6
CHAPTER

Fluid Kinematics

Q.1 Normal acceleration in fluid-flow situations exists only when
(a) the streamlines are straight and parallel
(b) the flow is two-dimensional
(c) the streamlines are curved
(d) the flow is unsteady

Q.2 A flownet is a graphical representation of streamlines and equipotential lines such that
(a) these lines indicate the direction and magnitude of velocity vector
(b) these lines intersect each other orthogonally forming curvilinear squares
(c) these lines intersect each other at various different angles forming irregular shaped nets
(d) the velocity potential increases in the direction of flow

Q.3 Stream lines, streak lines and path lines are all identical in case of
(a) uniform flow (b) steady flow
(c) unsteady flow (d) non-uniform flow

Q.4 Match List-I (Format of representation) with List-II (Context/Relevant to) and select the correct answer using the codes given below the lists:

List-I

A. $\frac{\delta u}{\delta x}+\frac{\delta v}{\delta y}$

B. $\frac{\delta v}{\delta x}-\frac{\delta u}{\delta y}$

C. $u\frac{\delta u}{\delta x}+v\frac{\delta v}{\delta y}$

D. $\frac{q\theta}{2\pi}$

List-II
1. Relevant to a velocity potential
2. Rate of rotation about a relevant axis
3. Pressure gradient in a relevant direction
4. Continuity of flow

Codes:

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

Q.5 In a converging steady flow, there is
(a) no acceleration
(b) no temporal acceleration
(c) only convective acceleration
(d) convective and temporal acceleration

Q.6 The concept of stream function which is based on the principle of continuity is applicable to
(a) three dimensional flow
(b) two dimensional flow
(c) uniform flow cases only
(d) irrotational flow only

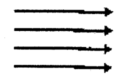
Q.7 The continuity equation for steady incompressible flow is expressed in vector notation as
(a) $\nabla . q = 0$ (b) $\nabla^2 . q = 0$
(c) $\nabla \times q = 0$ (d) $\nabla^2 \times q = 0$

Q.8 The Toricelli theorem gives velocity of jet as
(a) $\sqrt{gh}$ (b) $\sqrt{2gh}$
(c) $\frac{1}{\sqrt{2gh}}$ (d) $\sqrt{\frac{2gh}{3}}$

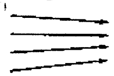
Q.9 Match List-I (stream line pattern) with List-II (type of acceleration) and select the correct answer using the code given below the lists:

List-I

A. Straight parallel stream line

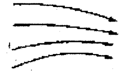


B. Straight converging straight line



C. Concentric stream line

D. Curved converging stream line



List-II
1. No acceleration
2. Convective normal acceleration
3. Convective tangential acceleration
4. Both tangential and normal convective acceleration

Codes:

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

Q.10 Both free vortex and forced vortex flow can be expressed mathematically in terms of tangential velocity v at the corresponding radius r. Choose the correct combination.

	Free vortex	Forced vortex
(a)	$v = r$ = constant	vr = constant
(b)	v^2r = constant	$v = r$ constant
(c)	vr = constant	$v^2 = r$ constant
(d)	vr = constant	$v = r$ constant

Q.11 For a fluid flow through a divergent pipe of length L having inlet and outlet radii of R_1 and R_2 respectively and a constant flow rate of Q, assuming the velocity to be axial and uniform at any cross-section, the acceleration at the exit is

(a) $\frac{2Q(R_1-R_2)}{\pi L R_2^3}$ (b) $\frac{2Q^2(R_1-R_2)}{\pi L R_2^3}$

(c) $\frac{2Q^2(R_1-R_2)}{\pi^2 L R_2^5}$ (d) $\frac{2Q^2(R_2-R_1)}{\pi^2 L R_2^5}$

Q.12 The velocity profile in fully developed laminar flow in a pipe of diameter D is given by $u = u_0(1-4r^2/D^2)$, where r is the radial distance from the center. If the viscosity of the fluid is μ the pressure drop across a length L of the pipe is

(a) $\frac{\mu u_0 L}{D^2}$ (b) $\frac{4\mu u_0 L}{D^2}$

(c) $\frac{8\mu u_0 L}{D^2}$ (d) $\frac{16\mu u_0 L}{D^2}$

Q.13 Consider the following equations :
1. $A_1 v_1 = A_2 v_2$
2. $\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0$
3. $\int_S \rho v dA+\frac{\partial}{\partial t}\left(\int_V \rho dV\right)=0$
4. $\frac{1}{r}\frac{\partial}{\partial r}(rv_r)+\frac{\partial}{\partial z}(v_z)=0$

Which of the above equations are forms of continuity equations? (Here u, v are velocities and V is volume)
(a) 1 only (b) 1 and 2
(c) 2 and 3 (d) 3 and 4

Q.14 Assertion (A): The velocity potential provides an alternative means of expressing velocity components.
Reason (R): The existence of velocity potential in a flow field ensures that the flow must be irrotational.
(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.15 If ϕ_1 and ϕ_2 are solutions of the Laplace equation, which of the following is also a solution of the Laplace equation?

(a) ϕ_1^2 (b) $\phi_1\phi_2$

(c) ϕ_1/ϕ_2 (d) $\phi_1+\phi_2$

Q.16 A water supply pipeline changes its alignment through a bend. When the flow in the pipeline is increased by operating a valve, the flow in the bend during the operation of the valve is classed as

(a) unsteady, uniform flow

(b) unsteady, non-uniform flow

(c) steady, uniform flow

(d) steady, non-uniform flow

Q.17 If 'ψ' is the stream function for a two dimensional incompressible flow, match List-I with List-II and select the correct answer using the codes given below the lists:

List-I

A. $\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}$

B. Along a streamline $\Psi =$

C. For irrotational flow $\nabla^2\Psi =$

D. For a rotational flow $\nabla^2\Psi =$

E. For a uniform flow of a stream in the x direction $\frac{\partial\Psi}{\partial y} =$

List-II

1. Zero
2. Constant
3. Non zero variable

Codes :

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

Q.18 If ϕ is a potential function for two dimensional flow with vector $\vec{V} = (u\hat{i} + v\hat{j})$, match List-I with List-II and select the correct answer using the codes given below the lists:

List-I

A. Along the streamline $\phi =$

B. $\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}$

C. For uniform flow of a stream in the x direction $\frac{\partial\phi}{\partial y} =$

D. Curl $\vec{V} =$

List-II

1. Zero
2. Not a constant
3. Constant

Codes :

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

Q.19 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I

A. Rotational flow

B. Vortex flow

C. Free vortex

D. Forced vortex

List-II

1. A fluid motion in which stream lines are concentric circles
2. The fluid particles moving in concentric circles may not rotate about their mass centre
3. The fluid particles moving in concentric circles may rotate about their centre of mass
4. Flow near a curved solid boundary

Codes:

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

Q.20 Match List-I (Phenomenon) with List-II (Condition) and select the correct answer using the codes given below the lists :

List-I

A. Rotational flow

B. Irrotational flow

C. Singularities

D. Streamline spacing

List-II

1. Velocity zero or infinite
2. Proportional to velocity
3. Vorticity is zero
4. Vorticity exists

Codes:

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

Q.21 Assertion (A) : There is no flow in the direction perpendicular to a stream line at any point on it.
Reason (R) : Stream line consists of a number of infinitesimally small segments such that all of them lie along the directions of velocity vectors of fluid particles at those segments.

(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.22 At a point on a streamline, the velocity is 3 m/s and the radius of curvature is 9 m. If the rate of increase of velocity along the streamline at this point is 1/3 m/s/m, then the total acceleration at this point would be

(a) 1 m/s^2 (b) 3 m/s^2

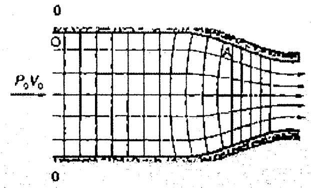
(c) 1/3 m/s^2 (d) $\sqrt{2}$ m/s^2

Q.23 The streamlines of a flow net are concentric circles. If the velocity at a radius of 0.6 m is 2.7 m/s, the velocity at a radius of 0.9 m will be

(a) 3.6 m/s (b) 2.7 m/s

(c) 1.8 m/s (d) 1.2 m/s

Q.24 Figure shows the flow net for two-dimensional contraction. The size of mesh square at O is 7 mm, and at point a, the mesh size is 3.5 mm.



The dimensionless pressure at A, $\frac{\Delta p}{\frac{\rho V_0^2}{2}}$ is equal to

(a) 2 (b) – 0.75

(c) – 3 (d) – 4

Q.25 The motion of air mass in a tornado is a

(a) free vortex motion

(b) forced vortex motion

(c) free vortex at centre and forced vortex outside

(d) forced vortex at centre and free vortex outside

Q.26 In a compressible flow, the area of flow, the velocity of flow and the mass density are denoted by a, v and m respectively. At a particular section, the differential form of the continuity equation is given by

(a) $\frac{d_a}{a} = \frac{d}{v} + \frac{d_m}{m}$ (b) $\frac{d_a}{a} = \frac{d}{v} - \frac{d_m}{m}$

(c) $\frac{d_a}{a} = -\frac{d_v}{v} + \frac{d_m}{m}$ (d) $\frac{d_a}{a} = -\frac{d_v}{v} - \frac{d_m}{m}$

Q.27 Which of the following groups constitutes a set of parameters of identical dimensions?

(a) Velocity potential, stream function, vorticity

(b) Power, torque, bending moment

(c) Relative roughness, friction factor, sub-layer thickness

(d) Rate of angular deformation, velocity gradient, speed in rpm

Q.28 Consider the following statements:

1. In a source, equipotential lines are circles.
2. Flownet is a representation of 2-dimensional irrotational flow of incompressible fluid.
3. Boundaries act of limiting equipotential lines in a flow net.
4. In uniform flow region, streamlines will be parallel and equidistant.

Which of these statement is correct?

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

Q.29 The following stream function

$$\psi = \frac{x^3}{3} - x^2 - xy^2 + y^2$$

will represent/satisfy

(a) rotational flow and Laplace equation
(b) irrotational flow and Laplace equation
(c) irrotational flow and equation of continuity
(d) irrotational flow, Laplace equation and equation of continuity

Q.30 Stream function $y = uy - vx$ represents the

(a) free vortex motion
(b) uniform flow parallel to x-axis
(c) uniform flow parallel to y-axis
(d) uniform flow inclined to x-axis

Q.31 Which one of the following statements relating to vortex flow is incorrect?

(a) In the formation of a free vortex, streamlines are axis-symmetric and irrotational.
(b) In a forced vortex, work transfer between the fluid and the surroundings takes place and the flow is rotational.
(c) In a free vortex, 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, there is no variation of energy from streamline to streamline and irrotationality is not deviated from near the core.

Q.32 The acceleration component of fluid particle are denoted as

1. Local tangential acceleration
2. Convective tangential acceleration
3. Local normal acceleration
4. Convective normal acceleration

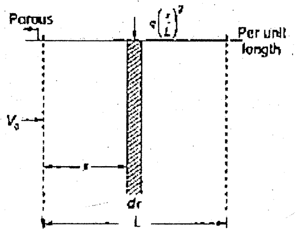
In a curve nozzle fitted to the end of a straight pipeline carrying water under variable head, the acceleration components that are present would include

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

Q.33 In a 2-D incompressible irrotational fluid motion, if y-component of velocity $v = 6xy - x^2 + y^2$ the x-component of velocity at that point is given by, $u =$

(a) $2xy - 3(x^2 - y^2)$
(b) $-3xy - 2(x^2 + y^2)$
(c) $-3xy - 2(x^2 - y^2)$
(d) $+2xy + 3(x^2 - y^2)$

Q.34 A pipe has porous section of length L as shown in the figure. Velocity at the start of this section is V_0. If the fluid leakes into the pipe through the porous section at volumetric rate per unit area = $q\left(\frac{x}{L}\right)^2$. What will be the axial velocity in the pipe length of any x. Assume incompressible one dimensional flow (No gradient in radial direction)



(a) $V_x = V_0 + \frac{qx^3}{L^2d}$ (b) $V_x = V_0 + \frac{qx^3}{3L^2}$

(c) $V_x = V_0 + \frac{2qx^3}{L^3}$ (d) $V_x = V_0 + \frac{4qx^3}{3L^2d}$

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Answers Fluid Kinematics

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

Explanations Soil Types and Formations

6. (b)

Velocity potential function is valid for 3-dimensional flow while stream function is valid for 2 dimensional flow.

10. (d)

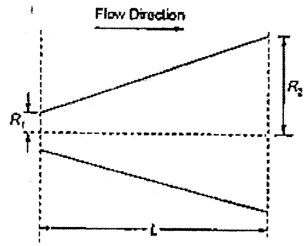
For forced vortex flow

$$v = r\omega$$
$$v \propto r$$

For free vortex flow

$$mvr = \text{constant}$$
$$vr = \text{constant}$$

11. (c)



Inlet velocity, $V_1 = \frac{Q}{\pi R_1^2}$

Outlet velocity, $V_2 = \frac{Q}{\pi R_2^2}$

Acceleration $= \frac{dV}{dx}$

$$= \frac{V_2 - V_1}{L} = \frac{Q}{\pi L}\left[\frac{1}{R_2^2} - \frac{1}{R_1^2}\right]$$

Acceleration at exit

$$= V_2\frac{dV}{dx} = \frac{Q}{\pi R_2^2}\frac{Q}{\pi L}\left[\frac{R_1^2 - R_2^2}{R_1^2 R_2^2}\right]$$

$$= \frac{Q^2}{\pi^2 R_2^2 L}\left[\frac{(R_1 - R_2)(R_1 + R_2)}{R_1^2 R_2^2}\right]$$

Consider limiting case i.e. $R_1 \to R_2$. Then Acceleration at the exit

$$= \frac{Q^2}{\pi^2 R_2^2 L}\left[\frac{(R_1 - R_2)2R_2}{R_2^4}\right]$$

$$= \frac{2Q^2(R_1 - R_2)}{\pi^2 R_2^5}$$

12. (d)

We know that

Pressure drop across a length L of pipe is

$$\Delta p = \frac{32\mu\, u_{av} L}{D^2} \quad \text{... (i)}$$

and

$$u_{av} = \frac{u_0}{2} \quad \text{... (ii)}$$

From equation (i) and (ii)

$$\Delta p = \frac{16\mu u_0 L}{D^2}$$

17. (b)

For uniform flow in x direction u = constant

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

$$\Rightarrow \quad \frac{\partial \psi}{\partial y} = \text{Constant}$$

22. (d)

$$a = \sqrt{a_s^2 + a_n^2}$$

$$a_s = v\frac{dv}{ds} = 3\times\frac{1}{3} = 1\ m/s^2$$

$$a_n = \frac{v^2}{r} = \frac{3^2}{9} = 1\ m/s^2$$

$\therefore$ $$a = \sqrt{1^2+1^2} = \sqrt{2}\ m/s^2$$

23. (c)

Velocity at a radius of 0.9 m

$$= \frac{2.7\times0.6}{0.9} = 1.8\ m/s$$

24. (c)

$$\frac{P_0}{\rho}+\frac{V_0^2}{2} = \frac{P}{\rho}+\frac{(2V_0)}{2}$$

(velocity will be double at A since mesh size is half of the size at O) gives

$$\frac{P-P_0}{\rho\frac{V_0^2}{2}} = -3$$

32. (c)

1. Exist because flow is unsteady
2. Exist because cross-section is reducing
3. Not exist because as flow is a confined flow, curvature of streamline at a point cannot change with time. Hence local normal acceleration = 0
4. Exist because liquid is moving along a curved path.

33. (a)

For incompressibility

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

For irrotationality

$$\Rightarrow \quad \frac{\partial v}{\partial x}-\frac{\partial u}{\partial y} = 0$$

$$\Rightarrow \quad 6y-2x-\frac{\partial u}{\partial y} = 0$$

$$\Rightarrow \quad u = \int(6y-2x)dy$$

$$\Rightarrow \quad u = 3y^2 - 2xy + f(x),$$

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

$$-2y+\frac{\partial f(x)}{\partial x}+(6x+2y) = 0$$

$$\Rightarrow \quad \frac{\partial}{\partial x}f(x) = -6x$$

$$\Rightarrow \quad f(x) = -3x^2 + C$$

$$\therefore \quad u = 3y^2 - 2xy - 3x^2 + C$$

34. (d)

Discharge added in length, x

$$= \int_0^x q\left(\frac{x}{L}\right)^2 \times \pi D\times dx$$

$$= \frac{q\pi D}{L^2}\times\frac{x^3}{3}$$

Net discharge at $x = \left(V_0 \times \frac{\pi D^2}{4}\right)+\frac{q\pi Dx^3}{3L^2}$

$$V_x = \frac{\text{Net discharge at } x}{\left(\frac{\pi D^2}{4}\right)}$$

$$= \frac{V_0\times\frac{\pi D^2}{4}+\frac{4qx^3}{3L^2D}\times\frac{\pi D^2}{4}}{\frac{\pi D^2}{4}}$$

$$V_x = V_0 + \frac{4qx^3}{3L^2D}$$

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