CLASS TEST   Sl. : 04DLSKCE_OMNPQD_281125

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FLUID MECHANICS

CIVIL ENGINEERING

Date of Test : 28/11/2025

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (a)

Dynamic viscosity of gases decrease with decrease in fluid temperature as the momentum transfer between the fluid particles decreases.

2. (b)

$$u = \frac{1}{4\mu}\left(-\frac{dP}{dx}\right)\left(R^2 - r^2\right)$$

3. (d)

4. (d)

Static Piezometric pressure, $= \frac{P}{\rho g} = 2.0 \text{ m}$

Stagnation pressure, $= \frac{P}{\rho g} + \frac{v^2}{2g} = 2.2 \text{ m}$

Now, Stagnation pressure – Static pressure = Velocity head

$$\Rightarrow \quad 2.2 - 2.0 = \frac{v^2}{2g}$$

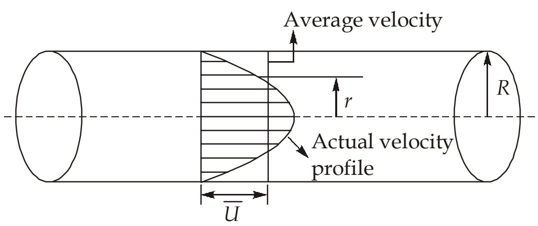
$$\Rightarrow \quad v^2 = 0.2 \times 2g = 0.2 \times 2 \times 9.81$$

$$\Rightarrow \quad v = \sqrt{3.924} = 1.98 \text{ m/s}$$

5. (d)

6. (c)

The velocity variation in a laminar flow through circular pipe is parabolic.



The distance (r) at which local velocity becomes equal to average velocity $= \frac{R}{\sqrt{2}} = 0.707R$

$$\therefore \quad r = 0.707 \times 125 = 88.4 \text{ mm}$$

7. (a)

Equation of stream line is given as,

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

$$\Rightarrow \quad \frac{dx}{\cos\theta} = \frac{dy}{\sin\theta}$$

$$\Rightarrow \quad dx = \frac{\cos\theta}{\sin\theta}dy$$

Integrating both sides, we get

$$\int dx = \int \frac{\cos\theta}{\sin\theta}dy$$

$$\Rightarrow \quad x = y \cot\theta + C$$

As the line is passing through origin, therefore, $C = 0$.

8. **(a)**

9. **(b)**

Since the pipes are connected in series

$$\therefore \quad \frac{L}{d^5} = \frac{L_1}{d_1^5} + \frac{L_2}{d_2^5}$$

$$\Rightarrow \quad \frac{800}{d^5} = \frac{300}{400^5} + \frac{500}{300^5}$$

$$\Rightarrow \quad d^5 = 3.403 \times 10^{12}$$

$$\Rightarrow \quad d = 320.91 \text{ mm}$$

10. **(d)**

For turbulent flow in rough pipes, the coefficient of friction is a function of relative roughness.

For laminar flow, $f = \dfrac{64}{R_e}$

For turbulent flow in smooth pipes,

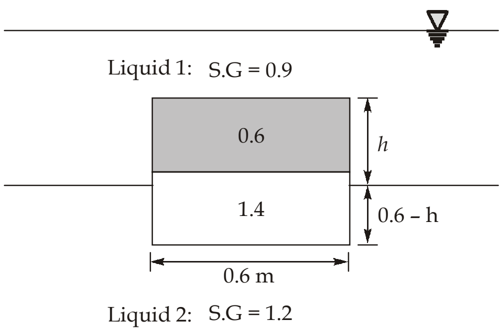
$$f = \frac{0.316}{(R_e)^{1/4}} \text{(Blasius)}$$

$$= 0.0032 + \frac{0.221}{R_e^{0.237}} \text{(Nikuradse)}$$

For turbulent flow in rough pipes,

$$\frac{1}{\sqrt{f}} = 2\log_{10}\left(\frac{R}{k}\right) + 1.74$$

11. **(c)**



Buoyant force, F_B = Weight of fluid displaced

$\Rightarrow$ $F_B = [(0.9 \times 9.81) \times 0.6 \times 0.6 \times h] + [(1.2 \times 9.81) \times 0.6 \times 0.6 \times (0.6 - h)]$

Now, $F_B = (-1.0595h + 2.5428)$ kN

Weight of block $= (1.4 \times 9.81 \times 0.6 \times 0.6 \times 0.3) + (0.6 \times 9.81 \times 0.6 \times 0.6 \times 0.3)$

$= 2.11896$ kN

For stable equilibrium,

Weight of block = Buoyant force

$\Rightarrow$ $2.11896 = -1.0595h + 2.5428$

$$\Rightarrow \quad h = \frac{2.5428 - 2.1189}{1.0595}$$

$\Rightarrow$ $h = 0.4 \text{ m} = 40 \text{ cm}$

12. (b)

Horizontal force at curved gate, $F_H = \rho g A_v \times \bar{h}$

$\Rightarrow$ $F_H = 9.81 \times 3 \times 4 \times (1.5)$

$\Rightarrow$ $F_H = 176.58$ kN

Vertical force at curved gate, $F_V = \rho g \forall$

= Wt. of fluid above curved surface upto free surface

$$\Rightarrow \quad F_V = 9.81 \times \left(9 - \frac{\pi}{4}(3)^2\right) \times 4$$

$\Rightarrow$ $F_V = 75.929$ kN

Resultant force acting at the centroid of curved gate,

$$F_R = \sqrt{F_H^2 + F_V^2} = \sqrt{176.58^2 + 75.929^2}$$

$\Rightarrow$ $F_R = 192.212$ kN

13. (a)

Given, $U_0 = V_A = 30$ m/s, $\delta^* = 1$ mm, $A_A = 100 \times 100$ mm^2

$A_B = (100 - \delta^*)(100 - \delta^*)$ mm^2

Using continuity equation

$$A_A V_A = A_B V_B$$

$$\Rightarrow \quad V_B = \frac{A_A V_A}{A_B} = \frac{100 \times 100 \times 30}{(100-2)(100-2)}$$

$\Rightarrow$ $V_B = 31.237$ m/s

14. (a)

Applying Bernoulli's equation between 1 and 2

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

As $p_1 = p_2 = P_{atm}$

and $V_1 = 0$ (Free surface of reservoir)

$$Z_1 = \frac{V_2^2}{2g} + Z_2$$

$$\Rightarrow \quad \frac{V_2^2}{2g} = Z_1 - Z_2 = 0.6 - (-0.25) = 0.85$$

$$\Rightarrow \quad V_2^2 = 2g \times 0.85$$

$$\Rightarrow \quad V_2 = \sqrt{2 \times 9.81 \times 0.85}$$

$$\Rightarrow \quad V_2 = 4.08 \text{ m/s} \simeq 4.1 \text{ m/s}$$

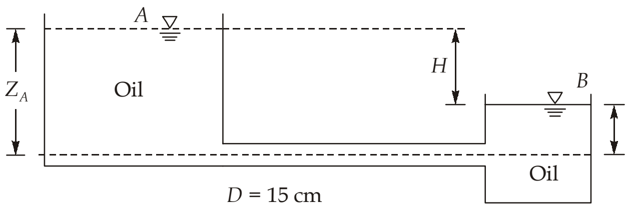
15. (a)

$$V = \sqrt{2g\Delta h}$$

$$\Delta h = h\left[\frac{\rho_m}{\rho_w} - 1\right] = \frac{6}{100}\left[\frac{13.6}{1} - 1\right] = 0.756 \text{ m}$$

$$V = \sqrt{2 \times 9.81 \times 0.756} = 3.85 \text{ m/s}$$

16. (a)



Applying Bernoulli's equation between (A) and (B)

$$\frac{P_A}{\rho g} + \frac{V_A^2}{2g} + Z_A = \frac{P_B}{\rho g} + \frac{V_B^2}{2g} + Z_B + \text{Head loss}$$

But $\quad P_A = P_B = P_{atm}$

$V_A = V_B = 0$

$\therefore \quad Z_A = Z_B + \text{Head loss}$

$$H = \frac{32\mu \bar{U} L}{\rho g D^2}$$

As ρ, μ, g, L, D are constant. So maximum difference in elevation (H) occurs when velocity is maximum. Velocity is maximum when Reynolds number is maximum.

For laminar flow, $(\text{Re})_{max} = 2000$

$$\therefore \quad \text{Re} = \frac{\rho \bar{U} D}{\mu}$$

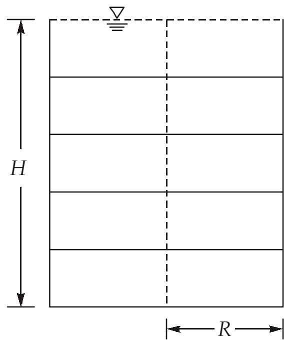
$$\Rightarrow \quad \bar{U} = \frac{\text{Re}\,\mu}{\rho D}$$

So, $$H = \frac{32\mu L}{\rho g D^2} \times \frac{\text{Re} \times \mu}{\rho D}$$

$$= \frac{32 \times (8 \times 10^{-2})^2 \times 200 \times 2000}{(950)^2 \times 9.81 \times 0.15^3}$$

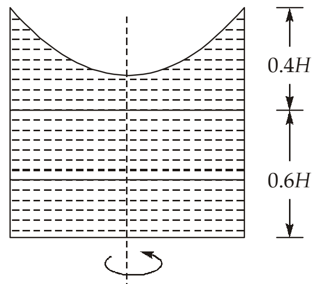
$$\therefore \quad H = 2.74 \text{ m}$$

17. (c)



Original value of water = $\pi R^2 H$

After rigid body rotation is given,

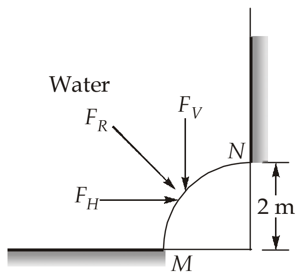


Given pressure at centre at bottom =0.6H m of liquid.

$$\text{Volume of water spilled out} = \frac{\pi R^2}{2} \times 0.4H$$

$$\therefore \quad \frac{\text{Volume of water spilled out}}{\text{Original volume of water}} = \frac{\frac{\pi R^2 \times 0.4H}{2}}{\pi R^2 H} = 0.2$$

18. (d)



Horizontal component of the force, $F_H = \rho g A_p \bar{h}$

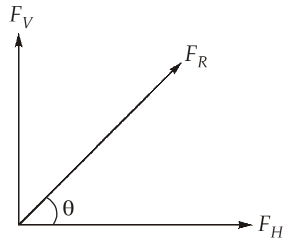
$$F_H = 1000 \times 9.81 \times [2 \times 2] \times [3 + 1] \text{ N} = 156.96 \text{ kN}$$

Vertical component of the force, $F_V = \rho g V$

$$F_V = 1000 \times 9.81 \times \left[5 \times 2 \times 2 - \frac{\pi(2)^2 \times 2}{4}\right]$$

$$= 1000 \times 9.81\ [20 - 2\pi] \text{ N} = 134.56 \text{ kN}$$

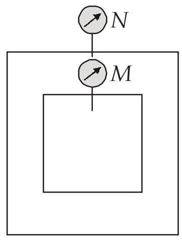
Vector diagram of forces



$$\tan\theta = \frac{F_V}{F_H} = \frac{134.56}{156.96}$$

$\Rightarrow$ $$\theta = 40.606° \simeq 40.61°$$

19. (d)



A bourdon gauge records the gauge pressure relative to the pressure of medium surrounding the tube. Local atmospheric pressure is measured by the aneroid barometer.
In the present case, local atmospheric pressure outside the gauge N = 750 mm of mercury.
Hence absolute pressure at N,

$$(P_N)_{abs.} = 750 + \left(\frac{35 \times 10^3 \times 1000}{13.6 \times 1000 \times 9.81}\right) = 1012.34 \text{ mm of mercury}$$

The gauge M reads relative to its surrounding pressure of 1012.34 mm of mercury (abs.)

Hence, $$(P_M)_{abs} = 1012.34 + \left(\frac{20 \times 10^3 \times 1000}{13.6 \times 1000 \times 9.81}\right) = 1162.25 \text{ mm of mercury}$$

∴ difference in magnitude of absolute pressure

$$= (P_M)_{abs} - (P_N)_{abs}$$
$$= 1162.25 - 1012.34$$
$$= 149.91 \text{ (mm of mercury)}$$

20. (a)

Now, $$a_x = \frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}$$
$$= 2t + (t^2 + 3y) \times 0 + (4t + 5x) \times 3$$
$$= 14t + 15x$$

Similarly, $$a_y = \frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y}$$
$$= 4 + (t^2 + 3y)(5) + (4t + 5x)(0)$$
$$= 4 + 5t^2 + 15y$$

At point (5, 3) and t = 2 units,

$$a_x = 14 \times 2 + 15 \times 5 = 103 \text{ unit}$$

$$a_y = 4 + (5 \times 2^2) + (15 \times 3) = 69 \text{ unit}$$

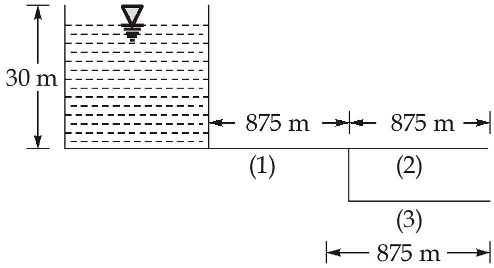
$$a = \sqrt{a_x^2 + a_y^2} = \sqrt{(103)^2 + (69)^2}$$

$$= 123.975 \text{ units} \simeq 123.98 \text{ units}$$

21. (b)

Let Q be the initial discharge.

Diameter, d = 0.55 m, Length, l = 1.75 km = 1750 m



Before addition of pipe, $$h_f = \frac{8flQ^2}{\pi^2 g D^5} \quad \text{... (i)}$$

$\Rightarrow$ $$30 = \frac{8(0.04) \times (1750) Q^2}{\pi^2 (9.81) \times (0.55)^5}$$

Solving, Q = 0.51 m^3/sec

After addition of pipe, $$h_f = h_{f1} + h_{f2} \quad \text{... (ii)}$$

Where, h_{f2} is Head loss in pipe 2, h_{f3} is Head loss in pipe 3

Also, $$h_{f2} = h_{f3}$$

$\therefore$ $$\frac{f l_2 v_2^2}{2gD_2} = \frac{f l_3 v_3^2}{2gD_3}$$

$$v_2 = v_3$$

Also, let Q' be the final discharge

Now, $$Q' = Q_2 + Q_3$$

[$\because$ Continuity equation]

$\because$ $$Q_2 = Q_3$$

[$\because V_2 = V_3, A_2 = A_3$]

$\Rightarrow$ $$Q_2 = Q_3 = \frac{Q'}{2}$$

Substituting values in (ii)

$$h_f = \frac{8fl_1 Q'^2}{\pi^2 g D_1^5} + \frac{8fl_2 (Q'/2)^2}{\pi^2 g D_2^5}$$

$$30 = \frac{8 \times 0.04 \times 875}{\pi^2 \times 9.81 \times 0.55^5}\left(Q'^2 + \frac{Q'^2}{4}\right)$$

Solving, Q' = 0.65 m^3/s

$$\% \text{ increase} = \frac{Q' - Q}{Q} \times 100 = \frac{0.65 - 0.51}{0.51} \times 100 = 27.45\%$$

22. (b)

The Reynold's number must be the same in the model and the prototype for similar pipe flows

$$\frac{V_p \cdot D_p}{\nu_p} = \frac{V_m D_m}{\nu_m}$$

$$V_m = \frac{V_p \cdot D_p}{D_m} \cdot \frac{\nu_m}{\nu_p}$$

Here, $$V_p = \frac{Q}{\frac{\pi}{4} \times D^2} = \frac{3}{\frac{\pi}{4} \times (1.5)^2} = 1.7 \text{ m/s}$$

$\therefore$ $$V_m = 1.7 \times \frac{1.5}{0.15} \times \frac{0.01}{0.03} = 5.67 \text{ m/s}$$

$\therefore$ Q_m = Discharge in model

$$= V_m \cdot A_m$$

$$= V_m \times \frac{\pi}{4} \times D_m^2$$

$$= 5.7 \times \frac{\pi}{4} \times 0.15^2 = 0.1 \text{ m}^3\text{/sec}$$

23. (c)

In river model,

$$(Fr)_{\text{model}} = (Fr)_{\text{prototype}}$$

$$V_r = \sqrt{L_{rv}}$$

$\therefore$ $$Q_r = \frac{Q_m}{Q_p} = V_r \cdot A_r = \sqrt{L_{rv}} \cdot L_{rH} \cdot L_{rv}$$

$\Rightarrow$ $$Q_r = L_{rH} \cdot (L_{rv})^{3/2}$$

$\Rightarrow$ $$\frac{Q_m}{Q_p} = \left(\frac{1}{400}\right) \cdot \left(\frac{1}{500}\right)^{3/2}$$

$\Rightarrow$ $$\frac{1.2}{Q_p} = \frac{1}{400 \times 500^{1.5}}$$

$\Rightarrow$ $$Q_p = 5.367 \times 10^6 \text{ m}^3\text{/day}$$

$$= 62.12 \text{ m}^3\text{/sec}$$

24. (b)

Displacement thickness, $$\delta^* = \int_0^{\delta} \left(1 - \frac{u}{U_\infty}\right) dy = \int_0^{\delta} \left(1 - \frac{3}{2}\frac{y}{\delta} + \frac{1}{2}\frac{y^3}{\delta^3}\right) dy$$

$$= \left[y - \frac{3}{4}\frac{y^2}{\delta} + \frac{1}{8}\frac{y^4}{\delta^3}\right]_0^{\delta}$$

$$= \delta - \frac{3}{4}\delta + \frac{1}{8}\delta = \frac{3\delta}{8}$$

25. (d)

Rotational stability of a completely submerged body:

G lies below B	Stable equilibrium
G lies above B	Unstable equilibrium
G coincides with B	Neutral equilibrium

Rotation stability of floating body:

In this case, the stability of the body not only depends on the relative position of the centre of gravity and centre of buoyancy but also depends on the position of metacentre relative to the centre of gravity.

G lies below M	Stable equilibrium
G lies above M	Unstable equilibrium
G coincides with M	Neutral equilibrium

In case of liquid mass subjected to vertical acceleration,

$$\frac{\partial p}{\partial z} = -\gamma\left(1+\frac{a}{g}\right) = -p\cdot g_{eff} \qquad [g_{\text{eff}} = (g + a)]$$

26. (c)

Let x be the distance from the leading edge

$$\therefore \quad F_{Dx} = \frac{1}{2}F_{DL}$$

$$= C_{Dfx}(B.x)\cdot\frac{\rho U^2}{2}$$

$$F_{DL} = C_{DfL}(B.L)\cdot\frac{\rho U^2}{2}$$

$$\therefore \quad \frac{C_{Dfx}}{C_{DfL}}\cdot\frac{x}{L} = \frac{F_{Dx}}{F_{DL}} = \frac{1}{2}$$

But
$$C_{Dfx} = \frac{1.328}{\sqrt{R_{ex}}} = \frac{1.328}{\sqrt{\frac{U.x}{\nu}}}$$

and
$$C_{DfL} = \frac{1.328}{\sqrt{\frac{U.L}{\nu}}}$$

$$\therefore \quad \left(\frac{L}{x}\right)^{1/2}\cdot\frac{x}{L} = \frac{1}{2}$$

$$\Rightarrow \quad x = \frac{1}{4}L$$

27. (c)

Head loss in converging cone, $H_{L_1} = \left(1 - C_d^2\right) \Delta h$

$$\Delta h = y\left(\frac{S_m}{S_p} - 1\right) = 0.2\left(\frac{13.6}{1} - 1\right)$$

$$= 2.52 \text{ m}$$

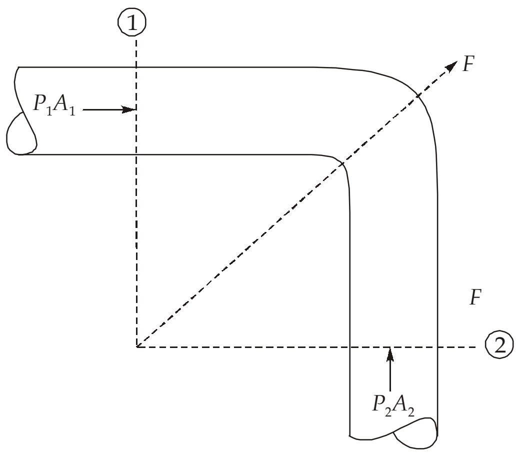
$$\therefore \quad H_{L_1} = \left(1 - 0.96^2\right) \times 2.52$$

$$= 0.198 \text{ m}$$

Head loss in diverging cone, $H_{L_2} = 10 \times \frac{V^2}{2g} = 10 \times \frac{1.1^2}{2 \times 2.98} = 0.62 \text{ m}$

So, total head loss $= H_{L_1} + H_{L_2} = 0.198 + 0.62 = 0.82 \text{ m}$

28. (a)



Mean velocity in the bend,

$$V_1 = V_2 = \frac{4Q}{\pi d^2} = \frac{4 \times 1.6}{\pi \times (0.8)^2} = 3.18 \text{ m/s}$$

Applying Bernoulli's equation between sections (1) and (2) including the loss of head,

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

But $V_1 = V_2$

$$\therefore \quad \frac{p_2}{\gamma} = \frac{p_1}{\gamma} - 2$$

$$= \frac{1500 \times 10^{-3} \times 10^5}{0.85 \times 9810} - 2 = 15.98 \text{ m of oil} \quad (\because 1 \text{ bar} = 10^5 \text{ Pa})$$

$$\therefore \quad p_2 = (0.85 \times 9810) \times 15.98 = 133249.23 \text{ N/m}^2 = 133.25 \text{ kN/m}^2$$

Momentum equation in x direction

$$p_1A_1 + F_x = \rho Q(0 - V_1)$$

$$\Rightarrow (1500 \times 10^{-3} \times 10^5) \times \frac{\pi}{4}(0.8)^2 + F_x = 850 \times 1.6\ (0 - 3.18)$$

$$\Rightarrow \quad 75398.2 + F_x = -4324.8 \text{ N}$$

$$F_x = -79723 \text{ N}$$

Momentum equation in y-direction

$$P_2A_2 + F_y = \rho Q(-V_2 - 0)$$

$$\Rightarrow \quad 133249.23 \times \frac{\pi}{4}(0.8^2) + F_y = \frac{8338.5}{9.81} \times 1.6(-3.18)$$

$$\Rightarrow \quad 66978.37 + F_y = -4324.8$$

$$\Rightarrow \quad F_y = -71303.17 \text{ N}$$

$$\therefore \quad F_R = \sqrt{F_x^2 + F_y^2}$$

$$= \sqrt{(-79723)^2 + (-71303.17)^2}$$

$$= 106957.46 \text{ N} = 106.957 \text{ kN} \simeq 106.96 \text{ kN}$$

29. (c)

For an incompressible fluid, the equation of continuity is

$$\frac{\partial U}{\partial x} + \frac{\partial V}{\partial y} + \frac{\partial W}{\partial z} = 0 \quad \text{...(i)}$$

Here, $$\frac{\partial U}{\partial x} = 3x^2$$

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

By substitution in equation (i),

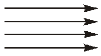
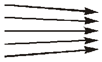
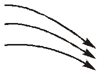
$$3x^2 - x^2 - z - x + \frac{\partial W}{\partial z} = 0$$

$$\Rightarrow \quad \frac{\partial W}{\partial z} = x + z - 2x^2$$

$$\Rightarrow \quad dW = (x + z - 2x^2)\,dz$$

$$\Rightarrow \quad W = \left(xz + \frac{z^2}{2} - 2x^2z\right) + f(x, y)$$

30. (c)

S.No.	Streamline pattern		Type of acceleration
1.	Straight parallel stream lines		No acceleration
2.	Straight converging streamlines		Convective tangential acceleration
3.	Concentric streamlines		Convective normal acceleration
4.	Curved converging streamlines		Both tangential and normal convective acceleration

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