# Chapter 10:Fluids


Lecture 2
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## 10-4] Atmospheric Pressure ($P_{atm}$)

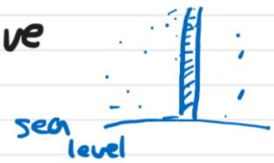
The air around us has mass $\Rightarrow$ it has weight. The weight of the air leads to what we define atmospheric pressure $P_{atm}$.

Atmospheric pressure varies with altidude.

At sea level, the average atmospheric pressure is

$P_{atm} = 1.013 \times 10^5\ Pa$ . $1\ bar = 1 \times 10^5\ Pa \Rightarrow 1\ P_{atm} = 1.013\ bar$

This means a force of $1.013 \times 10^5\ N/m^2$ due to the weight of the column of air above the ground.




How could our bodies withstand such high pressure?

Our body cells maintain an internal pressure close to that of $P_{atm}$ inside the cells.

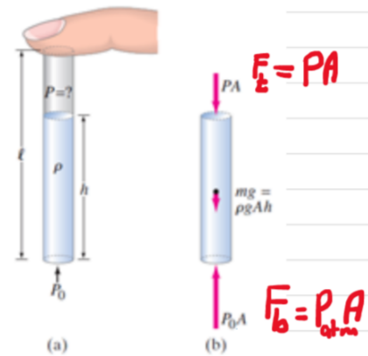
A balloon maints an internal pressure $\sim P_{atm}$.

The tire of a car maintains an internal pressure much higher than $P_{atm}$.

Example 10-4] Holding water in a straw.

The portion of water inside the straw is in <u>static</u> <u>equilibrium</u>.

$\Rightarrow \Sigma F_y = 0$.




P: pressure of the air at the top, which is entrapped between the water and the finger.

$\uparrow^{+}$ $F_b - F_t - mg = 0$

$$P_{atm} A - PA - mg = 0$$

$$P_{atm} A - PA - \rho_f V g = 0$$

but $V = Ah$ $\Rightarrow$

$$P_{atm} \cancel{A} = P \cancel{A} + \rho_f \cancel{A} h g$$

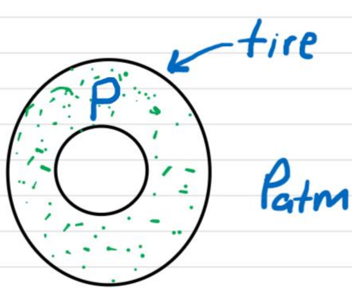
$$\therefore \quad P_{atm} = P + \rho_f g h$$

## Gauge Pressure

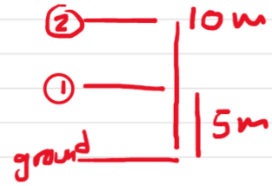
Tire gauges measure the pressure inside the tire with respect to the atmospheric pressure (i.e relative to the atmospheric pressure).

P: actual pressure inside tire called absolute pressure.

$P_{atm}$: atmospheric pressure.




What does the pressure gauge in the picture measure?




It measures $P - P_{atm}$ which is called the gauge pressure $P_G$ $\Rightarrow$

$$P_G = P - P_{atm}$$

So, the absolute (actual) pressure inside the tire is given by

$$P = P_G + P_{atm}$$

If the gauge reads $220\,\overset{10^3}{k}Pa$ $\Rightarrow$ the pressure inside the tire is $P = 220\,kPa + 101.3\,kPa$

$\therefore P = 321.3\,kPa = 3.213 \times 10^5\,Pa \simeq 3.17\,atm.$

$1\,atm = 1.013 \times 10^5\,Pa$, one atmospheric pressure

$1\,bar = 1 \times 10^5\,Pa$

$760\,mmHg \equiv 1\,atm \equiv 1.013 \times 10^5\,Pa = 1.013\,bar$

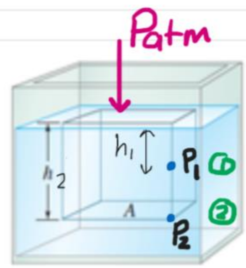
# 10-5] Pascals Principle

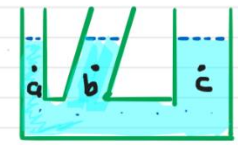
Pascal's principle states that if an external pressure is applied to a confined fluid, the pressure at every point within the fluid increases by that amount.

Remember
$P = \rho g h \Rightarrow$ all points at the same depth have the same pressure.

$P_1 = \rho_f g h_1$ , $P_2 = \rho_f g h_2$

$P_1$ and $P_2$ are pressures due to the fluid ONLY.




$P_a = P_b = P_c$

The water container is open to the atmosphere. Thefore, we have the atmospheric pressure Patm acting at the water surface.

According to Pascal's principle, the pressure at each point of the fluid must increase by an amount $P_{atm}$.

$$P_1^{tot} = P_{atm} + P_1 = P_{atm} + \rho g h_1$$

← Presure at point ① due to the liquid ONLY.

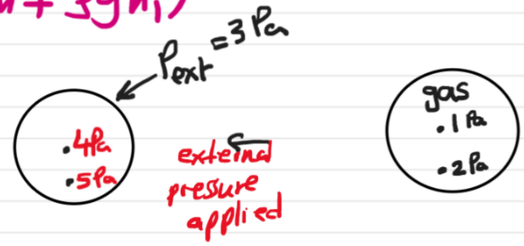
↑ pressure at point ① due to the liquid and air.

Similarly :

$$P_2^{tot} = P_{atm} + P_2 = P_{atm} + \rho g h_2$$

Note: $P_2^{tot} - P_1^{tot} = (\cancel{P_{atm}} + \rho g h_2) - (\cancel{P_{atm}} + \rho g h_1)$

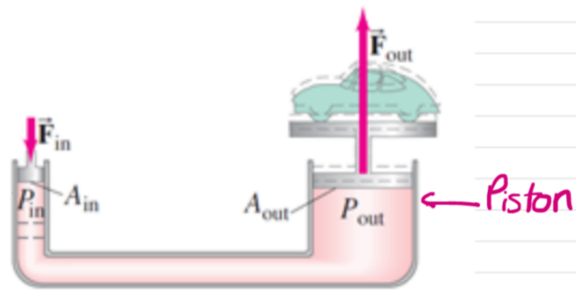
$= \rho g (h_2 - h_1) = \rho g \Delta h$




Hydraulic Lift

A device that lifts a car with a small force.

It makes use of Pascal's principle.




Assume the levels of the fluid in both out and in pistons to be the same.

$\therefore \quad P_{in} = P_{out}$

applied force (we apply to lift the car) → $\dfrac{F_{in}}{A_{in}} = \dfrac{F_{out}}{A_{out}}$ ← the load force (weight of the car we want to lift)

$\boxed{MA >> 1}$

$\therefore \quad \dfrac{F_{out}}{F_{in}} = \dfrac{A_{out}}{A_{in}} >> 1$ NOTE: $A_{out} >> A_{in}$.

$\Rightarrow$ We can lift a heavy car by applying a small force.

Example: The weight of the car $W = 10000\ N$
$A_{out} = 20\ A_{in}$. Find how much force we need to apply to lift the car and keep it in equilibrium.

$F_L$

$$\frac{F_{out}}{F_{in}} = \frac{A_{out}}{A_{in}} = 20$$

$F_a$

$$\therefore\ F_{in} = \frac{1}{20} F_{out} = \frac{W}{20} = \frac{10000}{20} = 500\ N$$

ONLY!!

$\therefore$ Can lift a weight of 10000 N using a force of 500 N only!

Hydraulic breaks in a car also use Pascal's principle.

Another example is the power steering in a car.

10-6] Measurement of Pressure; Gauges and Barometer

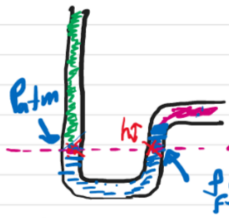
# Open-tube manometer

The two points ① and ② are at the same height.

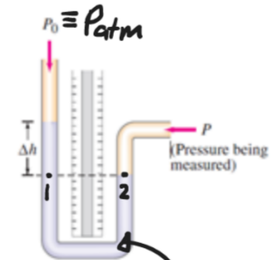
$P_1 = P_2$

$P_{atm} + \rho_f g \Delta h = P_{gas}$

$\cdot \; P_{gas} = P_{atm} + \rho_f g \Delta h$




$\rho_f gh + P_{gas}$




(a) Open-tube manometer

mercury

$P_{atm} = P_{gas} + \rho g h$

$P_{gas} = P_{atm} - \rho g h$

$P_{gas} + \rho g h = P_{atm} \Rightarrow P_{gas} = P_{atm} - \rho g h$

Sometimes, instead of calculating $\rho_f gh$ only the value of $\Delta h$ is given and the unit of pressure in this case is mmHg.

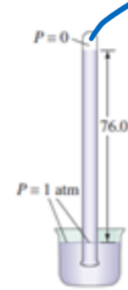
$1\ atm = 1.013 \times 10^5\ Pa \equiv 760\ mmHg = 1.013\ bar.$

This means that the pressure of a column of mercury of height 760 mm is equivalent to the atmospheric pressure.

# Mercury barometer

A column of mercury of height 760 mm (76 cm) results in a pressure equivalent to that of atmospheric pressure.

vacuum



$\equiv 760$ mm

FIGURE 10–8 A mercury barometer, invented by Torricelli, is shown here when the air pressure is standard atmospheric, 76.0 cm-Hg.

Question: If water is used instead of mercury, find the height of the water column to balance the atmospheric pressure.

$$\rho_w g h = P_{atm} = 1.013\times10^5 \text{ Pa}$$

$$\therefore \quad h = \frac{1.013\times10^5 \frac{N}{m^2}}{\left(1000\frac{kg}{m^3}\right)\left(9.8\frac{m}{s^2}\right)} = 10.3 \frac{N s^2}{kg}$$

$$h = 10.3 \frac{(kg\, m/s^2)\, s^2}{kg} = 10.3 \text{ m}.$$

For mercury

$$\rho_{Hg}\, g\, h_{Hg} = 1.013 \times 10^5 \Rightarrow h_{Hg} = \frac{1.013 \times 10^5}{\rho_{Hg} \times g} = 0.76\,m$$

remember $\rho_{Hg} \gg \rho_w$