CLASS TEST

Sl. : 03DLSK_CE_DEFGH_250826

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FLUID MECHANICS

CIVIL ENGINEERING

Date of Test : 25/08/2026

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (d)

$$u = \lambda xy^3 - x^2y$$

$$v = xy^2 - \frac{3}{4}y^4$$

For incompressible flow,

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

$$\frac{\partial u}{\partial x} = \lambda y^3 - 2xy$$

$$\frac{\partial v}{\partial y} = 2xy - 3y^3$$

$$\lambda y^3 - 2xy + 2xy - 3y^3 = 0$$

$$\Rightarrow \quad \lambda = 3$$

2. (b)

For laminar boundary layer over a flat plate

$$\tau = C_f \frac{\rho v^2}{2}$$

where $$C_f = \frac{0.664}{\sqrt{R_{ex}}}$$

$$\Rightarrow \quad \tau \propto \frac{1}{\sqrt{x}}$$

$$\Rightarrow \quad \frac{\tau_1}{\tau_2} \propto \sqrt{15}$$

3. (a)

4. (d)

In case of parallel connection, head loss remains same for all the pipes.

$$\therefore \quad h_{f1} = h_{f2}$$

$$\Rightarrow \quad \frac{8Q_1^2}{\pi^2 g} \times \frac{fL}{D_1^5} = \frac{8Q_2^2}{\pi^2 g} \times \frac{fL}{D_1^5}$$

where Q_1 and Q_2 are discharges in smaller and larger diameter pipe respectively

Since, f and L are equal for both the pipes,

$$\therefore \quad \frac{Q_1^2}{D_1^5} = \frac{Q_2^2}{D_2^5}$$

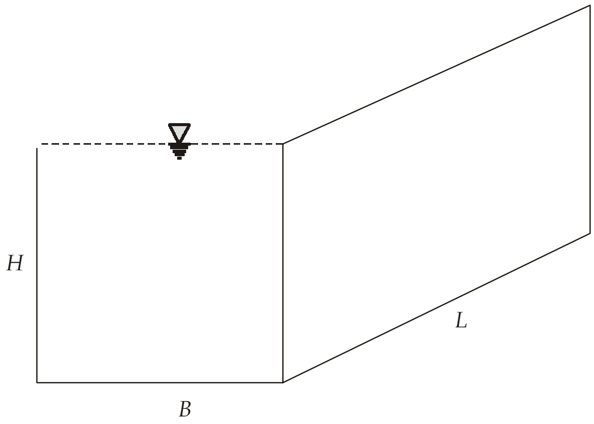
Here, $$D_1 = 20 \text{ cm}$$

and $$D_2 = 35 \text{ cm}$$

$$\therefore \quad \frac{Q_1}{Q_2} = \sqrt{\left(\frac{D_1}{D_2}\right)^5} = \sqrt{\left(\frac{20}{35}\right)^5} = 0.2468 \approx 0.25$$

5. (b)

Let L, B, H be the length, breadth and height of rectangular tnak.



L : B : H = 2 : 1 : 2

Hydrostatic force on the bottom of tank,

$$F_1 = (\text{Pressure at bottom}) \times \text{Area}$$

$$= \rho g H \times LB$$

Hydrostatic force on vertical surface

$$F_2 = (\text{Average pressure}) \times \text{Area}$$

$$= \frac{1}{2}\rho g H \times LH$$

$$\therefore \quad \frac{F_1}{F_2} = \frac{\rho g HLB}{\frac{1}{2}\rho g H^2 L} = \frac{2B}{H} = \frac{2\times 1}{2} = 1$$

6. (a)

$$\psi = 2xy$$

$$\because \quad u = -\frac{\partial \psi}{\partial y} = -2x$$

$$v = \frac{\partial \psi}{\partial x} = 2y$$

At (2, –2), $U = 4$, $v = 4$

$$\therefore \quad |\vec{V}| = \sqrt{u^2 + v^2} = 4\sqrt{2}$$

7. (c)

$$\frac{q}{Q} = \frac{1}{40} \times \frac{1}{9}\sqrt{\frac{1}{9}}$$

$$\Rightarrow \quad Q = 1080 \text{ lps}$$

8. (b)

$$Q = C_d \frac{8}{15}\sqrt{2g}\tan\left(\frac{\theta}{2}\right) H^{5/2}$$

$$\therefore \quad \frac{\partial Q}{Q} = \frac{5}{2}\frac{\partial H}{H} = \frac{5}{2} \times 4 = 10\%$$

9. (b)

In pipe, limiting Reynolds is 2000. (Re ≤ 2000) In general.

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

$$f = \frac{64}{2000} = 0.032$$

10. (d)

Displacement thickness, $\delta^* = \int_0^\delta \left(\frac{u}{U}\right) \cdot dy = \int_0^\delta \left(1 - \frac{y^2}{\delta^2}\right) dy = \left[y - \frac{y^3}{3\delta^2}\right]_0^\delta = \delta - \frac{\delta}{3} = \frac{2\delta}{3}$

11. (a)

For pipes in series

$$\frac{L}{d^5} = \frac{L_1}{d_1^5} + \frac{L_2}{d_2^5} + \frac{L_3}{d_3^5}$$

$$\Rightarrow \quad \frac{6000}{d^5} = \frac{1000}{(0.2)^5} + \frac{2000}{(0.4)^5} + \frac{3000}{(0.6)^5}$$

$$\Rightarrow \quad d = 0.282 \text{ m} \quad \text{or} \quad d = 282 \text{ mm}$$

12. (d)

$$h_L = \frac{Q^2 f1}{12.1D5}$$

$$\dot{m} = \rho Q$$

$$\frac{900}{60} = 0.9 \times 10^3 \times Q$$

$$\therefore \quad Q = 0.0167 \text{ m}^3/\text{sec}$$

$$Re = \frac{\rho VD}{\mu} = \frac{VD}{\nu}$$

$$V = \frac{Q}{A} = \frac{4Q}{\pi D^2}$$

$$h_L = \frac{64}{Re} \times \frac{LQ^2}{12.1D^5} = \frac{64LQ^2}{12.1D^5} \times \frac{\nu}{VD} = \frac{64LQ^2}{12.1D^5} \times \frac{\nu}{D} \times \frac{\pi D^2}{4Q}$$

$$h_L = 4.15 \frac{LD\nu}{D^4}$$

$$8 = \frac{4\pi}{3} \times \frac{400 \times 0.0167 \times 0.0002}{D^4}$$

$$D = 0.1622 \text{ m}$$

13. (d)

Maximum head available at the outlet of the pipe = $H - h_f$

$$= H - \frac{H}{3} = \frac{2H}{3} = \frac{2\times 400}{3} = 266.67 \text{ m}$$

$\therefore$ Maximum power available = $\rho Qg(H - h_f)$

$$= \frac{1000\times 9.81\times 0.2\times 266.67}{1000} \text{ kW} = 523.2 \text{ kW}$$

14. (a)

Equating pressure at interface level,

$$P_A + \rho_0\, g(0.15) = \rho_{Hg}\, g(0.1)$$

where ρ_0 is density of oil and ρ_{Hg} is density of mercury

$\Rightarrow$ $P_A + (0.85\times 10^3)\times g\times 0.15 = (13.6\times 10^3)\times g\times 0.10$

$\Rightarrow$ $P_A = 12090.825 \text{ N/m}^2$

$= 12.09 \text{ kN/m}^2$

15. (b)

Reynold's number, $\text{Re} = \frac{\rho Vd}{\mu}$

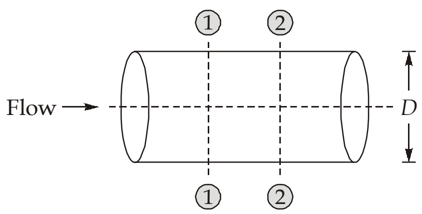
$$= \frac{0.8\times 1000\times 2.8\times 0.25}{1.5}$$

$$= 373.33 < 2000$$

So, flow is laminar.

For laminar flow through circular pipe,

Shear stress at wall, $\tau_0 = \frac{R}{2}\left(\frac{-\partial P}{\partial x}\right) = \frac{D}{4}\left(\frac{-\partial P}{\partial x}\right)$ ...(i)



From Hagen-Poiseuille's equation,

$$\frac{-\partial P}{\partial x} = \left(\frac{P_1 - P_2}{L}\right) = \frac{32\mu\bar{u}}{D^2} \quad \text{...(ii)}$$

Putting (ii) in (i), we get

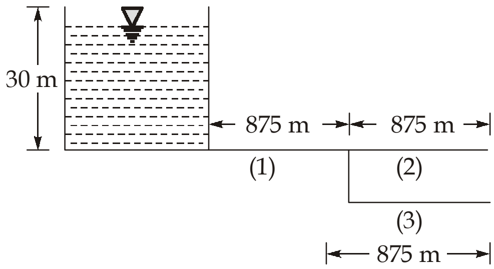
$$\tau_0 = \frac{D}{4}\left(\frac{32\mu\bar{u}}{D^2}\right)$$

$$= \frac{8\mu\bar{u}}{D} = \frac{8\times 1.5\times 2.8}{0.25} = 134.4 \text{ Pa}$$

16. (b)

Let Q be the initial discharge.

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



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

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

Solving, Q = 0.51 m^3/sec

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

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

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

$$\therefore \quad \frac{fl_2v_2^2}{2gD_2} = \frac{fl_3v_3^2}{2gD_3}$$

$$v_2 = v_3$$

Also, let Q' be the final discharge

Now, $Q' = Q_2 + Q_3$ [$\because$ Continuity equation]

$\because$ $Q_2 = Q_3$ [$\because$ $V_2 = V_3$, $A_2 = A_3$]

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

Substituting values in (ii)

$$h_f = \frac{8fl_1Q^2}{\pi^2 gD_1^5} + \frac{8fl_2(Q'/2)^2}{\pi^2 gD_2^5}$$

$$30 = \frac{8\times0.04\times875}{\pi^2\times9.81\times0.55^5}\left(Q^2 + \frac{Q'^2}{4}\right)$$

Solving, Q' = 0.65 m^3/s

$$\%\text{ increase} = \frac{Q'-Q}{Q}\times100 = \frac{0.65-0.51}{0.51}\times100 = 27.45\%$$

17. (d)

Given, $\theta = 60°$

Distance, $$AC = \frac{h}{\sin 60°} = \frac{2h}{\sqrt{3}}$$

The gate will start tipping about hinge B if the resultant pressure force acts at B. If the resultant pressure force passes through a point which is lying from B to C anywhere on the gate, the gate will tip over the hinge. Hence for the given position, point B becomes the centre of pressure.

Depth of centre of pressure,

$$h^* = (h-3) \text{ m} \quad \text{...(i)}$$

But h^* is also given by, $$h^* = \frac{I_G \sin^2\theta}{A\bar{h}} + \bar{h}$$

Taking width of gate unity, then

Area, $$A = AC \times 1 = \frac{2h}{\sqrt{3}} \times 1; \quad \bar{h} = \frac{h}{2}$$

$$I_G = \frac{bd^3}{12} = \frac{1 \times AC^3}{12} = \frac{1 \times \left(\frac{2h}{\sqrt{3}}\right)^3}{12}$$

$$= \frac{8h^3}{12 \times 3 \times \sqrt{3}} = \frac{2h^3}{9 \times \sqrt{3}}$$

$$h^* = \frac{2h^3}{9\sqrt{3}} \times \frac{\sin^2 60}{\frac{2h}{\sqrt{3}} \times \frac{h}{2}} + \frac{h}{2}$$

$\Rightarrow$ $$h^* = \frac{2h^3 \times \frac{3}{4}}{9h^2} + \frac{h}{2} = \frac{2h}{3} \quad \text{...(ii)}$$

From (i) and (ii)

$$h - 3 = \frac{2h}{3}$$

$\Rightarrow$ $$h = 9 \text{ m}$$

$\therefore$ Height of water required for tipping the gate = 9 m

18. (d)

1 and 3 are correct

A submerged body becomes unstable if the centre of gravity is above the centre of buoyancy. While a floating body may remain stable even if centre of gravity is above the centre of buoyancy so statement 2 is wrong.

For a submerged body if the centre of gravity coincides with the centre of buoyancy, the equilibrium is said to be neutral stability so statement 4 is wrong.

19. (b)

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

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

$$f = 0.015$$

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

where, $$V = V_{avg} = \frac{Q}{A} = \frac{0.64}{\frac{\pi}{4} \times 0.6^2} = 2.264 \text{ m/s}$$

∴ $$\tau_{wall} = \frac{1000 \times 0.015 \times 2.264^2}{8} = 9.61 \text{ N/m}^2$$

20. (a)

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

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

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

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

21. (c)

$$d_1 = 30 \text{ cm}$$

∴ $$a_1 = \frac{\pi}{4} \times 30^2 = 706.86 \text{ cm}^2 = 0.070686 \text{ m}^2$$

$$d_2 = 15 \text{ cm}$$

∴ $$a_2 = \frac{\pi}{4} \times 15^2 = 176.71 \text{ cm}^2 = 0.017671 \text{ m}^2$$

Specific gravity of oil, S_o = 0.9

Specific gravity of mercury,

$$S_g = 13.6$$

Differential manometer reading,

$$x = 30 \text{ cm}$$

∴ $$h = \left(\frac{p_1}{\rho g} + Z_1\right) - \left(\frac{p_2}{\rho g} + Z_2\right) = x\left(\frac{S_g}{S_o} - 1\right)$$

$$= 30\left(\frac{13.6}{0.9} - 1\right) = 30(15.11 - 1)$$

$$= 30 \times 14.11$$

$$= 423.33 \text{ cm of oil} = 4.23 \text{ m of soil}$$

$$C_d = 1.0 \text{ (since losses are zero)}$$

$$\therefore \quad \text{Discharge, } Q = \frac{C_d a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$$

$$\Rightarrow \quad Q = \frac{(1)\times(0.070686)\times(0.017671\times\sqrt{2\times 9.81\times 4.23}}{\sqrt{0.070686^2 - 0.017671^2}}$$

$$\Rightarrow \quad Q = 0.1663 \text{ m}^3/\text{s} = 166.3\ l/\text{s}$$

22. (b)

In order to apply the hydrostatic relation for the air pressure calculation, the density of fluid X must be found. Neglecting the buoyancy of the air on the upper part of the block, then

$$0.6\,\gamma_{water}\,V = \gamma_x\,(0.75\,V)$$

$$\gamma_x = 0.8\,\gamma_{water}$$

$$= 0.8\,\rho_{water}\,g$$

$$= 0.8 \times 1000 \times 9.81$$

$$= 7848 \text{ N/m}^3.$$

The air gauge pressure may then be calculated as

$$0 - \gamma_x\,(0.4) = P_{air}$$

$$P_{air} = -7848 \times 0.4 = -3139.2 \text{ Pa}$$

23. (b)

For circular cylindrical jet of liquid,

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

$$\Rightarrow \quad R = \frac{\sigma}{\Delta P} = \frac{73\times 10^{-3}}{40}$$

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

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

24. (a)

From Bernoulli's equation, we have

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

$$\Rightarrow \quad \frac{14\times 10^4}{1000\times 9.81} + \frac{1.6^2}{2\times 9.81} = \frac{12\times 10^4}{1000\times 9.81} + \frac{6.4^2}{2\times 9.81} + h_c$$

$$\Rightarrow \quad h_c = 0.0816 \text{ m}$$

Now, $$h_c = \frac{V_2^2}{2g}\left[\frac{1}{C_c} - 1\right]^2$$

$$\Rightarrow \quad 0.0816 = \frac{V_2^2}{2g}\left[\frac{1}{C_c} - 1\right]^2$$

$$\Rightarrow \quad 0.0816 = \frac{6.4^2}{2\times 9.81}\left[\frac{1}{C_c} - 1\right]^2$$

$$\Rightarrow \quad C_c = 0.835 \simeq 0.84$$

25. (d)

$$\text{Velocity, } V = \frac{100 \times 10^3}{3600} = 27.78 \text{ m/s}$$

$$\text{Reynolds number, Re} = \frac{Vx}{\nu}$$

where x is the distance upto which laminar boundary layer exists.

$$\therefore \quad x = \frac{\nu \text{Re}}{V} = \frac{1.49 \times 10^{-5} \times 3 \times 10^5}{27.78}$$

$$= 0.161 \text{ m}$$

Thickness of laminar boundary layer,

$$\delta = 5\sqrt{\frac{x\nu}{V}} = 5 \times \sqrt{\frac{0.161 \times 1.49 \times 10^{-5}}{27.78}}$$

$$= 1.47 \times 10^{-3} \text{ m} = 1.47 \text{ mm}$$

26. (a)

The volume of the air before and after the rotation must be the same. Recognizing that the volume of a paraboloid of revolution is half of the volume of a circular cylinder of the same radius and height.

The height of the paraboloid of revolution is determined as:

$$\pi \times 0.16^2 \times 0.02 = \frac{1}{2}\pi \times (0.16)^2 h$$

$$\therefore \quad h = 0.04 \text{ m}$$

Using equation, $$z = \frac{r^2\omega^2}{2g}$$

$$\Rightarrow \quad 0.04 = \frac{0.16^2 \times \omega^2}{2 \times 9.81}$$

$$\Rightarrow \quad \omega = 5.54 \text{ rad/s}$$

The pressure, on the bottom as a function of the radius r is $p(r)$ which is given by

$$p - p_0 = \frac{\rho\omega^2}{2}\left(r^2 - r_1^2\right)$$

where, $$p_0 = 9810 \times (0.22 - 0.04) = 1765.8 \text{ Pa} = 1766 \text{ Pa}$$

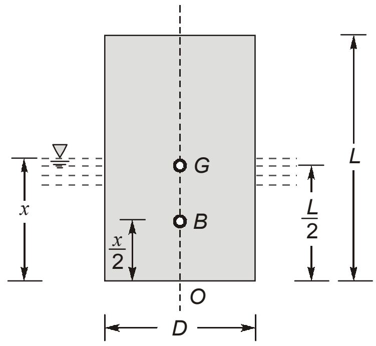
So, $$p = \frac{1000 \times 5.54^2}{2} r^2 + 1766 = 15346 r^2 + 1766$$

This pressure is integrated over the area to find the force

$$= \int_0^{0.16} \left(15346 r^2 + 1766\right) 2\pi r dr = 157.8 \text{ N}$$

27. (d)

As shown in figure, if the depth of immersion is x, then



$$\text{Buoyant force} = \text{weight of solid cylinder}$$

$$\Rightarrow \quad \left(\frac{\pi D^2}{4} x\right) \times 1.0 = \left(\frac{\pi D^2}{4} \times L\right) \times 0.6$$

$$\Rightarrow \quad x = \left(\frac{0.6}{1.0}\right) L = \frac{3}{5} L$$

So, $$OB = \frac{x}{2} = \frac{3}{10} L$$

Since, $$\overline{BM} = \frac{I}{V}$$

where, $$I = \frac{\pi D^4}{64}; \quad V = \left(\frac{\pi D^2}{4} \times \frac{3}{5} L\right) = \frac{3\pi D^2}{20} L$$

$$\Rightarrow \quad \overline{BM} = \left(\frac{\pi D^4}{64} \times \frac{20}{3\pi D^2 L}\right) = \frac{5D^2}{48L}$$

and, $$\overline{BG} = \overline{OG} - \overline{OB} = \left(\frac{L}{2} - \frac{3}{10} L\right) = \frac{L}{5}$$

For neutral equilibrium,

$$\overline{BM} = \overline{BG}$$

$$\Rightarrow \quad \frac{5D^2}{48L} = \frac{L}{5}$$

$$\Rightarrow \quad \frac{L^2}{D^2} = \frac{25}{48}$$

$$\Rightarrow \quad \frac{L}{D} = \frac{5}{4\sqrt{3}}$$

28. (a)

$$\text{Buoyant Force } (F_B) = \text{Drag Force } (F_D) \qquad \text{[Neglect weight of the bubble]}$$

$$\left(\frac{\pi d^3}{6}\right)\gamma = 3\pi\mu V d$$

$$\Rightarrow \quad \mu = \frac{\gamma d^2}{18V} \quad \therefore \quad \nu = \frac{\mu}{\rho} = \frac{gd^2}{18V}$$

$$\Rightarrow \quad \nu = \frac{9.81\times(10^{-3})^2}{18\times 8\times 10^{-3}} = 6.8125\times 10^{-5}\ \text{m}^2/\text{s} \simeq 6.813\times 10^{-5}\ \text{m}^2/\text{s}$$

29. (a)

$$\text{Local acceleration} = \frac{\partial V}{\partial t} = 2\left(1-\frac{x}{2L}\right)^2$$

$$\text{at } t = 3\text{s and } x = 0.5\text{m}$$

$$\Rightarrow \quad \frac{\partial V}{\partial t} = 2\left(1-\frac{0.5}{2\times 0.8}\right)^2 = 0.945\text{m/s}^2$$

$$\text{Convective acceleration} = V\frac{\partial V}{\partial x} = 2t\left(1-\frac{x}{2L}\right)^2 \cdot 2t\ 2\left(1-\frac{x}{2L}\right)\left(-\frac{1}{2L}\right)$$

$$= -\frac{4t^2}{L}\left(1-\frac{x}{2L}\right)^3$$

$$\text{at } t = 3\text{s and } x = 0.5\text{m}$$

$$\text{Convective acceleration} = -\frac{4\times 3^2}{0.8}\left(1-\frac{0.5}{2\times 0.8}\right)^3 = -14.623\ \text{m/s}^2$$

$$\text{Total Acceleration} = \text{(Local + Convective) Acceleration}$$

$$= 0.945 - 14.623 = -13.68\ \text{m/s}^2$$

30. (a)

$$D_1 = 150\ \text{mm}$$

$$A_1 = \frac{\pi}{4}\times(0.150)^2 = 0.01767\ \text{m}^2$$

$$D_2 = 300\ \text{mm} = 0.3\ \text{m}$$

$$A_2 = \frac{\pi}{4}\times(0.3)^2 = 0.0707\ \text{m}^2$$

$$Q = 0.25\ \text{m}^3/\text{s}$$

$$V_1 = \frac{Q}{A_1} = \frac{0.25}{0.01767} = 14.15\ \text{m/s}$$

$$V_2 = \frac{Q}{A_2} = \frac{0.25}{0.0707} = 3.536\ \text{m/s}$$

Loss of head due to enlargement is given as:

$$h_e = \frac{(V_1-V_2)^2}{2g} = \frac{(14.15-3.536)^2}{2g} = 5.742\ \text{m of water}$$

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