Higher Education Center at McAllen, Texas

MMET 303
FLUID MECHANICS AND POWER

PRACTICE PROBLEMS WITH SOLUTIONS

By:

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PREFACE

This content is designed to help students and professionals alike to improve their problem-solving skills, in fluid mechanics. Whether you are preparing for a test or simply want to sharpen your abilities, the practice problems included here, offer a diverse range of challenges that will help you develop a deeper understanding of key concepts of fluid fundamentals.

The problems are focused on the specific topics, such as viscosity, density, specific gravity, specific weight, absolute pressure, continuity equation, energy equation, losses in pipe flows, pipe connections and includes a collection of practice problems with step-by-step solutions. These problems are carefully crafted to illustrate important concepts and techniques and are designed to build on one another as you progress through the concepts.

In addition to the practice problems, a detailed list of formulae is also included along with the tips and tricks for solving problems efficiently and effectively. Whether you are new to a subject or looking to deepen your understanding, these problems will provide you with the tools you need to succeed.

I hope that this problem set will serve as a valuable resource for students and professionals alike, and that the practice problems and solutions contained within will help you achieve your academic and professional goals.

PROBLEM 1

What will be a tire gauge reading at the top of a mountain where the local atmospheric pressure is 10 psi, if the tire gauge had a reading of 20 psi in Houston where the local atmospheric pressure was 14.7 psi?

Given :

In Houston, Gauge pressure = 20 psi

Local Atmospheric pressure = 14.7 psi

At mountain top, Local Atmospheric pressure = 10 psi

Find : Gauge pressure at mountain top.

Solution :

$$\text{Absolute Pressure} = \text{Gauge Pressure} + \text{Local Atmospheric Pressure}$$

∴ In Houston,

$$\begin{aligned}\text{Absolute Pressure} &= \text{Gauge pressure in Houston} + \text{Local Atmospheric Pressure in Houston}\\ &= 20\text{ psi} + 14.7\text{ psi}\\ &= 34.7\text{ psi}\end{aligned}$$

$$\text{Absolute pressure in Houston} = \text{Absolute pressure at mountain top} = 34.7\text{ psi}$$

∴ At mountain top,

$$\text{Absolute pressure} = \text{Gauge pressure at mountain top} + \text{Local Atmospheric Pressure at mountain top}$$

or, $$34.7\text{ psi} = \text{Gauge pressure at mountain top} + 10\text{ psi}$$

$$\therefore \text{Gauge pressure at mountain top} = (34.7 - 10)\text{ psi} = \boxed{24.7\text{ psi}}$$

Answer

PROBLEM 2

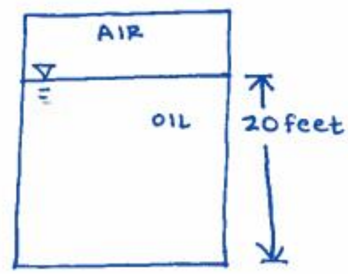
The atmospheric pressure above an oil surface in a closed tank is 30 psi. Calculate pressure 20 ft below the surface of the oil. The specific gravity of the oil is 0.75.

Given :

Atmospheric pressure above oil = 30 psi

Height of the oil column = 20 ft

Specific Gravity of oil = 0.75



Find : Pressure at 20 ft. below the oil surface.

Solution :

Pressure at 20 ft. from oil surface = Atmospheric pressure above oil surface + Pressure due to the oil column of 20 ft.

$$= 30 \text{ psi} + (\gamma h)_{oil}$$

$$= 30 \text{ psi} + SG_{oil}\, \gamma_{water}\, h_{oil}$$

$$= 30 \text{ psi} + \left\{ \frac{0.75 \times 62.4}{144} \times 20 \text{ ft} \right\} \text{psi}$$

$$= 30 \text{ psi} + 6.5 \text{ psi}$$

$$= 36 \text{ psi}$$

∴ Pressure at 20 feet below the oil surface

$$= \boxed{36 \text{ psi}}$$ Answer.

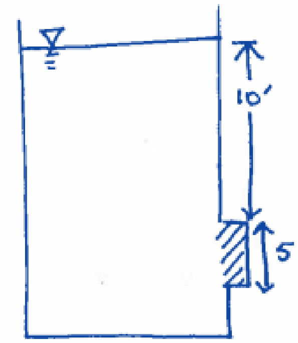
PROBLEM 3

A rectangular tank with an open top, has a 5.0 ft diameter vertical gate on one wall. If the water surface is 10.0 ft above the top of the gate, calculate the magnitude and location of the force on the gate.

Given :

Diameter of vertical gate = 5 ft

Height of water column above gate = 10 ft



Find : Magnitude of force on gate

Location of force on gate

Solution :

Force on a plane submerged surface

$$F = \gamma h_c A$$

$\therefore$ Magnitude of force on gate

$$= \gamma_{water} \, h_c \, A_{gate}$$

$$= 62.4 \, lb_f/ft^3 \times \left[10' + \frac{5'}{2}\right] \times \frac{\pi}{4} (5')^2$$

$$= \boxed{15307.5 \text{ lb}}$$ Answer

Center of Pressure is given by:

$$y_p = y_c + \frac{I_c}{y_c A}$$

$\therefore$ Location of force on gate

$$= y_c + \frac{I_c}{y_c A}$$

$$= \left[10' + \frac{5'}{2}\right] + \frac{\frac{\pi}{64} \times (5')^4}{\left[10' + \frac{5'}{2}\right]\left[\frac{\pi}{4}(5')^2\right]}$$

$$= \boxed{12.625 \text{ feet}}$$ Answer

PROBLEM 4

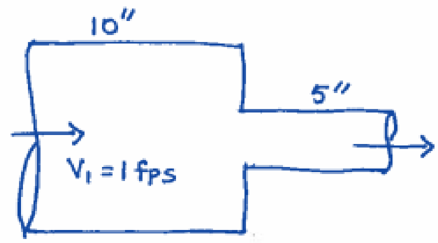
Water is flowing from a10 in. pipe to a 5 in. pipe. If the velocity of flow is 1 ft/sec in the larger pipe, calculate the velocity in the smaller pipe and the flowrate in gpm.

Given :

Diameter of large pipe = 10"

Diameter of smaller pipe = 5"

Velocity of water through the larger pipe = 1 fps



Find : Flowrate in gpm

Velocity of water flow through smaller pipe

Solution :

For steady state, continuity equation for liquids, is given by :

$$Q = A_1 V_1 = A_2 V_2 \quad \rightarrow (1)$$

$\therefore$ For larger pipe, $A_1 V_1 = \frac{\pi}{4}\left\{\left(\frac{10}{12}\right)'\right\}^2 (1)$

$\therefore$ For smaller pipe, $A_2 V_2 = \frac{\pi}{4}\left\{\left(\frac{5}{12}\right)'\right\}^2 (V_2)$

$\therefore$ From (1), $A_1 V_1 = A_2 V_2$

$$\text{or, } V_2 = \frac{A_1 V_1}{A_2} = \frac{\frac{\pi}{4} \times \frac{10 \times 10}{12 \times 12} \times 1}{\frac{\pi}{4} \times \frac{5 \times 5}{12 \times 12}}$$

$$\therefore V_2 = \boxed{4 \text{ fps}}$$ Answer.

$\therefore$ Velocity of flow through smaller pipe = 4 fps.

1 ft³/sec = 449 gpm

$$\therefore \text{Flowrate} = Q = A_1 V_1 = \frac{\pi}{4} \times \frac{10 \times 10}{12 \times 12} \times 1 \times 449$$

$$= \boxed{244.767 \text{ gpm}}$$ Answer

PROBLEM 5

A liquid with a specific gravity of 1.5 flows through a pipe at a rate of 10 cfs. The pressure is 20 psi. at a point where the pipe diameter is 36 in. Find the pressure in psi at a second point where the pipe diameter is 24 in. if the second point is 5 ft lower than the first point. Neglect all losses.

Given :

Specific Gravity of Liquid = 1.5

Flowrate = 10 cfs

Diameter of first point = 36″ = 3′

Diameter of second point = 24″ = 2′

Pressure at first point (P_1) = 20 psi

Distance of second pt. from first point = 5′

Losses = 0

$\boxed{\text{Find: } P_2}$

Solution :

Energy equation is given as :

$$\frac{P_1}{\gamma_1} + \frac{V_1^2}{2g} + Z_1 + h_m + h_t = \frac{P_2}{\gamma_2} + \frac{V_2^2}{2g} + Z_2 + h_L \rightarrow (1)$$

$$\text{Flowrate} = A_1 V_1 = A_2 V_2 = Q \rightarrow (2).$$

From (2),

$$\left.\begin{aligned} V_1 &= \frac{Q}{A_1} = \frac{10}{\frac{\pi}{4}(3')^2} = 1.415 \text{ fps} \\ V_2 &= \frac{Q}{A_2} = \frac{10}{\frac{\pi}{4}(2')^2} = 3.1847 \text{ fps}. \end{aligned}\right\} \rightarrow (3)$$

From (1), and given information, and (3),

$$\frac{20 \times 144}{1.5 \times 62.4} + \frac{1.415^2}{2 \times 32.2} + 5 + 0 + 0$$

$$= \frac{P_2 \times 144}{1.5 \times 62.4} + \frac{3.184^2}{2 \times 32.2} + 0 + 0$$

$$\therefore P_2 = \boxed{23.174 \text{ psi}} \text{ Answer}$$

$\therefore$ Pressure at second point = 23.174 psi

PROBLEM 6

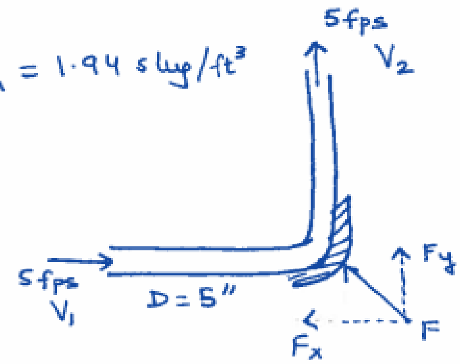
Water is deflected by a 90° vane that is in a horizontal plane. If the stream is 5 in. in diameter, and velocity is 5 ft/sec, determine the force exerted by the vane.

Given :

Angle of the vane = 90° , $\rho_{water} = 1.94 \text{ slug/ft}^3$

Diameter of the pipe = 5"

Velocity through the pipe = 5 fps



Find : Force (F) exerted by vane.

Solution :

After resolution of the force (F), we have,

$$-F_x = \rho Q (V_{2x} - V_{1x}) \rightarrow (1)$$

$$F_y = \rho Q (V_{2y} - 0) \rightarrow (2)$$

From the figure, $V_{1x} = 5 \text{ fps}$, $V_{1y} = 0 \rightarrow (3)$

$V_{2x} = 0$, $V_{2y} = 5 \text{ fps} \rightarrow (4)$

From (1), (3) and given information & (4) :

$$-F_x = 1.94 \times \left[\frac{\pi}{4}\left(\frac{5}{12}\right)^2 \times 5\right] \times [0 - 5]$$

$$\therefore F_x = 6.609 \text{ lb}_f$$

From (2), (4) and given information & (3) :

$$F_y = 1.94 \times \left[\frac{\pi}{4}\left(\frac{5}{12}\right)^2 \times 5\right] \times [5 - 0]$$

$$\therefore F_y = 6.609 \text{ lb}_f$$

$\therefore$ Force exerted by the vane $= F = \sqrt{F_x^2 + F_y^2}$

$$= \sqrt{(6.609)^2 + (6.609)^2} \text{ lb}_f$$

$$= \boxed{9.346 \text{ lb}_f}$$ Answer

PROBLEM 7

Water flows in a 6 in. diameter, one mile long at a flowrate of 1000 gpm. The temperature of the water is 60° F. The kinematic viscosity of water at 60° F is 1.217 x 10-5 ft^2/sec. Measure of roughness is 0.00020 feet. Calculate:

a. Velocity

b. Reynolds Number

c. Is the flow laminar or turbulent?

d. Darcy's friction factor

e. Head loss in ft by Darcy's formula

f. Pressure drop in psi by Darcy's formula

g. Horsepower of the pump if efficiency of the pump is 70%

h. Pressure drop in psi if C=120 in Hazen Williams formula

Given :

Fluid = Water at 60°F

Kinematic viscosity of water at 60°F $= 1.217 \times 10^{-5}\ ft^2/sec$

Roughness of pipe $\epsilon = 0.00020$ ft

Diameter of pipe, D = 6 in

Flow rate = Q = 1000 gpm

Length of pipe = 1 mile = 5280'

Solution :

a) Find : Velocity

$$Q = VA \Rightarrow V = \frac{Q}{A} = \frac{(1000/449)}{\frac{\pi}{4}\left[\frac{6}{12}\right]^2} = 11.35\ fps$$

$\therefore$ Velocity = $\boxed{11.35\ fps}$ Answer

b) Find : Reynold's Number

$$Re = \frac{VD}{\nu} = \frac{11.35 \times \left(\frac{6}{12}\right)}{1.217 \times 10^{-5}} = 4.66 \times 10^5$$

$\therefore$ Reynold's Number = $\boxed{4.66 \times 10^5}$ Answer

c) Find Turbulent or Laminar

Since $Re = 4.66 \times 10^5 > 10{,}000$,

hence the flow is $\boxed{\text{turbulent}}$ Answer

d) Find Darcy's Friction factor.

$$f = \text{function}\left(Re, \frac{\epsilon}{D}\right)$$

$$Re = 4.66 \times 10^{5} \quad \rightarrow (1)$$

$$\frac{\epsilon}{D} = \frac{0.00020}{0.5} \doteq 0.0004 \quad \rightarrow (2)$$

Using (1), (2) & Moody's diagram, $\boxed{f = 0.017}$ Answer

e) Find head loss in ft by Darcy's formula

Darcy's equation : $h_L = \frac{f\,L}{D}\,\frac{V^2}{2g} \quad \rightarrow (3)$

From (3), evaluated values & given information,

$$h_L = \frac{0.017 \times 5280' \times 11.35^2}{\left[\frac{6}{12}\right] \times 2 \times 32.2} = 359.10 \text{ ft}$$

$\therefore$ Head Loss in ft $= \boxed{359.10 \text{ feet}}$ Answer

f) Pressure drop in psi

$$\Delta P = \gamma h_L = (62.4 \times 359.10) \text{ lb/ft}^2$$

$$= \left(\frac{62.4 \times 359.10}{144}\right) \text{psi}$$

$$= 155.61 \text{ psi}$$

$\therefore$ Pressure drop in psi $= \boxed{155.61 \text{ psi}}$ Answer

g) Horsepower of a 70% efficient pump.

$e = 70\% = 70/100 = 0.7$

$$HP = \frac{QHS}{e\,(3956)} = \frac{1000 \times 359.10 \times 1}{0.7 \times 3956} = 129.67 \text{ hp}$$

$\therefore$ Required horsepower of the pump = $\boxed{129.67 \text{ hp}}$ Answer

h) Pressure drop in psi if $C = 120$ in Hazen-Williams formula

Hazen-Williams formula is :

$$h_L = \frac{4.72\, L\, Q^{1.85}}{C^{1.85}\, D^{4.87}}$$

$$= \frac{4.72 \times 5280 \times \left(\frac{1000}{449}\right)^{1.85}}{(120)^{1.85} \times \left(\frac{6}{12}\right)^{4.87}}$$

$$= 456.6 \text{ feet}$$

$\therefore$ Pressure drop $= \gamma_{water}\, h_L$

$$= (62.4 \times 456.6)\ \text{lb}_f/\text{ft}^2$$

$$= \left(\frac{62.4 \times 456.6}{144}\right)\ \text{lb}_f/\text{in}^2$$

$$= 197.7 \text{ psi}$$

PROBLEM 8

What will be the pump horsepower required in PROBLEM 7; if the following valves and fittings are attached to the pipe: 2-Globe valve, 1-Gate valves, 2-Swing check valve, and 5-90° standard elbows. The joints are flanged. Figure out the losses due to valves and fittings via velocity head method and equivalent length method respectively. Use Darcy's formula for the head loss calculations. The efficiency of the pump is 70%.

VALVES / FITTINGS	EQUIVALENT LENGTH	K = Coefficient for the valves
Globe	190'	6.4
Gate	3.2'	0.2
Swing-check	63'	2.5
Elbow	8.9'	0.9

Given :

FITTINGS	NUMBER	EQUIVALENT LENGTH	K
Globe Valve	2	190'	6.4
Gate Valve	1	3.2'	0.2
Swing - check Valve	2	63'	2.5
Elbows	5	8.9'	0.9

Find : HP of pump (70% efficient) via both methods.

Solution :

Always assume the valves to be fully open, unless otherwise mentioned in the problem.

Velocity Head Method.

Globe Valve	6.4×2
Gate Valve	0.2×1
Swing Check Valve	2.5×2
Elbows (90°)	0.9×5

$$\Sigma K = 22.5$$

Additional loss due to valves and fittings $= (\Sigma K) \dfrac{V^2}{2g}$

From Problem 7, $V = 11.35$ fps , $h_L = 359.10$ ft, $Q = 1000$ gp

$\therefore$ Additional loss $= \dfrac{22.5 \times 11.35^2}{2 \times 32.2} = 45.007$ ft

$\therefore$ Total loss due to straight pipe and the fittings

$= 359.10 \text{ ft} + 45.007 \text{ ft} = 404.107 \text{ ft}$

$\therefore$ Total loss $= 404.107$ ft

Pump efficiency $= 0.7$

$\therefore$ Pump horsepower $= \dfrac{Q\,H\,S}{e\,(3956)}$

$$= \frac{1000 \times 404.107 \times 1}{0.7 \times 3956}$$

$$= 145.929 \text{ hp}$$

$\therefore$ Horsepower of the pump, when losses are calculated via Darcy's method and velocity head method

$= \boxed{145.929 \text{ hp}}$ Answer

Equivalent Length Method

Globe Valve	$190' \times 2$
Gate Valve	$3.2' \times 1$
Swing-Check Valve	$63' \times 2$
Elbows (90°)	$8.9' \times 5$
	$\Sigma L = 553.7'$

From problem 7, Length of straight pipe $= 5280'$, $V = 11.35$ f[illegible]
$D = 6$ inch, $f = 0.017$, $Q = 1000$ gpm

$\therefore$ Total equivalent length of the pipe

$$= \Sigma L + 5280'$$

$$= 553.7' + 5280'$$

$$= 5833.7'$$

$\therefore \quad L_e = 5833.7'$

$\therefore$ Using Darcy's formula, total head loss

$$= h_{L_{new}} = \frac{f\,L_e}{D}\,\frac{V^2}{2g}$$

$$= \frac{0.017 \times 5833.7' \times 11.35^2}{\left[\frac{6}{12}\right] \times 2 \times 32.2}$$

$$= 396.76 \text{ ft}$$

$\therefore$ New head loss due to the straight pipe and the additional fittings $= 396.76$ ft

$\therefore$ Pump horsepower $= \dfrac{Q\,H\,S}{e\,(3956)}$

$$= \frac{1000 \times 396.76' \times 1}{0.7 \times 3956}$$

$$= 143.27 \text{ hp.}$$

$\therefore$ Horsepower of the pump, when the losses are calculated via Darcy's method and equivalent length method

$= \boxed{143.27 \text{ hp}}$ Answer

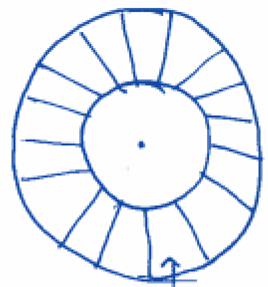
PROBLEM 9

A 12 in. diameter pipe is placed concentric in a 36 in. diameter pipe and the flow takes place only in the annular space. Calculate hydraulic diameter in ft.

Given :

Diameter of inner pipe = 12" = 1'

Diameter of outer pipe = 36" = 3'



Find : Hydraulic Diameter in ft.

Solution :

$$\text{Hydraulic Radius} = \frac{\text{Cross-Sectional Area}}{\text{Wetted Perimeter}}$$

$$\therefore R_H = \frac{\text{Area of outer pipe} - \text{Area of inner pipe}}{\text{Circumference of outer pipe} + \text{Circumference of inner pipe}}$$

or, $$R_H = \frac{\frac{\pi}{4}(3')^2 - \frac{\pi}{4}(1')^2}{\pi(3') + \pi(1')}$$

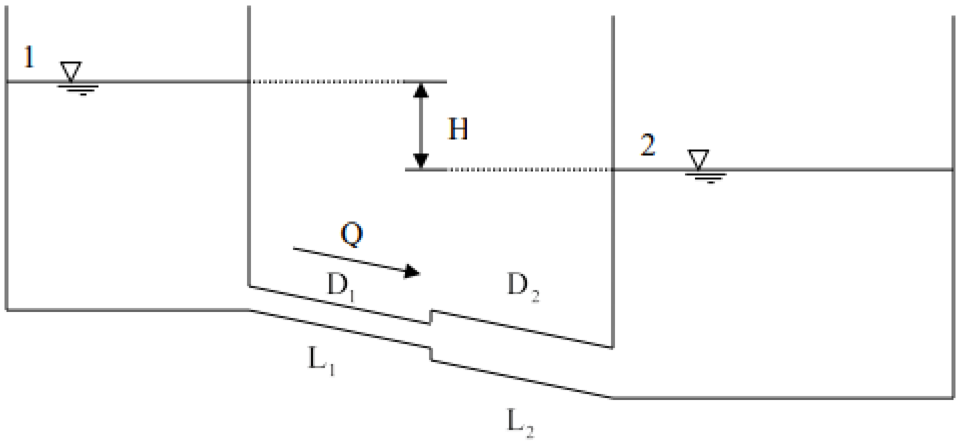
$$\therefore R_H = 0.5'$$

$$\therefore \text{Hydraulic Diameter} = 4 \times \text{Hydraulic Radius}$$
$$= 4 \times 0.5'$$
$$= 2'$$

$$\therefore \text{Hydraulic Diameter} = \boxed{2'}$$ Answer

PROBLEM 10

Apply the energy equation and find the simplified expression for "H," by considering all the possible losses in the given flow.



Given : Schematic of the flow, where pipes are connected in series.

Find : Expression for H

Solution :

Applying the Energy equation to points 1 and 2 on the reservoir free surface of the liquid.

$$\frac{P_1}{\gamma_1} + \frac{V_1^2}{2g} + z_1 + h_m + h_t + I_1$$

$$= \frac{P_2}{\gamma_2} + \frac{V_2^2}{2g} + z_2 + I_2 + \text{Losses} \quad \rightarrow (3)$$

Now, Liquid at 1 is same as Liquid at 2, $\gamma_1 = \gamma_2$

Temperature of liquid at 1 = Temperature of Liquid at 2

$\Rightarrow I_1 = I_2$

No pumps added, $h_m = 0$

No heat added, $h_t = 0$

Gauge pressure at 1 = 0 = Gauge pressure at 2

$\therefore P_1 = P_2 = 0$

Velocity at free surface = 0 = $V_1 = V_2$

Based on the assumptions (above-mentioned), 3 can be written as:

$$\frac{0}{\gamma} + \frac{0}{2g} + H + 0 + 0 + 0 = \frac{0}{\gamma} + \frac{0}{2g} + 0 + 0 + \text{Losses}$$

$$\therefore H = \text{Losses} \rightarrow 4$$

Now considering the 2 pipes for the losses.

Let the velocity of flow in pipe 1 of length $L_1 = V_1$

Let the velocity of flow in pipe 2 of length $L_2 = V_2$

Let the friction factor of pipe 1 of length $L_1 = f_1$

Let the friction factor of pipe 2 of length $L_2 = f_2$

Let K_e be the entrance loss coefficient

From (4) and the above-mentioned assumptions,

$$H = \text{Losses}$$

or, H = Entrance Loss + head loss in pipe 1 by Darcy's method + Sudden ~~exp~~ expansion los

+ head loss in pipe 2, by Darcy's method + Exit Loss

$$\text{or,} \quad H = k_e \frac{V_1^2}{2g} + \frac{f_1 L_1}{D_1} \frac{V_1^2}{2g} + \frac{(V_1 - V_2)^2}{2g} + \frac{f_2 L_2}{D_2} \frac{V_2^2}{2g} + \frac{V_2^2}{2g} \rightarrow (5)$$

∴ Required expression for H is :

$$\boxed{H = k_e \frac{V_1^2}{2g} + \frac{f_1 L_1}{D_1} \frac{V_1^2}{2g} + \frac{(V_1 - V_2)^2}{2g} + \frac{f_2 L_2}{D_2} \frac{V_2^2}{2g} + \frac{V_2^2}{2g}}$$

Answer

PROBLEM 11

Find the total flowrate Q when two pipes, Pipe 1 [Q_1=4cfs, L_1=100 ft, D_1= 12 in, f1= 0.02] and Pipe 2 [L_2= 50 ft, D_2=24in, f_2=0.016] are connected in parallel.

Given :

2 Pipes connected in parallel

<u>Pipe 1</u>

$L_1 = 100$ feet

$Q_1 = 4$ cfs

$D_1 = 12 \text{ in} = 1 \text{ ft}$

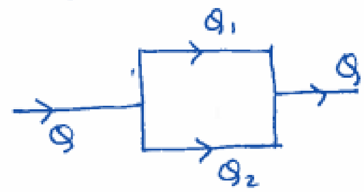
$f_1 = 0.02$

<u>Pipe 2</u>

$L_2 = 50 \text{ ft}$

$D_2 = 24 \text{ in}$

$f_2 = 0.016$



Find : Total flowrate Q

Solution :

$$Q = \text{Flowrate in Pipe 1} + \text{Flowrate in Pipe 2}$$

$$Q = Q_1 + Q_2 \rightarrow (1)$$

Since pipes are connected in parallel,

Head loss in pipe 1 = Head loss in pipe 2

$$h_{L_1} = h_{L_2} \rightarrow (2)$$

Velocity of flow in pipe 1 $= V_1 = \dfrac{Q_1}{A_1}$

or, $V_1 = \dfrac{4 \text{ cfs}}{\frac{\pi}{4}(1')^2} = 5.095 \text{ fps} \rightarrow (3)$

$\therefore$ From (2), (3) and given information,

$$h_{L_1} = h_{L_2}$$

or, $$\frac{f_1 L_1}{D_1} \frac{V_1^2}{2g} = \frac{f_2 L_2}{D_2} \frac{V_2^2}{2g}$$

$$\text{or,} \quad \frac{0.02 \times 100 \times 5.095^2}{1 \times 2 \times 32.2} = \frac{0.016 \times 50 \times V_2^2}{2 \times 2 \times 32.2}$$

$$\text{or,} \quad V_2^2 = \frac{0.02 \times 1\cancel{0}0^{2} \times 5.095^2 \times \cancel{2} \times 2 \times \cancel{32.2}}{1 \times \cancel{2} \times \cancel{32.2} \times 0.016 \times \cancel{5}\cancel{0}}$$

$$\text{or,} \quad V_2^2 = 129.79 \quad \Rightarrow \quad V_2 = 11.39 \text{ fps}$$

$\therefore$ Velocity through pipe 2 = 11.39 fps

$\therefore$ Flowrate through pipe 2 = $A_2 V_2$

$$\text{or,} \quad Q_2 = \left\{ \frac{\pi}{4} (2)^2 \times 11.39 \right\} \text{ cfs}$$

$$\therefore \quad Q_2 = 35.76 \text{ cfs}$$

$\therefore$ Total flowrate = $Q = Q_1 + Q_2$

$$= (4 + 35.76) \text{ cfs}$$

$$= 39.76 \text{ cfs}$$

$$\therefore \boxed{Q = 39.76 \text{ cfs}}$$ Answer

PROBLEM 12

A 4 ft wooden cube is thrown in water. The specific gravity of wood is 0.75. Determine the following:

a. Will the cube float or sink? Explain.

b. What is the volume of the wood above the water?

c. How much weight should be placed on the top of the cube to fully submerge it in the water?

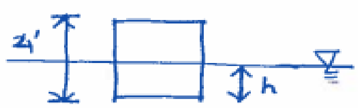
Given : A cube of side 4 ft
SG of wood = 0.75
Fluid = Water

Solution :

a) Find : Cube floats or sinks

The specific gravity of the cube is less than that of water, so the cube will float in water. (Answ.

b) Find : Volume of wood above water.



The cube is floating, Weight of cube = Force of buoyancy

$\therefore \quad W_{cube} = F_B$

or, $\gamma_{wood} \times$ Volume of wood $= \gamma_{water} \times$ Volume of displaced water

or, $\gamma_{water} \times SG_{wood} \times V_{wood} = \gamma_{water} \times h \times 4 \times 4$

or, $\cancel{\gamma_{water}} \times 0.75 \times 4 \times \cancel{4} \times \cancel{4} = \cancel{\gamma_{water}} \times h \times \cancel{4} \times \cancel{4}$

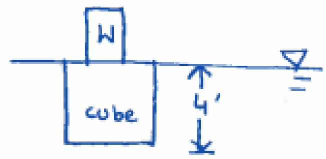
$\therefore \quad h = 3$ ft.

$\therefore$ Height of cube submerged in water = 3 ft.

$\therefore$ Height of cube above water = (4 − 3) ft = 1 ft

$\therefore$ Volume of cube above water = $1' \times 4' \times 4' = \boxed{16\ ft^3}$ Ans.

c) Find : Weight "W" to be added to completely submerge the wooden cube.



From the diagram, $W + W_{cube} = F_B$

or, $W = F_B - W_{cube}$

or, $W = \gamma_{water} V_{displaced} - \gamma_{wood} V_{cube}$

or, $W = \gamma_{water} (4' \times 4' \times 4') - SG_{wood} \gamma_{water} (4' \times 4' \times 4')$

or, $W = [62.4 \times 64] - [0.75 \times 62.4 \times 64]$

$\therefore W = 998.4 \, lb_f$

$\therefore$ Weight of the additional block = $\boxed{998.4 \, lb_f}$ Answer

LIST OF IMPORTANT FORMULAE

- Specific Weight

$$\gamma = \rho g$$

- Specific Gravity

$$S = \frac{\gamma_s}{\gamma_w} = \frac{\rho_s}{\rho_w}$$

- Force on a submerged plane surface

$$F = \gamma h_c A$$

- Center of Pressure

$$y_p = y_c + \frac{I_c}{y_c A}$$

- Moment of Inertia

$$I_c = \frac{\pi}{64} \mathrm{D}^4 \quad (\text{circular plate})$$

$$= \frac{\mathrm{bd}^3}{12} \quad (\text{Rect. plate})$$

- Continuity Equation

$$Q = A_1 V_1 = A_2 V_2 \qquad \textit{for liquids}$$

$$\dot{m} = \rho_1 A_1 V_1 = \rho_2 A_2 V_2 \qquad \textit{for gases}$$

- Energy Equation

$$\frac{P_1}{\gamma_1} + \frac{V_1^2}{2g} + Z_1 + h_p = \frac{P_2}{\gamma_2} + \frac{V_2^2}{2g} + Z_2 + Losses$$

- Darcy's Formula

$$h_L = \frac{fL}{D}\frac{V^2}{2g}$$

- Reynold's Number

$$\mathrm{Re} = \frac{VD\rho}{\mu} = \frac{VD}{\nu} \quad \text{Dimensionless}$$

- Pump Horsepower

$$\frac{\gamma QH}{e550} \qquad Q \text{ in } ft^3/sec$$

$$\frac{QHS}{e3956} \qquad Q \text{ in gpm} \qquad S = 1 \text{ for water}$$

- Hazen Williams Formula

$$\mathbf{h_L = \frac{4.72LQ^{1.85}}{C^{1.85}D^{4.87}}\ ft} \qquad \textbf{Q in cfs L and D in ft}$$

- Hydraulic radius
  R_H= Cross-sectional Area / Wetted Perimeter

- Hydraulic Diameter
  D_H= 4 x Hydraulic Radius

- Pipes in series
  $Q=Q_1=Q_2=Q_3$

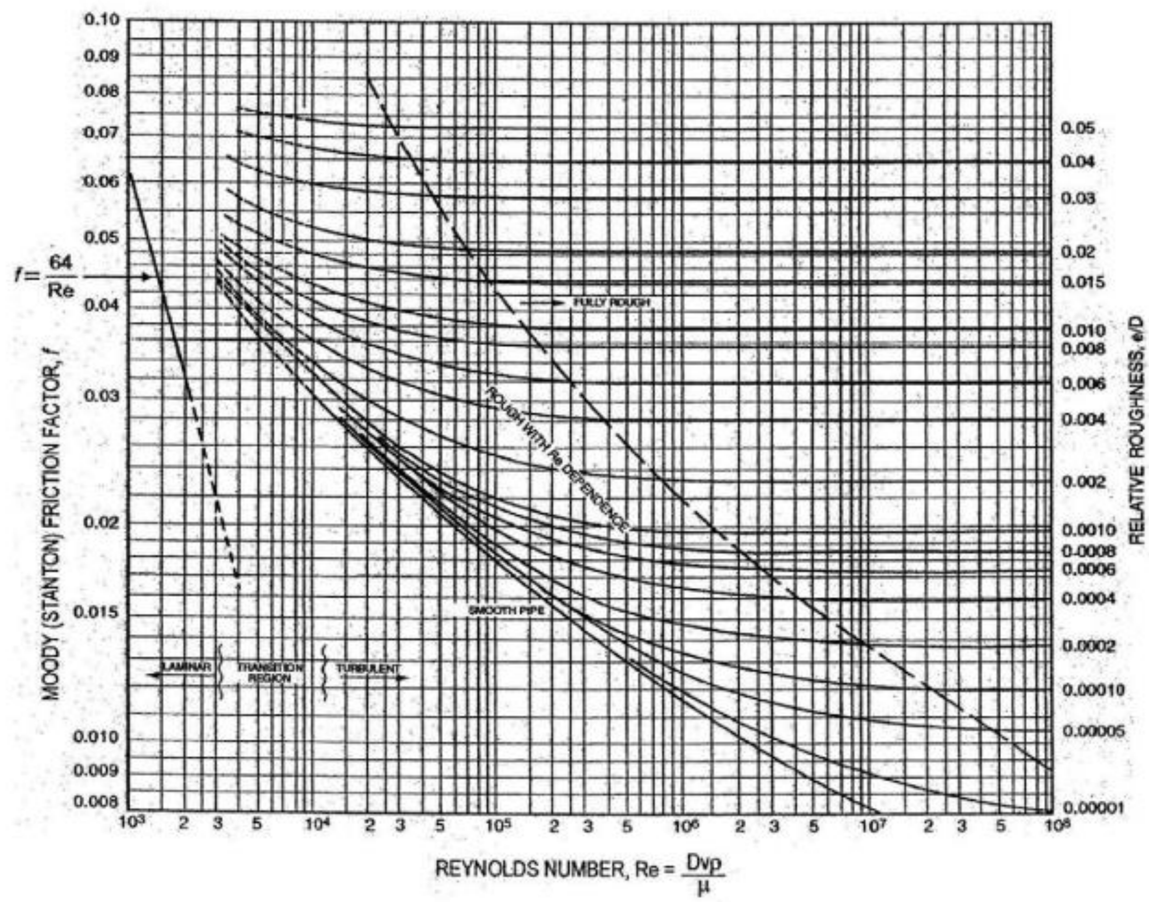
- Pipes in parallel
  $H_{L1}=H_{L2}=H_{L3}$

- For a floating body, Weight of the body = Force of Buoyancy

- Force of Buoyancy = Weight of the volume of fluid displaced

MOODY (STANTON) DIAGRAM

Material	e (ft)	e (mm)
Riveted steel	0.003–0.03	0.9–9.0
Concrete	0.001–0.01	0.3–3.0
Cast iron	0.00085	0.25
Galvanized iron	0.0005	0.15
Commercial steel or wrought iron	0.00015	0.046
Drawn tubing	0.000005	0.0015



From ASHRAE (The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.)