Problem 1

Fluid Mechanics: Ideal Gas Law

Ideal Gas Law: The volume (L) of 1 mol of H_2O at 546 K and 1.00 atm pressure is most nearly:

a) 11.2

b) 14.9

c) 22.4

d) 44.8

Problem 1

$$P \forall = n \, R \, T \leftarrow \text{Temperature (Rankine / Kelvin) } 546 \, K$$

↑ 1 atm
101.3 kPa
101,300 Pa

# of moles (1)

Universal gas constant $\left(8.314 \frac{J}{mol \cdot K}\right)$

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$$\forall = \frac{n \, R \, T}{P} = \frac{1 \, mol \left(8.314 \frac{J}{mol \cdot K}\right)\left(546 \, °K\right)}{101,300 \, Pa} = 0.0448 \, m^3 \left(\frac{1000 \, L}{m^3}\right) = \boxed{44.8 \, L}$$

Problem 2

Fluid Mechanics: Hydrostatic Forces

The rectangular homogeneous gate shown below is 3.00 m high × 1.00 m wide and has a friction-less hinge at the bottom. If the fluid on the left side of the gate has a density of 1,600 kg/m³, the magnitude of the force **F** (kN) required to keep the gate closed is most nearly:

(A)   0
(B)   22
(C)   24
(D)   220

FLUID

3.00 m

FRICTIONLESS
HINGE
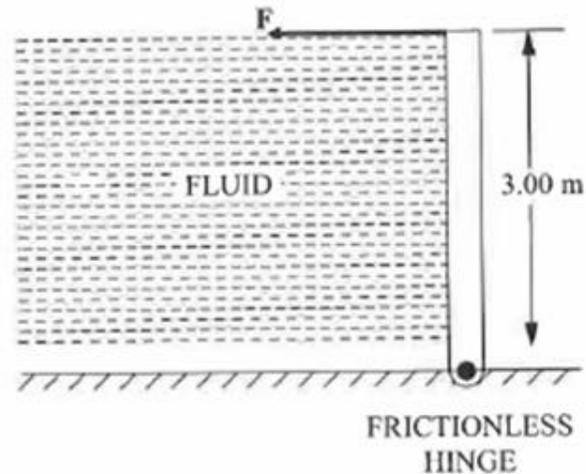
Problem 2

$$\stackrel{\curvearrowright}{+} M_{Hinge} = 0$$

$$F_{R-Fluid}\left(\frac{1}{3} \cdot 3m\right) - F(3m) = 0$$

$$F = \frac{F_{R-Fluid}}{3} = \frac{\gamma_{Fluid} \frac{h}{2}(3m)(1m)}{3}$$

$$= \frac{1600 \frac{kg}{m^3}\left(9.81 \frac{m}{s^2}\right) 3m^2 (1.5m)}{3} = 23,500N$$

$$\boxed{\begin{array}{l} = 23.5 \, KN \\[2mm] \text{Answer is } C \end{array}}$$

Problem 3

Fluid Mechanics: Fluid Properties

Which of the following statements is true of viscosity?
a) It is the ratio of inertial to viscous force.
b) It always has a large effect on the value of the friction factor
c) It is the ratio of the shear stress to the rate of shear deformation.
d) It is usually low when turbulent forces predominate

Problem 3

Fluid Mechanics: Fluid Properties

Which of the following statements is true of viscosity?

$\frac{VD}{\nu} \leftarrow$ Inertial forces

$\nu \leftarrow$ Kinematic viscosity

a) It is the ratio of inertial to viscous force. $\leftarrow Re$ #

b) It always has a large effect on the value of the friction factor

c) It is the ratio of the shear stress to the rate of shear deformation.

d) It is usually low when turbulent forces predominate

Newton's law of Viscosity

$$\tau = \mu \frac{du}{dy}$$

Shear stress $\uparrow$

rate of shear deformation $\nwarrow$

$$\mu = \frac{\tau}{\frac{du}{dy}}$$

Problem 4

Fluid Mechanics: Linear Momentum Application
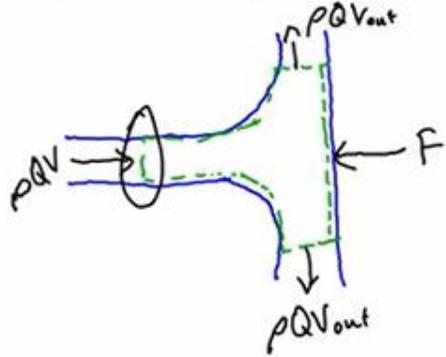
A horizontal jet of water (density = 1,000 kg/m^3) is deflected perpendicularly to the original jet stream by a plate as shown below. The magnitude of force F (kN) required to hold the plate in place is most nearly:

(A) 4.5
(B) 9.0
(C) 45.0
(D) 90.0

FLOW ⟶

JET

JET AREA = 0.01 m^2
JET SPEED = 30 m/s

F

PLATE
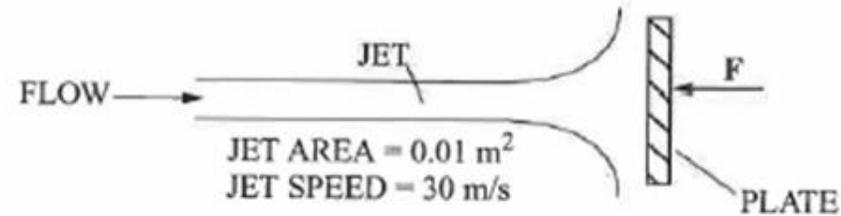
Problem 4

Draw a CV for the fluid

Linear momentum equation

$$\Sigma F_x = \rho Q V_{out-x} - \rho Q V_{in-x}$$

$$+\vec{\Sigma} F_x = -F$$

$$\rho Q V_{out-x} = 0$$

$$\rho Q V_{in-x} = 1000 \frac{Kg}{m^3} \left(30 \frac{m}{s} \left(0.01 m^2\right)\right) 30 \frac{m}{s} = 9000N$$

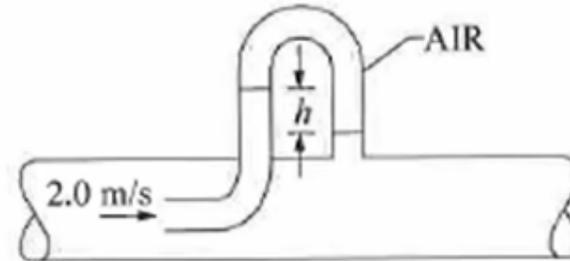$$-F = 0 - \rho Q V_{in-x} \implies F = \rho Q V_{in-x} = 9000N = 9KN$$

Answer is B

Problem 5

Fluid Mechanics : Bernoulli's

The pitot tube shown below is placed at a point where the velocity is 2.0 m/s. The specific gravity of the fluid is 2.0, and the upper portion of the manometer contains air. The reading h (m) on the manometer is most nearly:

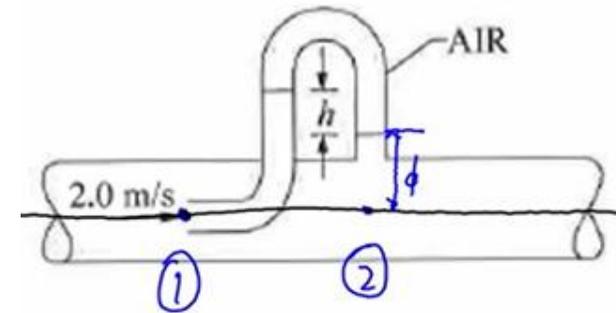(A)   20.0
(B)   10.0
(C)   0.40
(D)   0.20

Problem 5

$$\frac{P_1}{\gamma} + \cancel{z_1}_0 + \frac{V_1^{\cancel{2}}}{\cancel{2g}}_0 = \frac{P_2}{\gamma} + \cancel{z_2}_0 + \frac{V_2^2}{2g}$$

$$P_1 = P_2 - \cancel{\gamma_{Fluid}\, d} - \cancel{\gamma_{air} h}_0 + \gamma_{Fluid}\, h + \cancel{\gamma_{Fluid}\, d}$$

$$P_1 - P_2 = \gamma_{Fluid}\, h \qquad \Rightarrow \qquad h = \frac{P_1}{\gamma} - \frac{P_2}{\gamma}$$

$$\frac{V_2^2}{2g} = h \qquad \Rightarrow \qquad h = \frac{4\,\frac{m^2}{s^2}}{2\left(9.81\,\frac{m}{s^2}\right)} = \boxed{0.2\,m}$$

$$\boxed{Answer \quad is \quad D}$$

Problem 6

Hydraulics : Calculating Velocity from Manning's Equation

A 12 inch diameter concrete sanitary sewer (n=0.013, constant with depth) flows half full and is constructed on a grade of 0.5%. The flow velocity (ft/sec) in this sewer is most nearly:

a) 1.6

b) 2.0

c) 3.2

d) 32.4

Problem 6

$$Q = \frac{K}{n} A R^{2/3} S^{1/2} \qquad V = \frac{K}{n} R^{2/3} S^{1/2}$$

$$R = \frac{A}{P} \leftarrow \text{Wetted Perimeter}$$

For 1 ft diameter Pipe (half full)

$$A = \pi r^2 \left(\frac{1}{2}\right) = 0.39 ft^2$$

$$P = \frac{\pi D}{2} \leftarrow \text{circumference} \quad = 1.57 ft$$

$$K = BC \text{ units} \qquad 1.486$$

$$S = 0.005 \frac{ft}{ft}$$

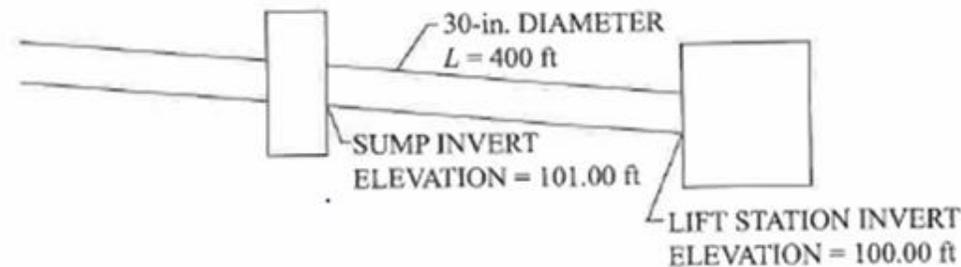$$V = \frac{1.486}{0.013} \left(\frac{0.39^{2/3}}{1.57^{2/3}}\right) 0.005^{1/2} = 3.2 \frac{ft}{s}$$

Answer is C

Problem 7

Hydraulics : Calculating Flowrate from Manning's

A sanitary sewer delivers flow from a sump to a lift station as shown in the figure below. The sewer length is 400 ft, and the diameter is 30 in. The sewer is made of concrete (Manning's roughness coefficient, $n = 0.013$, and is constant with depth).

30-in. DIAMETER
$L = 400$ ft

SUMP INVERT
ELEVATION = 101.00 ft

LIFT STATION INVERT
ELEVATION = 100.00 ft

For full pipe flow with water surface elevations in the upstream sewer sump and lift station wet well of 105.00 and 103.50 ft, respectively, the discharge (cfs) is most nearly:

(A) 46.1
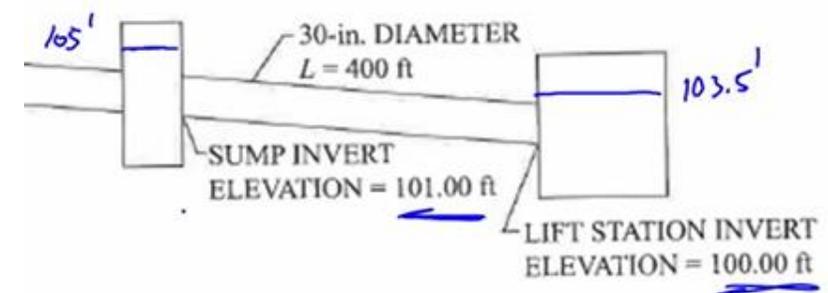(B) 25.1
(C) 13.8
(D)   5.1

Problem 7

$$Q = \frac{1.486}{n} A R^{2/3} S_f^{1/2}$$

$$= \frac{1.486}{0.013} \left(\pi \left(\frac{15''}{12} \right)^2 \right) \left(\frac{\pi \left(\frac{15}{12} \right)^2}{\pi \left(\frac{30}{12} \right)} \right)^{2/3} 0.00375^{1/2}$$

$$\boxed{= 25.1 \frac{ft^3}{s}}$$

Answer is B

30-in. DIAMETER
L = 400 ft

105'

103.5'

SUMP INVERT
ELEVATION = 101.00 ft

LIFT STATION INVERT
ELEVATION = 100.00 ft

th water surface elevations in the upstream sewer sump and lift
3.50 ft, respectively, the discharge (cfs) is most nearly:

$$S_f = \frac{105' - 103.5'}{400'} = 0.00375 \frac{ft}{ft}$$

Problem 8

Hydraulics: Hazen-Williams Equation

Two tanks are connected by a 500-ft length of 1 inch (I.D.) PVC pipe. The appropriate value for the Hazen-Williams coefficient C is 150. Water at 60°F is flowing through the pipe at a velocity of 10 ft/sec. The tanks are open to the atmosphere. Entrance, exit and minor losses are negligible. The difference in water surface elevation (ft) between the two tanks is most nearly:
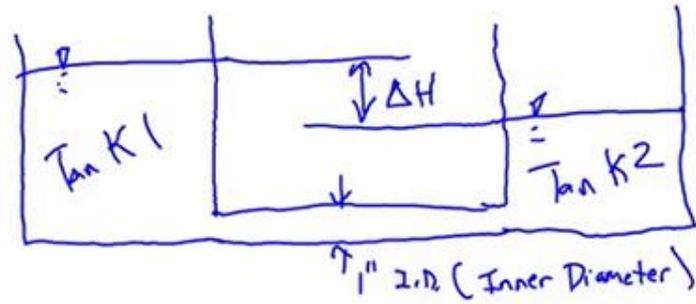
a) 81   b) 167   c)182   d) 447

Problem 8

Assume flowing full

$$V = 1.38 \, \text{C} \, R^{0.63} \, S^{0.54} \quad \leftarrow \text{Empirical Formula}$$

$$\downarrow$$
$$150$$

$$R = \frac{A}{P} = \frac{\pi D^2}{4} \left(\frac{1}{\pi D} \right) = \frac{D}{4}$$

$$10 \frac{ft}{s} = 1.38 \, (150) \left(\frac{\left(\frac{1}{12} \right)}{4} \right)^{0.63} S^{0.54}$$

Solve for S to get our friction slope $\Rightarrow$ $S = 0.364 \frac{ft}{ft}$

$$\boxed{\Delta H = 500 \, ft \left(0.364 \frac{ft}{ft} \right) = 182 \, ft}$$ $\rightarrow$ Answer is C

Problem 27

Problem 27

27. Refer to the Fluid Flow Characterization section in the Fluid Mechanics section of the *FE Reference Handbook*.

$Re = vD/v = (0.52 \text{ m/s}) \times (1.25 \text{ cm}) / (0.000001306 \text{ m}_2/\text{s}) (100 \text{ cm/m}) = 4{,}977$ or ~5,000

v = kinematic viscosity, which for water at 10▯C is 0.000001306 m₂/s, as shown on the Properties of Water table (SI) in the Fluid Mechanics chapter of the *FE Reference Handbook*.

The Reynolds number for this water flow is ~5,000, which would be considered transitional flow.

$Re < 2{,}100$ is laminar; $2{,}100 < Re < 10{,}000$ is transitional; and $Re > 10{,}000$ is turbulent.

THE CORRECT ANSWER IS: B

Problem 46

Problem 46

46. Refer to the Characteristics of a Static Liquid section in the Fluid Mechanics chapter of the *FE Reference Handbook*.

The mean pressure of the fluid acting on the gate is evaluated at the mean height, and the center of pressure is 2/3 of the height from the top; thus, the total force of the fluid is:

$$F_f = \rho g \frac{H}{2}(H) = 1,600(9.807)\frac{3}{2}(3) = 70,610 \text{ N}$$

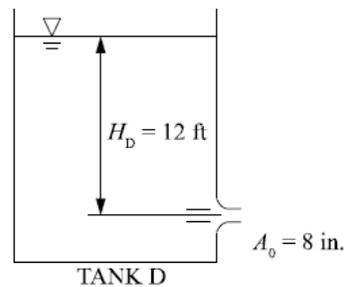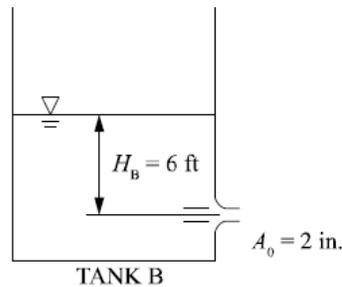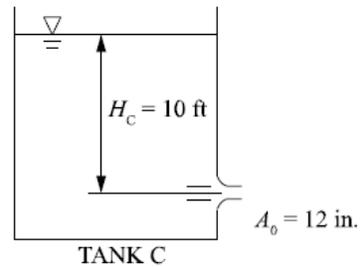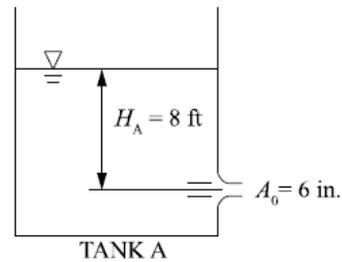and its point of application is 1.00 m above the hinge. A moment balance about the hinge gives:

$$F(3) - F_f(1) = 0$$

$$F = \frac{F_f}{3} = \frac{70,610}{3} = 23,537 \text{ N}$$

THE CORRECT ANSWER IS: C

Problem 47

47. Four water tanks are shown with varying water heights H and varying nozzle cross-sectional areas A_0. Assume no minor losses in the discharge and a common coefficient of discharge $C = 0.6$ for all the nozzles. Match the discharge velocity (ft/sec) to the correct tank.

$H_A = 8$ ft

$A_0 = 6$ in.

TANK A

$H_C = 10$ ft

$A_0 = 12$ in.

TANK C

$H_B = 6$ ft

$A_0 = 2$ in.

TANK B

$H_D = 12$ ft

$A_0 = 8$ in.

TANK D

Discharge Velocity (ft/sec)

13.6

11.8

14.3

15.2

16.7

Problem 47

Refer to the Orifice Discharging Freely into Atmosphere section in the Fluid Mechanics chapter of the *FE Reference Handbook*.

$Q = CA_0(2gh)^{1/2}$

$Q = VA$

$V = C(2gh)^{1/2}$

$V_A = 0.6(2 \times 32.2 \text{ ft/sec}^2 \times 8 \text{ ft})^{1/2} = 13.6 \text{ ft/sec}$

$V_B = 0.6(2 \times 32.2 \text{ ft/sec}^2 \times 6 \text{ ft})^{1/2} = 11.8 \text{ ft/sec}$

$V_C = 0.6(2 \times 32.2 \text{ ft/sec}^2 \times 10 \text{ ft})^{1/2} = 15.2 \text{ ft/sec}$

$V_D = 0.6(2 \times 32.2 \text{ ft/sec}^2 \times 12 \text{ ft})^{1/2} = 16.7 \text{ ft/sec}$

THE CORRECT ANSWER IS SHOWN.

Problem 40

40. A 10-ft-wide rectangular concrete channel is to be built to convey storm water runoff. The channel
grade is 0.2%. The Manning's roughness coefficient n is 0.015. If the depth of flow is 2 ft, the
discharge (cfs) is most nearly:

○ A. 110

○ B. 150

○ C. 250

○ D. 500

Problem 40

Refer to the Manning's Equation section in the Fluid Mechanics chapter of the *FE Reference Handbook*.

$$Q = \frac{1.486}{n} A(R)^{2/3} S^{1/2}$$

$$Q = \frac{1.486}{0.015} (WD) \left(\frac{WD}{W + 2D} \right)^{2/3} (0.002)^{1/2}$$

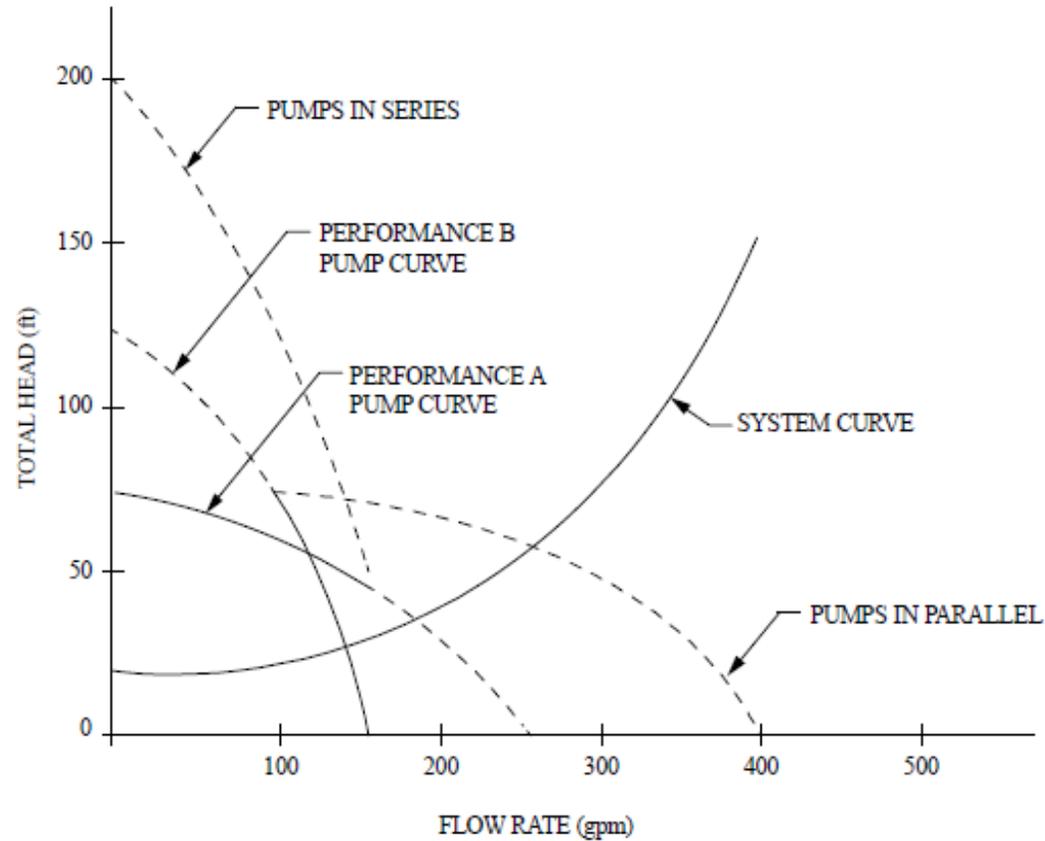$$Q = 4.430(WD) \left(\frac{WD}{W + 2D} \right)^{2/3}$$

Using: $W = 10$ and $D = 2$;

$\qquad Q = 112$ cfs
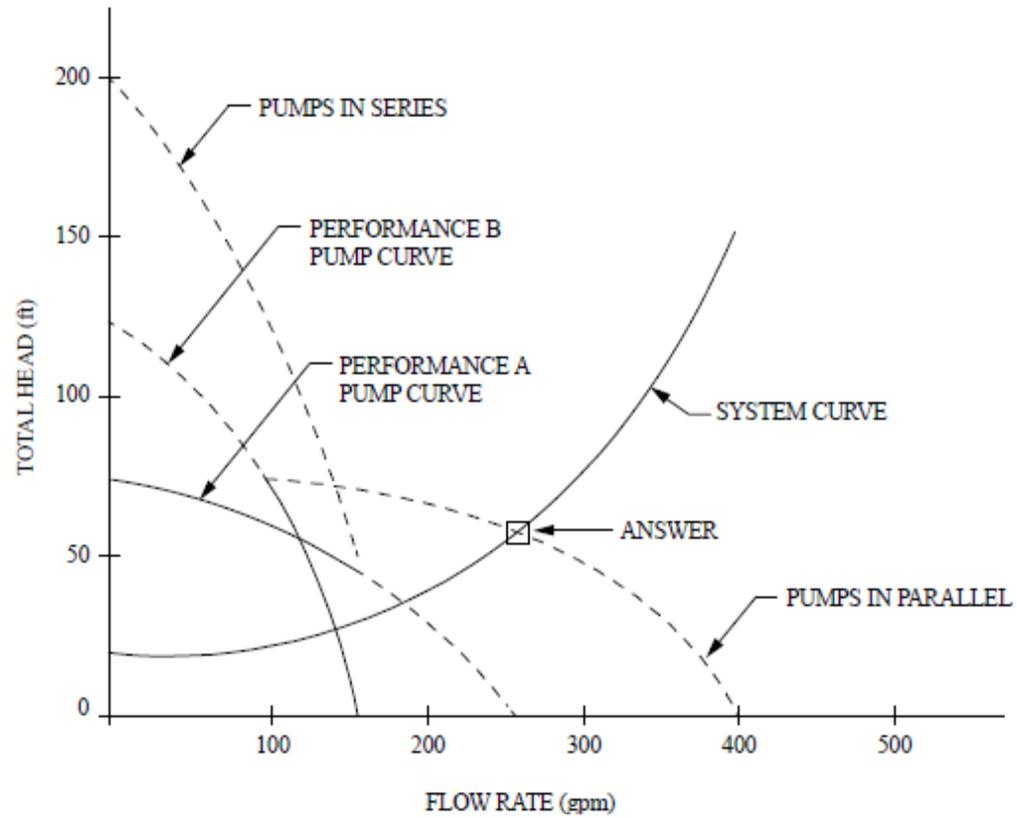
THE CORRECT ANSWER IS: A

Problem 41

41. Mark the point on the system curve that shows the head and flow when the two pumps, Pumps A and Pump B, are working in parallel in the system.

Problem 41

Refer to the Fluid Flow Machinery section in the Fluid Mechanics chapter of the *FE Reference Handbook*.

THE CORRECT ANSWER IS SHOWN ON THE GRAPH.

Problem 4

Problem 4

Example: **P.3.70**. In the pipe contraction shown in Fig. P3.70, water flows steadily with a velocity of $V_1 = 0.5$ m/s and $V_2 = 1.125$ m/s. Two piezometer tubes are attached to the pipe at sections 1 and 2. Determine the height H. Neglect any losses through the contraction.

Bernoulli

$$\frac{P_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{v_2^2}{2g} + z_2$$

$z_1 = z_2$

$\frac{P_1}{\gamma} = 0.25\,m$

Fig. P3.70

$$0.25 + \frac{0.5^2}{19.6} = H + \frac{1.125^2}{19.6}$$
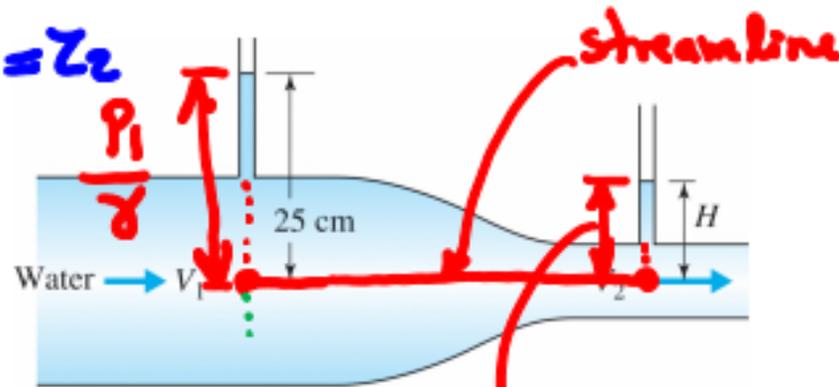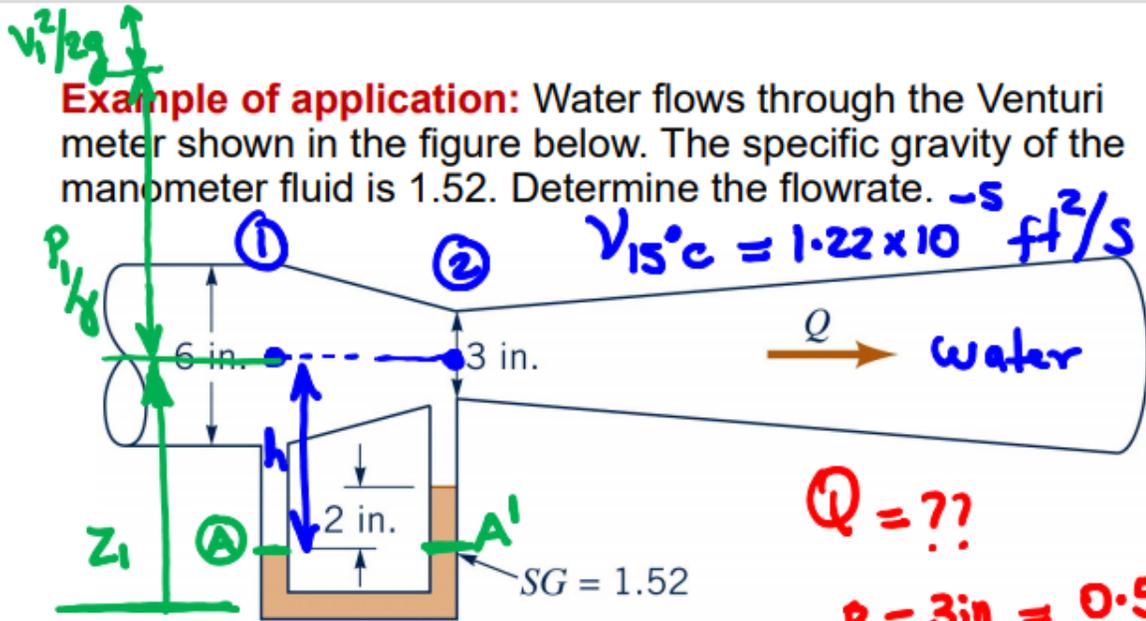
$$H = 0.20\ m$$

Problem 5

Problem 5

$v_1^2/2g \uparrow$

Example of application: Water flows through the Venturi meter shown in the figure below. The specific gravity of the manometer fluid is 1.52. Determine the flowrate.

$v_{15°c} = 1.22 \times 10^{-5} \, ft^2/s$

① ②

P_1/γ

6 in. --- 3 in.

$\xrightarrow{Q}$ water

2 in.

Z_1 Ⓐ A'

$SG = 1.52$

$Q = ??$

$Q_{actual} = K A_o \sqrt{2g(h_1 - h_2)}$

here:

$h_1 = \frac{P_1}{\gamma} + Z_1$

$h_2 = \frac{P_2}{\gamma} + Z_2$ $(Z_1 = Z_2)$

$\therefore h_1 - h_2 = \frac{P_1 - P_2}{\gamma_w}$

$\beta = \frac{3in}{6in} = 0.5$

$A_o = \frac{\pi}{4}\left(\frac{3}{12}\right)^2 = \frac{\pi}{64}$

✳ from manometer $P_A = P_{A'}$

$P_1 + \gamma_w h = P_2 + \gamma_w \left(h - \frac{2}{12}\right) + 1.52 \gamma_w \left(\frac{2}{12}\right)$

$\frac{P_1 - P_2}{\gamma_w} = -2 \frac{\gamma_w}{12 \gamma_w} + 2 \times 1.52 \frac{\gamma_w}{12 \gamma_w}$

$h_1 - h_2 = \frac{P_1 - P_2}{\gamma_w} = 0.08667$

✳ Ⓚ requires Re, $Re = f(Q)$

Guess K to find Q, Repeat process until convergence.

$K = 1.0$, $Q_{calculated} = 1.0 \times \frac{\pi}{64} \sqrt{2 \times 32.2 (0.08667)}$

$Q_{calc} = 0.116 \, ft^3/s$

$Re_o = \frac{4Q}{\pi D_o \nu} = \frac{4 \times 0.116}{3.1416 \times \frac{3}{12} \times 1.22 \times 10^{-5}} = 48425$

$K_{new} = 1.0$ Because $K_{guess} = K_{new}$,

Then $Q_{actual} = 0.116 \, ft^3/s$

Let's say $K = 0.97 \underset{new}{\rightarrow}$ New Q using

Ⓔ 1.00
    0.97
    0.96
    0.96

$K = 0.97$

$Re \rightarrow Ⓚ$

Problem 6

Problem 6

Example: P.4.63. A 1-m diameter cylindrical tank initially contains liquid fuel and has a 2-cm diameter rubber plug at the bottom as shown in the figure below. If the plug is removed, how long will it take to empty the tank.

$$\frac{DM}{Dt} = \frac{d}{dt}\int \rho \, d\forall + \int V dA = Q$$

$$\int_{c.s.} \rho\,\hat{n}\cdot\vec{V}\,dA = 0$$
c.v.

$$\cancel{\int \frac{d\forall}{dt}} + \cancel{\int\int}\hat{n}\cdot\vec{V}\,dA = 0$$
c.s.

$$\boxed{\frac{d\forall}{dt} + V_e A_e = 0} \quad \cdots \; ①$$

$$\forall = \pi \times 0.5^2 h, \quad A_e = \frac{\pi \times 0.02^2}{4}$$

Fig. P4.63 exit (e)

1 m (1)

1.5 m

Rubber Plug air

V_e
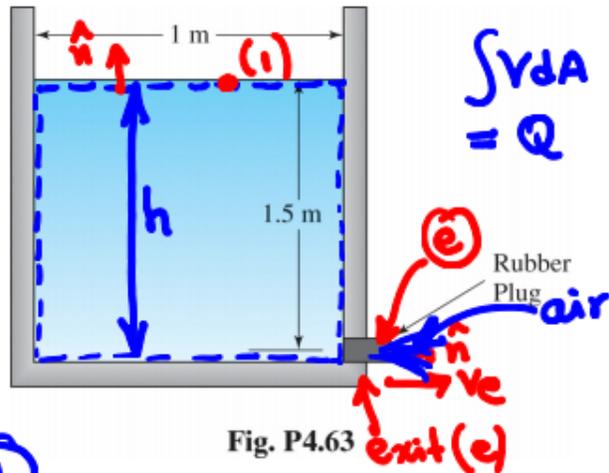
$V_e = ??$ Bernoulli Eq.

$$\frac{\cancel{P_1}}{\gamma} + \frac{V_1^2}{2g}^{\;0(negligible)} + z_1 = \frac{\cancel{P_e}}{\gamma}^{\;0(atmospheric)} + \frac{V_e^2}{2g} + z_e$$

$$h = \frac{V_e^2}{2g} \rightsquigarrow V_e = \sqrt{2gh}$$

In ①

$$\pi \times 0.5^2 \frac{dh}{dt} + \sqrt{2g}\; h^{1/2} \times \pi \times 0.01^2 = 0$$

$$\boxed{-\frac{0.5^2}{0.01^2 \sqrt{2g}}} \int h^{-1/2}\,dh = \int_0^t dt$$
1.5   ↑M

$$\int x^n dx = \frac{x^{n+1}}{n+1}$$

$$-2M h^{1/2}\Big|_{1.5}^{0} = time$$

M = 564.7

$$\boxed{time = 1383 \; seconds}$$

Problem 7

Problem 7

Problem 8

Problem 8

Problem 9

Problem 9

Problem 10

Problem 10