SI

A certain gas weighs 18.0 N/m³ at a certain temperature and pressure. What are the values of its density, specific volume, and specific gravity relative to air weighing 12.0 N/m³?

Eq. 2.1: $\rho = 18/9.81 = 1.835\ \text{kg/m}^3$ ◄

Eq. 2.2: $\nu = 1/1.835 = 0.545\ \text{m}^3/\text{kg}$ ◄

$s = 18/12 = 1.500$ ◄

11.3 *At 60°F what is the kinematic viscosity of the gasoline in Fig. 2.4, the specific gravity of which is 0.680? Give the answer in both BG and SI units.*

B

Fig. 2.4: $4.8 \times 10^{-6}\ \text{ft}^2/\text{sec}$ ◄

Fig. 2.4: $4.5 \times 10^{-7}\ \text{m}^2/\text{s} = 0.0045\ \text{cm}^2/\text{s} = 0.45$ centistokes ◄

2.11.6 *A flat plate 250 mm × 800 mm slides on oil ($\mu = 0.65\ N{\cdot}s/m^2$) over a large plane surface. What force is required to drag the plate at 1.5 m/s, if the separating oil film is 0.5 mm thick?*

SI

Eq. 2.9: $\tau = \mu \dfrac{dv}{dy} = 0.65 \dfrac{1.5}{0.000\ 54} = 1950\ \text{N/m}^2$

From Eq. 2.9: $F = \tau A = 1950(0.25 \times 0.8) = 390\ \text{N}$ ◄

2.11.8 *A space 20 mm wide between two large plane surfaces is filled with SAE 30 Western lubricating oil at 30°C. (a) What force is required to drag a very thin plate of 0.4-m² area between the surfaces at a speed of 0.2 m/s if this plate is equally spaced between the two surfaces? (b) If it is at a distance of 5 mm from one surface?*

SI

Fig. 2.3 for SAE Western lubricating oil at 30°C: $\mu = 0.215\ \text{N}{\cdot}\text{s/m}^2$

(*a*) Eq. 2.9: $\tau = 0.215\left(\dfrac{0.2}{10/1000}\right) = 4.30\ \text{N/m}^2$; From Eq. 2.9: Force $= 4.30(2)0.4 = 3.44$ N ◄

(*b*) Eq. 2.9: $\tau_1 = 0.215\left(\dfrac{0.2}{5/1000}\right) = 8.60\ \text{N/m}^2$; $\tau_2 = 0.215\left(\dfrac{0.2}{15/1000}\right) = 2.87\ \text{N/m}^2$

From Eq. 2.9: $F_1 = \tau_1 A = 8.60(0.4) = 3.44$ N ; $F_2 = \tau_2 A = 2.87(0.4) = 1.147$ N

$\therefore$ Force $= F_1 + F_2 = 4.59$ N ◄

Neglecting the pressure upon the surface and the compressibility of water, what is the pressure in kPa at a depth of a wreck 4 km below the surface of the ocean? The specific weight of ocean water under ordinary conditions is 10.05 kN/m³.

SI

Eq. 3.4: $p = \gamma h = 10.05(4000) = 40\ 200\ \text{kN/m}^2$ ◄

Sec 3.3: Pressure Expressed in Height of Fluid -- *Exercises*

3.3.1 *An open tank contains 6.0 m of water covered with 2.5 m of oil ($\gamma = 8.0\ kN/m^3$). Find the gage pressure at the interface and at the bottom of the tank.*

SI

Eq. 3.4: $p = \gamma h = (8\ \text{kN/m}^3)2.5\ \text{m} = 20\ \text{kN/m}^2 = 20$ kPa at interface ◄

$p_b = 20 + (9.81)6 = 78.9\ \text{kN/m}^2 = 78.9$ kPa at tank bottom ◄

If the atmospheric pressure is 860 mb abs and a gage attached to a tank reads 370 mmHg vacuum, what is the absolute pressure within the tank?

Eq. 3.4: $p_{gage} = \gamma h = (13.56 \times 9.81\ \text{kN/m}^3)(0.37\text{m}) = 49.2\ \text{kN/m}^2$ vac. $= -49.2\ \text{kN/m}^2$

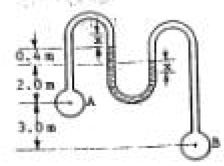
$p_{atm} = (860\ \text{mb abs})(0.1\ \text{kPa/mb}) = 86.0$ kPa abs

Eq. 3.7: $p_{abs} = p_{atm} + p_{gage} = 86.0 - 49.2 = 36.8\ \text{kN/m}^2$ abs ◄

Sec. 3.6: Measurement of Pressure -- *Problems*

3.5 *What would be the manometer reading in Sample Prob. 3.4 if $p_B - p_A = 120$ kPa?*

Sample Prob. 3.4: Manometer fluid = Hg. $\gamma_A = 8.4$ kN/m³, $\gamma_B = 12.4$ kN/m³, $p_B = 207$ kPa, find p_A. Express all pressure heads in terms of liquid B.



SI

$$\frac{p_B}{\gamma} - \frac{p_A}{\gamma} = \frac{120\text{ kN/m}^2}{12.4\text{ kN/m}^3} = 9.68\text{ m (of liquid B)}$$

$$\frac{p_A}{\gamma} - (2.4 + x)\frac{8.4}{12.4} + (2x + 0.4)\frac{13.56(9.81)}{12.4} + (5 - x) = \frac{p_B}{\gamma}$$

$-1.626 - 0.677 + 21.46 + 4.29 + 5.0 - x = 9.68$; $x = 0.1017$ m

Manometer reading $= 0.4 + 2x = 0.603$ mHg ◄

3.8.19 *In Fig. X3.8.19 the rectangular flashboard MN shown in cross-section is pivoted at B. (a) What must be the maximum height of B above N if the flashboard is on the verge of tipping when the water surface rises to M? (b) If the flashboard is pivoted at the location determined in (a) and the water surface is 1 m below M, what are the reactions at B and N per m length of board perpendicular to the figure?*

SI

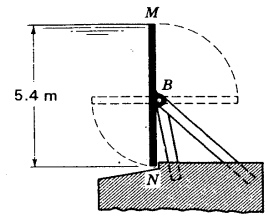


Figure X3.8.19

(a) For critical stability, center of pressure must be at B.

Thus B will be $5.4/3 = 1.80$ m above N. ◄ $Y_p = Y_c + \frac{I_c}{Y_c A}$.

(b) For 4.4 m depth of water, Eq. 3.16: $F = 9.81(4.4/2)4.4$

$= 95.0$ kN/m

$\Sigma M_B = 0 = 95.0(1.8 - 4.4) - 1.8N_x$; $N_x = 17.59$ kN/m ◄

$\therefore B_x = 95.0 - 17.59 = 77.4$ kN/m ◄ $B_y = 0$ ◄

3.8.17 *Find the magnitude and point of application of the force on the circular gate shown in Fig. X3.8.17.*

SI

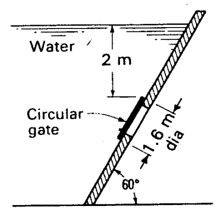


Figure X3.8.17

Eq. 3.16: $F = \gamma h_c A = 9.81(2 + 0.8\sin 60°)\pi(0.8)^2 = 53.1$ kN ◄

$$\frac{I_c}{y_c A} = \frac{(\pi/64)(1.6)^4}{(2/\cos 30° + 0.8)\pi(0.8)^2} = 0.0515 \text{ m}$$

Eq. 3.18: $y_p = y_c + \frac{I_c}{y_c A}$ (slope distance)

$y_p = 2/\cos 30° + 0.8 + 0.0515 = 3.16$ m ◄

3.9.2 *A tank with vertical ends contains water and is 6 m long normal to the plane of Fig. X3.9.2. The sketch shows a portion of its cross-section where MN is one-quarter of an ellipse with semiaxes b and d. If b = 2.5 m, d = 4 m, and a = 1.0 m, find, for the surface represented by MN, the magnitude and position of the line of action of (a) the horizontal component of force; (b) the vertical component of the force; (c) the resultant force and its direction with the horizontal.*

SI

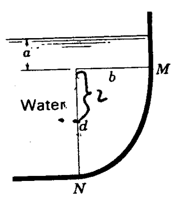


Figure X3.9.2

(a) Eqs. 3.20, 3.16: $F_x = \gamma h_c A = (9.81)3.0(4 \times 6) = 706$ kN ◄ Acts at:

$$h_p = y_c + \frac{I_c}{y_c A} = y_c + \frac{h^2}{12 y_c} = 3.0 + \frac{4^2}{12(3.0)} = 3.44 \text{ m below surface}$$ ◄

(b) Using Table A.7: Eq. 3.21: $F_y = W = 6\left(\frac{2.5\,\pi 4}{4} + 1.0 \times 2.5\right)9.81 = 609$ kN ◄

Acts at: $x_c = \frac{4b}{3\pi} = \frac{4(2.5\text{ m})}{3\pi} = 1.061$ m to right of N ◄

(c) $R = \sqrt{F_x^2 + F_y^2} = \sqrt{706^2 + 609^2} = 933$ kN ◄

Acts through intersection of F_x and F_y. ◄ $\theta = \tan^{-1}(F_y/F_x) = \tan^{-1}(609/706) = 40.8°$ ◄

3.9.4 *The cross section of a tank is as shown in Fig. X3.9.4. BC is a cylindrical surface. If the tank contains water to a depth of 10 ft, determine the magnitude and location of the horizontal- and vertical-force components on the wall ABC.*

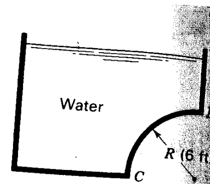
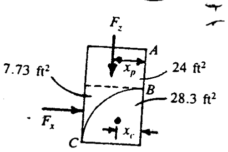


Figure X3.9.4

BG

Eqs. 3.20, 3.16: $F_x = \gamma h_c A = 62.4(1/2 \times 10)10 = 3120$ lb/ft ◄

F_x acts at: $y_p = (2/3)10 = 6.67$ ft below surface ◄



$(\pi/4)6^2 = 28.3\ \text{ft}^2$; $10(6) - 28.3 = 31.7\ \text{ft}^2$

$x_c = 4r/(3\pi) = 2.55$ ft (Table A.7)

Eq. 3.21: $F_z = W = 62.4(31.7) = 1980$ lb/ft ◄

$x_p(31.7) + 2.55(28.3) = (10 \times 6)3$

F_z acts at: $x_p = 3.40$ ft to left of AB ◄

3.10.5 *For the conditions shown in Figure X3.10.5, find the force F required to lift the concrete-block gate if the concrete weighs 23.6 kN/m³. Neglect friction.*

SI

$\Sigma F_z = 0$; $F +$ (salt w.) $-$ (fresh w.) $-$ (conc. block) $= 0$

$F + 9.81(1.025)1.5\pi(0.3)^2 - 9.81(3)\pi 0.3^2 - 23.6(0.3)\pi 0.3^2 = 0$

$F + 4.26 - 8.32 - 2.00 = 0$; $F = 6.06$ kN ◄

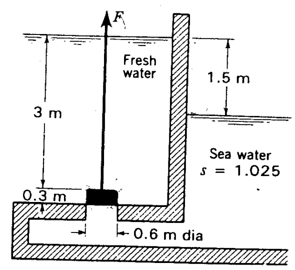


Figure X3.10.5

Refer to Sample Problem 5.11. If the depths upstream and downstream of the gate were 8.0 ft and 4.0 ft respectively, find the flow rate per foot of channel width.

BG

Energy Eq: $8 + 0 + V_1^2/2g = 4 + 0 + V_2^2/2g$

Continuity: $A_1V_1 = A_2V_2$ yields $V_2 = (8/4)V_1$

Combining these two equations gives $V_1 = 9.27$ fps

Hence $Q = A_1V_1 = (8 \times 1)9.27 = 74.1$ cfs per ft of channel width ◄

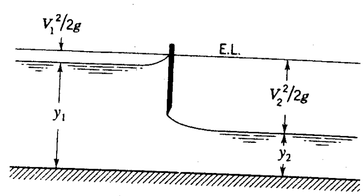


Figure S5.11

Refer to Sample Prob. 5.11. If the depths upstream and downstream of the gate were 2.0 m and 0.6 m respectively, find the flow rate per meter of channel width.
See Fig. S5.11 with Solution 5.15.1.

SI

Energy Eq. 5.15: $2 + 0 + V_1^2/2g = 0.6 + 0 + V_2^2/2g$

Continuity: $A_1V_1 = A_2V_2$ yields $V_2 = (2/0.6)V_1$

Combining these two equations gives $V_1 = 1.648$ m/s

Hence $Q = A_1V_1 = (2 \times 1)1.648 = 3.30$ m³/s per m ◄

5.5.4 *A vertical pipe 1.8m in diameter and 22 m long has a pressure head at the upper end of 5.6 m of water. When the flow of water through it is such that the mean velocity is 5 m/s, the friction loss is h_L = 1.15 m. Find the pressure head at the lower end of the pipe when the flow is (a) downward (b) upward.*

SI

(*a*) Eq. 5.14: $5.6 + 22 + \frac{5^2}{2(9.81)} = \frac{p_2}{\gamma} + 0 + \frac{5^2}{2(9.81)} + 1.15$ (velocity heads cancel)

$\frac{p_2}{\gamma} = 26.5$ m for downflow ◄

(*b*) Eq. 5.14: $\frac{p_2}{\gamma} + 0 + \frac{5^2}{2(9.81)} = 5.6 + 22 + \frac{5^2}{2(9.81)} + 1.15$ (velocity heads cancel)

$\frac{p_2}{\gamma} = 28.8$ m for upflow ◄

SI

If the difference in elevation between A and B in Fig. X5.5.6 is 10 m and the pressures at A and B are 160 and 260 KN/m² respectively, find the direction of flow and the head loss in meters of liquid. Assume the liquid has a specific gravity of 0.88.

Fig. X5.5.6: See with Solution 5.5.6 above.

$SG = \frac{\gamma}{\gamma_w}$

Assume flow is from *A* to *B*.

Eq. 5.14: $\frac{160 \text{ kN/m}^2}{(0.88)9.81 \text{ kN/m}^3} + 10 + \frac{V^2}{2g} = \frac{260 \text{ kN/m}^2}{(0.88)9.81 \text{ kN/m}^3} + 0 + \frac{V^2}{2g} + h_L$

$h_L = 18.53 + 10 - 30.12 = -1.58$ m ◄ so flow is from *B* to *A* ◄

7.1 *Assume the flow to be frictionless in the siphon shown in Fig. X5.7.1. Find the rate of discharge in cfs and the pressure head at B if the pipe has a uniform diameter of 4 in.*

BG

Eq. 5.24 from *M* to *N* (elevation datum at *N*):

$0 + 0 + 16 = 0 + V_N^2/2g + 0$; $V_N = V_B = 32.1$ fps

$Q = \pi(2/12)^2 32.1 = 2.80$ cfs ◄

Eq. 5.24 from *M* to *B*:

$0 + 0 + 16 = p_B/\gamma + V_B^2/2g + 20$; $p_B/\gamma = -20.0$ ft ◄

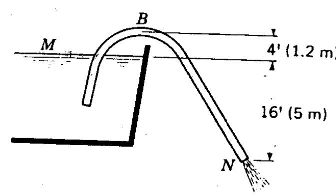


Figure X5.7.1

.2 *Referring to Fig. X5.7.1, assume the flow to be frictionless in the siphon. Find the rate of discharge in m³/s and the pressure head at B if the pipe has a uniform diameter of 18 cm.*

Fig. X5.7.1: See with Solution 5.7.1 above.

SI

Eq. 5.24 from *M* to *N* (elevation datum at *N*): $0 + 0 + 5 = 0 + V_N^2/2g + 0$; $V_N = V_B = 9.90$ m/s

$Q = \pi(0.18/2)^2 9.90 = 0.252 \text{ m}^3/\text{s}$ ◄

Eq. 5.24 from *M* to *B*: $0 + 0 + 5 = p_B/\gamma + V_B^2/2g + 6.2$; $p_B/\gamma = -6.20$ m ◄