CLASS TEST

Sl. : 01JP_CE_29062024

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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 dimensions of kinetic energy correction factor α is
(a) $M^0 L^{-1} T^{-1}$
(b) $M^1 L^2 T^{-2}$
(c) $M^0 L^1 T^{-2}$
(d) Dimensionless quantity

Q.2 What will be the kinematic viscosity of a fluid having density of 981 kg/m^3, if the shear stress at a point in the fluid is 0.2452 N/m^2 and velocity gradient at that point is 0.2 per second?
(a) 12.5 stokes (b) 1.22 stokes
(c) 125 stokes (d) 122 stokes

Q.3 Consider the following statements:
1. Dilatant fluid is shear thickening, increasing its resistance with increasing strain rate.
2. Pseudoplastic is shear thinning fluid and it is less resistant at high strain rates.
3. The fluids which require a gradually increasing shear stress to maintain a constant strain rate are called rheopectic fluid.

Which of the above statements are correct?
(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3

Q.4 The least radius of gyration of a ship is 8 m and its metacentric height is 70 cm. What will be the time period of oscillation of the ship?
(a) 3.05 sec (b) 19.18 sec
(c) 60.07 sec (d) 38.36 sec

Q.5 Consider the following statements:
1. The stream function is defined by continuity, the Laplace equation for ψ results from irrotationality.
2. The velocity potential is defined by irrotationality, the Laplace equation for ϕ results from continuity.

Which of the above statement(s) is/are correct?
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

Q.6 A steady, incompressible, two dimensional velocity field is given by
$$u = x + y + 1$$
$$v = x - y - 2$$
The stagnation point is at:
(a) (0.5, –1.5) (b) (0.5, 1.5)
(c) (–0.5, 1.5) (d) (–0.5, –1.5)

Q.7 Given u and v are the components of velocity in x and y directions respectively which are given by:
$$u = ax + by$$
$$v = dx + cy$$
The condition to be satisfied for possible case of fluid flow is:
(a) $a + b + c + d = 0$ (b) $a + d = 0$
(c) $a + c = 0$ (d) $b + d = 0$

Q.8 Calculate the diameter of a circular cylindrical jet of water if the pressure difference between inside and outside of the curved surface is 40 Pa. Coefficient of surface tension of water is 73×10^{-3} N/m.
(a) 1.825 mm (b) 3.65 mm
(c) 7.3 mm (d) 14.6 mm

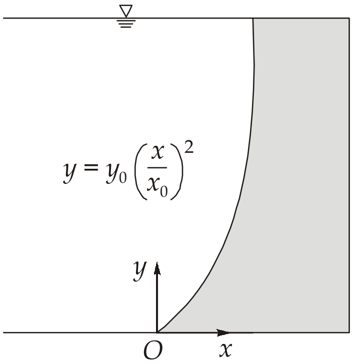
Q.9 The terminal velocity of a body in a stationary mass of fluid corresponds to the situation when the
(a) Body acquires a constant velocity in any direction.
(b) Net force acting on the body equals zero.
(c) Weight of the body is greater than buoyant force acting on it.
(d) Net force acting on the body acts in vertical direction.

Q.10 Consider the following statements:
1. Real fluids have lower viscosity than ideal fluids.
2. Cavitation occurs when pressure falls below vapour pressure.
3. Surface energy is responsible for surface tension.

Which of the statements are correct?
(a) 2 and 3 (b) 1 and 3
(c) 2 only (d) all the above

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

Q.11 A dam has a parabolic shape $y = y_0\left(\frac{x}{x_0}\right)^2$ as shown in the figure below having (x_0, y_0) as (6 m, 9 m). The fluid is water with density 1010 kg/m^3. What is the vertical thrust exerted by water on the dam? [The dam is 6 meter long.]

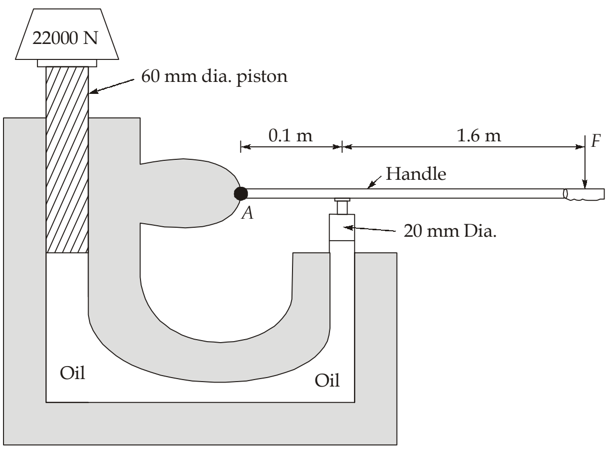


(a) 356.70 kN (b) 2140.15 kN
(c) 1070.1 kN (d) 1670.82 kN

Q.12 An open circular cylinder of 15 cm diameter and 100 cm long contains water upto a height of 70 cm. What is the speed at which the cylinder is to be rotated about its vertical axis so that the axial depth of water becomes zero?

(a) 327 rpm (b) 421 rpm
(c) 486 rpm (d) 564 rpm

Q.13 The hydraulic jack shown in the figure is filled with oil of specific gravity 0.86. Neglecting the weight of the two pistons, what force F on the handle is required to support 22000 N weight?



(a) 244.4 N (b) 143.8 N
(c) 153.4 N (d) 202.8 N

Q.14 Consider a steady uniform flow of water in a pipe of diameter 325 mm. If average velocity is 2 m/s and the friction factor is 0.024, then the boundary shear stress will be:

(a) 6.4 N/m^2 (b) 8.4 N/m^2
(c) 16.8 N/m^2 (d) 12.0 N/m^2

Q.15 Consider the following statements:

1. When surface tension effect predominants in addition to inertia force, Euler's model is used.
2. When pressure force controls flow in addition to inertial force, Weber's model is used.
3. Weber's model is applicable in case of aerodynamic testing.

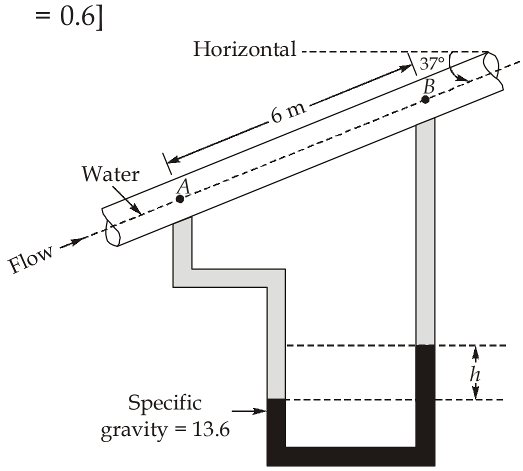
Which of the above statements are incorrect?

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

Q.16 A pontoon of rectangular cross-sectional area is 8 m long, 3 m wide and 1.5 m high. The depth of submergence of the pontoon is 0.9 m and its centre of gravity is 0.8 m above its bottom. The metacentric height is

(a) 0.375 cm (b) 0.483 cm
(c) 0.521 cm (d) 0.40 cm

Q.17 For the manometer arrangement as shown, there is flow of water from A towards B. The manometer reading is 5 cm. The pressure difference $P_B - P_A$ is [Take sin37° = 0.6]



(a) 30.6 kPa (b) 49.5kPa
(c) –30.6 kPa (d) –41.5kPa

Q.18 The equation of streamline for a two-dimensional flow described by $u = xe^{-kt}$ and $v = y$ is given by

(a) $y = Cxe^{kt}$ (b) $y = Cx^{e^{-kt}}$

(c) $y = Cx^{e^{kt}}$ (d) $y = Cxe^{-kt}$

where C is a constant.

Q.19 A 30 cm diameter pipe is required for a town's water supply. As pipes of this diameter were not available in the market, it was decided to lay two parallel pipes of equal diameter and same length. The diameter of the parallel pipe is______.

(**Note:** Discharge and headloss to remain same in both the cases)

(a) 157 mm (b) 219 mm
(c) 614 mm (d) 227 mm

Q.20 A glass sphere (R_d = 2.7) 1 mm in diameter is observed to have a fall velocity of 1.25 cm/s in an oil of density 920 kg/m^3. The coefficient of dynamic viscosity of the oil is

(a) 0.04 Pa.S
(b) 0.078 Pa.S
(c) 0.021 Pa.S
(d) Can't be determined

Q.21 If the bulk modulus of elasticity of a fluid is given as 1.5×10^9 Pa, then the increase in pressure required (in GPa) for the volume of this fluid to reduce by 6% would be

(a) 9 (b) 0.09
(c) 90000 (d) 9×10^7

Q.22 In a pipe of 300 mm diameter, the maximum velocity of flow is found to be 3.5 m/s. If the flow in the pipe is laminar, then the distance from the wall of pipe where local velocity becomes equal to average velocity is

(a) 4.39 cm (b) 4.11 cm
(c) 3.90 cm (d) 5.20 cm

Q.23 There is a river model of horizontal scale $\frac{1}{625}$ and vertical scale $\frac{1}{36}$. If the model discharge is 0.025 m^3/s, then determine the prototype discharge for the given distorted model.

(a) 3375 m^3/s (b) 3750 m^3/s
(c) 2275 m^3/s (d) 1460.25 m^3/s

Q.24 Water flows over a flat plate at a free stream velocity of 0.20 m/s. There is no pressure gradient and boundary layer thickness at the location is 8 mm. Assuming a sinusoidal velocity profile given by $\frac{u}{V_0} = \sin\frac{\pi}{2}\left(\frac{y}{\delta}\right)$

where, δ is the boundary layer thickness, V_0 is the free steam velocity and u is the velocity at a distance y from the wall. Determine the value of local shear stress at the wall, if $\mu = 1.02 \times 10^{-3}$ Ns/m^2 and ρ = 1000 kg/m^3

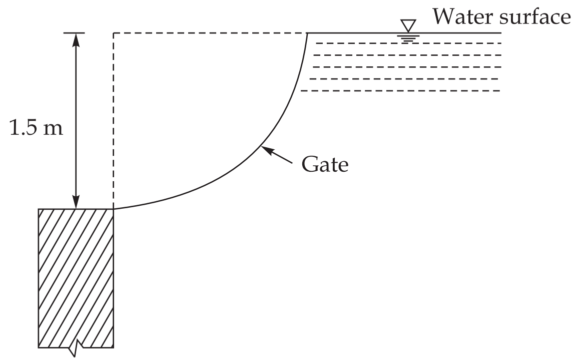
(a) 0.005 N/m^2 (b) 0.02 N/m^2
(c) 0.04 N/m^2 (d) 1.05 N/m^2

Q.25 Water is flowing in a rough pipe of 600 mm diameter and 1000 m length at the rate of 0.64 m^3/s. Assume the height of roughness projection as 0.20 mm. The value of wall shear stress is:

(a) 15.88 N/m^2 (b) 9.61 N/m^2
(c) 4.80 N/m^2 (d) 79.19 N/m^2

Q.26 A gate having a quadrant shape of radius 1.5 m is subjected to water pressure as shown in figure. The resultant force which will be acting on the gate if the width of gate is 3 m is:

(γ_w = 9.81 kN/m^3).



(a) 6.28 kN (b) 33.11 kN
(c) 61.65 kN (d) 52 kN

Q.27 An aeroplane weighing 40 kN is flying in a horizontal direction with a velocity of 540 km/hr. The aeroplane spans 20 m and wing surface area is 36 m^2. If drag coefficient C_D = 0.04 and for air. ρ = 1.20 kg/m^3, then the power required to drive the aeroplane is

(a) 3541 hp (b) 3720 hp
(c) 3909 hp (d) 4215 hp

Q.28 If δ_1 is the thickness of laminar boundary layer at a distance x_1 from the leading edge of the flat plate, then the thickness δ_2 at $x_2 = 2x_1$ is equal to

(a) $2\delta_1$ (b) $4\delta_1$
(c) $\delta_2^{1/2}$ (d) $\sqrt{2}\,\delta_1$

Q.29 The velocity distribution in a pipe is given by $v = V_{max}\left(1 - \frac{r}{R}\right)^n$ where R is the radius of the pipe, r is any radius at which the velocity is v and n is a constant index. The mean velocity V is given by

(a) $\frac{V_{max}}{(n+1)(n+2)}$ (b) $\frac{2V_{max}}{(n+1)(n+2)}$

(c) $\frac{V_{max}}{(n-1)(n+2)}$ (d) $\frac{2V_{max}}{(n-1)(n+2)}$

Q.30 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

■■■■

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FLUID MECHANICS

CIVIL ENGINEERING

Date of Test : 29/06/2024

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (d)

Kinetic energy correction factor is given by

$$\alpha = \frac{1}{AV^3}\int u^3 dA$$

2. (a)

Given, $\rho = 981 \text{ kg/m}^3$

and $\tau = 0.2452 \text{ N/m}^2$

Velocity gradient, $\frac{du}{dy} = 0.2 \text{ s}^{-1}$

Now, using the equation

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

$$\Rightarrow \quad 0.2452 = \mu \times 0.2$$

$$\Rightarrow \quad \mu = \frac{0.2452}{0.2} = 1.226 \text{ Ns/m}^2$$

Kinematic viscosity is given by

$$\nu = \frac{\mu}{\rho} = \frac{1.226}{981} = 0.125\times10^{-2} \text{ m}^2/\text{sec}$$

$$= 12.5 \text{ cm}^2/\text{sec}$$

$$= 12.5 \text{ stokes}$$

3. (a)

4. (b)

Given: Least radius of gyration,

$$k = 8 \text{ m}$$

Metacentric height, $GM = 70 \text{ cm} = 0.7 \text{ m}$

Time period of oscillation is given by

$$T = 2\pi\sqrt{\frac{k^2}{g(GM)}}$$

$$= 2\pi\sqrt{\frac{8\times8}{9.81\times0.7}}$$

$$= 19.18 \text{ sec}$$

5. (c)

For steady incompressible flow, the continuity equation

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

$$\frac{\partial u}{\partial x}\left(-\frac{\partial \phi}{\partial x}\right)+\frac{\partial}{\partial y}\left(-\frac{\partial \phi}{\partial y}\right)+\frac{\partial}{\partial z}\left(-\frac{\partial \phi}{\partial z}\right) = 0$$

$$\Rightarrow \quad \frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} + \frac{\partial^2 \phi}{\partial z^2} = 0 \quad \text{...(i)}$$

$$\nabla^2 \phi = 0$$

The above eq. (i) is a Laplace equation, thus any function ϕ which satisfies Laplace equation will represent some fluid flow i.e., satisfies continuity equation.

For no rotation:

$$\omega_z = 0$$

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

$$\Rightarrow \quad \frac{\partial v}{\partial x} = \frac{\partial u}{\partial y}$$

$$\frac{\partial^2 \psi}{\partial x^2} = -\frac{\partial^2 \psi}{\partial y^2}$$

$$\Rightarrow \quad \frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} = 0$$

$$\nabla^2 \psi = 0$$

If ψ (stream function) satisfies Laplace equation flow is irrotational.

6. (a)

At the stagnation point, $u = 0$ and $v = 0$

$\therefore \quad u = x + y + 1 = 0$

$\Rightarrow \quad x + y = -1 \quad$ ...(i)

and $\quad v = x - y - 2 = 0$

$\Rightarrow \quad x - y = 2 \quad$ ...(ii)

Solving eq. (i) and (ii)

$\Rightarrow \quad x = 0.5$

$y = -1.5$

$\therefore$ Stagnation point is (0.5, –1.5)

7. (c)

Continuity equation must be satisfied

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

$$\Rightarrow \frac{\partial}{\partial x}(ax + by) + \frac{\partial}{\partial y}(dx + cy) = 0$$

$$\Rightarrow \quad a + c = 0$$

8. (b)

For circular cylindrical jet of liquid,

$$\Delta P = \frac{\sigma}{R}$$

$$\Rightarrow \qquad R = \frac{\sigma}{\Delta P} = \frac{73\times10^{-3}}{40}$$

$$= 1.825 \times 10^{-3} \text{ m} = 1.825 \text{ mm}$$

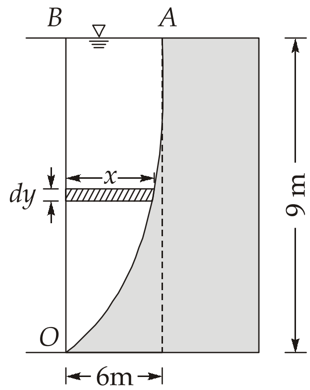
$$\therefore \qquad \text{Diameter} = 2R = 1.825 \times 2 = 3.65 \text{ mm}$$

9. (b)

10. (a)

Ideal fluid has zero viscosity.

11. (b)



Equation of curve OA is $y = y_0\left(\frac{x}{x_0}\right)^2 = 9\left(\frac{x}{6}\right)^2 = \frac{x^2}{4}$

$$\therefore \qquad x = \sqrt{4y}$$

$$x = 2\sqrt{y}$$

Length of dam = 6 m

Vertical thrust exerted by water,

$$F_v = \rho g V \qquad \text{(Weight of water in portion } ABO\text{)}$$

$$= \rho g \times \text{Area of } OAB \times \text{Length of dam}$$

$$= 1010\times9.81\times\left[\int_0^9 x\times dy\right]\times6$$

$$= 1010\times9.81\left[\int_0^9 2\sqrt{y}\,dy\right]\times6$$

$$= 1010\times9.81\times2\times\frac{2}{3}\times9^{3/2}\times6$$

$$= 2140149.6 \text{ N}$$

$$\therefore \qquad F_v = 2140.15 \text{ kN}$$

12. (d)

Given: Diameter of cylinder = 15 cm

$$\text{Radius} = \frac{15}{2} = 7.5 \text{ cm}$$

Height of cylinder = 100 cm

Initial height of water = 70 cm

When axial depth is zero, the depth of paraboloid is 100 cm

Using the relation, $Z = \dfrac{\omega^2 r^2}{2g}$

$\Rightarrow \quad 100 = \dfrac{\omega^2 \times 7.5^2}{2 \times 981}$

$\Rightarrow \quad \omega^2 = \dfrac{100 \times 2 \times 981}{7.5^2}$

$\Rightarrow \quad \omega = 59.05$ rad/sec

Speed, N is given by, $\omega = \dfrac{2\pi N}{60}$

$\Rightarrow \quad 59.05 = \dfrac{2\pi N}{60}$

$\Rightarrow \quad N = \dfrac{60 \times 59.05}{2 \times \pi}$

$\Rightarrow \quad N \simeq 564$ rpm

13. (b)

The pressure against the large and small piston is the same

Hence pressure in large piston,

$$p = \frac{W_1}{A} = \frac{22000N}{\frac{\pi}{4} \times 60^2}$$

$\Rightarrow \quad p = 7.78\ \text{N/mm}^2$

Let Q is the force required to be applied at small piston to the handle the weight W_1

$$Q = p \times A$$

$$= 7.78\ \text{N/mm}^2 \times \frac{\pi}{4} \times 20^2$$

$$= 2444.16\ \text{N}$$

For the handle, $\Sigma M_A = 0$

$\Rightarrow \quad 0 = (1.6 + 0.1) \times F - Q \times 0.1$

$\Rightarrow \quad 1.7F - 0.1Q = 0$

$\Rightarrow \quad F = \dfrac{0.1 \times 2444.16}{1.7}$

$= 143.77\ \text{N} \simeq 143.8\ \text{N}$

14. (d)

In steady uniform flow

Shear friction velocity, $V_* = \sqrt{\dfrac{\tau_0}{\rho}}$ ...(i)

Also, $$V_* = \sqrt{\frac{f}{8}} \times V_{avg} \quad \text{...(ii)}$$

From eq. (i) and (ii)

$$\sqrt{\frac{\tau_0}{\rho}} = \sqrt{\frac{f}{8}} \times V_{avg}$$

Squaring both sides, $$\frac{\tau_0}{\rho} = \frac{f}{8} \times V_{avg}^2$$

$$\Rightarrow \quad \tau_0 = \frac{0.024}{8} \times 2 \times 2 \times 1000$$

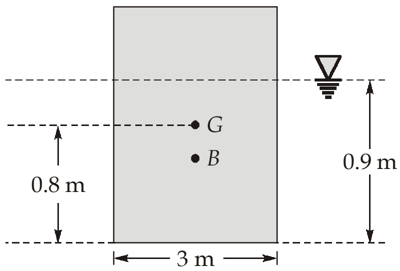
$$= 12 \text{ N/m}^2$$

15. (d)

When surface tension effect predominants in addition to inertia force, then Weber's model is used. When pressure force controls flow in addition to inertia force, then Euler's model is used. Mach model law is applicable in case of aerodynamics testing.

16. (b)

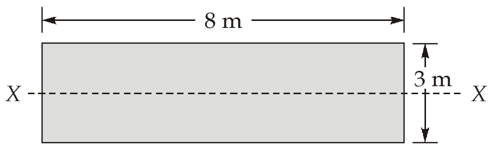
Metacentric height is given as GM = BM – BG



$$BG = 0.8 - \frac{0.9}{2}$$

$$= 0.8 - 0.45$$

$$= 0.35 \text{ m}$$

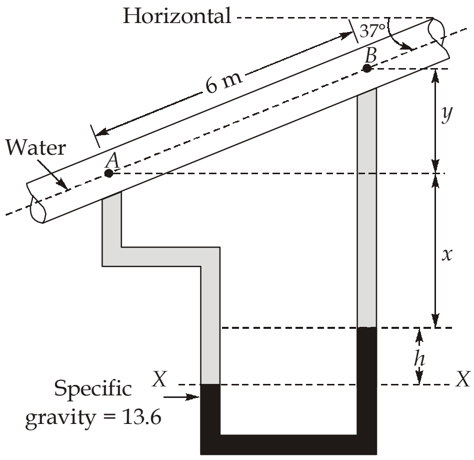


Top view

$$BM = \frac{I}{\forall} = \frac{18}{21.6} = 0.833 \text{ m} \qquad \left[\begin{array}{l} I_{xx} = \dfrac{8 \times 3^3}{12} = 18 \text{ m}^4 \\ \forall_{disp} = 8 \times 3 \times 0.9 = 21.6 \text{ m}^3 \end{array}\right]$$

$$\therefore \quad GM = 0.833 - 0.35 = 0.483 \text{ m}$$

17. (d)



Equating the pressures on both the limbs at the horizontal plane XX (y = 6 sin37 = 3.6 m)

$P_A + 9.81 \times x + 9.81 \times 0.05 = P_B + 9.81 \times 3.6 + 9.81 \times x + 13.6 \times 9.81 \times 0.05$

$$\Rightarrow \quad P_A + 0.4905 = P_B + 35.316 + 6.6708$$

$$\Rightarrow \quad P_B - P_A = -41.4963 \text{ kN/m}^2 \simeq -41.5 \text{ kN/m}^2$$

18. (c)

Given: $u = xe^{-kt}$ and $v = y$

Equation of a streamline is given by

$$\frac{dx}{u} = \frac{dy}{v}$$

$$\Rightarrow \quad \frac{dx}{xe^{-kt}} = \frac{dy}{y} \qquad \left[\text{Let } e^{-kt} = \lambda\right]$$

$$\Rightarrow \quad \frac{dx}{xk} = \frac{dy}{y}$$

$$\therefore \quad \ln x = k \ln y + \ln d$$

where 'd' is a constant.

$$\Rightarrow \quad \ln x = \ln y^{\lambda} + \ln d$$

$$\Rightarrow \quad x = dy^{\lambda}$$

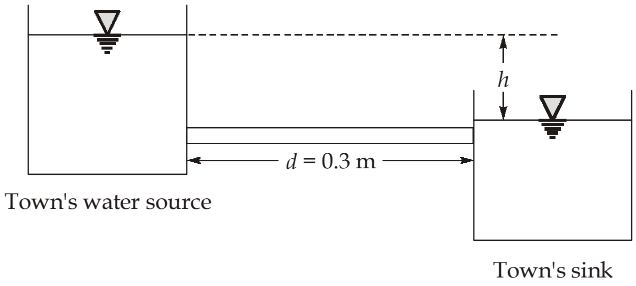
$$\Rightarrow \quad y^{\lambda} = \frac{1}{d}x$$

$$\Rightarrow \quad y = \left(\frac{1}{d}\right)^{1/\lambda} x^{1/\lambda} = Cx^{1/e^{-kt}} \qquad \left[\text{where } \left(\frac{1}{d}\right)^{1/\lambda} = C\right]$$

$$\Rightarrow \quad y = Cx^{e^{kt}}$$

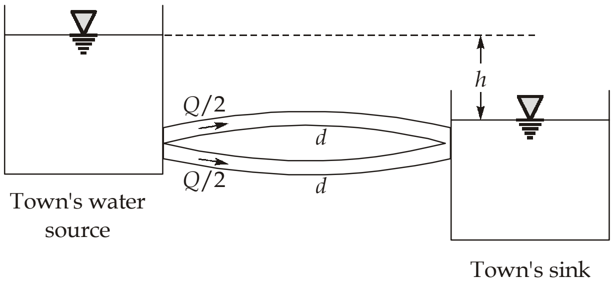
19. **(d)**

Case 1: Single pipe connection



$$h = \frac{flQ^2}{12(0.3)^5} \quad \text{... (i)}$$

Case 2: Dual pipe connection



$$h = \frac{fl(Q/2)^2}{12d^5} \quad \text{... (ii)}$$

Using (i) and (ii)

$$\frac{flQ^2}{12(0.3)^5} = \frac{fl(Q/2)^2}{12d^5}$$

$\Rightarrow$ $d = 0.2274 \text{ m} = 22.74 \text{ cm}$

$\Rightarrow$ $\text{d} = 227.4 \text{ mm} \simeq 227 \text{ mm}$

20. **(b)**

Given data:

Relative density of glass sphere = 2.7

Diameter of glass sphere = 1 mm

Velocity of sphere = 1.25 cm/s

Density of oil = 920 kg/m^3

$$\text{Reynold's number} = \frac{\rho v d}{\mu}$$

Let us assume that Stokes' law is valid then,

$$V = \frac{1}{18} D^2 \left(\frac{\gamma_s - \gamma_f}{\mu}\right)$$

$$\frac{1.25}{100} = \frac{1}{18} \times \frac{(10^{-3})^2 (2.7 \times 1000 \times 9.81 - 920 \times 9.81)}{\mu}$$

$$\mu = 0.0776 \text{ Pa.S}$$

$$\text{Reynold's number} = \frac{\rho VD}{\mu} = \frac{920 \times \frac{1.25}{100} \times 10^{-3}}{0.0776} = 0.148 < 1$$

Hence Stokes law is valid.
Therefore dynamic viscosity, μ = 0.0776 Pa.S

21. (b)

Let V be the volume of fluid

$$\therefore \quad dV = \frac{-6}{100} \times V$$

$$\Rightarrow \quad \frac{-dV}{V} = 0.06$$

$$\therefore \quad \text{Increase in pressure } \Delta P = \frac{-\Delta V}{V} \times K$$

$$= 1.5 \times 10^9 \times 0.06 \text{ Pa}$$

$$= 0.090 \text{ GPa}$$

22. (a)

Distance from the centre where average velocity equal is to local velocity $= \frac{R}{\sqrt{2}}$

$\therefore$Distance from boundary of pipe $= R - \frac{R}{\sqrt{2}} = 150\left(1 - \frac{1}{\sqrt{2}}\right) \text{ mm} = 4.39 \text{ cm}$

23. (a)

$$\text{Discharge ratio,} \quad Q_r = \frac{Q_m}{Q_p} = L_{r_h}\left(L_{r_v}\right)^{3/2}$$

$$= \frac{1}{625} \times \left(\frac{1}{36}\right)^{3/2} = \frac{1}{135000}$$

$$\therefore \quad Q_p = \frac{Q_m}{Q_\gamma} = 0.025 \times 135000$$

$$= 3375 \text{ m}^3/\text{s}$$

24. (c)

$$u = V_0 \sin\frac{\pi}{2}\left(\frac{y}{\delta}\right)$$

$$\therefore \quad \frac{du}{dy} = V_0 \cos\frac{\pi}{2}\left(\frac{y}{\delta}\right) \times \frac{\pi}{2\delta}$$

$$\text{Local shear stress,} \quad \tau_0 = \mu\left(\frac{du}{dy}\right)_{y=0}$$

$$= \mu \times \frac{V_0 \pi}{2\delta}$$

$$= 1.02\times10^{-3}\times\frac{0.20\times\pi}{2\times8\times10^{-3}}$$

$$= 0.04 \text{ N/m}^2$$

25. (b)

For rough pipe,
$$\frac{1}{\sqrt{f}} = 2\log_{10}\left(\frac{R}{k_s}\right)+1.74$$

$$= 2\log_{10}\left(\frac{0.30}{0.20\times10^{-3}}\right)+1.74 = 8.09$$

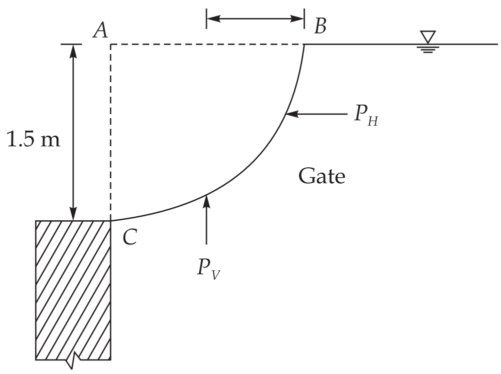
$$f = 0.015$$

$$\tau_{wall} = \rho\frac{fV^2}{8}$$

where,
$$V = V_{avg} = \frac{Q}{A} = \frac{0.64}{\frac{\pi}{4}\times0.6^2} = 2.264 \text{ m/s}$$

$\therefore$
$$\tau_{wall} = \frac{1000\times0.015\times2.264^2}{8} = 9.61 \text{ N/m}^2$$

26. (c)



P_H = Force on the projected area of the curved surface on vertical plane
= Force on AC
= Pressure at CG of plate × Projected area of plate

$$= \gamma_w\times\frac{1.50}{2}\times1.5\times3 = 3.375\ \gamma_w \text{ kN}$$

Vertical force, P_V = Weight of water supported by BC

$$= \gamma_w\times\frac{\pi r^2}{4}\times\text{width} = \gamma_w\times\frac{\pi\times1.5^2}{4}\times3$$

$$= 5.301\ \gamma_w \text{ kN}$$

Resultant force $= \sqrt{(3.375\gamma_w)^2+(5.301\gamma_w)^2}$

$= 6.284\ \gamma_w$

$$= 61.65 \text{ kN}$$

27. (c)

Power required to drive the aeroplane =Drag force × Velocity

Drag force, $$F_D = C_d \times \frac{\rho V^2}{2} \times A$$

$$= \frac{0.04 \times 1.2}{2} \times \left(\frac{540 \times 1000}{3600}\right)^2 \times 36$$

$$= 19.44 \times 10^3 \text{ N}$$

∴ $$P = 19.44 \times 10^3 \times 150 = 2916 \text{ kW}$$

$$= \frac{2916}{0.746} = 3908.85 \text{ hp}$$

28. (d)

For a laminar boundary layer

$$\frac{\delta}{x} = \frac{5}{\sqrt{R_{ex}}}$$

⇒ $$\frac{\delta}{x} = \frac{5}{\sqrt{\frac{\rho v x}{\mu}}}$$

∴ $$\delta \propto \sqrt{x}$$

∴ $$\frac{\delta_2}{\delta_1} = \sqrt{\frac{2x_1}{x_1}} \Rightarrow \delta_2 = \sqrt{2}\,\delta_1$$

29. (b)

The velocity of flow V is given by

$$Q = \pi R^2 V = \int_0^R 2\pi r\, V_{\max}\left(1 - \frac{r}{R}\right)^n dr$$

$$Q = \frac{2\pi R^2 V_{\max}}{(n+1)(n+2)}$$

$$V = \frac{Q}{A} = \frac{2V_{\max}}{(n+1)(n+2)}$$

and $$\frac{v}{V} = \frac{(n+1)(n+2)}{2}\left(1 - \frac{r}{R}\right)^n$$

30. (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.

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