



Fundamentals of Hydraulic Engineering Systems

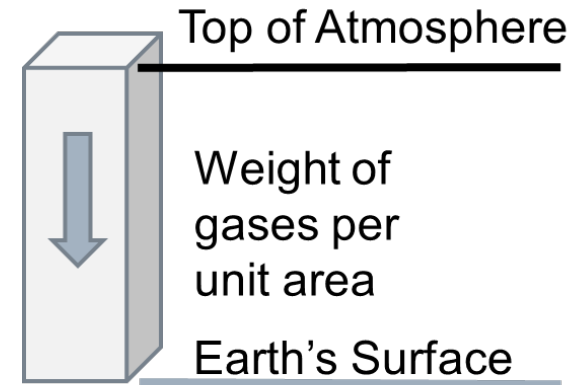
Fifth Edition

Chapter 2a

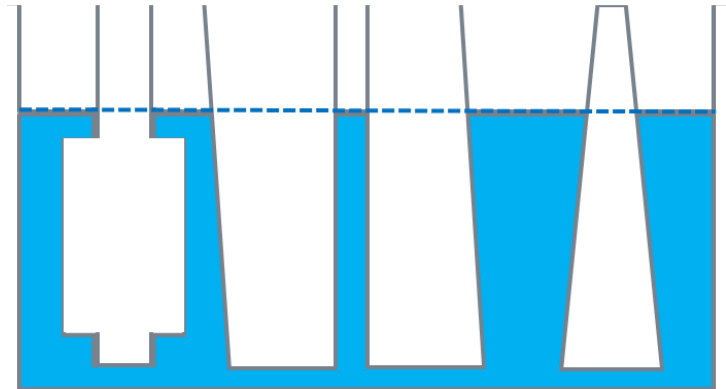
Water Pressure and
Pressure Forces

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: $1.014 \times 10^5 \text{ N/m}^2 \text{ (Pa)} = 1 \text{ bar}$)



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

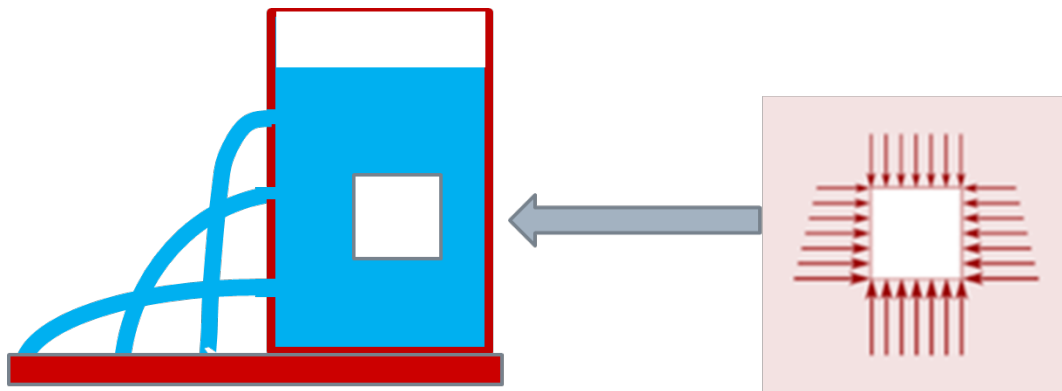


Pressure Variation in a Static Fluid (1 of 3)

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

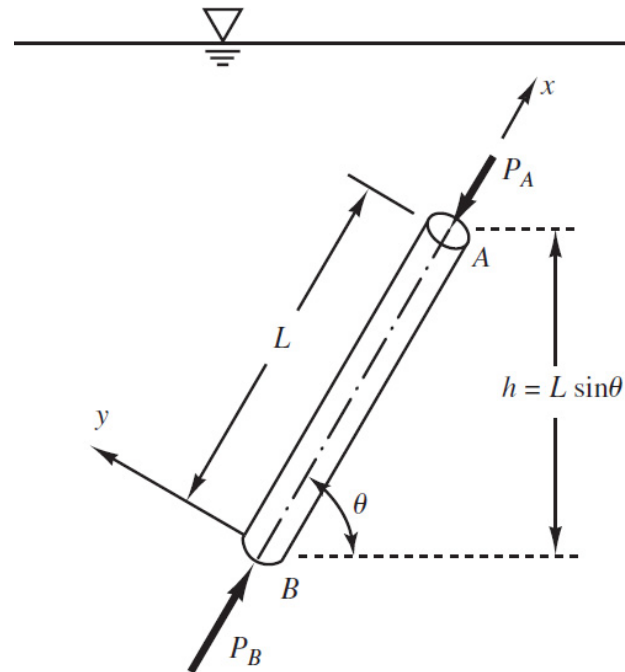
Concept: All surfaces in a static fluid are subject to normal pressure forces, but not shear forces since there is no fluid motion. Recall that $\tau = \mu \left(\frac{dv}{dy} \right)$, but $\left(\frac{dv}{dy} \right) = 0$.

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

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

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.**

ES = equal pressure surface

NES = nonequal pressure surface

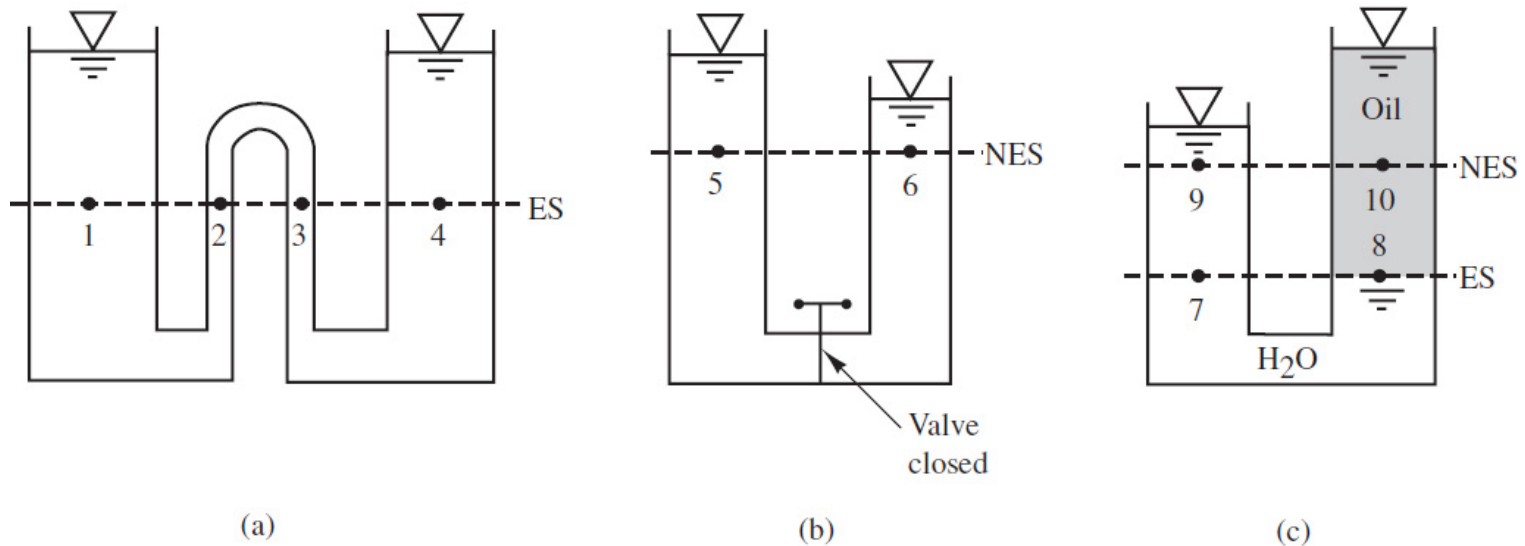
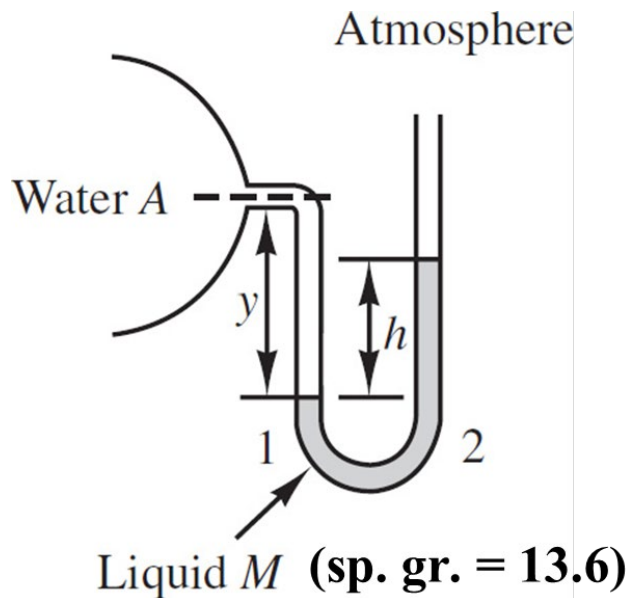


Figure 2.4 Hydraulic pressure in vessels

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.



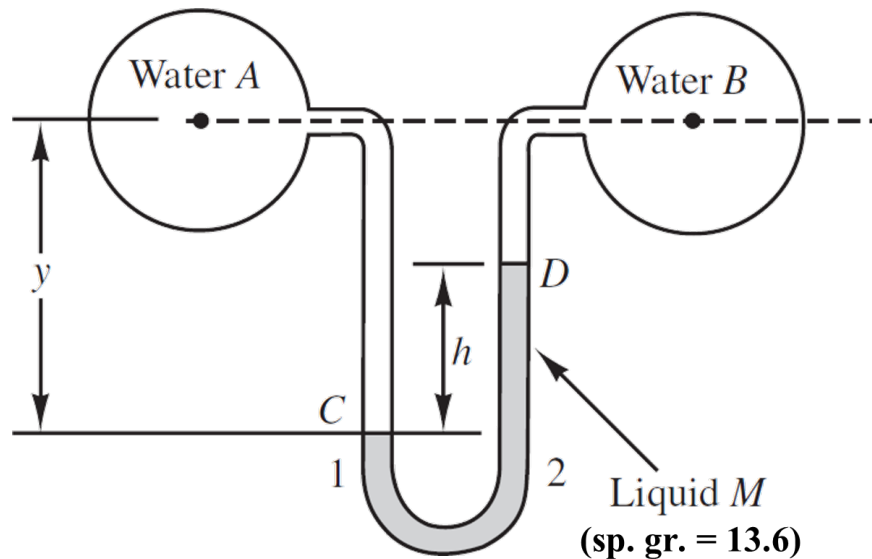
$$P_A = 7.21 \text{ kPa}$$

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 $P_B = 30$ kPa, $y = 20$ cm, $h = 10$ cm, and M is mercury. Note: $1 \text{ kPa} = 1,000 \text{ N/m}^2$

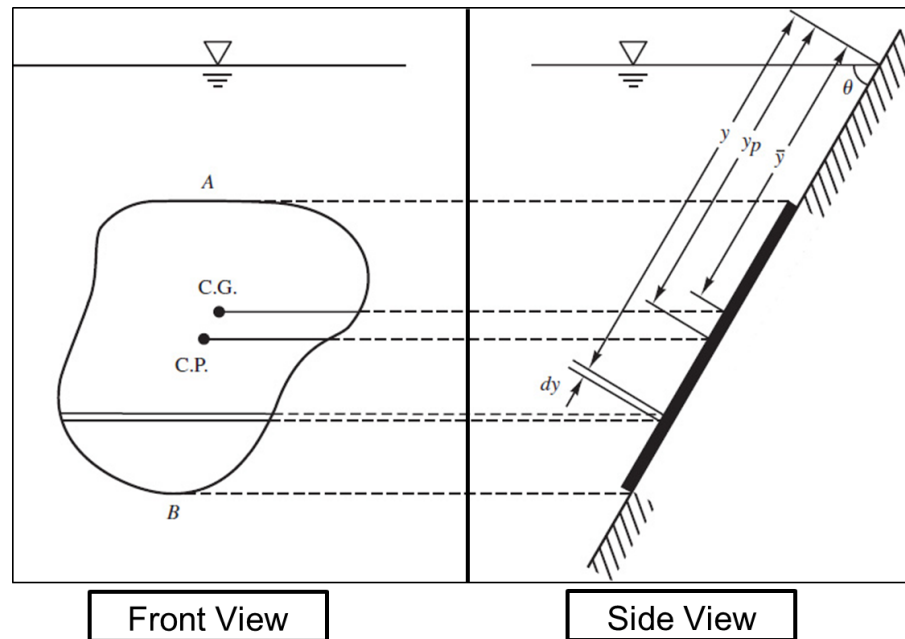


$$P_A = 42.3 \text{ kPa}$$

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 ?

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

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

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

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

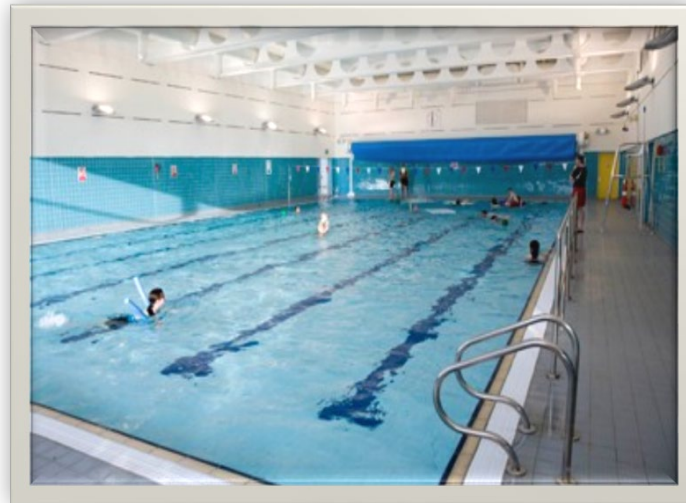
The location of this hydrostatic (pressure) force is:

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

Purpose (of finding hydrostatic forces): Moment Calculations

Hydrostatic Force Example Problems (1 of 2)

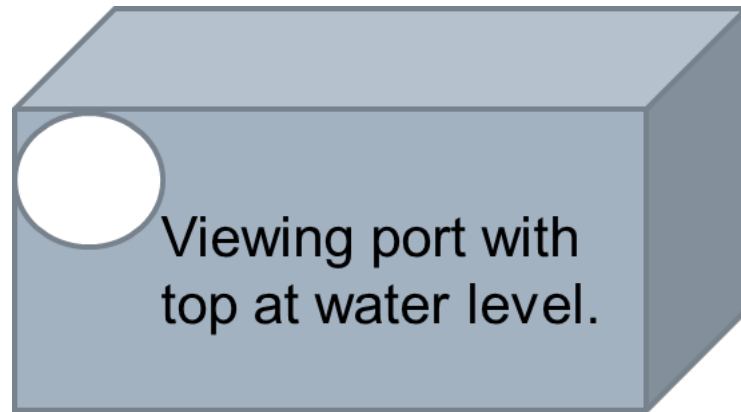
1. A swimming pool is 75 ft long, 30 ft wide, and 5 ft deep. Find the hydrostatic force on the bottom of pool.
2. Find the force on the 30-ft-wide wall and its location.



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

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.

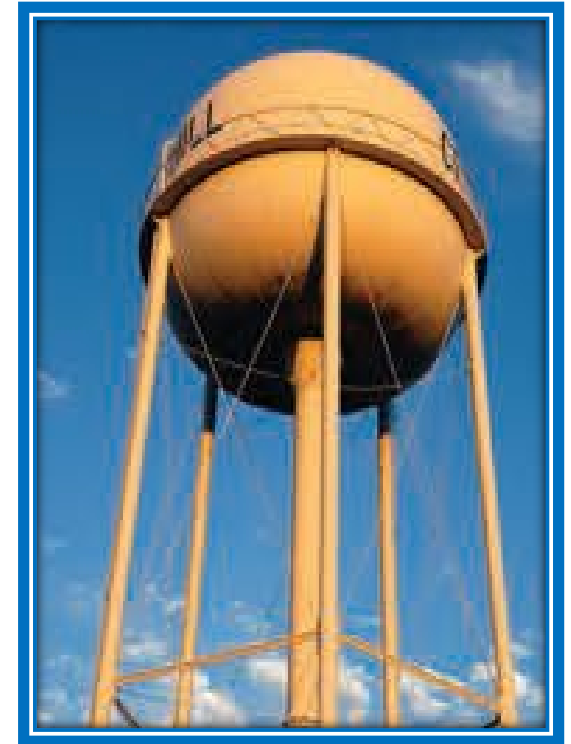


$$F_{\text{port}} = 196 \text{ lbs}$$

$$h_p = 1.25 \text{ ft}$$

Homework Problems:

Hydrostatic Force Applications



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

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