7
CHAPTER

Fluid Dynamics

Q.1 A Pitot-static tube, with a coefficient of velocity 0.98 is used to measure the velocity of water in a pipe. The stagnation pressure recorded is 3 m and the static pressure is 0.5 m. What is the velocity of flow?
(a) 7.2 m/s (b) 6.9 m/s
(c) 5.9 m/s (d) 5.2 m/s

Q.2 The integral momentum equation requires the following assumption in the flow
(a) uniform (b) unidirectional
(c) incompressible (d) steady

Q.3 To avoid the tendency of separation of flow at the throat in a Venturimeter, the ratio of the diameter of the throat to the diameter of the pipe should be
(a) 1/16 to 1/8 (b) 1/8 to 1/4
(c) 1/4 to 1/3 (d) 1/3 to 1/2

Q.4 A pipe of length more than double the diameter of the orifice fitted internally or externally to the orifice is called
(a) notch (b) weir
(c) mouthpiece (d) nozzle

Q.5 A fluid jet discharging from a 4 cm diameter orifice has a diameter 3 cm at its vena contracta. If the coefficient of velocity is 0.98, the coefficient of discharge for the orifice will be
(a) $0.98 \times (0.75)^2$ (b) $(0.75)^2/0.98$
(c) $0.98 \times (1.33)^2$ (d) $0.98/(1.33)^2$

Q.6 The coefficient of velocity for an orifice is given by (using usual notation)
(a) $\frac{x}{2\sqrt{yH}}$ (b) $\frac{2x}{\sqrt{yH}}$
(c) $\frac{x}{\sqrt{yH}}$ (d) $\sqrt{\frac{x^2}{2yH}}$

Q.7 If C_v, C_c, D_d and C_r are the hydraulic coefficients of an orifice, then
(a) $C_d = C_c C_v$ (b) $C_r = 1 + C_v^2/C_d$
(c) $C_v = C_c + C_d$ (d) $C_c = C_v/C_d$

Q.8 Match List-I with List-I and select the correct answer using the codes given below the lists:

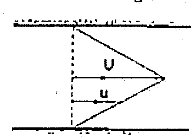
List-I
A. Moment of momentum equation
B. Bernoulli's equation
C. Euler's equation
D. Hagen-Poiseuilles-equation

List-II
1. Equation for energy loss in a pipeline
2. Equation of motion for one-dimensional steady flow of ideal and incompressible fluid
3. Equation based on conservation of momentum principle applicable to circulatory flows
4. Three-dimensional equation of motion based on principle of conservation of momentum for ideal and incompressible fluid flow

Codes:

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

Q.9 The momentum correction factor for triangular velocity distribution for flow between parallel plates as shown in the figure is



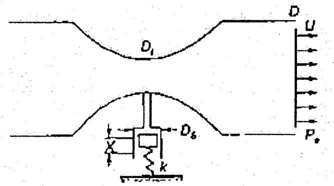
(a) 2.00 (b) 1.50
(c) 1.33 (d) 1.00

Q.10 If the coefficient of velocity of flow through a orifice is c_v and coefficient of resistance is c_r, then

(a) $C_v = \sqrt{\frac{1}{1+C_r}}$ (b) $C_v = \left(\frac{1}{C_r^2} - 1\right)$

(c) $C_v = \sqrt{\frac{1}{1-C_r}}$ (d) $C_v = \left(\frac{1}{C_r^2} + 1\right)$

Q.11 Air flows through a venturi and into atmosphere. Air density is ρ; atmospheric pressure is p_a; throat diameter is D_t; exit diameter is D and exit velocity is U. The throat is connected to a cylinder containing a frictionless piston attached to a spring. The spring constant is k. The bottom surface of the piston is exposed to atmosphere. Due to the flow, the piston moves by distance x. Assuming incompressible frictionless flow, x is



(a) $\left(\frac{\rho U^2}{2k}\right)\pi D_s^2$

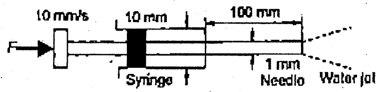
(b) $\left(\frac{\rho U^2}{8k}\right)\left(\frac{D^2}{D_t^2} - 1\right)\pi D_s^2$

(c) $\left(\frac{\rho U^2}{2k}\right)\left(\frac{D^2}{D_t^2} - 1\right)\pi D_s^2$

(d) $\left(\frac{\rho U^2}{8k}\right)\left(\frac{D^4}{D_t^4} - 1\right)\pi D_s^2$

Data for Q. 12-13 are given below. Solve the problem and choose the correct answer.

A syringe with a frictionless plunger contains water and has at its end a 100 mm long needle of 1 mm diameter. The internal diameter of the syringe is 10 mm. Water density is 1000 kg/m^3. The plunger is pushed in at 10 mm/s and the water comes out as a jet.



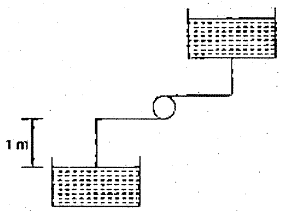
Q.12 Assuming ideal flow, the force F in newtons required on the plunger to push out the water is

(a) 0 (b) 0.04
(c) 0.13 (d) 1.15

Q.13 Neglect losses in the cylinder and assume fully developed laminar viscous flow throughout the needle; the Darcy friction factor is $64/R_e$, where Re is the Reynolds number. Given that the viscosity of water is 1.0×10^{-3} kg/s-m, the force F in newtons required on the plunger is

(a) 0.13 (b) 0.16
(c) 0.3 (d) 4.4

Q.14 A horizontal - shaft centrifugal pump lifts water at 65°C. The suction nozzle is one meter below pump center line. The pressure at this point equals 200 kPa gauge and velocity is 3 m/s. Steam tables show saturation pressure at 65°C is 25 kPa, and specific volume of the saturated liquid is 0.001020 m^3/kg. The pump's net positive suction head (NPSH) in meters is



(a) 24 (b) 26
(c) 28 (d) 30

Q.15 Assertion (A): A Pitot tube works on the principle of converting kinetic energy into potential energy.
Reason (R): The oncoming upstream velocity of fluid decelerates and comes to rest at the stagnation point at the tip of the Pitot tube.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

Q.16 In a real-fluid flow through a pipe, the hydraulic grade line

(a) always slopes in the direction of flow
(b) is always above the centre line of the pipe
(c) is always below the datum line
(d) is always below the centre line of the pipe

Q.17 The energy loss in flow through orifice is given by

(a) $H(1 - w^2)$ (b) $H(w^2 - 1)$

(c) $H\left(1 - \frac{1}{w^2}\right)$ (d) $H\left(\frac{1}{w^2} - 1\right)$

Q.18 Which of the following equations are used to develop Rayleigh lines?

(a) momentum and energy
(b) energy and continuity
(c) momentum and continuity
(d) momentum, energy and continuity

Q.19 Time of emptying liquid from a hemispherical vessel through an orifice at its bottom, is

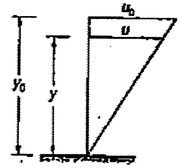
(a) $\frac{\pi R^{3/2}}{15 C_d a\sqrt{2g}}$ (b) $\frac{2\pi R^{3/2}}{15 C_d a\sqrt{2g}}$

(c) $\frac{7\pi R^{3/2}}{15 C_d a\sqrt{2g}}$ (d) $\frac{14\pi R^{5/2}}{15 C_d a\sqrt{2g}}$

Q.20 The time taken for a tank (filled to a height H above its flat base) to empty through an orifice in the base varies as the following power of H

(a) 1 (b) 1/2
(c) -1/2 (d) -1

Q.21 The momentum correction factor for the velocity distribution shown in figure is



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

Q.22 When a particular discharge is flowing in a horizontal pipe, a mercury-water U-tube manometer connected to the entrance and throat of a venturimeter fitted in the pipe recorded a deflection of 25 cm. If the same discharge flowed through the same pipe kept at an inclination of 45° to the horizontal, then the corresponding deflection by the U-tube manometer will be

(a) $25\sqrt{2}$ cm (b) $25/\sqrt{2}$ cm
(c) 25/2 cm (d) 25 cm

Q.23 The time required to empty a concrete tank through a rectangular weir at the side from a head of 16 cm to 8 cm over the crest was found to be 16 minutes. The time required to empty if further up to the crest will be

(a) 16 minutes (b) 24 minutes
(c) 256 minutes (d) infinite

Q.24 Least possible value of correction factor for

1. Kinetic energy is zero
2. Kinetic energy is 1
3. Momentum is zero
4. Momentum is 1

The correct statements are

(a) 1 and 3 (b) 2 and 3
(c) 1 and 4 (d) 2 and 4

Q.25 In the most general form of Bernoulli's equation

$\frac{P}{w} + \frac{V^2}{2g} + z =$ constant, each term represents

(a) energy per unit mass
(b) energy per unit weight
(c) energy per unit volume
(d) None of these

Q.26 Which of the following is an incorrect statement?
(a) Coefficient of contraction of a venturimeter is unity.
(b) Flow nozzle is cheaper than venturimeter but has higher energy loss.
(c) Discharge is independent of orientation of venturimeter whether it is horizontal, vertical or inclined.
(d) None of the above statements are correct.

Q.27 When no external energy is imposed, which of the following statements would be true?
1. Energy line always falls in the direction of flow.
2. Hydraulic gradient line never rises in the direction of flow.
3. Specific energy may increase or decrease in the direction of flow.
4. Energy line and hydraulic gradient line can cross each other.

Select the correct answer using the codes given below:
Codes:
(a) 1 and 2 (b) 2 and 3
(c) 3 and 4 (d) 1 and 3

Q.28 A horizontal pipe reduces from 10 cm to 5 cm in diameter. If the pressure head at 10 cm section is 10 metres and velocity head is 1 meter, then
(a) total head at any point is 11 metres
(b) pressure head at the 5 cm section is negative
(c) discharge varies proportionate to the diameter
(d) datum head at all sections is constant

Q.29 Which one of the following statements is not correct?
(a) In free votex flow, streamlines are concentric spirals and grow continuously in circles
(b) In free vortex flow, the velocity is in tangential direction only and varies inversely as the distance from the origin.
(c) In a free vortex, flow is rotational at the core and irrotational away from it.
(d) In a forced vortex, flow is rotational, that is, fluid particles undergo rotation about their mass centre.

Q.30 The momentum correction factor (β) is used to account for
(a) change in the direction of flow
(b) change in total energy
(c) change in mass rate of flow
(d) non-uniform distribution of velocities

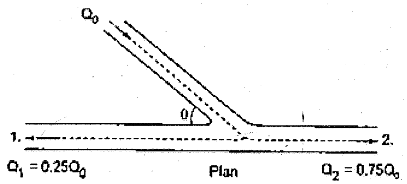
Q.31 Consider the following statements:
1. In Lagrangian method of describing the motion of fluid, an observer concentrates on a point in the fluid system.
2. The components of acceleration of the fluid particle are $\frac{Vdv}{dS}$ and $\frac{dv}{dt}$.
3. A particle moving in a curved path will always have a normal acceleration $\frac{V^2}{r}$ towards the centre of the curved path.

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

Q.32 A venturimeter in an oil [sp. gr. = 0.8] pipe is connected to a differential manometer in which gauge liquid is mercury. For a flow of 0.16 m^3/s, the manometer registered a gauge differential of 20 cm. The oil mercury manometer being unavailable, an air oil differential manometer is connected to the same venturimeter. What is the new gauge differential for a flow rate of 0.08 m^3/s
(a) 64 cm (b) 68 cm
(c) 80 cm (d) 85 cm

Q.33 A 30 cm diameter 90° elbow has limb vertical. Average velocity of flow of water through the elbow is 5 m/s and the pressure intensity is 4 kPa. Neglecting the effect of weight the vertical component of force to keep the elbow in position will be
(a) 0.28 kN (b) 1.49 kN
(c) 1.77 kN (d) 2.05 kN

Q.34 A horizontal jet strikes a frictionless vertical plate. It is than divided into 1:3 ratio as shown in figure. If the impact loss is neglected, what is the value of θ.



(a) 15° (b) 30°
(c) 45° (d) 60°

Q.35 In a siphon, the summit is 4 m above the water level in the reservoir from which the flow is being discharged out. If the head loss from the inlet of the siphon to the summit is 2 m and the velocity head at the summit is 0.5 m the pressure at the summit is
(a) –63.77 kPa
(b) –9.0 m of water
(c) 6.5 m of water (cabs)
(d) –39.16 kPa

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Answers Fluid Dynamics

1. (b)	2. (c)	3. (d)	4. (c)	5. (a)	6. (a)	7. (a)	8. (d)	9. (c)	10. (a)
11. (d)	12. (b)	13. (c)	14. (a)	15. (d)	16. (b)	17. (a)	18. (c)	19. (d)	20. (b)
21. (c)	22. (d)	23. (d)	24. (d)	25. (b)	26. (d)	27. (d)	28. (d)	29. (a)	30. (d)
31. (d)	32. (c)	33. (d)	34. (b)	35. (a)					

Explanations Fluid Dynamics

1. (b)

$$V = C_v\sqrt{2g(p_{stag} - p_{static})}$$

$$= 0.98 \times \sqrt{2 \times 9.81 \times (3-05)}$$

$$= 6.86 \text{ m/s} \simeq 6.9 \text{ m/s}$$

3. (d)

The ratio of throat to inlet diameters d_2/d_1 may range between 0.75 and 0.25, but the most commonly used ratio is 0.50

A smaller ratio gives a higher difference in the piezometric heads (between the inlet and the throat) which can be measured more accurately by a differential manometer. At the same time, a smaller throat (that is a lower d_2/d_1 ratio) will mean higher throat velocities which may cause pressures low enough to liberate dissolved gases thereby creating conditions for cavitation to set in.

5. (a)

For an orifice, the coefficient of discharge C_d, coefficient of velocity C_v and coefficient of contraction C_c is related as

$$C_d = C_c \times C_v$$

8. (d)

A-3; B-2; C-4; D-1

Bernoulli's equation is derived from equation of motion for one-dimensional steady flow of ideal and incompressible fluid.

9. (c)

Triangular velocity distribution is achieved for Couette flow.

Average velocity $V_{av} = \frac{V}{2}$

Momentum correction factor

$$\beta = \frac{1}{h}\int_0^h\left(\frac{V}{V_{av}}\right)^2 dy = \frac{4}{3}$$

Energy correction factor

$$\alpha = \frac{1}{h}\int_0^h \left(\frac{V}{V_{av}}\right)^3 dy = 2.0$$

10. (a)

$$C_v = \sqrt{\frac{1}{1+C_f}} \Rightarrow C_f = \frac{1}{C_v^2} - 1$$

11. (d)

Applying continuity equation, we get

$$A_1V_1 = A_2V_2$$

$$\Rightarrow \quad V_1 = \left(\frac{A_2}{A_1}\right)V_2 = \left(\frac{\frac{\pi}{4}D^2}{\frac{\pi}{4}D_t^2}\right)U$$

$$V_1 = \left(\frac{D}{D_t}\right)^2 U \quad \text{...(i)}$$

Applying Bernoulli's equation

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} = \frac{p_2}{\rho g} + \frac{V_2^3}{2g}$$

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

$$\therefore \quad p_1 - p_2 = \frac{\rho}{2}(V_2^2 - V_1^2)$$

From equation (i)

$$p_1 - p_2 = \frac{\rho}{2}\left[U^2 - \left(\frac{D}{D_t}\right)^4 U^2\right]$$

$$= \frac{\rho}{2}U^2\left[1 - \left(\frac{D}{D_t}\right)^4\right] \quad \text{...(ii)}$$

Since, spring force = pressure force due to air

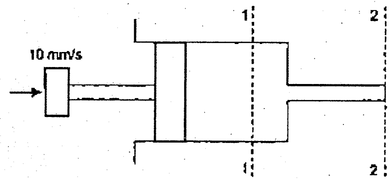
$$-kx = \frac{\pi}{4}D_s^2 \times (p_1 - p_2)$$

From equation (ii)

$$-kx = \frac{\pi}{4}D_s^2 \times \frac{\rho U^2}{2}\left[1 - \left(\frac{D}{D_t}\right)^4\right]$$

$$\therefore \quad x = \frac{\rho U^2}{8k}\left[\left(\frac{D}{D_t}\right)^4 - 1\right]\pi D_s^2$$

12. (b)



Applying continuity equation at point 1 and 2, we get

$$A_1V_1 = A_2V_2$$

$$V_2 = \left(\frac{A_1}{A_2}\right)V_1$$

$$V_1 = \frac{\frac{\pi}{4}\times(0.01)^2}{\frac{\pi}{4}\times(0.001)^2}\times 0.01$$

$$= 1 \text{ m/s}$$

Applying Bernoulli's equation at point 1 and 2, we get

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2$$

Since $z_1 = z_2$

and $p_2 = 0$ (atmospheric)

$$\therefore \quad \frac{p_1}{\rho g} = \frac{V_2^2 - V_1^2}{2g}$$

$$p_1 = \frac{\rho}{2}(V_2^2 - V_1^2)$$

$$= \frac{1000}{2}\left[(1)^2 - (0.01)^2\right]$$

$$= 499.95 \text{ N/m}^2$$

Force required on plunger

$$= p_1 \times A_1$$

$$= 499.95 \times \frac{\pi}{4} \times (0.01)^2$$

$$= 0.04 \text{ N}$$

13. (c)

$$R_e = \frac{\delta V_2 d_2}{\mu}$$

$$= \frac{1000 \times 1 \times 0.001}{1 \times 10^{-3}}$$

$$R_e = 1000$$

Now Darcy's friction factor,

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

$$f = 0.064$$

Head loss in needle,

$$h_f = \frac{fLV^2}{2gd}$$

$$= \frac{0.064 \times 0.1 \times (1)^2}{2 \times 9.81 \times 0.001}$$

$$= 0.3265 \text{ m of water}$$

Applying Bernoulli's equation at points 1 and 2, we get

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + h_f$$

Since $z_1 = z_2$

and $p_2 = 0$ (atmospheric)

$$\frac{p_1}{\rho g} = \left(\frac{V_2^2 - V_1^2}{2g}\right) + h_f$$

$$p_1 = \frac{\rho}{2}(V_2^2 - V_1^2) + \rho g h_f$$

$$= \frac{1000}{2}\left[(1)^2 - (0.01)^2\right] + 1000 \times 9.81 \times 0.3265$$

$p_1 = 3702.915 \text{ N/m}^2$

Force required on plunger

$$= p_1 \times A_1 = 3702.915 \times \frac{\pi}{4} \times (0.01)^2 = 0.3 \text{ N}$$

14. (a)

Net pressure difference

$$= 200 - (-25) \text{ kPa}$$

$$= 225 \text{ kPa} = 2.25 \text{ bar}$$

$$= \frac{2.25 \times 10.33}{1.013} \text{ m of water}$$

$$= 22.95 \text{ m of water}$$

Static head = 1 m

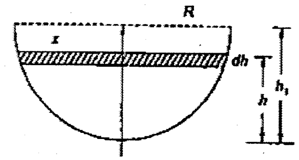
∴ Total net positive suction head (NPSH)

= pressure head + static head

= 22.95 + 1

= 23.95 = 24 m of water

19. (d)



$$A = \pi x^2$$

$$x = \sqrt{2Rh - h^2}$$

$$t = -\frac{\pi}{C_d a\sqrt{2g}}\int_{h_1}^{0}\frac{2Rh - h^2}{\sqrt{h}}dh$$

$$t = \frac{14\pi R^{5/2}}{15 C_d a\sqrt{2g}}$$

20. (b)

For a tank containing liquid upto a height 'H', for emptying the tank completely, time required is T

where, $T = \frac{2A\sqrt{H}}{C_d a\sqrt{2g}}$

where, A = area of tank

a = area of the orifice

H = initial height of liquid

C_d = coefficient of discharge

21. (c)

$$\beta = \frac{1}{A}\int\left(\frac{u}{v}\right)^2 dA$$

$$v = \frac{u_0}{2}$$

$$u = \frac{u_0}{y_0} \times y$$

22. (d)

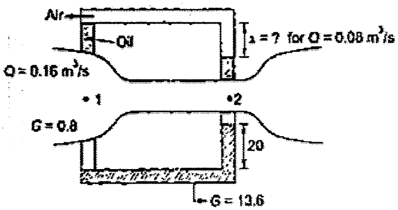
Discharge does not depend upon the orientation of venturimeter.

23. (d)

$$\frac{t_2}{t_1} = \frac{\int_8^0 \frac{1}{H^{3/2}}dH}{\int_{16}^8 \frac{1}{H^{3/2}}dH}$$

$$t_2 < 0$$

32. **(c)**



For air-oil $P_1 - P_2 = G_1\gamma_w x$

$$H = \left(\frac{P_1}{\gamma} + z_1\right) - \left(\frac{P_1}{\gamma} + z_2\right)$$

$$h = \frac{P_1 - P_2}{\gamma_{oil}} = \frac{G_1\gamma_w x}{G_1\gamma_w} = x$$

For mercury-oil

$$l = \left(\frac{G_2}{G_1} - 1\right)x$$

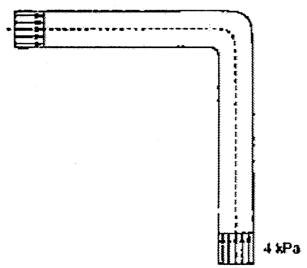
$$= \left(\frac{13.6}{0.8} - 1\right) \times 0.2 = 3.2$$

$\therefore$ $$Q = C\sqrt{h}$$

$$\frac{0.16}{0.8} = \frac{C\sqrt{3.2}}{C\sqrt{x}}$$

$\Rightarrow$ $$x = 80\text{ cm}$$

33. **(d)**



$$F_x = \rho Q(O - v)$$
$$= -\rho Q v$$
$$= -1000 \times \frac{\pi}{4} \times 0.3^2 \times 5 \times 5$$
$$= -1765\text{ N}$$
$$P_A + R_x = -1765\text{ N}$$
$$R_x + 4000 \times \frac{\pi}{4} \times 0.3^2 = -1765$$
$$R_x = 2.047\text{ kN}$$
$$F_y = \rho Q[v - o] = 1765\text{ kN}$$
$$-PA + R_y = 1765$$
$\Rightarrow$ $$R_y = 1765 + \frac{\pi}{4} \times (0.3)^2 \times 4000$$
$$R_y = 2.05\text{ kN} \downarrow$$

34. **(b)**

As the plate is frictionless, no force can be applied in the plane of plate (i.e., effects will be zero).

Impact lost neglected.

Hence applying energy eq. between (i) and (ii)

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z + \cancel{h_L}^{\,0}$$

$\Rightarrow$ $$V_1 = V_2$$

Now, $$F_x = 0$$

$$\rho \times 0.7QV - \rho \times 0.25QV - (\rho QV\sin\theta) = 0$$

$\Rightarrow$ $$\theta = 30^\circ$$

35. **(a)**

$$\frac{P_1}{\rho_1 g} + Z_1 + \frac{V_1^2}{2g} = \frac{P_2}{\rho_2 g} + Z_2 + \frac{V_2^2}{2g} + h_L$$

$\Rightarrow$ $$0 = \frac{P_2}{\rho g} + 4 + 0.5 + 2$$

$\Rightarrow$ $$\frac{P_2}{\rho g} = -63.77\text{ kPa}$$

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