# CLASS TEST

Sl.: 02DLSKME_IJKLMNO_30826

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# FLUID MECHANICS

## MECHANICAL ENGINEERING

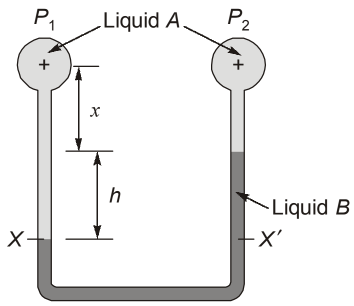
**Date of Test : 30/08/2026**

## ANSWER KEY

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

## DETAILED EXPLANATIONS

1. (c)




Taking point $X$ and $X'$ and equating the pressure on both sides

$$P_1 + (h + x) \times 0.88 \times 9.81 \times 10^3 = P_2 + x \times 0.88 \times 9.81 \times 10^3 + h \times 2.95 \times 9.81 \times 10^3$$

$$\Rightarrow \quad P_1 + h \times 0.88 \times 9.81 \times 10^3 + x \times 0.88 \times 9.81 = x \times 0.88 \times 9.81 + P_2 + h \times 2.95 \times 9.81 \times 10^3$$

$$\Rightarrow \quad P_1 - P_2 = h(2.95 \times 9.81 - 0.88 \times 9.81) \times 10^3$$

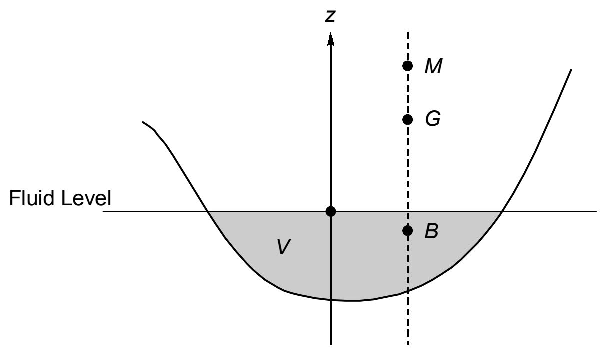
$$860 = h(2.3067 \times 10^3)$$

$$42.35 \times 10^{-3} = h$$

$$h = 42.35 \text{ mm}$$

2. (d)

Stable equilibrium condition




3. (a)

Given: $\psi = 2y(x^2 - y^2)$

Since, $$v = \frac{\partial \psi}{\partial x} = \frac{\partial}{\partial x}\left(2y\left(x^2 - y^2\right)\right)$$

$$v = 2y\,(2x) = 4xy$$

and, $$u = \frac{-\partial \psi}{\partial y} = \frac{-\partial}{\partial y}\left(2y(x^2 - y^2)\right)$$

$$u = -[2y\,(-2y) + (x^2 - y^2) \cdot 2]$$

$$= 4y^2 - 2x^2 + 2y^2$$

$$= 6y^2 - 2x^2$$

Thus, velocity field is

$$\vec{V} = u\hat{i} + v\hat{j}$$

$$\vec{V} = \left(6y^2 - 2x^2\right)\hat{i} + 4xy\,\hat{j}$$

4. (c)

$$\therefore \qquad \bar{V} = \frac{Q}{A} = \frac{Q}{\frac{\pi}{4}d^2} \Rightarrow \frac{4Q}{\pi d^2} = \frac{4\times 880\times 10^{-9}}{\pi\times 0.50^2\times 10^{-6}} = 4.48\,\text{m/s}$$

We know,
$$Q = \frac{\pi\,\Delta p\,D^4}{128\,\mu\,L}$$

$$\Rightarrow \qquad \mu = \frac{\pi\,\Delta p\,D^4}{128\,Q\,L} = \frac{\pi\times 10^6\times (0.5)^4\times 10^{-12}}{128\times 880\times 10^{-9}\times 1}$$

$$\mu = 1.74\times 10^{-3}$$

5. (c)

$$Re_{\text{critical}} = 2000 = \frac{VD}{\nu} = \frac{\rho VD}{\mu}$$

$$2000 = \frac{950\times V\times 0.15}{8\times 10^{-2}}$$

$$V = 1.123\text{ m/s}$$

$$\text{Head loss} = \frac{32\mu VL}{\rho g D^2} = \frac{32\times 8\times 10^{-2}\times 1.123\times 300}{950\times 9.81\times 0.15^2}$$

$= 4.113$ m $\Rightarrow$ Maximum difference in oil elevations.

7. (c)

8. (b)

$$\text{Sensitivity} = \frac{1}{\sin\theta} = \frac{1}{\sin 30^\circ} = 2$$

9. (b)

As for laminar flow,

Boundary layer thickness $(\delta) \propto \dfrac{1}{\sqrt{\text{Re}}}$

As the free stream, Speed $\uparrow\uparrow$, $\delta\downarrow\downarrow$

For turbulent flow,

Boundary layer thickness $(\delta) \propto \dfrac{1}{(\text{Re})^{1/5}}$

As the free stream velocity $\uparrow\uparrow$, $\delta\downarrow\downarrow$ and it also depending on the kinematic viscosity $\delta\uparrow\uparrow$ as kinematic viscosity $(\nu)\uparrow$.

10. (b)

For parallel pipes, head loss through the pipe is equal,

$$h_{f_1} = h_{f_2}$$

$$\Rightarrow \quad \frac{f_1 L_1 V_1^2}{2gd_1} = \frac{f_2 L_2 V_2^2}{2gd_2}$$

$$\Rightarrow \quad \frac{500\times(0.5)}{0.3\times 800}\times 2\times 9.81\times 0.35 = V_2^2 \qquad \left(\frac{V_1^2}{2g} = 0.5\text{ m}\right)$$

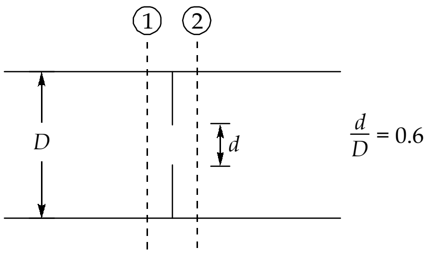
$$\Rightarrow \quad V_2 = 2.674\text{ m/s}$$

Discharge through pipe 2,

$$Q = A_2 V_2$$

$$= \frac{\pi}{4}(0.35)^2\times 2.476 = 0.2573\text{ m}^3\text{/s}$$

11. (d)




Applying Bernoulli's equation across the orifice,

$$\frac{P_1}{\rho g}+\frac{V_1^2}{2g}+h_1 = \frac{P_2}{\rho g}+\frac{V_2^2}{2g}+h_2$$

$$\frac{P_1-P_2}{\rho g} = \frac{V_2^2-V_1^2}{2g}$$

From continuity equation,

$$A_1V_1 = A_2V_2$$

$$\Rightarrow \quad D^2V_1 = d^2V_2$$

$$V_1 = (0.6)^2V_2$$

$$\Rightarrow \quad V_1 = 0.36V_2$$

$$\frac{43.5\times 10^3}{10^3\times g} = \frac{V_2^2-(0.36V_2)^2}{2g}$$

$$\Rightarrow \quad V_2^2 = 99.954$$

$$V_2 = 9.997\text{ m/s}$$

$$Q_{\text{theoretical}} = A_{\text{orifice}}\times V_2$$

$$= \frac{\pi}{4}\times\left(\frac{20}{\sqrt{\pi}}\right)^2 \times 10^{-6} \times 9.997$$

$$= 9.997 \times 10^{-4} \text{ m}^3/\text{s}$$

$$\text{Discharge coefficient, } c_d = \frac{Q_{act}}{Q_{theoretical}} = \frac{3\times10^{-4}}{9.997\times10^{-4}}$$

$$= 0.3$$

12. (d)

$$\text{Volume of cube} = a^3$$

$$a^3 = 125 \times 10^{-3} \times 10^{-3} \text{ m}^3$$

$$\Rightarrow \quad a = 5 \times 10^{-2}$$

$$\Rightarrow \quad a = 0.05 \text{ m}$$

$$F = p \times A$$

$$P_{bottom} = p_{atm} + h_1 g \rho_{oil} + h_2 \rho_{water}\, g$$

$$= 101325 + 0.5 \times 0.8 \times 1000 \times 9.81 + 0.3 \times 1000 \times 9.81$$

$$P_{bottom} = 108192 \text{ N/m}^2$$

$$F = P_{bottom} \times A = 108192 \times 0.05^2 = 270.48 \text{ N}$$

$$T = \text{Upthrust} - W$$

$$= 125 \times 10^{-6} \times 1000 \times 9.81 - 125 \times 10^{-6} \times 0.77 \times 1000 \times 9.81$$

$$= 0.282 \text{ N}$$

13. (c)

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

$$u = 2x^2 + (x + t)\, 2y$$

$\therefore$ for face $OB$, $\quad x \Rightarrow 0$

$$u_{OB} = 2t\,y$$

Discharge through $OB$

$$\therefore \quad Q_{OB} = \int_0^2 u_{OB}\cdot 5dy = \int_0^2 2ty\cdot 5dy$$

At $\quad t = 1$

$$Q_{OB} = 20 \text{ units}$$

$$\therefore \quad V = -\frac{\partial\psi}{\partial x} = -\left[4xy + y^2\right]$$

At $\quad y = 0$

$$V = 0$$

$$\therefore \quad Q_{OA} = 0$$

$$\therefore \quad Q_{AB} = Q_{OB} + Q_{OA}$$

$$= 20 + 0$$
$$= 20 \text{ units}$$

14. (d)

$$V_2 = \frac{Q}{A_2} = \frac{1.13\times10^{-6}}{\frac{\pi}{4}\times(0.0012)^2} \simeq 1 \text{ m/s}$$

$$\frac{P_1}{\rho g} + \frac{\alpha_1 V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \alpha_2 \frac{V_2^2}{2g} + z_2 + h_f$$

$$h_f = z_1 - z_2 - \frac{\alpha_2 V_2^2}{2g}$$

$$\Rightarrow \quad h_f = 0.6 - 0 - \frac{(2)(1)^2}{2\times9.81} = 0.5 \text{ m}$$

$$h_f = \frac{32\mu VL}{\rho g D^2}$$

$$\Rightarrow \quad 0.5 = \frac{32\times\mu\times0.3\times1}{9000\times0.0012^2}$$

$$\Rightarrow \quad \mu = 6.75\times10^{-4} \text{ Pa-s}$$

15. (c)

$$\mu = 0.97 \text{ poise} = 0.097 \text{ Ns/m}^2$$
$$\rho = 0.9\times998 = 898.2 \text{ kg/m}^3$$
$$\dot{m} = \text{mass rate of flow} = \frac{100}{30} = 3.333 \text{ kg/s}$$
$$Q = \text{Volume rate of flow}$$
$$= \frac{3.333}{898.2}$$
$$\Rightarrow \quad 3.711\times10^{-3} \text{ m}^3\text{/s} = 3.711 \text{ L/s}$$
$$\text{Area of flow} = A = \frac{\pi}{4}(0.1)^2 = 0.007854 \text{ m}^2.$$
$$\bar{U} = \frac{3.711\times10^{-3}}{0.007854} = 0.4725 \text{ m/s}$$
$$-\Delta P = \frac{32\mu\bar{U}L}{D^2} = \frac{32\times0.097\times0.4725\times10.0}{(0.1)^2}$$
$$-\Delta P = 1467 \text{ Pa}$$

16. (b)

$$Re_L = \frac{UL}{\nu} = \frac{1.75\times5}{1.475\times10^5}$$
$$Re_L = 5.932\times10^5$$
$$C_f = \frac{0.074}{Re_L^{1/5}} = \frac{0.074}{(5.932\times10^5)^{1/5}} = 5.183\times10^{-3}$$

Drag force on one side of the plate,

$$F_d = C_f \times \text{area} \times \frac{1}{2}\rho U^2$$

$$= 5.183\times10^{-3}\times(1.8\times5)\times1.22\times\frac{(1.75)^2}{2}$$

$$F_d = 0.0871 \text{ N}$$

17. (d)

$\because$ Continuity equation holds,

$$\therefore \quad \frac{\pi}{4}\times(5)^2\times2 = \frac{\pi}{4}\times3^2\times x$$

$$x = 5.55 \text{ m/s}$$

Mass flow rate

$$\Rightarrow \quad \dot{m} = \int_{\dot{m}} \rho A_1V_1 = 1000\times\frac{\pi}{4}\times0.05^2\times2 = 3.9269 \text{ kg/s}$$

Let $f_x$ and $f_y$ be the force in Right and vertically upward directions respectively to hold the box in position.

$\therefore$ Now, $\Sigma f_x = 0$ [Box is stationary after applying force]

$$-\dot{m}\times V_1\cos65° + f_x = -\dot{m}\times V_2\cos0°$$

$$-3.9269\times2\times\cos65° + f_x = -3.9269\times5.55\times1$$

$$f_x = -18.475 \text{ N.}$$

$f_x$ must be in left as $f_x$ comes out to be negative.

Similarly for vertical direction $\Sigma f_y = 0$

$$f_y - 3.9269\times2\times\sin65° = 0$$

$$f_y = 7.11 \text{ N}$$

$\therefore$ It is towards vertically upward direction.

18. (a)

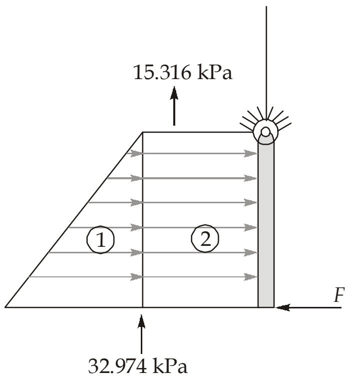
Gauge pressure at the upper end of the gate

$$= 80 + 0.9\times9.81\times4 - 100$$

$$= 15.316 \text{ kPa}$$

Gauge pressure at the lower end of the gate

$$= 80 + 0.9\times9.81\times6 - 100 = 32.974 \text{ kPa}$$




Using pressure diagram

For equilibrium,

Net moment about the hinge = 0

$$M_1 + M_2 = F \times 2$$

$$\frac{1}{2}\times(32.974-15.316)\times2\times4\times\left(\frac{2}{3}\times2\right)+15.316\times2\times4\times\frac{2}{2} = F\times2$$

On solving $F = 108.352$ kN

19. (b)

For dynamic similarity,

$$(Re)_m = (Re)_p$$

$$\Rightarrow \left(\frac{\rho VD}{\mu}\right)_m = \left(\frac{\rho VD}{\mu}\right)_p$$

$$\Rightarrow \frac{1000\times3\times0.15}{0.001} = \frac{1.2\times V\times2}{1.7\times10^{-5}}$$

$$V = 3.187 \text{ m/s}$$

For dynamic similarity,

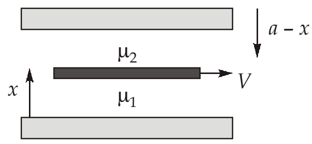
$C_D$ will be same.

$$\left(\frac{F_D}{\rho AU^2}\right)_m = \left(\frac{F_D}{\rho AU^2}\right)_p$$

$$\Rightarrow \frac{5}{1000\times(0.15)^2\times3^2\times\frac{\pi}{4}} = \frac{F_P}{1.2\times(2)^2\times\frac{\pi}{4}\times(3.187)^2}$$

$$F_P = 1.203 \text{ N}$$

20. (d)




$$\tau_1 = \text{shear stress at bottom}$$

$$= \mu_1 \times \frac{V}{x}$$

$$\tau_2 = \text{shear stress at top} = \mu_2\frac{V}{a-x}$$

$$\text{drag force} = (\tau_1+\tau_2)\times A = F_D$$

$$= F_D = A\times\left[\frac{\mu_1 V}{x}+\frac{\mu_2 V}{a-x}\right]$$

$$\frac{dF_D}{dx} = 0 = \frac{-\mu_1 V}{x^2}+\frac{\mu_2 V}{(a-x)^2} \Rightarrow \frac{\mu_1}{x^2} = \frac{\mu_2}{(a-x)^2}$$

$$a-x = \sqrt{\frac{\mu_2}{\mu_1}}x$$

$$\Rightarrow \frac{a\sqrt{\mu_1}}{\sqrt{\mu_1}+\sqrt{\mu_2}} = x$$

21. **(c)**

Given: $u = 2xy^2$, $v = 3\,xyt$

$$a_x = u\frac{\partial u}{\partial x} + v\frac{\partial v}{\partial y} + \frac{\partial u}{\partial t} = 2xy^2 \times 2y^2 + 3xyt \times 4xy$$

At (1, 1) and $t = 1$s, $a_x = 2 \times 2 + 12 = 16 \text{ m/s}^2$

$$a_y = u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + \frac{\partial v}{\partial t} = 2xy^2 \times 3yt + 3xyt \times 3yt + 3xy$$

At (1, 1) and $t = 1$s, $a_y = 6 + 9 + 3 = 18 \text{ m/s}^2$

$$a = \sqrt{a_x^2 + a_y^2} = \sqrt{16^2 + 18^2} = 24.08 \text{ m/ s}^2$$

22. **(a)**

(1) $u = x^2 \cos y$

$v = -2x \sin y$

Continuity equation

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

$$= \frac{\partial u}{\partial x}\left(x^2 \cos y\right) + \frac{\partial}{\partial y}(-2x \sin y)$$

$$(2x)\cos y - (2x)\cos y = 0$$

hence satisfy the continuity equation.

(2) $u = x + 2$

$v = 1 - y$

Continuity equation

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

$$= \frac{\partial}{\partial x}(x+2) + \frac{\partial}{\partial y}(1-y) = 1 - 1 = 0$$

hence satisfy the continuity equation.

(3) $u = xyt$

$$v = x^3 - y^2\frac{t}{2}$$

Continuity equation

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

$$= \frac{\partial}{\partial x}(xyt) + \frac{\partial}{\partial y}\left(x^3 - \frac{y^2 t}{2}\right) = yt - yt = 0$$

(4) $u = ln(x + y)$

$$v = xy - \frac{y}{x}$$

Continuity equation

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

$$= \frac{\partial}{\partial x} ln(x+y)+\frac{\partial}{\partial y}\left(xy-\frac{y}{x}\right) = \frac{1}{x+y}+x-\frac{1}{x} \neq 0$$

Hence, does not satisfy continuity equation.

23. (c)

Stream function and velocity potential : For a two dimensional, incompressible, irrotational flow, the velocity field can be expressed in terms of both $\psi$ and $\phi$.

$$u = -\frac{\partial \psi}{\partial y}; V=+\frac{\partial \psi}{\partial x}; u=-\frac{\partial \phi}{\partial x} \text{ and } v = -\frac{\partial \phi}{\partial y}$$

According to irrotationality condition,

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

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

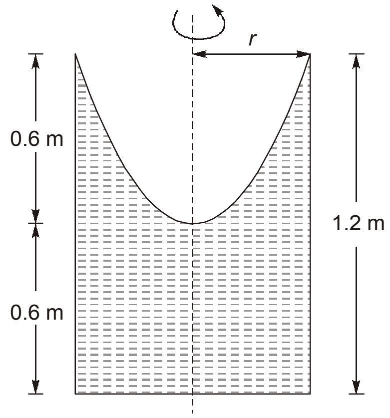
According to continuity equation,

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

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

In a flow net, equipotential lines and streamlines are mutually perpendicular to each other.

24. (a)




Original volume of

$$\text{Cylinder} = \pi r^2 h$$

$$V_1 = \pi r^2 \times 1.2$$

Volume of liquid spilled out

$$= \frac{1}{2}\pi r^2 \times h$$

$$V_2 = \frac{1}{2}\pi r^2 \times 0.6$$

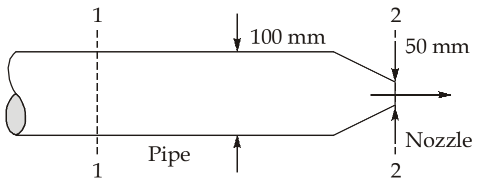
$$\therefore \quad \frac{V_2}{V_1} = \frac{\frac{1}{2}\times 0.6\pi r^2}{\pi r^2 \times 1.2} = \frac{1}{4}$$

25. (b)

$$V_1A_1 = V_2A_2$$

$$5\times\frac{\pi}{4}(0.1)^2 = V_2\times\frac{\pi}{4}(0.05)^2$$

$$\Rightarrow \quad V_2 = 20 \text{ m/s}$$




From force balance in $x$-direction

$$P_1A_1 + R_x - P_2A_2 = \rho Q(V_2 - V_1)$$

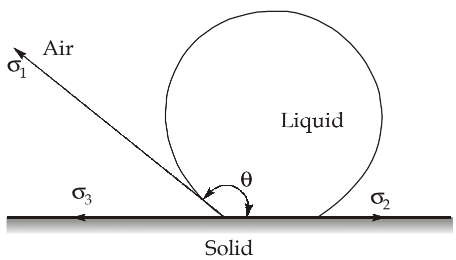
$$\Rightarrow \quad R_x = \rho Q(V_2 - V_1) + P_2A_2 - P_1A_1$$

$$= 1000\times\frac{\pi}{4}(0.1)^2\times 5(20-5) + 100\times 10^3\times\frac{\pi}{4}(0.05)^2 - 500\times 10^3\times\frac{\pi}{4}(0.1)^2$$

Force required to hold the nozzle, $R_x = -3141.6$ N

26. (c)

From force balance at point of contact,




$$\sigma_1\cos(180-\theta) + \sigma_3 = \sigma_2$$

$$\text{or} \quad \cos(180-\theta) = \frac{\sigma_2-\sigma_3}{\sigma_1} = -\cos\theta$$

$$\therefore \quad \sigma_1 = 0.0720 \text{ N/m} \quad \text{(liquid and air)}$$

$$\sigma_2 = 0.0418 \text{ N/m} \quad \text{(liquid and solid)}$$

$$\sigma_3 = 0.0008 \text{ N/m} \quad \text{(air and solid)}$$

$$\cos\theta = \frac{0.0008-0.0418}{0.072} = -0.56944$$

$$\theta = 124.7°$$

27. (a)

Difference between stream function

$$(\Delta\psi) = \text{Discharge per unit width}$$

$$\Delta\psi = \int_o^{h/2} U dy = U_{max} \int_o^{h/2} \left(1 - \frac{y^2}{h^2}\right) dy$$

$$= U_{max}\left[y - \frac{y^3}{3h^2}\right] = U_{max}\left[\frac{h}{2} - \frac{h^3}{24h^2}\right]$$

$$= U_{max}\frac{h}{2}\left[1 - \frac{1}{12}\right] = \frac{U_{max}h}{2} \times \frac{11}{12}$$

$$= \frac{100 \times 48}{2} \times \frac{11}{12} = 2200 \text{ mm}^2/\text{s}$$

28. (a)

$$(\text{Re})_{critical} = 2000 = \frac{VD}{\nu}$$

$$\Rightarrow \quad V = \frac{2000 \times 0.0098 \times 10^{-4}}{0.02} = 0.098 \text{ m/s}$$

Now,

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

$$u^* = V\sqrt{\frac{f}{8}} = 0.098 \times \sqrt{\frac{0.032}{8}} = \left(6.198 \times 10^{-3}\right)^2$$

$$\tau_{wall} = \rho u^{*2} = 1000 \times (6.198 \times 10)^{-3} = 0.0383 \text{ Pa}$$

29. (a)

$$\text{Re}_L \leq 2000$$

$$\Rightarrow \quad \frac{\rho VD}{\mu} \leq 2000$$

$$\Rightarrow \quad \frac{(0.92 \times 1000) \times \frac{Q}{A} \times (10 \times 10^{-2})}{0.9 \times 10^{-1}} \leq 2000$$

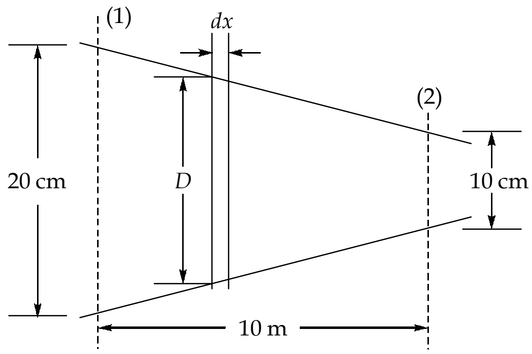
$$\Rightarrow \quad Q \leq \frac{2000 \times 0.9 \times 10^{-1} \times A}{(0.92 \times 1000) \times (10 \times 10^{-2})}$$

$$\Rightarrow \quad Q \leq 1.95652 \times \frac{\pi}{4} \times \left\{\frac{10}{100}\right\}^2$$

$$\Rightarrow \quad Q \leq 0.015366 \text{ m}^3/\text{s}$$

$$\Rightarrow \quad Q \leq 15.36 \simeq 15.4 \text{ L/s}$$

30. (b)




For the elemental length $dx$, head loss

$$dh_{fx} = \frac{f dx v^2}{2gD_x} = \frac{fQ^2 dx}{2g\left(\frac{\pi}{4}\right)^2 \times D_x^5}$$

Where, $$D_x = \left[0.2 - \frac{(0.2-0.1)}{10}x\right] = \frac{2-0.1x}{10} \text{ or } \left(\frac{20-x}{100}\right)$$

Hence, $$dh_{fx} = 0.08263 \times fQ^2 \times \frac{10^{10}}{(20-x)^5}dx \qquad [f = 0.02,\ Q = 0.05 \text{ m}^3/\text{s}]$$

$$= 41313\frac{dx}{(20-x)^5}$$

Total head loss, $$h_f = \int_x^{10} dh_{fx} = 41313 \times \int_0^{10} (20-x)^{-5}\, dx$$

$$= 41313 \times \left[\frac{1}{4(20-x)^4}\right]_0^{10} = 0.968 \text{ m}$$

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