Fundamentals of Hydraulic Engineering Systems

Fifth Edition

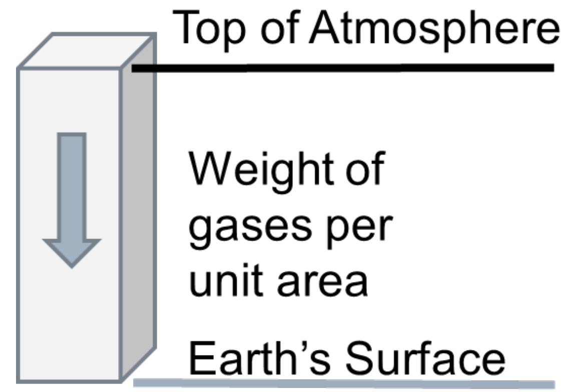
Chapter 2a

Water Pressure and Pressure Forces

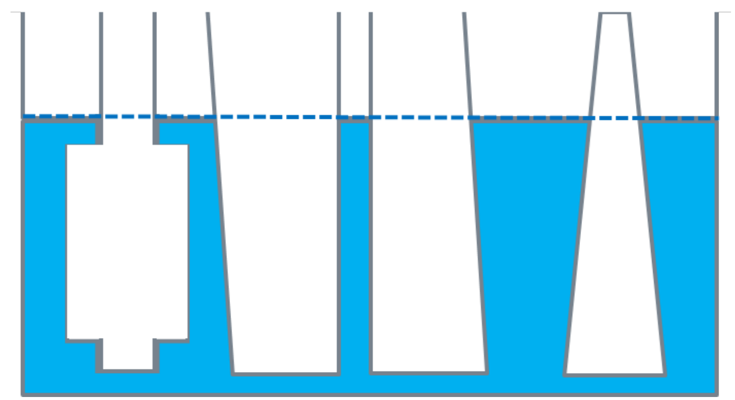
Pearson

Pressure Concepts and Definitions

Atmospheric Pressure: The weight of the atmospheric column of gases divided by the area upon which it acts. **(At sea level and normal conditions: $1.014 \times 10^5\ N/m^2\ (Pa) = 1\ bar$)**



Free Surface of Water: Water placed in a container seeks a horizontal surface minimizing its position (potential) energy. **("Water seeks its own level!")**

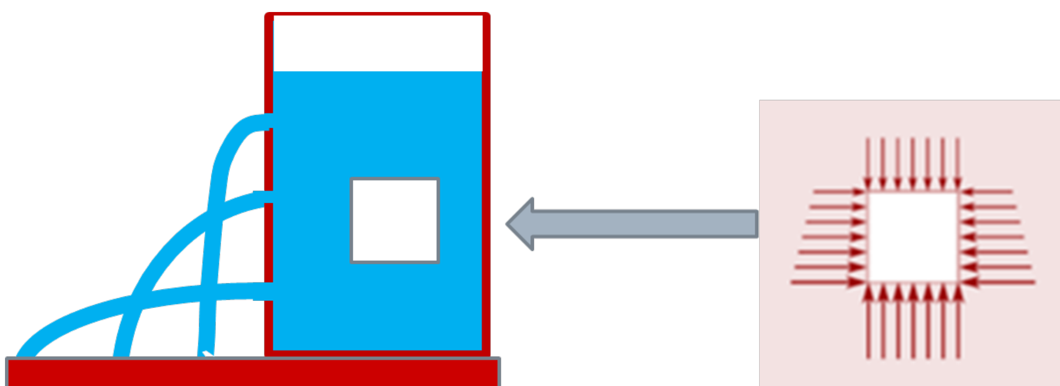


Pressure Variation in a Static Fluid (1 of 3)

Three holes are drilled in the container below. Will water shoot out the same distance? **Why or why not?**

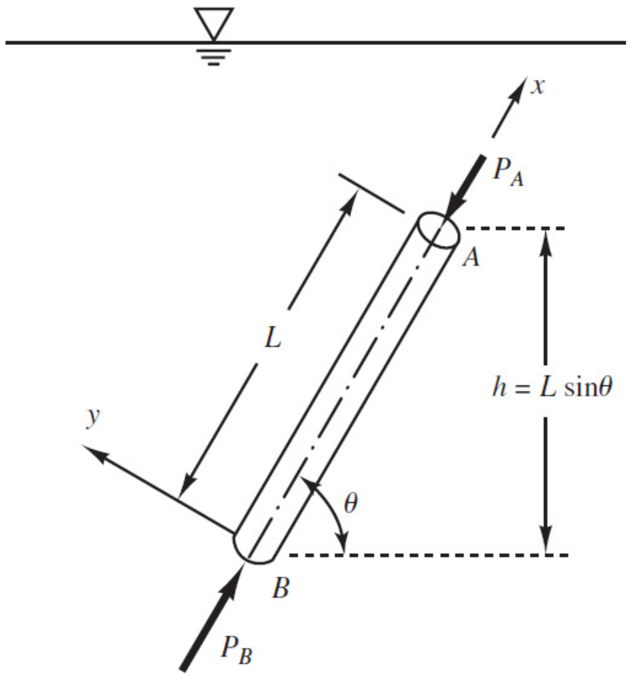
Concept: All surfaces in a static fluid are subject to normal pressure forces, but not shear forces since there is no fluid motion. Recall that $\tau = \mu\left(\frac{dv}{dy}\right)$, **but** $\left(\frac{dv}{dy}\right) = 0.$

Note: Pressure varies with depth!



Pressure Variation in a Static Fluid (2 of 3)

Figure 2.1 Hydrostatic pressure on a prism



Sum forces along the x-axis:

$$\sum F_x = P_A dA - P_B dA + \gamma L(dA)sin\theta = 0$$

Pressure Variation in a Static Fluid (3 of 3)

But $L(\sin\theta) = h$, thus simplifying

$$\boldsymbol{P_B - P_A = \gamma h}, \text{ or } \boldsymbol{P_B = P_A + \gamma h}$$

If A and B are at the same elevation?

$$P_B = P_A$$

What if A is at the water surface?

$$(P_B)_{abs} = \gamma h + P_A = \gamma h + P_{atm}$$

Pressure gages measure pressure above or below atmospheric. Thus, **Gage Pressure:** $P = P_{abs} - P_{atm} = \gamma h$;

Also, $h = P / \gamma$ (Pressure Head)

Surfaces of Equal Pressure

Identify equal pressure surfaces (ES) in the figure below. Equal pressure surfaces must: **1) have same elevation 2) be the same liquid, and 3) be connected.**

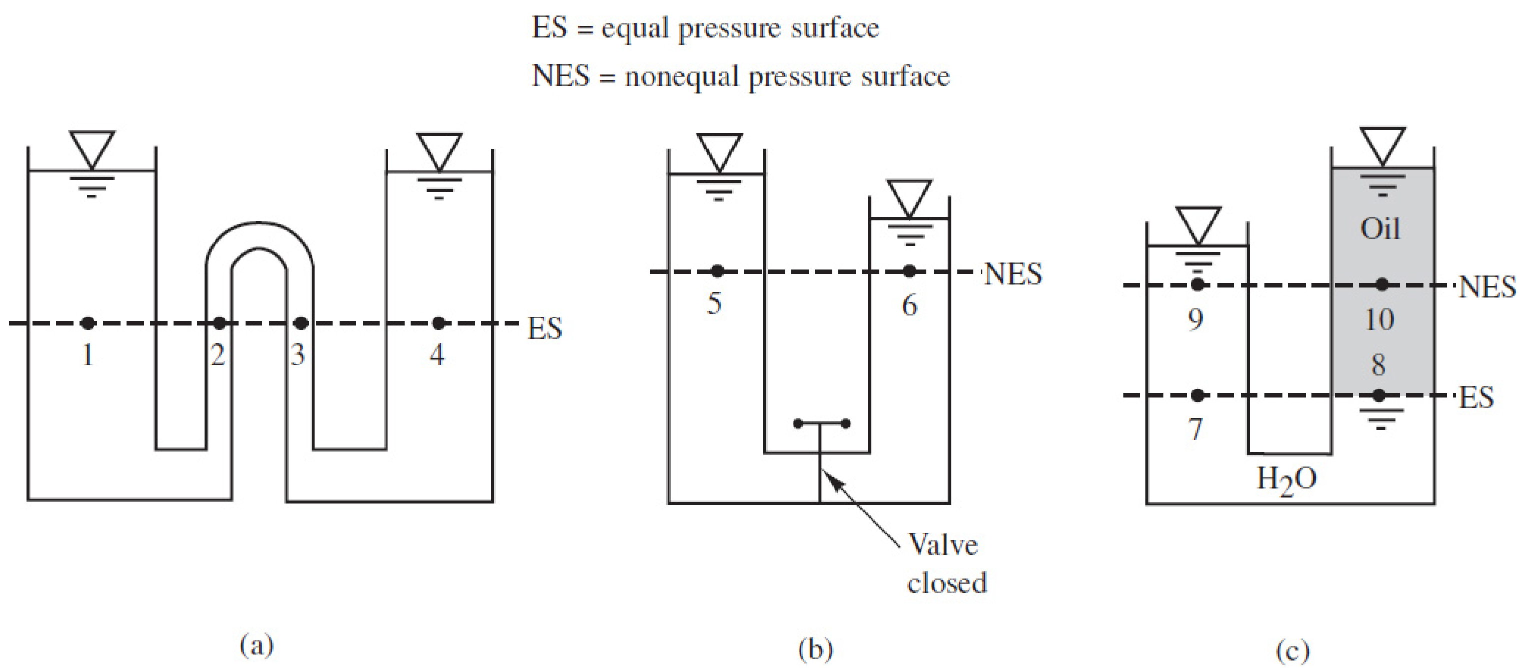
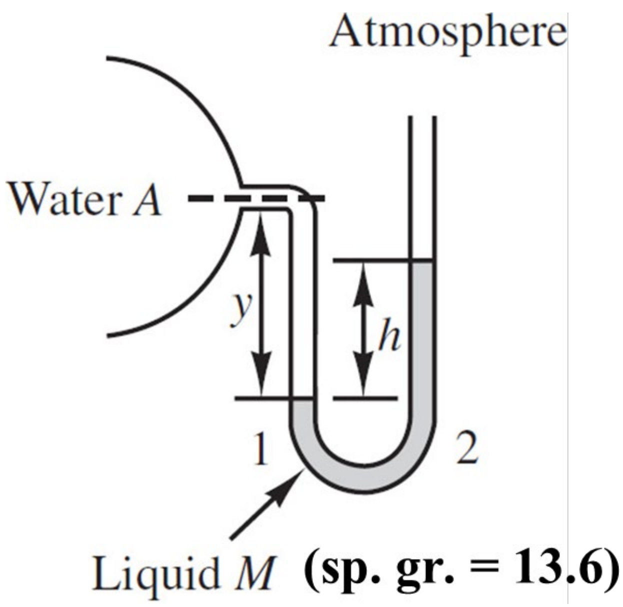


Figure 2.4 Hydraulic pressure in vessels

Manometer Applications

Example Problem – Solve on White Board

Find the pressure in the water pipe (P_A) if y = 8 cm, h = 6 cm, and M is mercury.



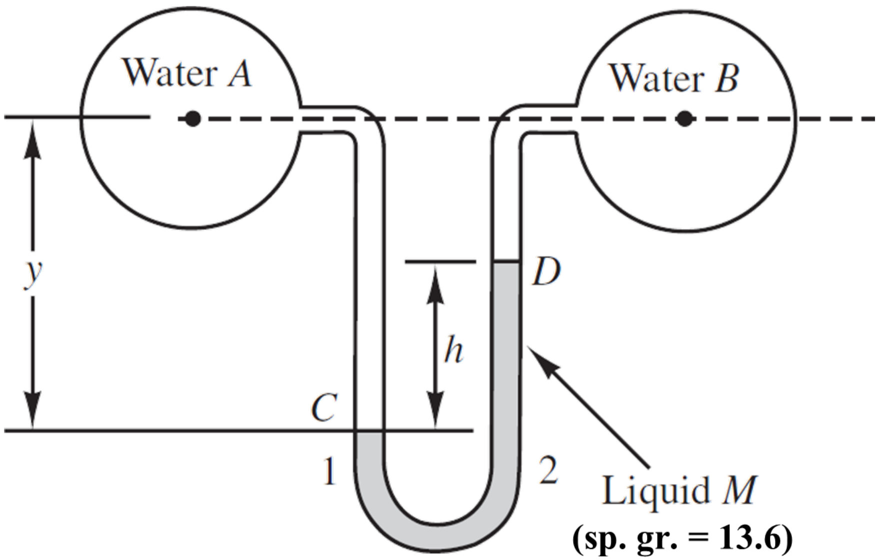
$$P_A = 7.21 \text{ kPa}$$

Note: Some people prefer the "swim-through" technique over the technique in the book.

Differential Manometers

Example Problem – Solve on White Board

Find the pressure in the water pipe A (P_A) if $P_b = 30\,\text{kPa}$, $y = 20$ cm, h = 10 cm, and M is mercury. Note: $1\,\text{kPa} = 1{,}000\,\text{N}/\text{m}^2$

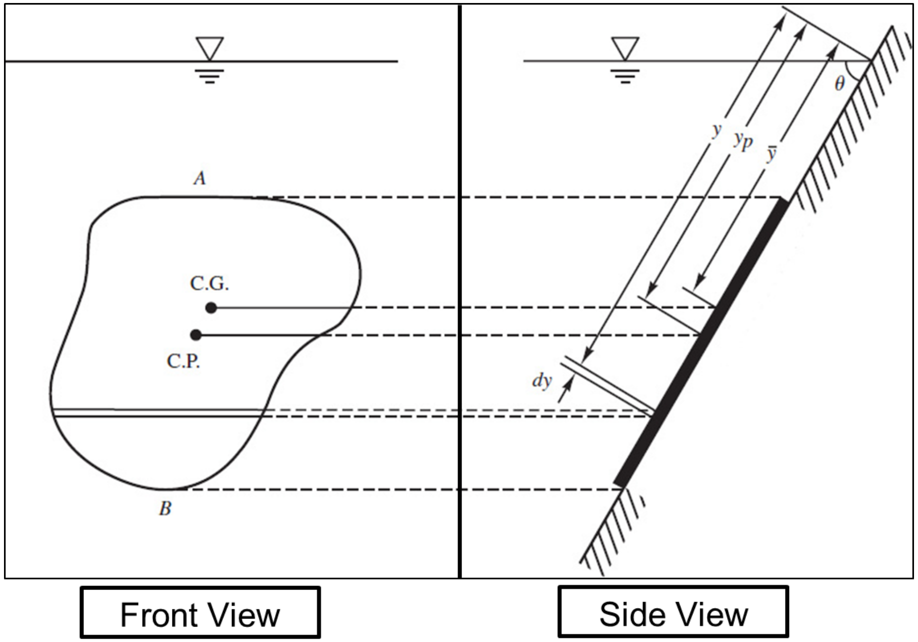


P_A = 42.3 kPa

Note: Some people prefer the “swim-through” technique over the technique in the book.

Hydrostatic Forces on Flat Surfaces (1 of 2)

Figure 2.9 Hydrostatic pressure on a plane surface



Find pressure on strip *dA* :

$$P = \gamma h = \gamma y(\sin\theta)$$

Hydrostatic Forces on Flat Surfaces (2 of 2)

Pressure force on strip *dA*?

$$dF = \gamma y(\sin\theta)dA$$

Pressure Force on area AB?

$$F = \int_A \gamma y(\sin\theta)dA$$

$$F = \gamma(\sin\theta)\int_A y\, dA, \textbf{ but}$$

$$\int_A y dA = \bar{y}A(\textbf{first moment of area})$$

$$\boldsymbol{F = \gamma(\sin\theta)\bar{y}A = \gamma\bar{h}A}(\textbf{see figure})$$

The location of this hydrostatic (pressure) force is:

$$\boldsymbol{y_p = [I_o/(A\bar{y})] + \bar{y}}\ \textbf{(location of CP or Center of Pressure)}$$

Purpose (of finding hydrostatic forces): Moment Calculations

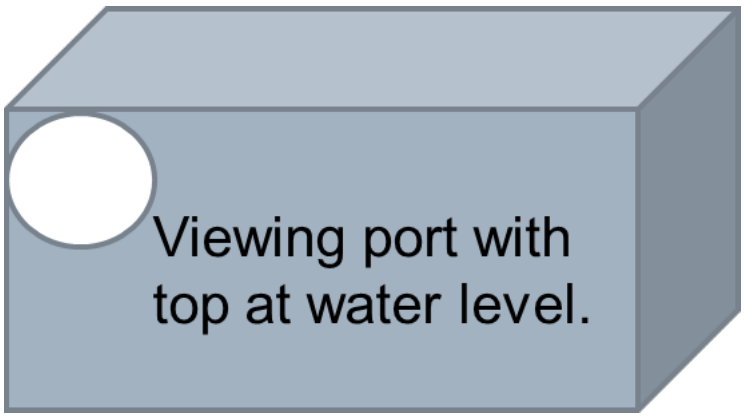
Hydrostatic Force Example Problems (1 of 2)

1. A swimming pool is 75 ft long, 30 ft wide, and 5 ft deep. Find the hydrostatic force on the bottom of pool.
2. Find the force on the 30-ft-wide wall and its location.

$F_{bottom} = 7.01 \times 10^5 \text{ lbs} \quad F_{wall} = 2.34 \times 10^4 \text{ lbs; } h_p = 3.33 \text{ ft}$

Hydrostatic Force Example Problems (2 of 2)

3. Find the force (and its location) on a 2-ft-diameter coach's viewing port on the side of the pool.

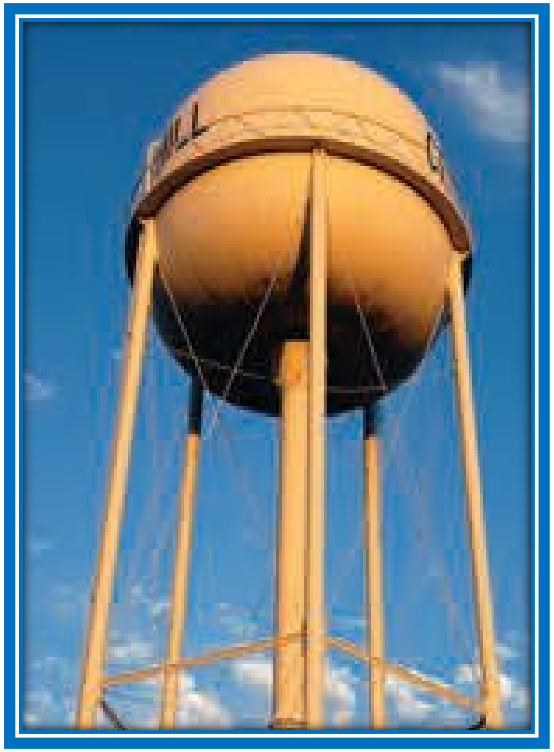


$F_{port} = 196$ lbs

$h_p = 1.25$ ft

Homework Problems:

Hydrostatic Force Applications



Grand Coulee Dam in the State of Washington and a typical water tower.

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