BC}{5}$$

$$\Rightarrow \quad BC = 1.53\text{ m}$$

$\therefore$ Volume of water spilled = Area (ΔABC) × Width of the tank

$$= \frac{1}{2} \times AB \times BC \times 2.5$$

$$= \frac{1}{2} \times 5 \times 1.53 \times 2.5$$

$$= 9.56\text{ m}^3$$

24. (a)

From Bernoulli's equation, we have

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + h_c$$

$$\Rightarrow \quad \frac{14 \times 10^4}{1000 \times 9.81} + \frac{1.6^2}{2 \times 9.81} = \frac{12 \times 10^4}{1000 \times 9.81} + \frac{6.4^2}{2 \times 9.81} + h_c$$

$$\Rightarrow \quad h_c = 0.0816\text{ m}$$

Now, $$h_c = \frac{V_2^2}{2g}\left[\frac{1}{C_c} - 1\right]^2$$

$$\Rightarrow \quad 0.0816 = \frac{V_2^2}{2g}\left[\frac{1}{C_c} - 1\right]^2$$

$$\Rightarrow \quad 0.0816 = \frac{6.4^2}{2 \times 9.81}\left[\frac{1}{C_c} - 1\right]^2$$

$$\Rightarrow \quad C_c = 0.835 \simeq 0.84$$

25. (d)

$$\text{Velocity, } V = \frac{100 \times 10^3}{3600} = 27.78 \text{ m/s}$$

$$\text{Reynolds number, Re}_x = \frac{Vx}{\nu}$$

where x is the distance upto which laminar boundary layer exists.

$$\therefore \quad x = \frac{\nu \text{Re}}{V} = \frac{1.49 \times 10^{-5} \times 3 \times 10^5}{27.78}$$

$$= 0.161 \text{ m}$$

Thickness of laminar boundary layer,

$$\delta = 5\sqrt{\frac{x\nu}{V}} = 5 \times \sqrt{\frac{0.161 \times 1.49 \times 10^{-5}}{27.78}}$$

$$= 1.47 \times 10^{-3} \text{ m} = 1.47 \text{ mm}$$

26. (a)

The volume of the air before and after the rotation must be the same. Recognizing that the volume of a paraboloid of revolution is half of the volume of a circular cylinder of the same radius and height.

The height of the paraboloid of revolution is determined as:

$$\pi \times 0.16^2 \times 0.02 = \frac{1}{2}\pi \times (0.16)^2 h$$

$$\therefore \quad h = 0.04 \text{ m}$$

$$\text{Using equation,} \quad z = \frac{r^2\omega^2}{2g}$$

$$\Rightarrow \quad 0.04 = \frac{0.16^2 \times \omega^2}{2 \times 9.81}$$

$$\Rightarrow \quad \omega = 5.54 \text{ rad/s}$$

The pressure, on the bottom as a function of the radius r is $p(r)$ which is given by

$$p - p_0 = \frac{\rho\omega^2}{2}\left(r^2 - r_1^2\right)$$

$$\text{where,} \quad p_0 = 9810 \times (0.22 - 0.04) = 1765.8 \text{ Pa} = 1766 \text{ Pa}$$

So, $$p = \frac{1000 \times 5.54^2}{2} r^2 + 1766 = 15346 r^2 + 1766$$

This pressure is integrated over the area to find the force

$$= \int_0^{0.16} \left(15346 r^2 + 1766\right) 2\pi r dr = 157.8 \text{ N}$$

27. (a)

Given
$$\tau_{wall} = 0.3\text{kPa}$$
$$\mu = 9 \text{ Poise} = 0.9 \text{ Pa-s}$$
$$R = 15 \text{ cm} = 0.15 \text{ m}$$

We know that,
$$\tau_{wall} = \frac{R}{2}\left(\frac{\partial P}{\partial x}\right)$$
$$0.3 \times 10^3 \text{ Pa} = \frac{0.15 \text{ m}}{2}\left(\frac{\partial P}{\partial x}\right)$$
$$\left(\frac{\partial P}{\partial x}\right) = 4 \text{ kPa/m}$$

For laminar flow in pipe,
$$u_{max} = \frac{1}{4\mu}\left(\frac{\partial P}{\partial x}\right)\left(R^2\right)$$
$$u_{max} = \frac{1}{4 \times 0.9 \text{ Pa-s}} \times \left(4 \times 10^3 \text{Pa/m}\right) \times (0.15)^2 \text{ m}^2$$
$$u_{max} = 25 \text{ m/s}$$

We know,
$$u_{mean} = \frac{u_{max}}{2} \quad \text{(For laminar flow in pipe)}$$
$$u_{mean} = 12.5 \text{ m/s}$$

28. (a)

$$\text{Buoyant Force } (F_B) = \text{Drag Force } (F_D) \quad \text{[Neglect weight of the bubble]}$$
$$\left(\frac{\pi d^3}{6}\right)\gamma = 3\pi\mu V d$$
$$\Rightarrow \quad \mu = \frac{\gamma d^2}{18V} \quad \therefore \quad \nu = \frac{\mu}{\rho} = \frac{g d^2}{18V}$$
$$\Rightarrow \quad \nu = \frac{9.81 \times (10^{-3})^2}{18 \times 8 \times 10^{-3}} = 6.8125 \times 10^{-5} \text{ m}^2\text{/s} \simeq 6.813 \times 10^{-5} \text{ m}^2\text{/s}$$

29. (b)

Buoyancy force acts through center of gravity of displaced liquid.

A large metacentric height in a vessel improves stability and makes time period of oscillation shorter.

30. (a)

$$D_1 = 150 \text{ mm}$$

$$A_1 = \frac{\pi}{4} \times (0.150)^2 = 0.01767 \text{ m}^2$$

$$D_2 = 300 \text{ mm} = 0.3 \text{ m}$$

$$A_2 = \frac{\pi}{4} \times (0.3)^2 = 0.0707 \text{ m}^2$$

$$Q = 0.25 \text{ m}^3/\text{s}$$

$$V_1 = \frac{Q}{A_1} = \frac{0.25}{0.01767} = 14.15 \text{ m/s}$$

$$V_2 = \frac{Q}{A_2} = \frac{0.25}{0.0707} = 3.536 \text{ m/s}$$

Loss of head due to enlargement is given as:

$$h_e = \frac{(V_1 - V_2)^2}{2g} = \frac{(14.15 - 3.536)^2}{2g}$$

$$= 5.742 \text{ m of water}$$

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