Pressure Gauges

Two types of pressure gauge:

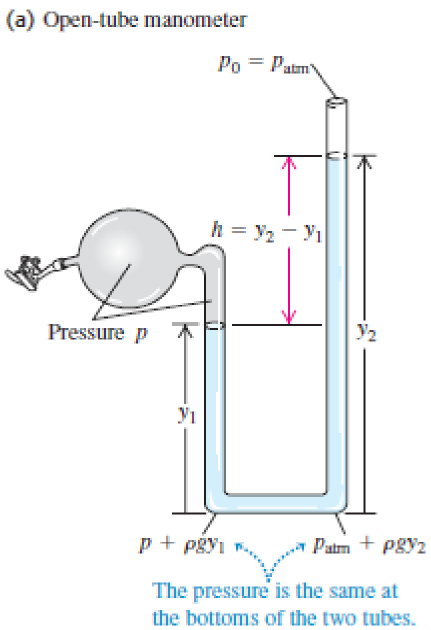
(a) The simplest pressure gauge is the open-tube *manometer* (Fig.1). The U-shaped tube contains a liquid of density ρ, often mercury or water.

The left end of the tube is connected to the container where the pressure (**p**) is to be measured, and the right end is open to the atmosphere at pressure ($p_0 = p_{atm}$).The pressure at the bottom of the tube due to the fluid in the left column is ($p+\rho g y_1$) and the pressure at the bottom due to the fluid in the right column is ($p_{atm}+\rho g y_2$) .These pressures are measured at the same level, so they must be equal:

$$p+\rho g y_1 = p_{atm}+\rho g y_2$$

$$p - p_{atm} = \rho g (y_2 - y_1) = \rho g h \qquad (8)$$

In Eq. (8), *p* is the *absolute pressure,* and the difference between absolute and atmospheric pressure is the gauge pressure. Thus the gauge pressure is proportional to the difference in height $h = y2 - y1$ of the liquid columns.



(b) Another common pressure gauge is the ***mercury barometer***. It consists of a long glass tube, closed at one end, that has been filled with mercury and then inverted in a dish of mercury (Fig. 2).

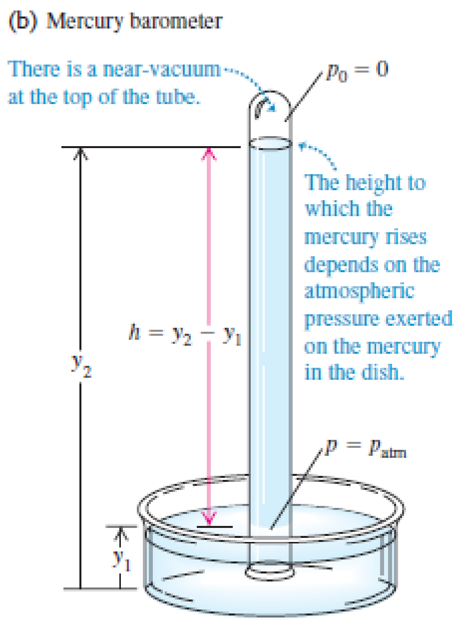
The space above the mercury column contains only mercury vapor; its pressure is negligibly small, so the pressure at the top of the mercury column is practically zero. From (Eq. 6)

$$p_{atm} = p = 0 + \rho g\,(y_2 - y_1) = \rho g h \qquad (9)$$

Note:

1- Thus the mercury barometer reads the atmospheric pressure directly from the height of the mercury column.

2- A pressure of 1 mm Hg is called 1 torr, But these units depend on the density of mercury, which varies with temperature, and on the value of g, which varies with location, so the pascal is the preferred unit of pressure.

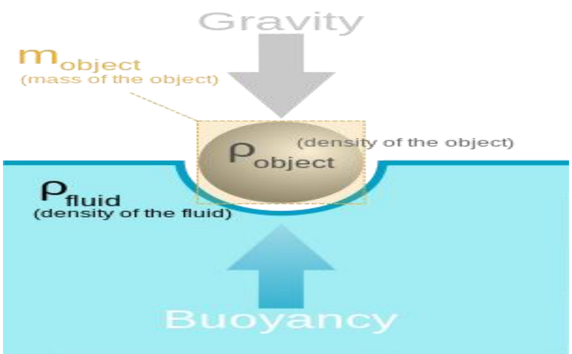


Buoyancy: is a familiar phenomenon: A body immersed in water seems to weigh less than when it is in air. When the body is less dense than the fluid, it floats.

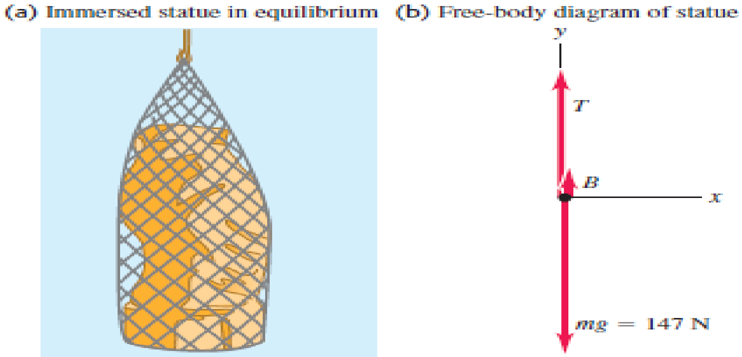
The human body usually floats in water, and a helium-filled balloon floats in air.

Archimedes's principle: When a body is completely or partially immersed in a fluid, the fluid exerts an upward force on the body equal to the weight of the fluid displaced by the body.

The name of this upward force exerted on body immersed or Floating objects in fluids is called the **buoyant force**.



EX.1 A 15.0-kg solid gold statue is raised from the sea bottom (Fig. 3). What is the tension in the hoisting cable (assumed massless) when the statue is (a) at rest and completely underwater and (b) at rest and completely out of the water?



(Fig. 3)

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In both cases the statue is in equilibrium and experiences three forces: its weight, the cable tension, and a buoyant force equal in magnitude to the weight of the fluid displaced by the statue (seawater in part (a), air in part (b)).

Our target variables are the values of the tension in seawater T_{sw} and in air T_{air} . We are given the mass m_{statue} , and we can calculate the buoyant force in seawater (B_{sw}) and in air (B_{air}) using Archimedes's principle.

(a) To find (B_{sw}), we first find the statues volume V using the density of gold which is = $19.3*10^3$ Kg/m^3

$$V = m_{statue}/\rho_{gold} = 15.0\ Kg / 19.3 * 10^3 Kg/m3 = 7.77 * 10^{-4} m^3$$

The buoyant force (Bsw), equals the weight of the same volume of seawater :

$$B_{sw} = W_{sw} = m_{sw} g = \rho_{sw} V g$$

$$= (1.03 * 10^3 Kg/m3)(7.77 * 10^{-4} m^3)(9.80\ m/s^2) = 7.84\ N$$

The statue is at rest, so the net external force acting on it is zero. From (fig.b)

$$\sum F_y = B_{sw} + T_{sw} + (-m_{statue}\, g) = 0$$

$$T_{sw} = (m_{statue} g - B_{sw}) = (15.0\ Kg)(9.80\ m/s^2) - 7.84\ N$$

=147 N - 7.84 N = 139 N

A spring scale attached to the upper end of the cable will indicate a tension 7.84 N less than the statue's actual weight

$m_{statue}\ g = 147$ N.The density of air is about 1.2 Kg/m3 , so the buoyant force of air on the statue is

$$B_{air} = \rho_{air}Vg = (1.2\ kg/m^3)(7.77 \times 10^{-4}\ m^3)(9.80\ m/s^2)$$
$$= 9.1 \times 10^{-3}\ N$$

This is negligible compared to the statue's actual weight $m_{statue}\ g = 147$ N. So within the precision of our data , the tension in the cable with the statue in air is $T_{air} = (m_{statue}\ g) = 147$ N .