FLUIDS

15-16 year-olds

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Pressure

Pressure, p, is a scalar magnitude that relates the perpendicular force F exerted to the surface S on which it acts:

$$p = \frac{F}{S}$$

Units

In the SI pressure is measured in $\mathrm{N/m^2}$, which is called **pascal** ($1\ \mathrm{Pa} = 1\ \mathrm{N/m^2}$). In the following table you can find different units of pressure and their equivalence:

https://en.wikipedia.org/wiki/Template:Pressure_Units

	Pascal (Pa)	Atmosphere (atm)	Bar (bar)	Torr (Torr)
1 Pa	1	9.8692×10^{-6}	10^{-5}	7.5006×10^{-3}
1 atm	101 325	1	1.013 25	760
1 bar	10^5	0.986 92	1	750.06
1 Torr	133.322 368 421	1/760	0.001 333 224	1

Pascal's principle

Formulation

Every pressure change in a certain point of an incompressible fluid contained in a closed container with non-deformable walls, is transmitted with the same magnitude in all directions and in every point of the fluid.

Applications of Pascal's principle include syringes or hydraulic presses.

Hydraulic press

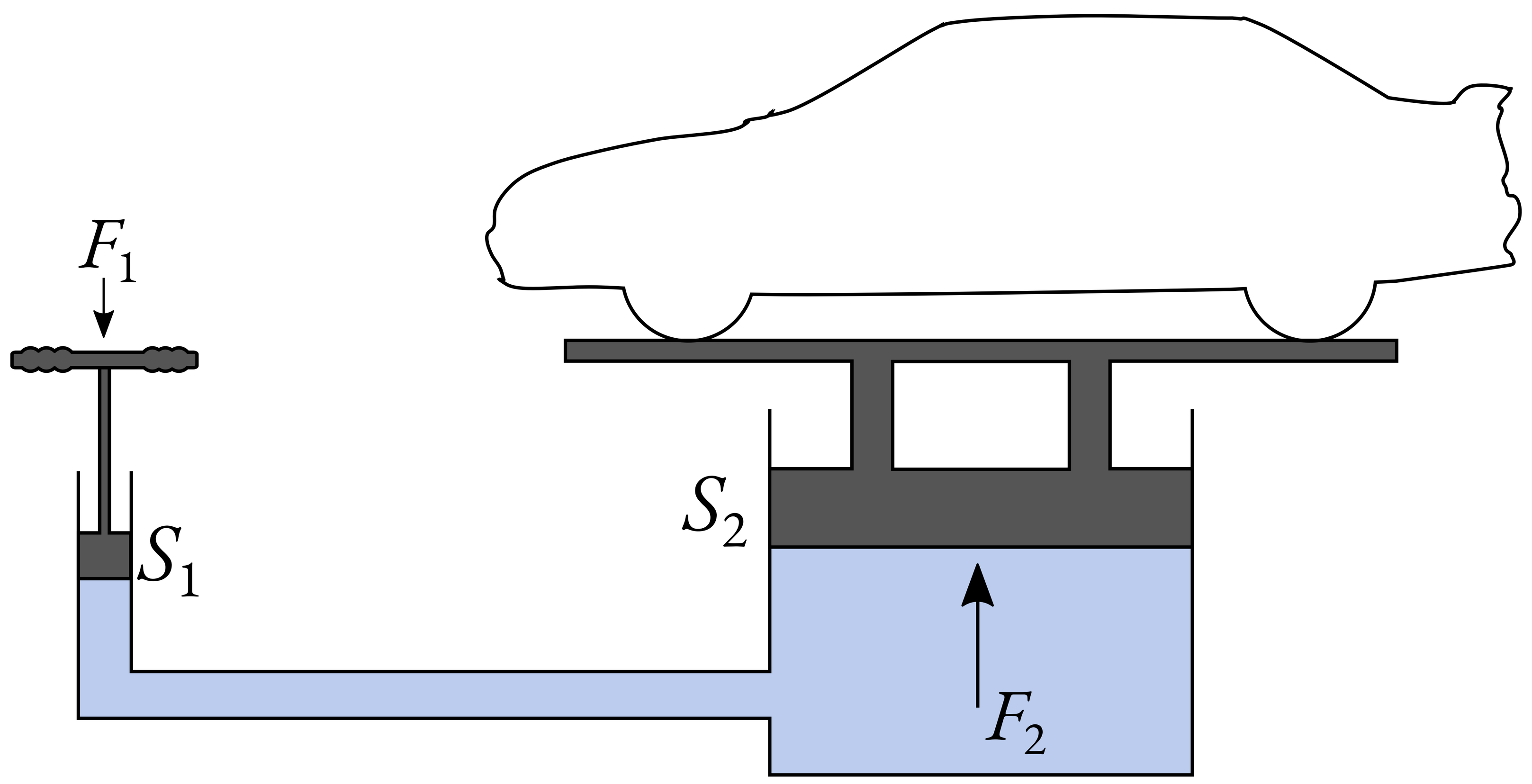


Figure 1. Hydraulic Press. A small force F_1 produces an increase of pressure F_1/S_1 which is transmitted along the liquid to the bigger piston. Since the pressure change is the same through the whole fluid (**Pascal's principle**), forces exerted on the pistons are related, being $F_2 > F_1$. Therefore, the hydraulic press allows to lift big weights with a small force (as levers do). Adapted from https://commons.wikimedia.org/wiki/File:Working_principle_of_a_hydraulic_jack.svg.

$$p_1 = p_2 \Rightarrow \frac{F_1}{S_1} = \frac{F_2}{S_2} \Rightarrow F_1 \cdot S_2 = F_2 \cdot S_1$$

Hydrostatic fundamental principle

Formulation

The pressure exerted by a fluid with a density d on a point located at a depth h from the surface is equal to the pressure exerted by a column of the same fluid with a height h:

$$p = \frac{F}{S} = \frac{m \cdot g}{S} = \frac{d \cdot V \cdot g}{S} = \frac{d \cdot S \cdot h \cdot g}{S} = d \cdot g \cdot h$$

If the surface of the fluid is also under a pressure p_0 (for example, the atmospheric pressure), the total pressure at a depth h will be:

$$p = p_0 + dgh,$$

that is the **fundamental equation of hydrostatic**.

Hydrostatic paradox. Communicating vessels

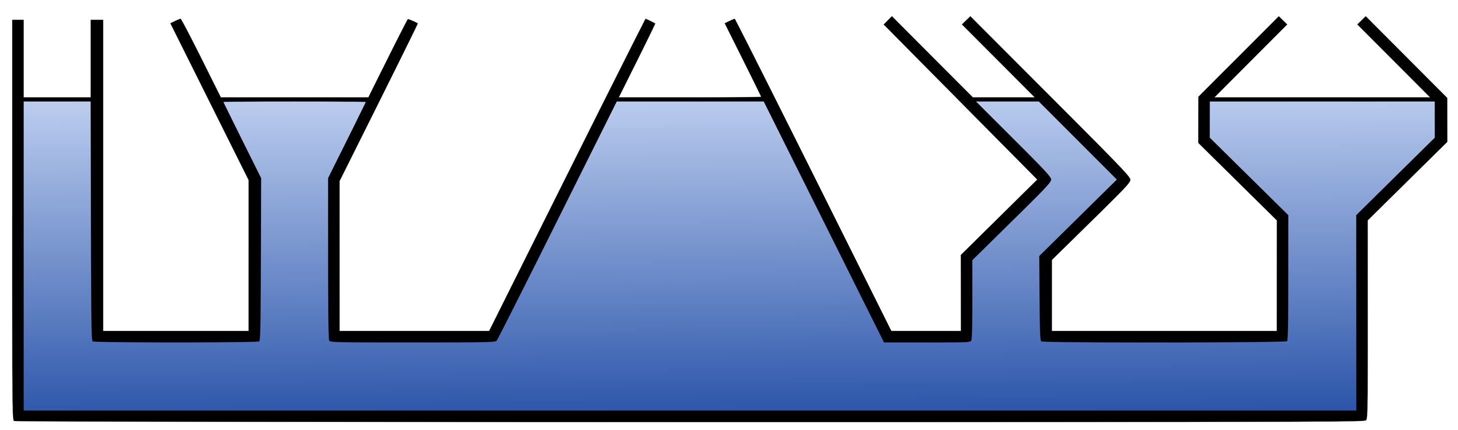


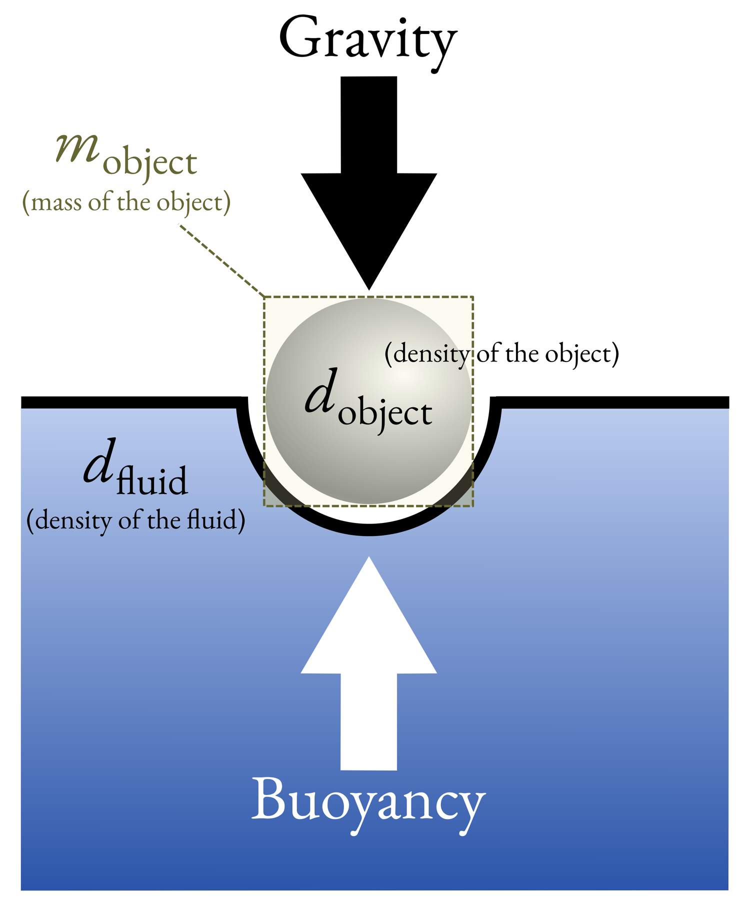
Figure 2. The **hydrostatic paradox** explains that the force exerted by a fluid on the bottom of a vessel does not depend on the shape or the amount of fluid, only on the height reached by the fluid. Then, when there are different containers communicated (**communicating vessels**), the fluid will reach the same height in all the vessels. Adapted from https://commons.wikimedia.org/wiki/File:Communicating_vessels.svg.

Archimedes' principle: Buoyancy

Formulation

Every body submerged totally or partially in a fluid, experiments an upward force (buoyant force F_B) equals to the weight of the fluid displaced by the body:

$$\begin{aligned} F_B &= F_{\text{weight displaced fluid}} \\ &= m_{\text{displaced fluid}} \cdot g \\ &= d_{\text{fluid}} \cdot V_{\text{displaced}} \cdot g \\ &= d_{\text{displaced}} \cdot V_{\text{submerged}} \cdot g \end{aligned}$$



Adapted from https://commons.wikimedia.org/wiki/File:Buoyancy.svg.

Buoyancy

$$\begin{cases} F_B < F_{\text{weight body}} & \text{it sinks} \\ F_B = F_{\text{weight body}} & \text{floats} \Rightarrow \dfrac{V_{\text{submerged}}}{V_{\text{body}}} = \dfrac{d_{\text{body}}}{d_{\text{fluid}}} \\ F_B > F_{\text{weight body}} & \text{upward force} \end{cases}$$

The apparent weight of a body can be calculated as:

$$F_{\text{weight apparent}} = F_{\text{weight body}} - F_B$$

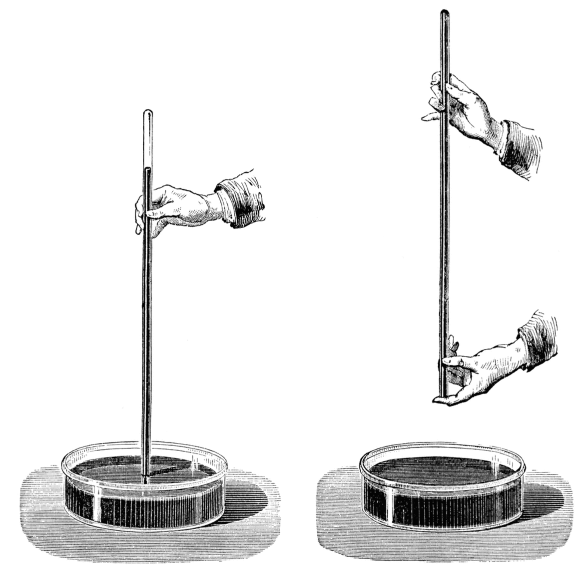
Atmospheric physics

Atmospheric pressure is the weight of the air column that a body bears per unit area.

Torricelli's experiment

Thanks to **Torricelli's experiment** atmospheric pressure was measured for the first time and also, the first vacuum in history was created. When a 100 cm height tube closed at one end filled with mercury (Hg) is placed with the open end on a mercury bucket, it is observed that the mercury drops until ≈ 76 cm, creating a vacuum in the remaining ≈ 24 cm:

$$\begin{aligned} p_{\text{atm}} &= d_{\text{Hg}} \cdot g \cdot h \\ &= 13\,534\ \mathrm{kg/m^3} \cdot 9.8\ \mathrm{N/kg} \cdot 0.76\ \mathrm{m} \\ &= 101\,325\ \mathrm{Pa} = 1\ \mathrm{atm} \end{aligned}$$



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Magdeburg hemispheres

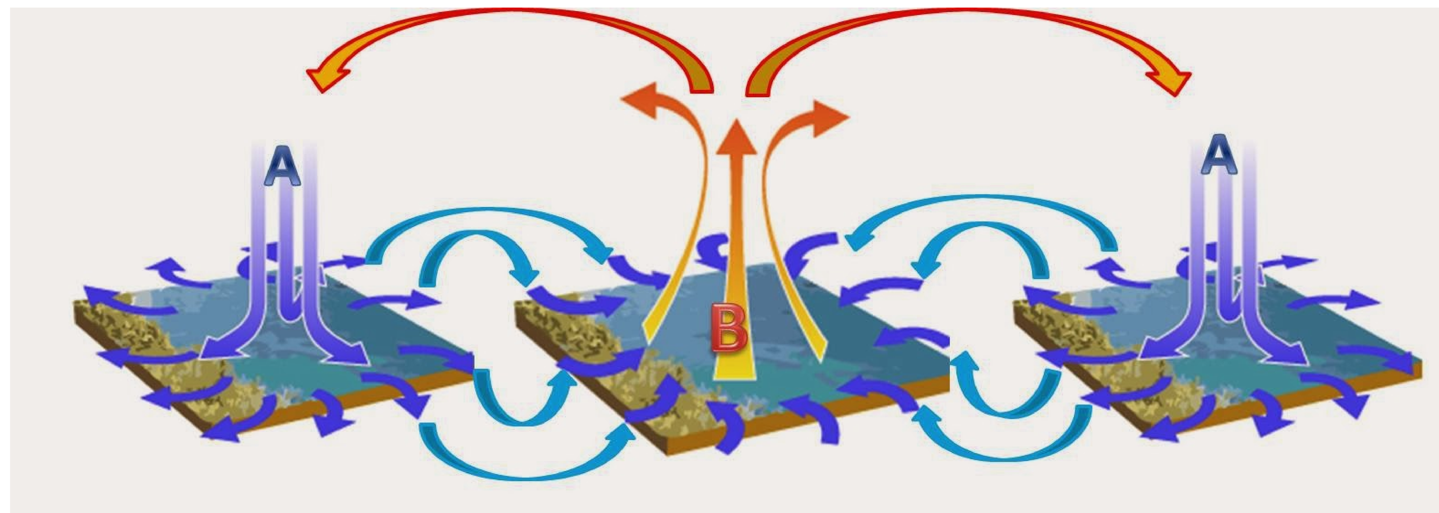
In 1654, the German scientist and major of Magdeburg **Otto von Guericke**, designed a couple of big copper hemispheres which could be paired forming a sphere. After sealing the edges he sucked the air with a vacuum pump that he had invented. Then 16 horses tried to separate both hemispheres without success, revealing the power of the atmospheric pressure.

Credit: Science Source

Meteorological phenomena

Caused by **differences** of **pressure** between different points in the atmosphere:

- **Wind** blow from regions with higher pressure to regions where the pressure is lower (usually because of a temperature difference)
- **Depressions** or **low pressure** zones are regions of the atmosphere where the atmosphere pressure is lower than the pressure of the surrounding air, which makes the wet air ascend, getting colder, condensing and originating **unstable weather**.
- A **anticyclone** is an atmospheric region with **high pressure**, where the atmospheric pressure is higher than the pressure of the surrounding air, which makes the air of the upper layers go down, producing **stable weather**.



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