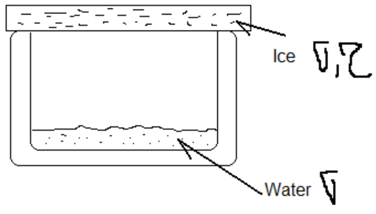
FLUID MECHANICS

STATIC FLUIDS

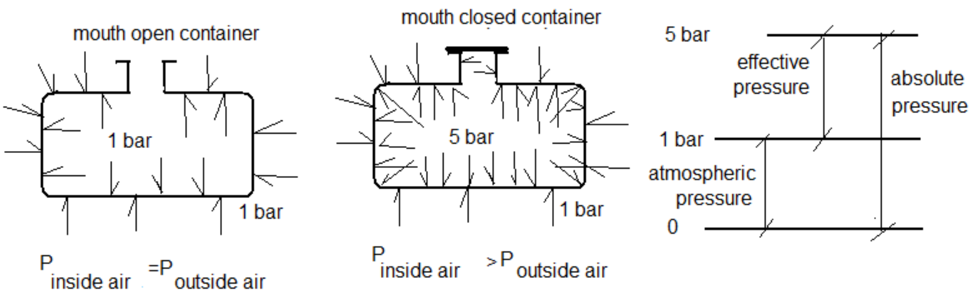
If a fluid does not change the shape or does not flow, it is static. The static fluid carry stress only surface normal direction. There is no shear stress in the fluid. Therefore, calculations are easy.



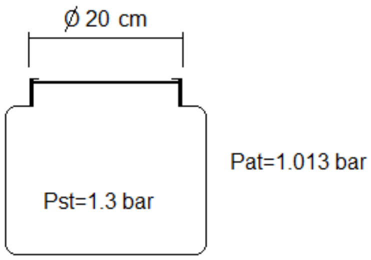
When the ice melted the shear stress is lost. Only normal stress remain.

Absolute pressure: We think that emptying the air in a closed container until the last molecule. If we assume zero the pressure in the container space, that is the referance value is required. Each pressure that we measure according to this reference value is absolute pressure. For example, the absolute pressure of static air at the sea level and 0 degrees Celsius is 1.013 bar. This value is standard air pressure at same time.

Effective pressure: The air acts an open container from inside and outside. These pressures have the same intensity but opposite direction, so the walls are not enforced. The lid is closed and the air is pressured, the internal pressure rises. The walls is enforced with a pressure difference of outside atmospheric pressure and inside pressure. This difference is called the effective pressure. Effective pressure is usually used in fluid mechanics. Effective pressure will be understood unless otherwise stated.



<u>Example</u>: How much force act the cover in 20 cm diameter when the inside absolute pressure raised to 1.3 bar in a pressure cooker.



$P_{\text{pressure forcing the lid}} = P_{\text{steam}} - P_{\text{athmospheric}}$

$P = P_{st} - P_{at}$

$P = 1.3 - 1.013 = 0.287$ bar

Pressure = Force/Area => $F = P*A = 28700\ N/m^2 * (\pi\ (0.2)^2/4\ m^2 = 901\ N \approx 92$ kgf

<u>Example</u>: 25 psi pressure applied to the wheel of a car. Write this in Pascal, Bar and Atmosperic pressure.

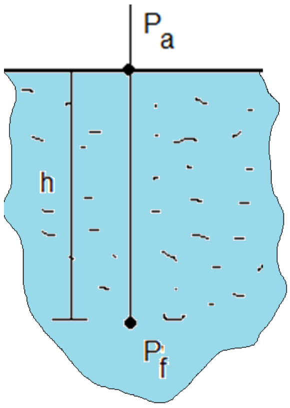
1 psi = 1 libre / 1 $inch^2$ = 0.453 kg 9.81 m/s^2 / $(0.0254 \times 0.0254)m^2$ = 6888.1 Pa * 25 psi = 171202.63 Pa ≈ 1.712 bar = 1.699 at.

<u>Annotation:</u>

[1 lb/in^2 (psi) =6894.76 Pa]

[1 atm =101325 Pa]

PRESSURE IN THE STATIC FLUID



Absolute pressure in any stagnant fluid will be given as;

$P_f = P_a + \varrho\, g\, h$

Effective pressure on the surface is zero, depth is as follows;

$P = P_f - P_a$

From here effective pressure;

$P = \varrho\, g\, h$

From this formula, the depth of a point that known pressure can be found as follows;

$h = \dfrac{P}{\varrho\, g}$

Example:Find the height of the water, oil and air providing 1.25 bar pressure. (ϱ_{water} =1000 kg/m^3, ϱ_{oil} =850 kg/m^3, ϱ_{air} =1.2 kg/m^3)

h_{water} = P/ (ϱ_{water} g) =(1.25 10^5 N/m^2)/ (1000 kg/m^3 9.81 m/s^2) =12.74 m

h_{oil} = P/ (ϱ_{oil} g) =(1.25 10^5 N/m^2)/ (850 kg/m^3 9.81 m/s^2) =15 m

h_{air} = P/ (ϱ_{air} g) =(1.25 10^5 N/m^2)/ (1.2 kg/m^3 9.81 m/s^2) =10618 m

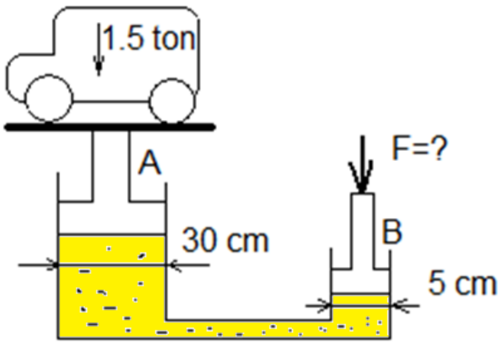
Example: How much the pressure difference between the first floor and the last floor of a 50 m building (ϱ_{air} =1.2 kg/m^3).

P= ϱ_{air} g h = 1.2 kg/m^3 9.81 m/s^2 50 m = 588.6 N/m^2 (Pa)

Example: What is the pressure exerted on a person who submerged in 10 m depth sea.(ϱ_{water} =1000 kg/m^3)

P= ϱ_{water} g h = 1000 kg/m^3 9.81 m/s^2 10 m = 98100 N/m^2 (Pa)

Example: How much force applied the B piston in order to remove the car on the hydrolic cylinder shown in the figure.

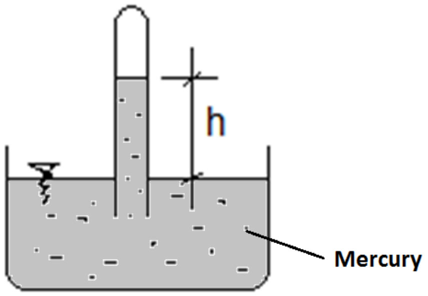


$P_A = \frac{F_A}{A}$, $P_B = \frac{F_B}{B}$ => $P_A = P_B$ => $\frac{F_A}{A} = \frac{F_B}{B}$ => $\frac{1500\ kg\ 9.81\ m/s2}{\frac{\pi\ 0.3^2}{4}} = \frac{F_B}{\frac{\pi\ 0.05^2}{4}}$ => F_B = 408.75 N = 41.6 kgf

PRESSURE MEASUREMENT

Pressure is measured by a manometer. Any pressure gauges measure the difference between the absolute pressure at the measured point and local atmospheric pressure.

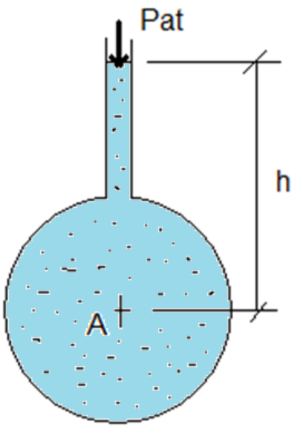
Mercury Barometer:Barometers measure open-air pressure. A glass tube closed at one end, reversed and open end of it emerged in a mercury filled container, than mercury barometer can be obtained.

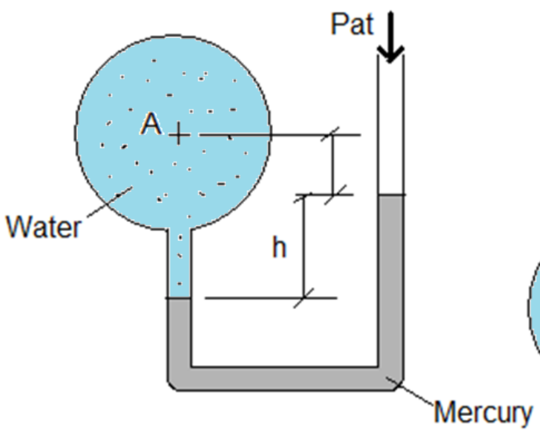


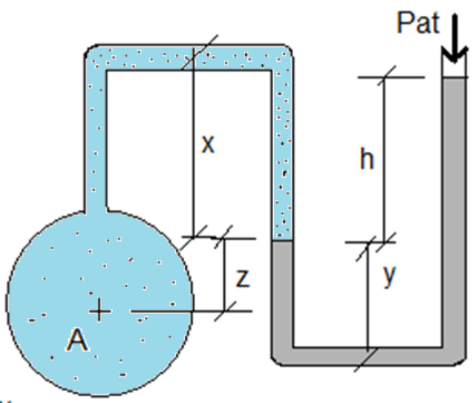
<u>Example</u>: The density of mercury is 13560 kg/m^3 at 15 ^{0}C and ambient atmospheric pressure is 1 bar then how much we read the height of the mercury in mm.

P= ϱ_{water} g h => h=P/ ϱ_{water} g =>h= 13560 kg/m^3 9.81 m/s^2 => h = 0.7517m => h=75.17 mm

Measuring the Pressure at a Point: It is called a measurement of the pressure difference, between a point in a container and air.





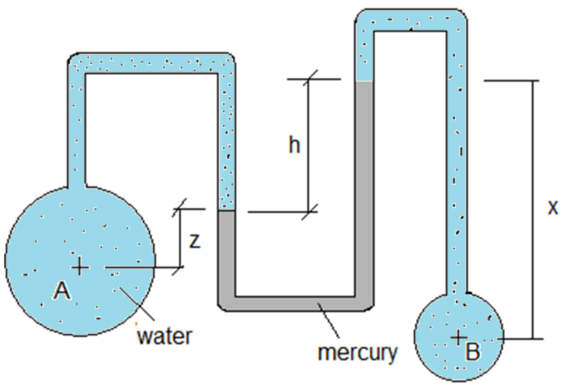


Here, to find A point pressure, pressures are calculated along the tube as +/- . Walls of the tube is exposed to atmospheric pressure, the atmospheric pressure ignored. Let's write the formula for third picture.

$P_{at} + P_A - \varrho_w g z - \varrho_w g x + \varrho_w g x + \varrho_m g y - \varrho_m g y - \varrho_m g h - P_{at} = 0$

$P_A = \varrho_w g z + \varrho_m g h$

Measurement of pressure between two points: It is measuring the pressure between two points in a closed container.

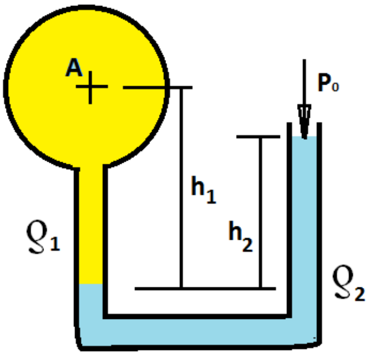


$P_A - \varrho_w g z - \varrho_m g h + \varrho_w g x - P_B = 0$

$P_A - P_B = \varrho_w g z + \varrho_m g h - \varrho_w g x$

$P_A - P_B = \varrho_w\, g\, (z-x) + \varrho_m\, g\, h$

Example: Fluid level in a manometer that located in a place which has P_0=101336 Pa open-air pressure, as shown. In this manometer h_1=40 cm, h_2=30cm, ϱ_1= 800 kg/m3 and ϱ_2=1000 kg/m3. Accordingly, what is the pressure in point A as pascal?



<u>Solution</u>

The container get off the atmosphere in the point A. Let's write the effects of pressure along the pipe.

$P_A + \varrho_1\, g\, h_1 - \varrho_2\, g\, h_2 - P_0 = 0$

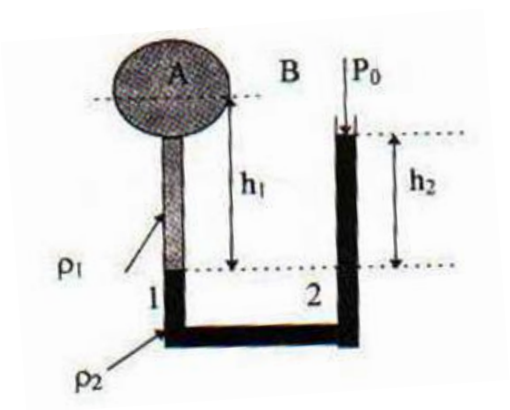
$P_A = \varrho_2\, g\, h_2 + P_0 - \varrho_1\, g\, h_1$

P_A = 1000 kg/m3 9.81 m/s2 0.30 m + 101336 N/m2 - 800 kg/m3 9.81 m/s2 0.40 m

P_A =

1) Örnek

Açık hava basıncının P_0=101336 Pa olduğu bir yerde bulunan bir manometredeki sıvı seviyesi şekildeki gibidir. Bu manometrede h_1=40 cm, h_2=30 cm , ρ_1=800 kg/m^3 ve ρ_2=1000 kg/m^3 olduğuna göre A'daki basınç kaç Pa dır? (g=10 m/s^2).

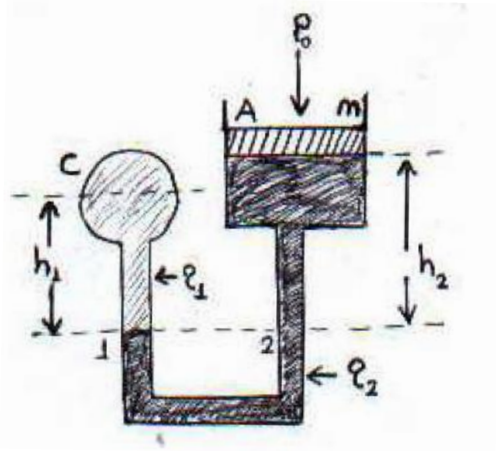


Çözüm: Aynı hizadaki basınçlar eşittir. $P_1=P_A+\rho_1 g h_1$, $P_2=P_0+\rho_2 g h_2$ ve $P_1=P_2$ 'den $P_A=P_0+\rho_2 g h_2-\rho_1 g h_1$=101336+1000.10.(0,30)-800.10.(0,40)=101336+3000-3200 =101136 Pa bulunur.

Example

Yer yüzeyindeki atmosferik basınç 101336 Pa olduğuna göre 2000 m yükseklikteki basınç değerini;
a)yoğunluğu ρ=1,2 kg/m^3 ve çekim ivmesini g=10 m/s^2 şeklinde sabit alarak,

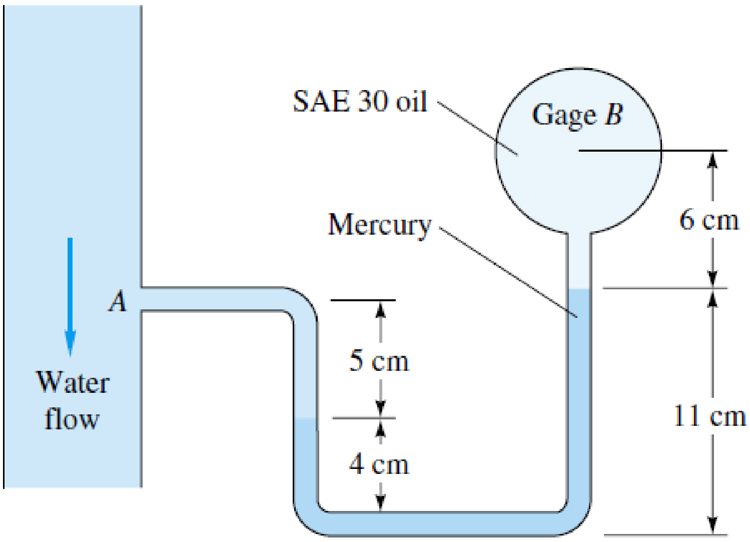
Çözüm: a)Sıkıştırılamaz akış için, $P_2=P_1-\rho g(z_2-z_1)$=101336-(1,2).10.2000= 77336 Pa



Çözüm: $P_1=P_c+\rho_1 gh_1$, $P_2=P_0+\rho_2 gh_2+mg/A$ ve $P_1=P_2$ den $m=A(P_c+\rho_1 gh_1-P_0-\rho_2 gh_2)/g$ bulunur. değerler yerine konduğunda m=0,01.(4.10^5+1000.10.0,5-101336-13600.10.1,5)/10 =0,01.(400000+5000-101336-204000)/10=99,664 kg

Example

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 Fig. E2.4.



E2.4

First list the specific weights from Table 2.1 or Table A.3:

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

Now proceed from A to B, calculating the pressure change in each fluid and adding:

$$p_A - \gamma_W(\Delta z)_W - \gamma_M(\Delta z)_M - \gamma_O(\Delta z)_O = p_B$$

or $$p_A - (9790\ \text{N/m}^3)(-\ 0.05\ \text{m}) - (133{,}100\ \text{N/m}^3)(0.07\ \text{m}) - (8720\ \text{N/m}^3)(0.06\ \text{m})$$

$$= p_A + 489.5\ \text{Pa} - 9317\ \text{Pa} - 523.2\ \text{Pa} = p_B = 87{,}000\ \text{Pa}$$

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

$$p_A = 96{,}351\ \text{Pa} = 96.4\ \text{kPa} \qquad \textit{Ans.}$$

The intermediate six-figure result of 96,351 Pa is utterly fatuous, since the measurements cannot be made that accurately.