CLASS TEST

S. NO.: 01JP-ME-03072023

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MECHANICAL 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 Consider the flow of an incompressible Newtonian fluid between two parallel plates which are separated by 4 mm. If the upper plate moves to right with U_1 = 3 m/s while the bottom one moves to the left with U_2 = 0.75 m/s, then the net flow rate at a cross section between two plates is (Take the plate width to be b = 5 cm)

(a) 215 cm^3/s (b) 255 cm^3/s
(c) 220 cm^3/s (d) 225 cm^3/s

Q.2 Two horizontal plates are placed 15 mm apart. The space between them being filled with oil of viscosity 5 poise. The shear stress on the upper plate if the upper plate moves with a velocity of 5 m/s is

(a) 77.76 N/m^2 (b) 112.21 N/m^2
(c) 166.67 N/m^2 (d) 201.32 N/m^2

Q.3 A steady, two-dimensional, incompressible flow field in the xy-plane has stream function given by $\psi = ax^2 + by^2 + cy$, where a, b and c are constants. The expression for the velocity component u is given by

(a) $2by + c$ (b) $-2ax$
(c) $-2ax + 2by + c$ (d) $2ax + 2by + c$

Q.4 An isosceles triangular plate of base 5 meters and height 5 meters is immersed vertically in a fluid of specific gravity 0.75. The base of the triangle is touching the top of the surface of the fluid horizontally and rest of its portion is within the fluid. The total pressure on the plate is

(a) 153.28 kN (b) 137.95 kN
(c) 122.57 kN (d) 115.95 kN

Q.5 For a floating body, G, B and M represent the centre of gravity, centre of buoyancy and the metacentre, respectively. The body will be stable if

(a) G is located above B
(b) B is located above M
(c) M is located above B
(d) M is located above G

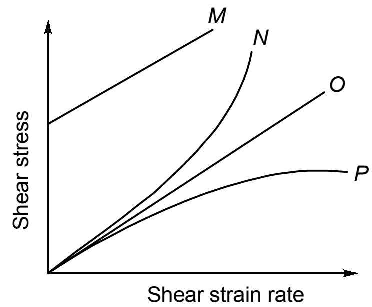
Q.6 A simple and accurate viscometer can be made from a length of capillary tubing. If the flow rate and pressure drop are measured, and the tube geometry is known, the viscosity of Newtonian liquid can be computed. A test of a certain liquid in a capillary viscometer gave the following data:

Flow rate: 880 mm^3/s, Tube length: 1 m, Tube diameter: 0.50 mm, Pressure drop: 1.0 MPa

Assuming the flow to be laminar, the viscosity of liquid will be (ρ_{liq} = 999 kg/m^3),

(a) 0.37×10^{-4} Ns/m^2
(b) 3.7×10^{-3} Ns/m^2
(c) 1.74×10^{-3} Ns/m^2
(d) 1.74×10^{-2} Ns/m^2

Q.7 Rheological diagram of different types of fluids is shown in figure. Column-I represents the nature of the fluid and Column-II represents the curve showing the variation of shear stress against shear strain rate.



Column-I	Column-II
(i) Newtonian	M
(ii) Shear thinning	N
(iii) Shear thickening	O
(iv) Bingham plastic	P

The most appropriate match between Column-I and Column-II is,

(a) (i) - O, (ii) - N, (iii) - P, (iv) - M
(b) (i) - O, (ii) - P, (iii) - N, (iv) - M
(c) (i) - P, (ii) - O, (iii) - M, (iv) - N
(d) (i) - P, (ii) - O, (iii) - N, (iv) - M

Q.8 In order to increase sensitivity of U-tube manometer, one leg is usually inclined by an angle 30°. What is the sensitivity of inclined tube compared to sensitivity of U-tube?

(a) 0.5 (b) 2
(c) $\frac{\sqrt{3}}{2}$ (d) $\frac{2}{\sqrt{3}}$

Q.9 Which one of the following is correct with respect to dimensional analysis?

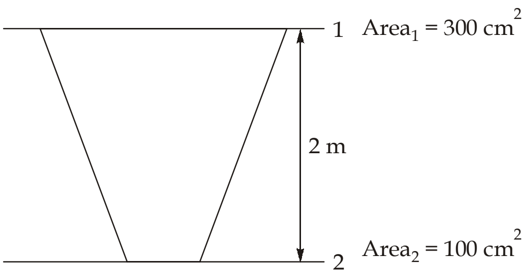
(a) A dimension is a measure of a physical quantity (without numerical values)

(b) A unit is a way to assign a number to the dimension

(c) Both (a) and (b)

(d) None of these

Q.10 A liquid is flowing downwards through the tapered pipe as shown in below figure. If the pressure at section 1 and section 2 is same, then the velocity of liquid at section 1 is



(a) 6.645 m/s (b) 3.3225 m/s

(c) 2.215 m/s (d) 1.1075 m/s

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

Q.11 The velocity distribution within a laminar boundary layer is described by the following parabolic function:

$$\frac{u}{U} = 2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2$$

Then the ratio of displacement thickness (δ^*) to boundary layer thickness (δ) is

(a) $\frac{2}{3}$ (b) $\frac{1}{4}$

(c) $\frac{1}{3}$ (d) $\frac{2}{5}$

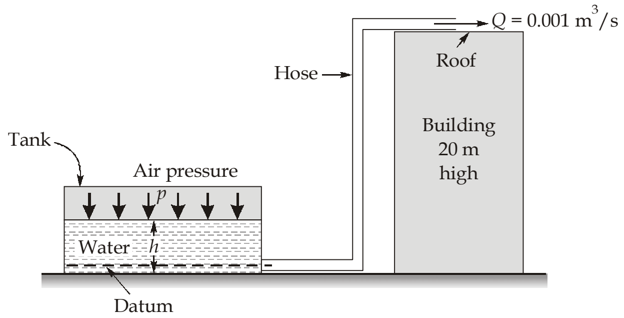
Q.12 Two reservoirs are connected by a pipeline. The diameter of the pipe is 0.5 m and the difference in levels of the two reservoirs is 12.5 m. The total length of the pipe is 1000 m. The velocity of flow in the pipe taking into account both major and minor losses will be

[Take, friction factor $f = 0.04$ and $g = 10\ m/sec^2$]

(a) 1.75 m/s (b) 3.2 m/s

(c) 4.5 m/s (d) 0.5 m/s

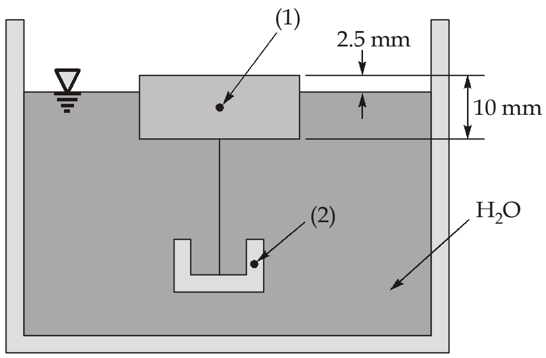
Q.13 A large tank partially filled with water, the air space above being under pressure. A 0.05 m diameter hose connected to the tank discharges on the roof of a building 20 m above the level of the tank. The friction loss is 0.06 m. The air pressure in terms of meters of water that must be maintained in the tank to deliver 0.001 m^3/s of the water to the roof is (Assume depth of water in tank negligible as compared to height of building)



(a) 12.125 m (b) 14.062 m

(c) 20.073 m (d) 22.018 m

Q.14 A metal part (object 2) is hanging by a thin cord from a floating wood block (object 1). The wood block has a specific gravity S_1 = 0.3 and dimensions of 50 × 50 × 10 mm^3. The metal part has a volume of 6600 mm^3 ($g = 9.8\ m/s^2$). The mass m_2 of the metal part is



(a) 0.01282 (b) 0.01540

(c) 0.01372 (d) 0.01785

Q.15 A 7-m-diameter hot air balloon that has a total mass of 350 kg is standing still in air on a windless day. The balloon is suddenly subjected to 40 km/h winds. Then the initial acceleration of the balloon in the horizontal direction is given by: [Assume drag coefficient $C_D = 0.2$, density of air ρ = 1.20 kg/m^3].

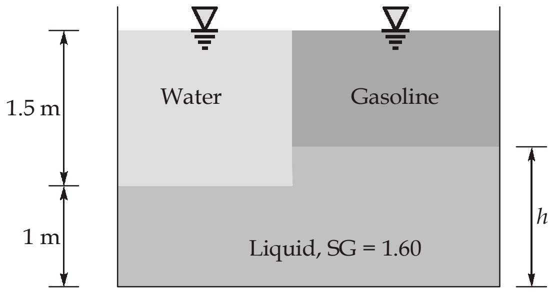
(a) 1.60 m/s^2 (b) 1.63 m/s^2

(c) 1.69 m/s^2 (d) 1.78 m/s^2

Q.16 A hemispherical bulge of diameter 1.5 m is provided in the bottom of a tank. If the depth of water above the horizontal floor of the tank is 5.0 m, the magnitude of resultant force on the hemisphere is approximately equal to

(a) 94 kN (b) 78 kN
(c) 88 kN (d) 72 kN

Q.17 As the tank shown below, water and gasoline surfaces is open to the atmosphere and at the same elevation. Then the height h of the liquid column is (Take density of gasoline = 667 kg/m^3)



(a) 1.5 m (b) 1.2 m
(c) 1.3 m (d) 1.8 m

Q.18 A fluid flow field is given by

$$V = x^2 y\hat{i} + y^2 z\hat{j} - \left(2xyz + yz^2\right)\hat{k}$$

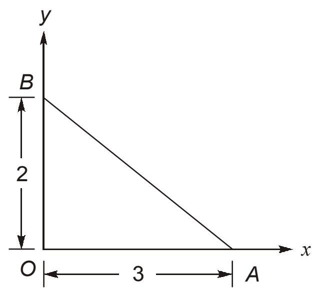
The x-component acceleration at point (3, 2, 1) is

(a) 232 units (b) 216 units
(c) 252 units (d) 200 units

Q.19 A stream function is given by

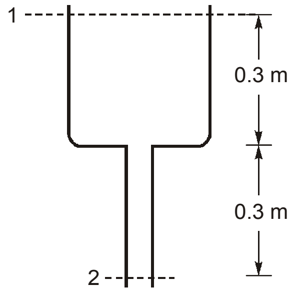
$\psi = 2x^2 y + (x + t)y^2$

The flow rates across the faces of the triangular prism OAB, having a thickness of 5 units in the Z-direction at time $t = 1$ will be



(a) OB = 20, OA = 0, AB = 10 units
(b) OB = 20, OA = 0, AB = 0 units
(c) OB = 20, OA = 0, AB = 20 units
(d) OB = 10, OA = 10, AB = 20 units

Q.20 A liquid of specific weight 9 kN/m^3 flows by gravity through a 0.3 m long tank and 0.3 m long capillary tube of diameter 1.2 mm at a rate of 1.13×10^{-6} m^3/s. Section 1 and 2 having kinetic energy correction factors of 1.5 and 2 respectively, are at atmospheric pressure. The viscosity of liquid neglecting entrance effects will be

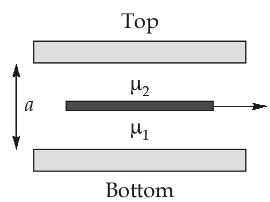


(a) 3.75×10^{-4} Pa-s (b) 4.75×10^{-4} Pa-s
(c) 5.75×10^{-4} Pa-s (d) 6.75×10^{-4} Pa-s

Q.21 1.80 m wide and 5 m long plate moves through a stationary air of density 1.22 kg/m^3 and viscosity of 1.8×10^{-4} poise at a velocity of 1.75 m/s parallel to its length. The drag force on one side of the plate assuming turbulent flow conditions is?

(a) 0.043 N (b) 0.087 N
(c) 0.056 N (d) 0.093 N

Q.22 A thin plate is placed inside narrow gap of height 'a'. The gap filled with oil of viscosity μ_1 at bottom, and oil of viscosity μ_2 at top. Position of plate from bottom if the drag is minimum.



(a) $\dfrac{a\sqrt{\mu_2}}{\sqrt{\mu_1}+\sqrt{\mu_2}}$ (b) $\dfrac{a\sqrt{\mu_1}}{\sqrt{\mu_1+\mu_2}}$

(c) $\dfrac{a\sqrt{\mu_1}}{\sqrt{\mu_1-\mu_2}}$ (d) $\dfrac{a\sqrt{\mu_1}}{\sqrt{\mu_1}+\sqrt{\mu_2}}$

V = velocity of plate

Q.23 An open circular cylinder 1.2 m high is filled with a liquid to its top. The liquid is given a rigid body rotation about the axis of the cylinder and the pressure at the centre line at the bottom surface is found to be 0.6 m of liquid. What is the ratio of volume of liquid spilled out of the cylinder to the original volume?

(a) 1/4 (b) 3/8
(c) 1/2 (d) 3/4

Q.24 A drop of a liquid is placed on a plane smooth glass. Liquid has surface tensions as given in following table:

Discontinuity type	σ (N/m)
1. Liquid and air	0.0720
2. Liquid and solid	0.0418
3. Air and solid	0.0008

If θ represents the contact angle in degrees, its value is equal to

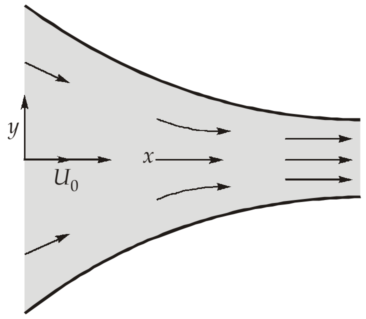
(a) 132.5° (b) 142.7°
(c) 124.7° (d) 174.2°

Q.25 For a fully developed flow of water in a pipe having diameter 0.1 m, velocity 10 cm/s and Kinematic viscosity 10^{-5} m^2/s, the value of Darcy friction factor is

(a) 0.64 (b) 0.16
(c) 0.064 (d) 0.016

Q.26 Converging duct flow as shown below is modeled by the steady, two-dimensional velocity field, then choose the correct option for the given flow field.

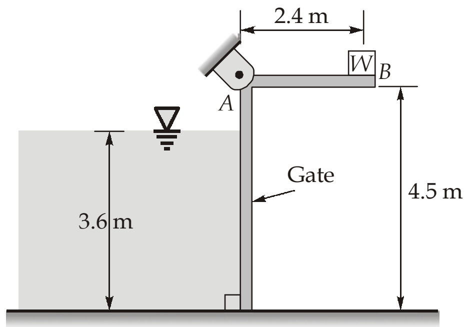
$$\vec{V} = (u,v) = (U_0 + bx)\vec{i} - by\vec{j}$$



Where, U_0 is the horizontal speed at $x = 0$.

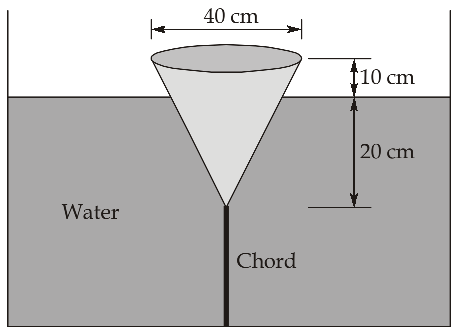
(a) Unsteady & irrotational
(b) Steady & rotational
(c) Unsteady & rotational
(d) Steady & irrotational

Q.27 The flow of water from a reservoir is controlled by a 1.5 m wide L-shaped gate hinged at point A, as shown in figure below. If it is desired that the gate open when the water height is 3.6 m, then the mass of the required weight W is



(a) 13.36×10^3 kg (b) 26.73×10^3 kg
(c) 17.0×10^3 kg (d) 8.50×10^3 kg

Q.28 An inverted cone is placed in a water tank as shown. If the weight of the cone is 16.5 N, what is the tensile force in the cord connecting the cone to the bottom of the tank?



(a) 16.5 N (b) 20 N
(c) 36.5 N (d) None of them

Q.29 A 6 cm-diameter soap bubble is to be enlarged by blowing air into it. Taking the surface tension of soap solution to be 0.039 N/m, then the work input required to inflate the bubble to a diameter 6.9 cm is

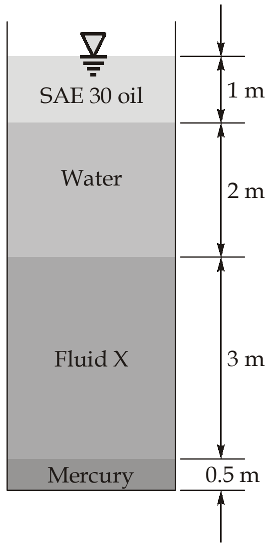
(a) 1.422×10^{-4} J
(b) 2.845×10^{-4} J
(c) 5.690×10^{-4} J
(d) 4.266×10^{-4} J

Q.30 For the tank shown below, the absolute pressure at the bottom is 323.33 kPa, then the specific gravity of fluid X is

(Take Atmospheric pressure as 101.33 kPa and g = 10 m/s^2)

Property data for fluids are

Fluids	Specific gravity (SG)
SAE 30 oil	0.872
Mercury	13.6



(a) 2.616
(b) 4.176
(c) 6.544
(d) 3.402

■■■■

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FLUID MECHANICS

MECHANICAL ENGINEERING

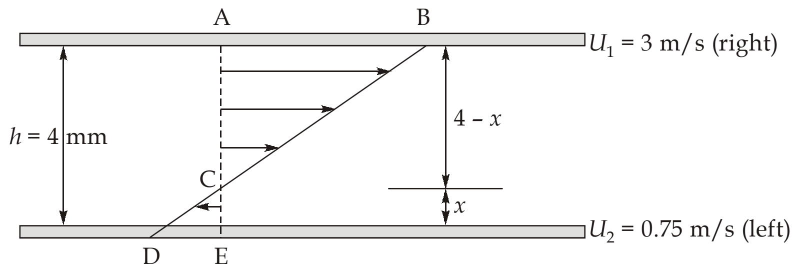
Date of Test : 03/07/2023

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (d)



From similar triangles, ΔABC and ΔCDE

$$\frac{4-x}{x} = \frac{3}{0.75}$$

$$3x = (4-x)(0.75)$$

$$3x = 3-0.75x$$

$$x = 0.8 \text{ mm}$$

$$y = 4-x = 3.2 \text{ mm}$$

$$\dot{V}_{net} = (3.2\times10^{-3})(5\times10^{-2})\frac{3}{2}-(0.8\times10^{-3})(5\times10^{-2})\frac{0.75}{2}$$

$$\dot{V}_{net} = 24\times10^{-5}-1.5\times10^{-5} = 225\times10^{-6} \text{ m}^3/\text{s} = 225 \text{ cm}^3/\text{s}$$

2. (c)

$$1 \text{ Poise} = 0.1 \text{ N-s/m}^2$$

$$\text{Shear stress, } \tau = \mu\frac{du}{dy}$$

$$\Rightarrow \quad \tau = \left(0.1\times5\frac{\text{N-s}}{\text{m}^2}\right)\times\left(\frac{5 \text{ m/s}}{0.015 \text{ m}}\right)$$

$$= 166.67 \text{ N/m}^2$$

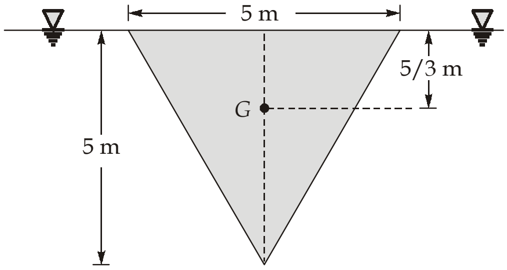
3. (a)

Velocity component in x-direction, $u = \dfrac{\partial\psi}{\partial y} = \dfrac{\partial}{\partial y}\left(ax^2+by^2+cy\right)$

$$u = 2by + c$$

Note that you can use other sign convention also.

4. (a)



Total pressure on the triangle,

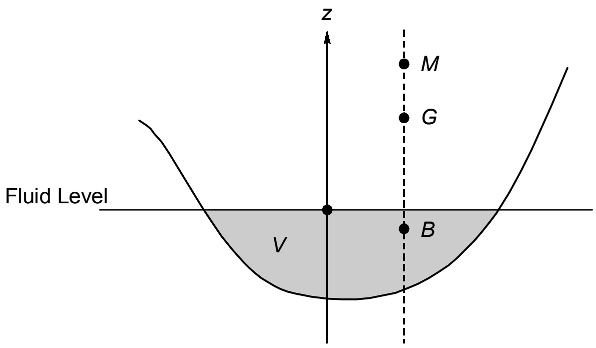
$$F = pA = \gamma h_c A$$

$$= (1000 \times 0.75 \times 9.81) \times \left(\frac{5}{3}\right) \times \left(\frac{1}{2} \times 5 \times 5\right)$$

$$= 750 \times 9.81 \times \frac{5}{3} \times \frac{25}{2} = 1250 \times \frac{25}{2} \simeq 153.28 \text{ kN}$$

5. (d)

Stable equilibrium condition



6. (c)

$$\therefore \quad \bar{V} = \frac{Q}{A} = \frac{Q}{\frac{\pi}{4} d^2} \Rightarrow \frac{4Q}{\pi d^2} = \frac{4 \times 880 \times 10^{-9}}{\pi \times 0.50^2 \times 10^{-6}} = 4.48 \text{ m/s}$$

We know,

$$Q = \frac{\pi \Delta P D^4}{128 \mu L}$$

$$\Rightarrow \quad \mu = \frac{\pi \Delta P D^4}{128 Q L} = \frac{\pi \times 10^6 \times (0.5)^4 \times 10^{-12}}{128 \times 880 \times 10^{-9} \times 1}$$

$$\mu = 1.74 \times 10^{-3}$$

8. (b)

$$\text{Sensitivity} = \frac{1}{\sin\theta} = \frac{1}{\sin 30°} = 2$$

9. (c)

A dimension is a measure of a physical quantity (without numerical values), while a unit is a way to assign a number to that dimension.

10. (c)

Applying Bernoulli's equation between section 1 and 2,

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

$$\Rightarrow \quad 0 + 0 + \frac{V_1^2}{2g} = 0 + (-2) + \frac{(3V_1)^2}{2g} \qquad (\text{as } A_1V_1 = A_2V_2)$$

$$\Rightarrow \quad 2 \times 2 \times 9.81 = 8\,V_1^2$$

$$\Rightarrow \quad V_1 = 2.215 \text{ m/s}$$

11. (c)

As per given data:

$$u^* = \frac{u}{U} \text{ and } y^* = \frac{y}{\delta}$$

$$dy^* = \delta^{-1}\,dy$$

The given parabolic velocity distribution and the expression for the displacement thickness can then be expressed as

$$u^* = 2y^* - y^{*2}, \text{ and } \delta^* = \delta\int_0^1 (1-u^*)\,dy^*$$

Combining these equations gives,

$$\delta^* = \delta\int_0^1 \left(1-2y^*+y^{*2}\right)dy^*$$

$$\delta^* = \delta\left[y^*-y^{*2}+\frac{1}{3}y^{*3}\right]_0^1$$

$$\delta^* = \frac{1}{3}\delta$$

$$\frac{\delta^*}{\delta} = \frac{1}{3}$$

12. (a)

Applying Bernoulli's equation between the two reservoirs, we get

$$12.5 = 0.5\frac{V^2}{2g}+\frac{fLV^2}{2gD}+\frac{V^2}{2g}$$

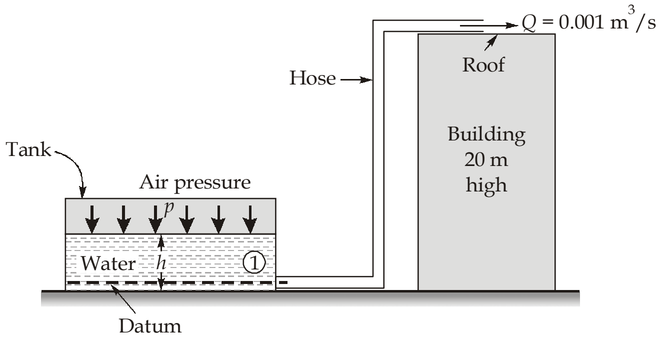
$$\Rightarrow \quad 12.5 = \frac{V^2}{2g}\left[1.5+\frac{fL}{D}\right]$$

$$\Rightarrow \quad 12.5 = \frac{V^2}{2\times10}\left[1.5+\frac{0.04\times1000}{0.5}\right]$$

$$\Rightarrow \quad 12.5 = \frac{V^2}{20}\times 81.5$$

$$\Rightarrow \quad V = 1.75 \text{ m/s}$$

13. (c)



Let 'p' be the air pressure inside the tank.

The velocity of water in the hose,

$$V = \frac{Q}{A} = \frac{0.001}{\frac{\pi}{4}\times(0.05)^2} = 0.509 \text{ m/s}$$

Applying the Bernoulli's equation to the inlet end (1) and the output end of the hose at 20 m height above the bottom level, (Assuming the horizontal line passing through (1) as the datum).

$$\frac{p}{\gamma}+h = 20+\frac{V^2}{2g}+0.06$$

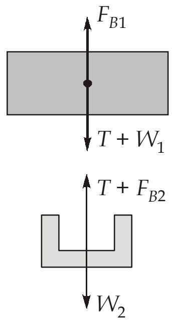
where, p is the pressure of air in the tank, h is the water depth.

Now, $h << 20$ m (given)

$$\frac{p}{\gamma} = 20+\frac{(0.509)^2}{2\times9.81}+0.06 = 20.073 \text{ m of water}$$

14. (d)

As the given data: Free body diagram



From ΣF_y

$$T = F_{B1} - W_1$$

$$F_{B1} = \rho g(V)_{\text{submerged}}$$

$$= (9.8 \times 1000)(50 \times 50 \times 7.5)(10^{-9})$$

$$F_{B1} = 0.18375 \text{ N}$$

$$W_1 = \gamma(\text{Specific gravity of block}) \times \text{Volume of block}$$

$$= (9.8 \times 1000)(0.3)(50 \times 50 \times 10)(10^{-9}) = 0.0735 \text{ N}$$

$$T = (0.18375 - 0.0735) = 0.11025 \text{ N}$$

3. Force equilibrium (vertical direction) applied to metal part:

$$F_{B2} = \gamma V_2 = (9800)(6600)(10^{-9})$$

$$= 0.06468 \text{ N}$$

$$W_2 = T + F_{B2} = (0.1102 \text{ N}) + (0.06468 \text{ N})$$

Mass of metal part, $$m_2 = \frac{W_2}{g} = 0.01785 \text{ kg}$$

15. (b)

The frontal area of a sphere is $A = \dfrac{\pi D^2}{4}$

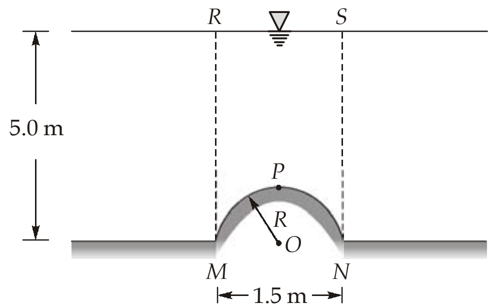
The drag force acting on the balloon is

$$F_D = C_D A \frac{\rho V^2}{2} = (0.2)\left[\frac{\pi(7)^2}{4}\right]\frac{(1.20)\left(\frac{40 \times 5}{18}\right)^2}{2} = 570.14 \text{ N}$$

Acceleration in the direction of the winds

$$a = \frac{F_D}{m} = \frac{570.14}{350} = 1.63 \text{ m/s}^2$$

16. (b)



By symmetry, the net horizontal force is zero.

Vertical force, F_V = Weight of fluid above the hemisphere MPN

$$= \gamma\left[\pi R^2 H - \frac{1}{2}\cdot\frac{4}{3}\pi R^3\right]$$

$$= 9.81\times\left[\pi(0.75)^2\times 5 - \frac{2}{3}\times\pi\times(0.75)^3\right]$$

$$= 78.01 \text{ kN}$$

Resultant force is same as the vertical force $F_V = 78.01$ kN acting vertically at the center of the hemisphere.

17. (a)

The bottom pressure must be the same whether we move down through the water or through the gasoline into the third fluid:

$$p_{\text{bottom}} = (1000\text{ g})(1.5) + 1.60(1000\text{ g})(1.0) = 1.60(1000\text{ g})h + (2.5 - h)\times 667\text{g}$$

Solve for $h = 1.535$ m

18. (c)

x-component acceleration,

$$a_x = u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}$$

$$a_x = x^2y(2xy) + y^2z(x^2) - (2xyz + yz^2)(0)$$

$$= 2x^3y^2 + x^2y^2z$$

$$= 2(3)^3(2)^2 + (3)^2(2)^2(1)$$

$$= 2\times 27\times 4 + 9\times 4\times 1$$

$$= 54\times 4 + 36$$

$$= 216 + 36$$

$$= 252 \text{ units}$$

19. (c)

$$u = \frac{\partial\psi}{\partial y}$$

$$u = 2x^2 + (x + t)\,2y$$

$\therefore$ for face OB, $\quad x \Rightarrow 0$

$$u_{OB} = 2ty$$

Discharge through OB

$$\therefore \quad Q_{OB} = \int_0^2 u_{OB}\cdot 5dy = \int_0^2 2ty\cdot 5dy$$

At $\quad t = 1$

$$Q_{OB} = 20 \text{ units}$$

$$\therefore \quad V = -\frac{\partial\psi}{\partial x} = -\left[4xy + y^2\right]$$

At $\quad y = 0$

$$V = 0$$

$$\therefore \quad Q_{OA} = 0$$

$$\therefore \quad Q_{AB} = Q_{OB} + Q_{OA}$$

$$= 20 + 0$$

$$= 20 \text{ units}$$

20. (d)

$$V_2 = \frac{Q}{A_2} = \frac{1.13\times10^{-6}}{\frac{\pi}{4}\times(0.0012)^2} \simeq 1 \text{ m/s}$$

$$\frac{P_1}{\rho g} + \frac{\alpha_1 V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \alpha_2\frac{V_2^2}{2g} + z_2 + h_f$$

$$h_f = z_1 - z_2 - \frac{\alpha_2 V_2^2}{2g}$$

$$\Rightarrow \quad h_f = 0.6 - 0 - \frac{(2)(1)^2}{2\times9.81} = 0.5 \text{ m}$$

$$h_f = \frac{32\mu VL}{\rho g D^2}$$

$$\Rightarrow \quad 0.5 = \frac{32\times\mu\times0.3\times1}{9000\times0.0012^2}$$

$$\Rightarrow \quad \mu = 6.75\times10^{-4} \text{ Pa-s}$$

21. (b)

$$Re_L = \frac{UL}{\nu} = \frac{1.75\times5}{1.475\times10^5}$$

$$Re_L = 5.932\times10^5$$

$$C_f = \frac{0.074}{Re_L^{1/5}} = \frac{0.074}{(5.932 \times 10^5)^{1/5}} = 5.183 \times 10^{-3}$$

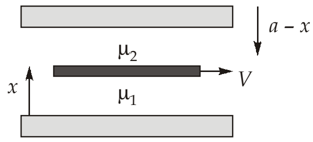
Drag force on one side of the plate,

$$F_d = C_f \times \text{area} \times \frac{1}{2}\rho U^2$$

$$= 5.183 \times 10^{-3} \times (1.8 \times 5) \times 1.22 \times \frac{(1.75)^2}{2}$$

$$F_d = 0.0871 \text{ N}$$

22. (d)



$$\tau_1 = \text{shear stress at bottom}$$

$$= \mu_1 \times \frac{V}{x}$$

$$\tau_2 = \text{shear stress at top} = \mu_2 \frac{V}{a-x}$$

$$\text{drag force} = (\tau_1 + \tau_2) \times A = F_D$$

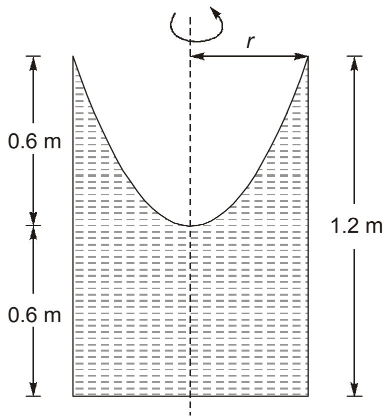
$$= F_D = A \times \left[\frac{\mu_1 V}{x} + \frac{\mu_2 V}{a-x}\right]$$

$$\frac{dF_D}{dx} = 0 = \frac{-\mu_1 V}{x^2} + \frac{\mu_2 V}{(a-x)^2} \Rightarrow \frac{\mu_1}{x^2} = \frac{\mu_2}{(a-x)^2}$$

$$a - x = \sqrt{\frac{\mu_2}{\mu_1}}x$$

$$\Rightarrow \quad \frac{a\sqrt{\mu_1}}{\sqrt{\mu_1} + \sqrt{\mu_2}} = x$$

23. (a)



Original volume of

$$\text{Cylinder} = \pi r^2 h$$

$$V_1 = \pi r^2 \times 1.2$$

Volume of liquid spilled out

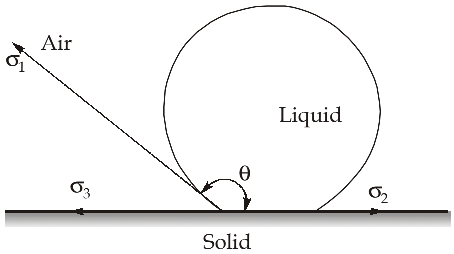
$$= \frac{1}{2}\pi r^2 \times h$$

$$V_2 = \frac{1}{2}\pi r^2 \times 0.6$$

$$\therefore \quad \frac{V_2}{V_1} = \frac{\frac{1}{2}\times 0.6\pi r^2}{\pi r^2 \times 1.2} = \frac{1}{4}$$

24. (c)

From force balance at point of contact,



$$\sigma_1\cos(180-\theta) + \sigma_3 = \sigma_2$$

or
$$\cos(180-\theta) = \frac{\sigma_2 - \sigma_3}{\sigma_1} = -\cos\theta$$

$\therefore$
$\sigma_1 = 0.0720$ N/m (liquid and air)
$\sigma_2 = 0.0418$ N/m (liquid and solid)
$\sigma_3 = 0.0008$ N/m (air and solid)

$$\cos\theta = \frac{0.0008 - 0.0418}{0.072} = -0.56944$$

$$\theta = 124.7°$$

25. (c)

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

$$Re = \frac{UD}{\nu} = \frac{0.1\times 0.1}{10^{-5}} = 1000$$

$$f = \frac{64}{1000} = 0.064$$

26. (d)

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

as
$$u = (U_o + bx)$$
$$v = -by$$

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

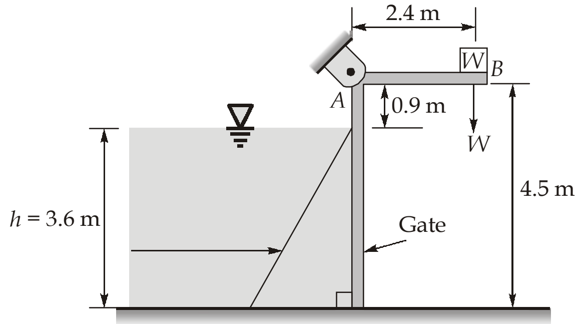
So,
$$\omega_z = 0$$

Hence, flow is steady and irrotational.

27. (a)

As per given information,

1.5 m wide, ρ_{water} = 1000 kg/m^3



The resultant hydrostatic force acting on the dam becomes,

$$F_R = \rho g \bar{x} A = 1000 \times 9.81 \times \frac{3.6}{2} \times 3.6 \times 1.5 \text{ N} = 95353.2 \text{ N}$$

The line of action of the force passes through the pressure centre which is $\frac{2h}{3}$ from the free surface.

$$\bar{h} = \frac{2h}{3} = \frac{2 \times 3.6}{3} = 2.4 \text{ m}$$

Taking the moment about point A and setting it equal to zero gives,

$$\Sigma M_A = 0$$

$$F_R\left(0.9 + \bar{h}\right) = W \times 2.4$$

$$W = 131110.65$$

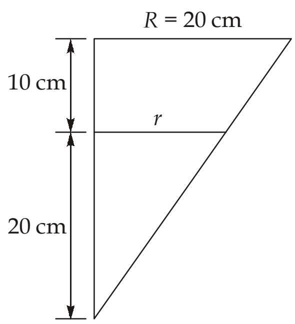
$$\text{Mass} = \frac{W}{9.81} = \frac{131110.65}{9.81} = 13365 \text{ kg} = 13.36 \times 10^3 \text{ kg}$$

28. (b)

Assumption: The buoyancy force in air is negligible,

$$\rho_{water} = 1000 \text{ kg/m}^3, \qquad h = 0.2 \text{ m}$$

From geometry



$$\frac{R}{30} = \frac{r}{20}$$

and $$r = \frac{2R}{3} = \frac{40}{3} = 13.33 \text{ cm}$$

The displaced volume of water is

$$\forall = \frac{1}{3}\pi r^2 h = \frac{1}{3} \times \pi \times 0.1333^2 \times 0.2$$

$$= 3.72 \times 10^{-3} \text{ m}^3$$

Therefore, the buoyancy force acting on the cone is

$$F_b = \rho g \forall = 9810 \times 3.72 \times 10^{-3} = 36.49 \text{ N}$$

For the static equilibrium,

$$F + W_c = F_b$$
$$F + 16.5 = 36.5$$
$$F = 20 \text{ N}$$

29. (b)

$$D_i = 6 \times 10^{-2} \text{ m}$$
$$D_f = 6.9 \times 10^{-2} \text{ m}$$

As soap bubble has two surfaces,

Therefore total change in surface area = $2\left[4\pi\left(R_f^2 - R_i^2\right)\right] = 2\left[\pi\left(D_f^2 - D_i^2\right)\right]$

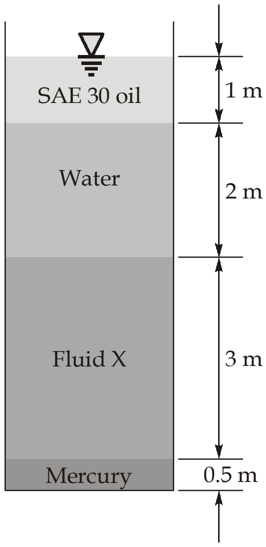
$$= 2\,(0.003647) = 7.294 \times 10^{-3} \text{ m}^2$$

Work input required, $W = \sigma \times \Delta A = 0.039 \times 7.294 \times 10^{-3}$

$$= 2.845 \times 10^{-4} \text{ Joule}$$

30. (b)

Simply apply the hydrostatic formula from top to bottom:



$$p_{\text{bottom}} = p_{\text{top}} + \Sigma wh,$$

$323.33 \times 10^3 = 101330 + 0.872 \times 10^3 \times 10 \times 1 + 10^3 \times 10 \times 2 + (SG)_x \times 10^3 \times 10 \times 3 + 13.6 \times 10^3 \times 10 \times 0.5$

or, $SG_X = 4.176$

■■■■