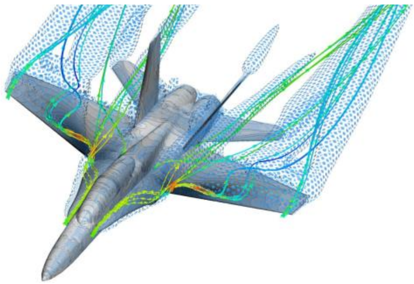
بسم الله الرحمن الرحيم

Fluid Mechanics I



Fayoum University

Faculty of Engineering
Mechanical Engineering Dept.

Lecture (2)

on

Fluid Statics

By

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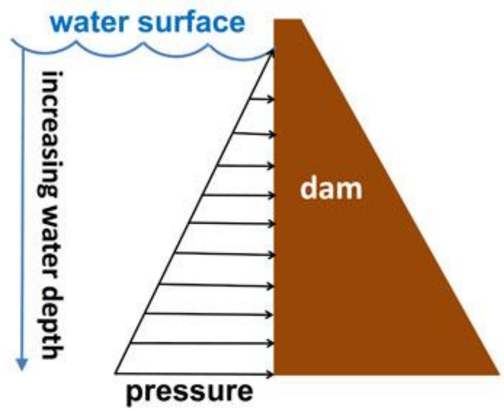
Mechanical Engineering Dept.
Faculty of Engineering
Fayoum University

2015 - 2016

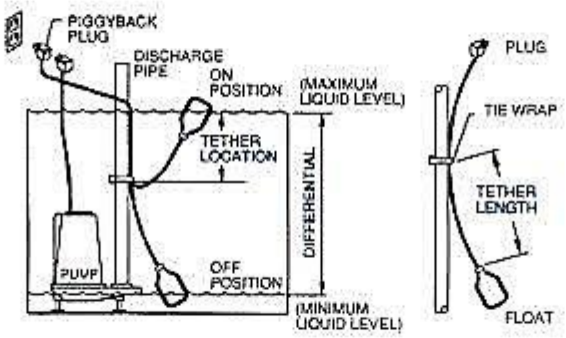
Fluid Statics Examples

Pressure measurement



Pressure behind dams or gates

Pressure vessels



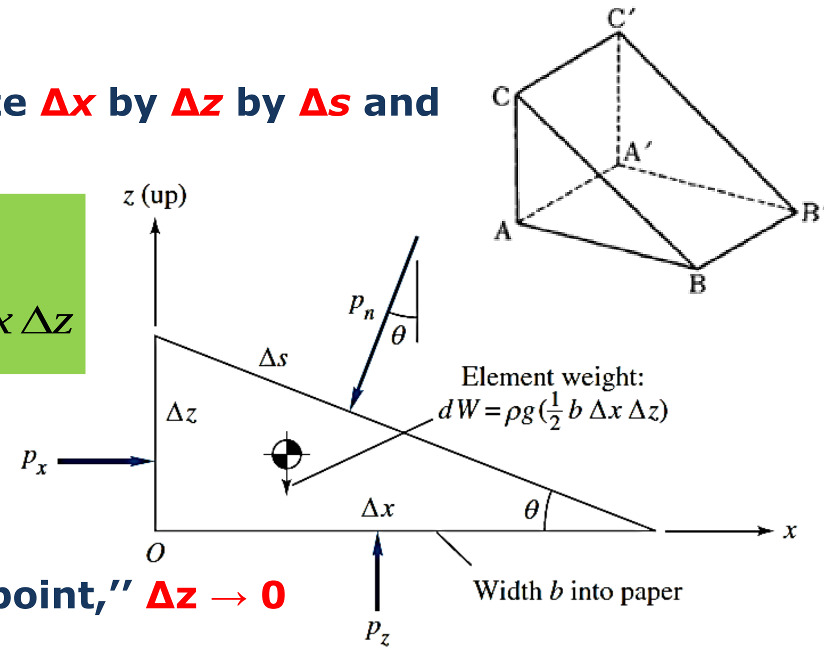
Buoyancy and floating

Characteristics of Pressure (Pascal’s law)

The pressure has the following three characteristics:

1. The **pressure** of a fluid always **acts perpendicular** to the wall in contact with the fluid.
2. The values of the **pressure** acting at any point in a fluid **at rest are equal** regardless of its direction.

Imagine a small wedge of fluid at rest of size **Δx** by **Δz** by **Δs** and depth ***b***



$$\sum F_x = 0 = p_x b\Delta z - p_n b\Delta s \sin\theta$$

$$\sum F_z = 0 = p_z b\Delta x - p_n b\Delta s \cos\theta - \frac{1}{2}\rho g b \Delta x \Delta z$$

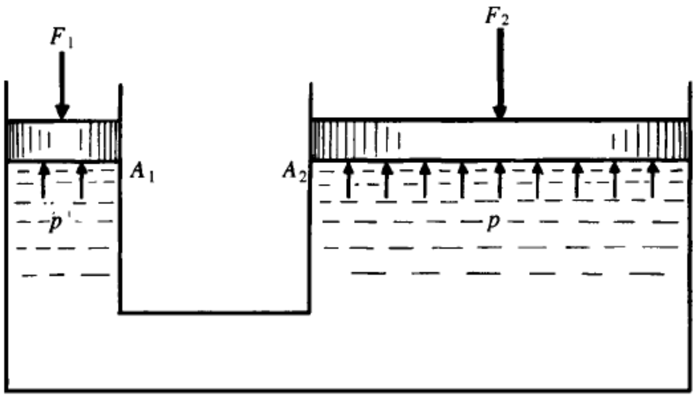
$$\Delta s \sin\theta = \Delta z \qquad \Delta s \cos\theta = \Delta x$$

$$\therefore\ p_x = p_n \qquad p_z = p_n + \frac{1}{2}\rho g \Delta z$$

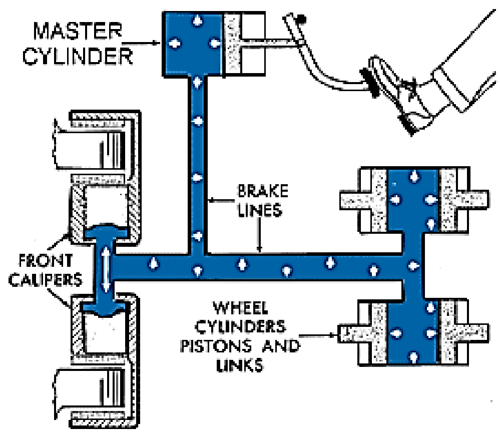
In the limit as the fluid wedge shrinks to a “point,” $\Delta z \rightarrow 0$

$$p_x = p_z = p_n = p$$

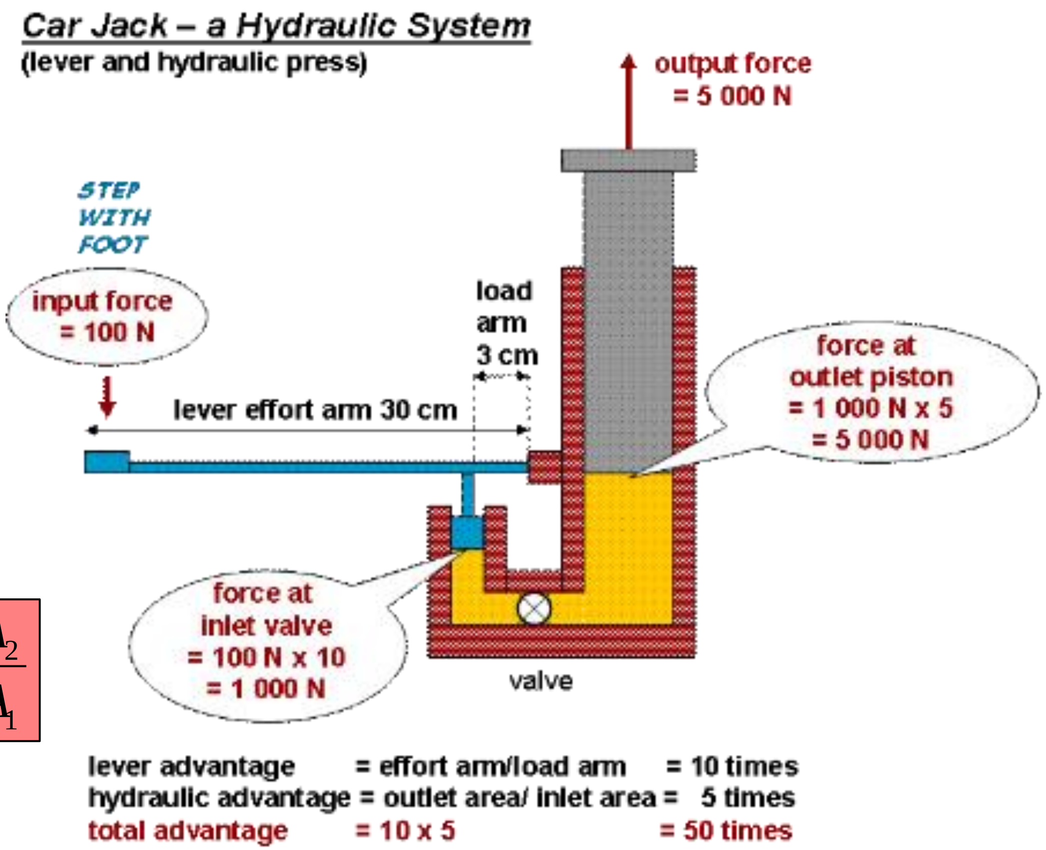
Hydraulic Press



$$p_1 = p_2 \Rightarrow \frac{F_1}{A_1} = \frac{F_2}{A_2}$$



$$\therefore\ F_2 = F_1 \frac{A_2}{A_1}$$



Pressure of Fluid at Rest

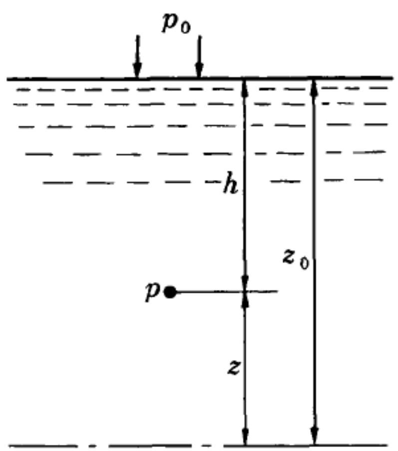
$$p\,dA-\left(p+\frac{dp}{dz}dz\right)dA-\rho g dA dz=0 \qquad \therefore\ \frac{dp}{dz}=-\rho g$$

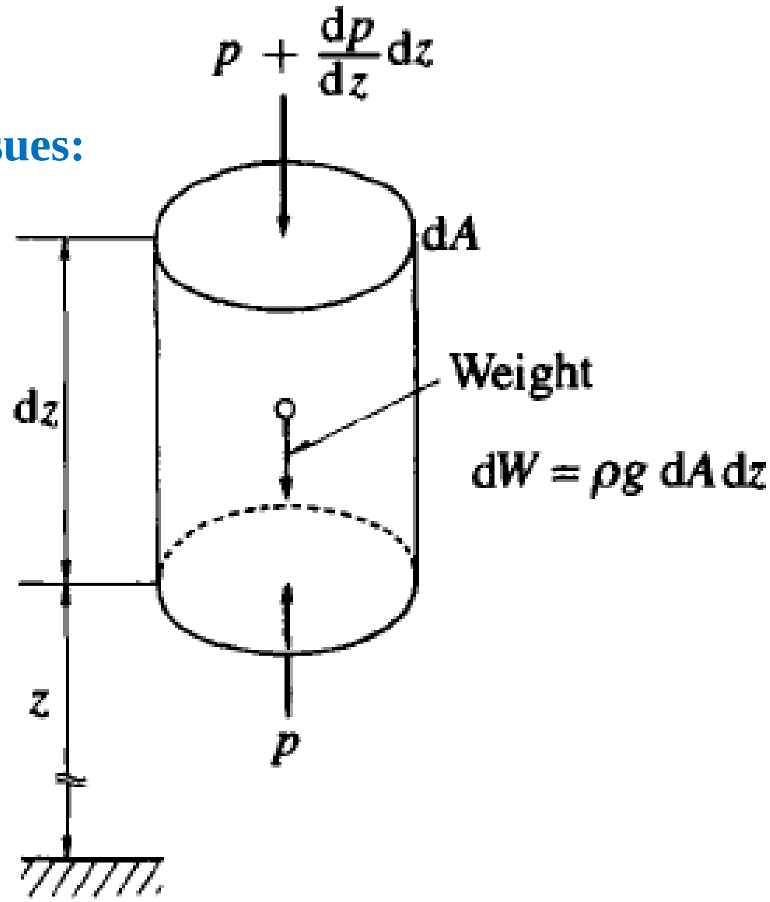
Assume ρ is constant, the following equation ensues:

$$p=-\rho g\int dz=-\rho gz+C$$

$p = p_0$ when $z = z_0$, so $\quad C = p_0+\rho g z_0$

$$p=p_0+(z_0-z)\rho g=p_0+h\rho g$$



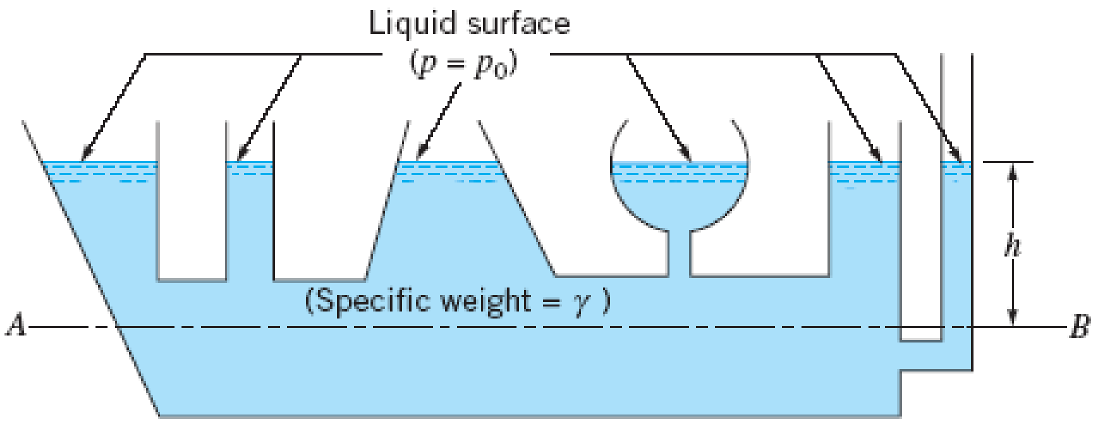


Pressure of Fluid at Rest

From the above relations illustrate two important principles of the hydrostatic condition:

(1) There is no pressure change in the horizontal direction.

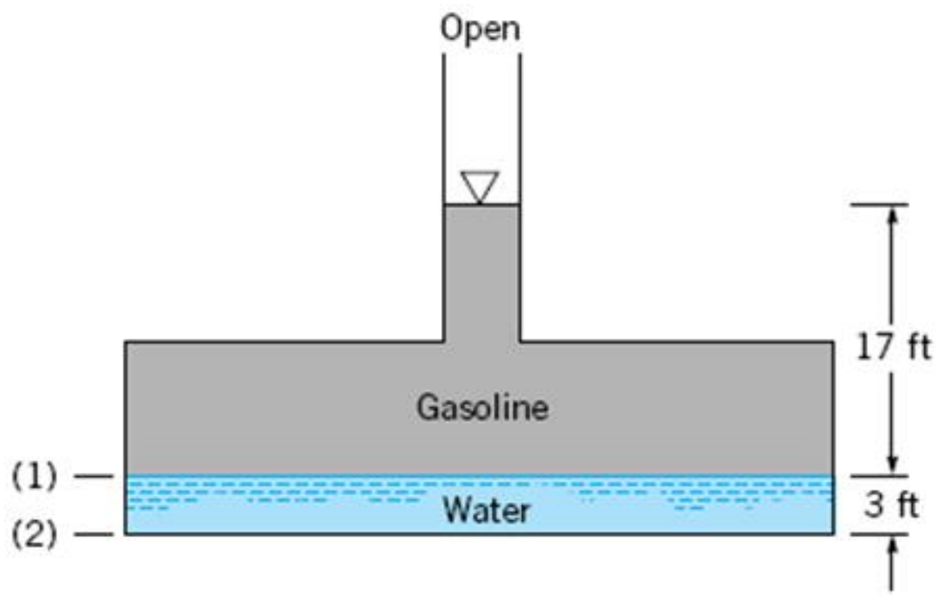
(2) There is a vertical change in pressure proportional to the density, gravity, and depth change.



Example 1: Pressure of Fluid at Rest

Because of a leak in a buried gasoline storage tank, water has seeped in to the depth shown in Fig. E2.1. If the specific gravity of the gasoline is $SG = 0.68$, determine the pressure at the gasoline-water interface and at the bottom of the tank. Express the pressure in units of lb/ft^2, lb/in.^2, and as a pressure head in feet of water.

$$p = \gamma h + p_0$$



$$\begin{aligned} p_1 &= SG\gamma_{H_2O} h + p_0 \\ &= (0.68)(62.4 \text{ lb/ft}^3)(17 \text{ ft}) + p_0 \\ &= 721 + p_0 \,(\text{lb/ft}^2) \end{aligned}$$

$$\begin{aligned} p_2 &= \gamma_{H_2O} h_{H_2O} + p_1 \\ &= (62.4 \text{ lb/ft}^3)(3 \text{ ft}) + 721 \text{ lb/ft}^2 \\ &= 908 \text{ lb/ft}^2 \end{aligned}$$

Example 2: Pressure of Fluid at Rest

Find the difference in pressure between two tubes under pressure

Pressure at surface *o*

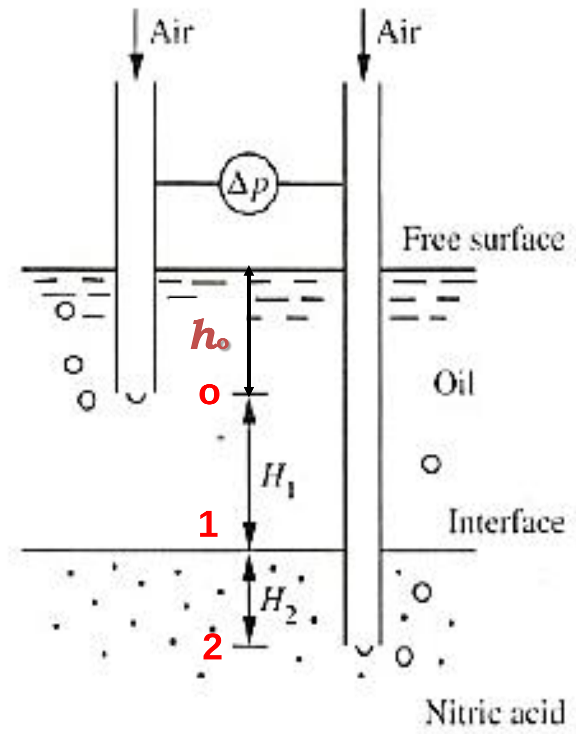
$$p_o = \rho_o g h_o + p_a$$

Pressure at surface *2*

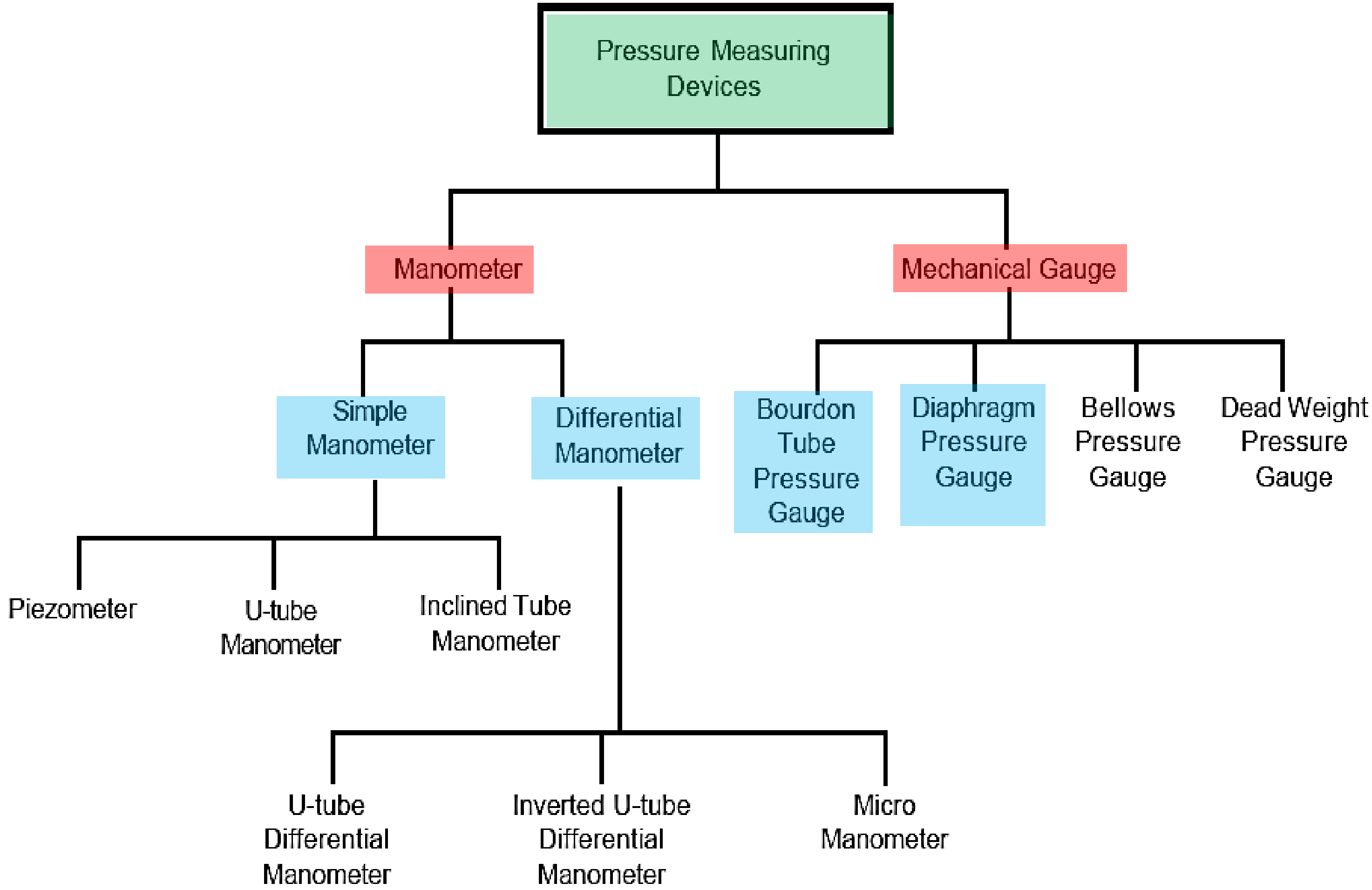
$$p_2 = \rho_o g h_o + \rho_o g H_1 + \rho_N g H_2 + p_a$$

$$\Delta p = p_2 - p_o$$

$$\Delta p = \rho_o g H_1 + \rho_N g H_2$$



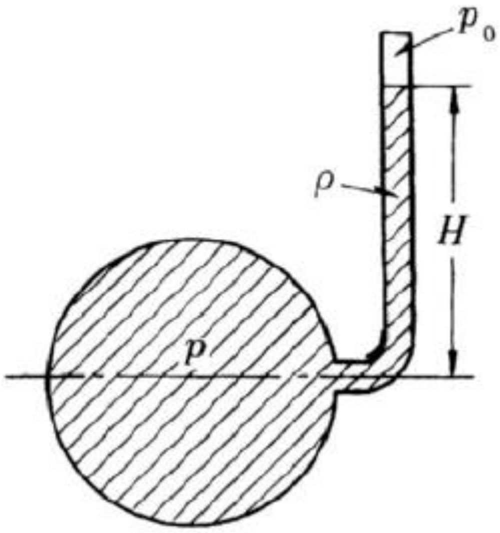
Measurement of Pressure

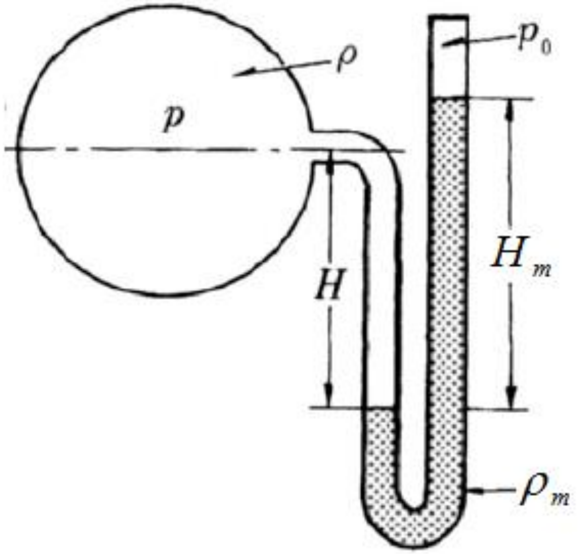


Measurement of Pressure

Simple Manometer

A device which measures the fluid pressure by the height of a liquid column is called a manometer.



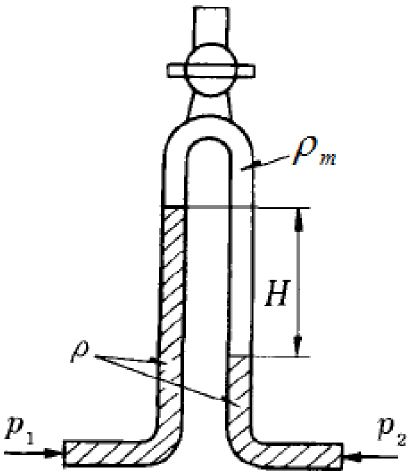


$$p = p_0 + H\rho g$$

$$p = p_0 + H_m \rho_m g - H\rho g$$

Measurement of Pressure

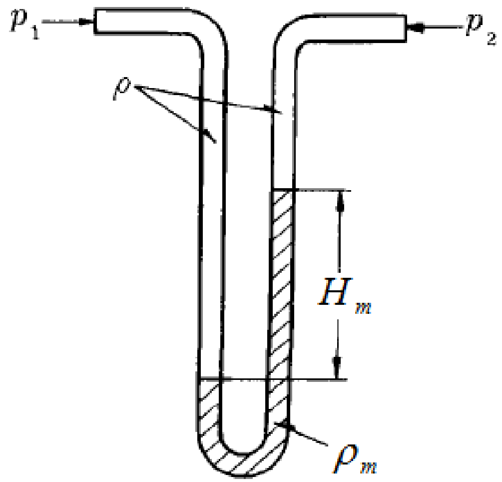
Differential Manometer



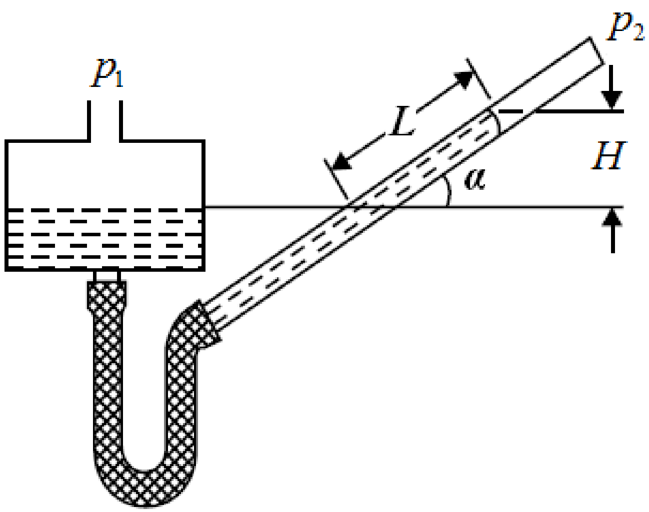
$$p_1 - p_2 = (\rho - \rho_m) gH$$

ρ_m is a gas,

$$p_1 - p_2 = H\rho g$$



$$p_1 - p_2 = (\rho_m - \rho) gH_m$$



$$H = L\sin\alpha$$

Measurement of Pressure

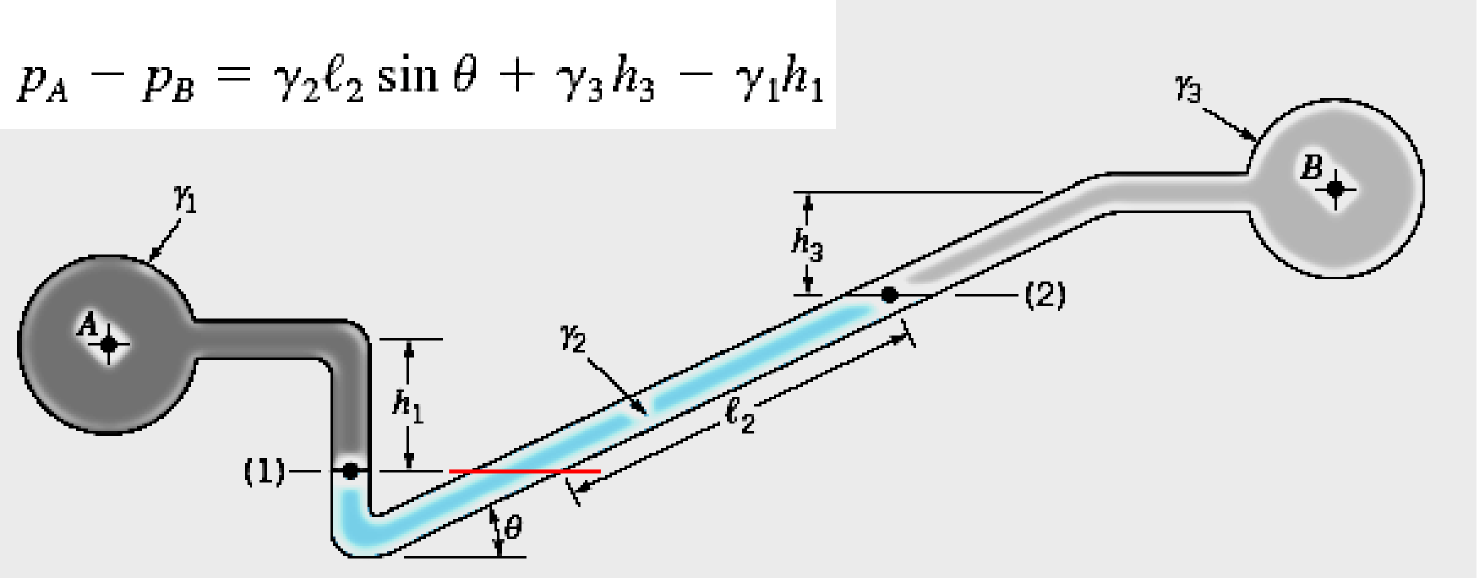
Differential Manometer

Inclined-Tube Manometer

$$p_A + \gamma_1 h_1 - \gamma_2 \ell_2 \sin\theta - \gamma_3 h_3 = p_B$$

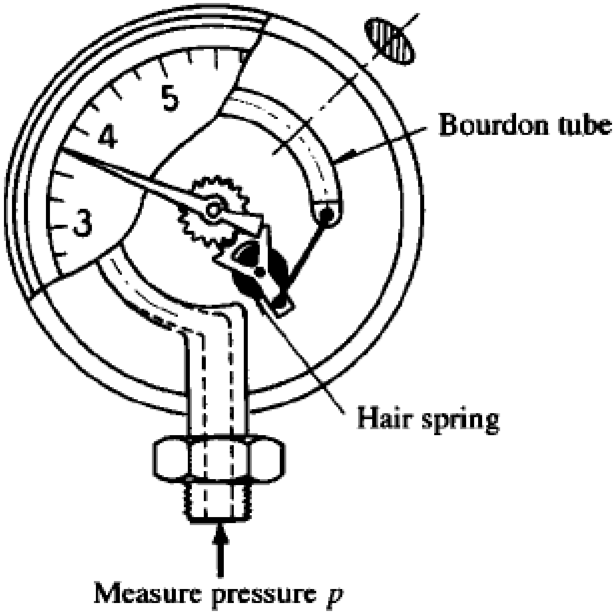
or

$$p_A - p_B = \gamma_2 \ell_2 \sin\theta + \gamma_3 h_3 - \gamma_1 h_1$$

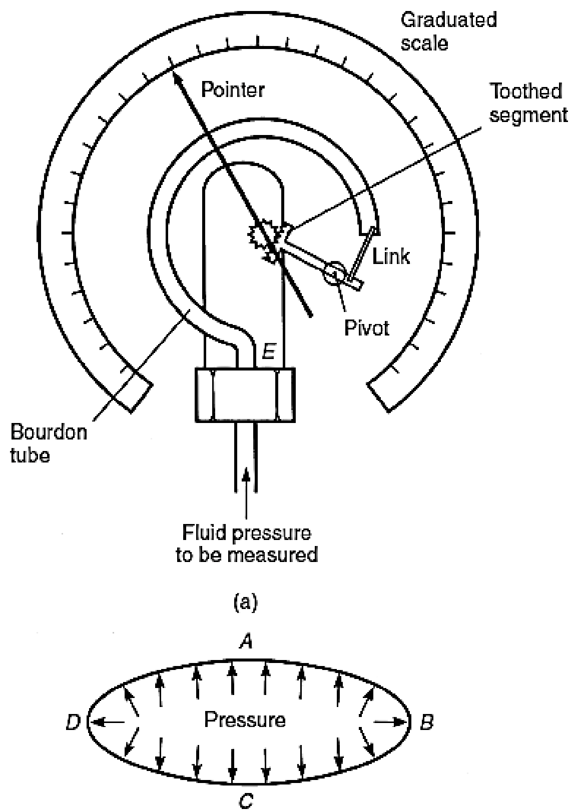


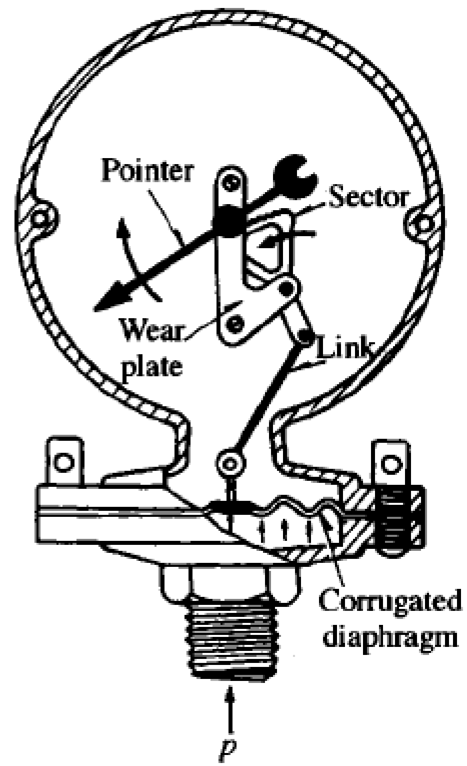
Measurement of Pressure

Elastic-type mechanical pressure gauge



Bourdon tube pressure gauge



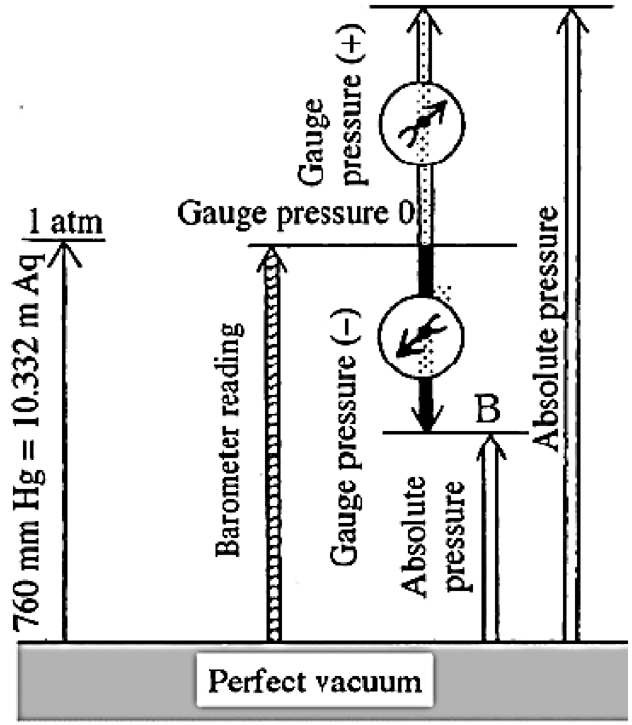


Diaphragm pressure gauge

Measurement of Pressure

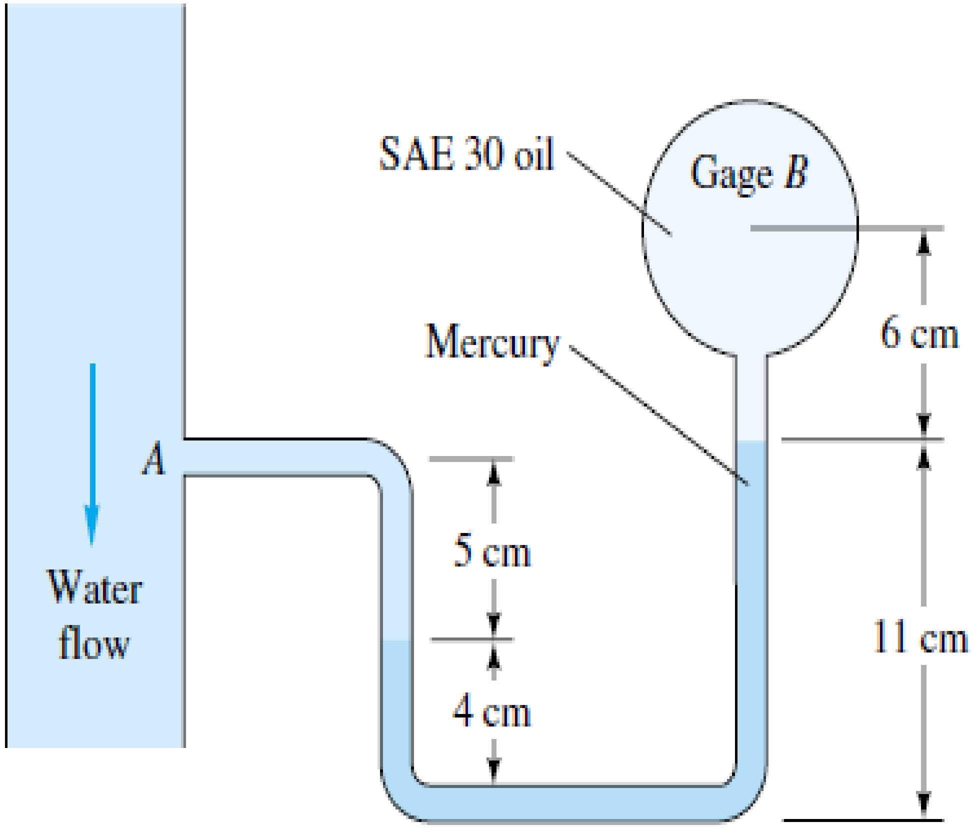
Absolute pressure and gauge pressure

gauge pressure = absolute pressure − atmospheric pressure



Example 3: Pressure of fluid at Rest

Pressure gage **B** is to measure the pressure at point **A** in a water flow. If the pressure at **B** is 87 kPa, estimate the pressure at **A**, in kPa. Assume all fluids are at 20°C. See the following figure.



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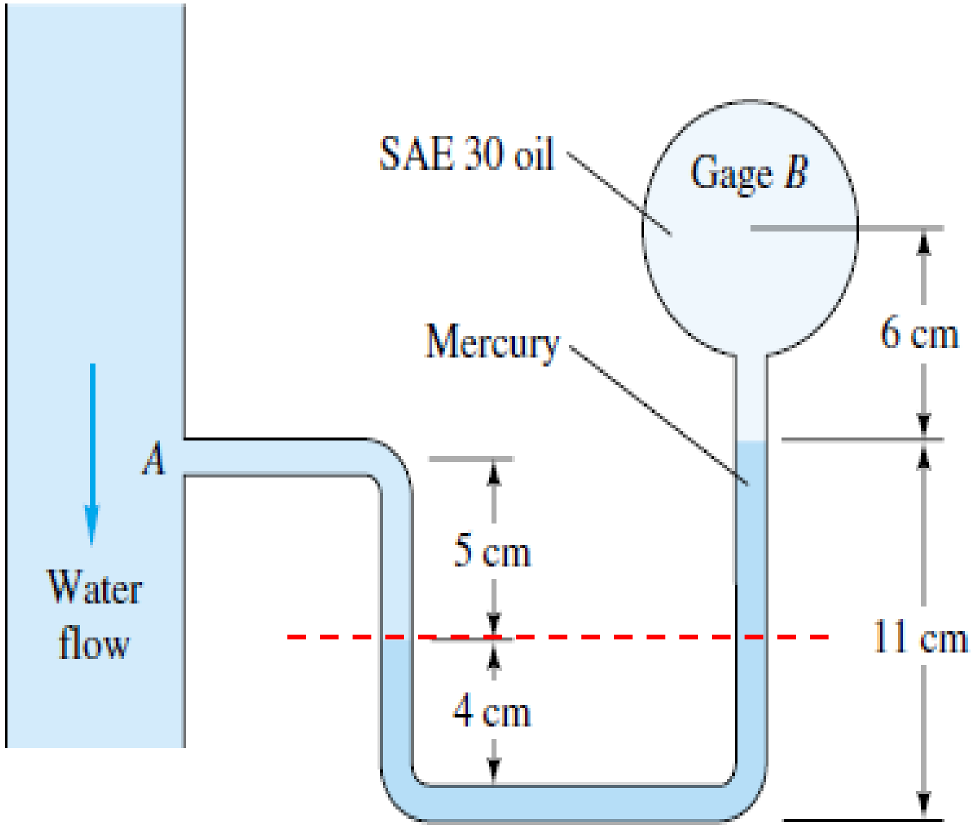


Example 3: Pressure of fluid at Rest

First list the specific weights from Table (A.1):

$\gamma_{water} = 9790\ N/m^3$ $\gamma_{mercury} = 133{,}100\ N/m^3$ $\gamma_{oil} = 8720\ N/m^3$

Now proceed from **A** to **B**, calculating the pressure change in each fluid and adding: $p_A - \gamma_w (\Delta z)_w - \gamma_M (\Delta z)_M - \gamma_o (\Delta z)_o = p_B$

$$p_A - \left[\left(9790\,(N/m^3)\right)\left(-0.05\,(m)\right)\right] - \left[\left(133100\,(N/m^3)\right)\left(0.07\,(m)\right)\right] - \left[\left(8720\,(N/m^3)\right)\left(0.06\,(m)\right)\right] = 87000\,Pa$$

where we replace N/m^2 by its short name, Pa. The value $\Delta z_M = 0.07$ m is the net elevation change in the mercury (11 cm - 4 cm). Solving for the pressure at point **A**, we obtain

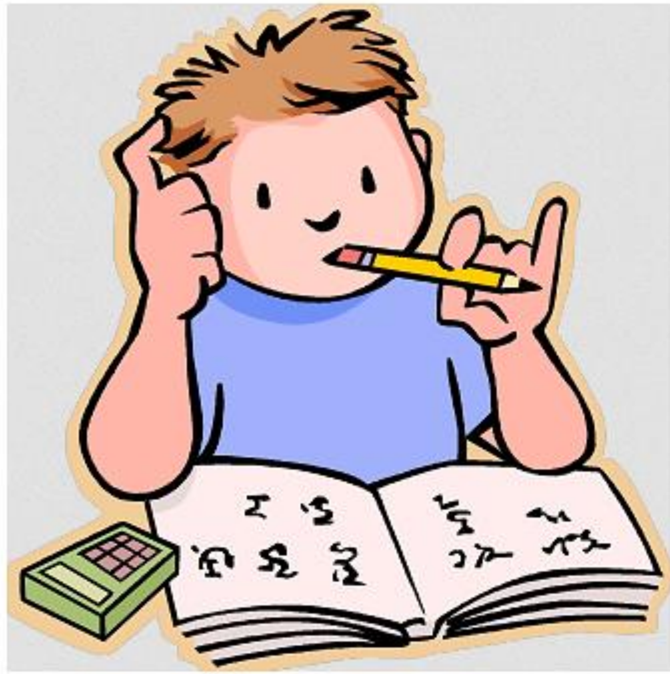
$p_A = 96351\ Pa$ ***Ans.***


QUIZ

Q (2)

The velocity profile is a laminar flow through a round pipe is expressed as, $u = 2U\left[1 - \left(r^2/r_0^2\right)\right]$ where U = average velocity, r_0 = radius of pipe. Draw dimensionless shear stress profile $\left(\tau/\tau_0\right)$ against $\left(r/r_0\right)$ where τ_0 is wall shear stress. Find τ_0, when oil flows with absolute viscosity 4×10^{-2} N.s/m^2 and velocity of 4 m/s in a pipe of diameter 150 mm.

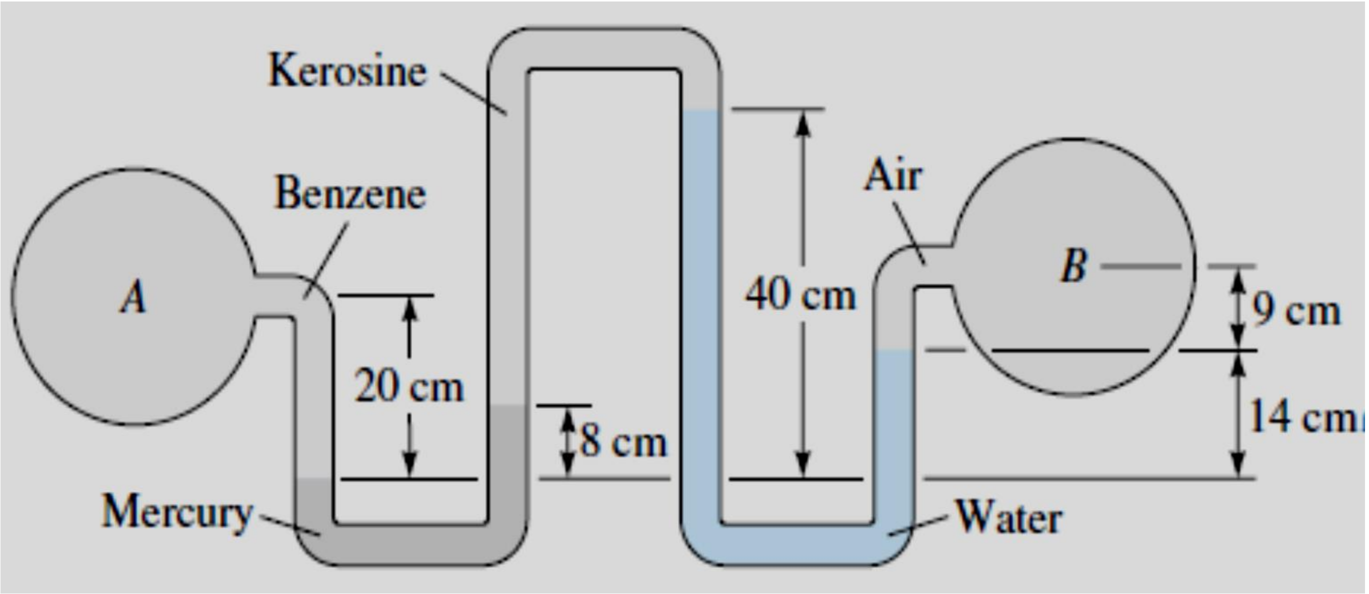
5



Homework

HW (2)

In the following figure all fluids are at 20°C. Determine the pressure difference (Pa) between points A and B.



Thank you