The atmospheric pressure

It is so difficult to measure the weight of air column at a point on the surface of the earth.

Torricelli's barometer : -

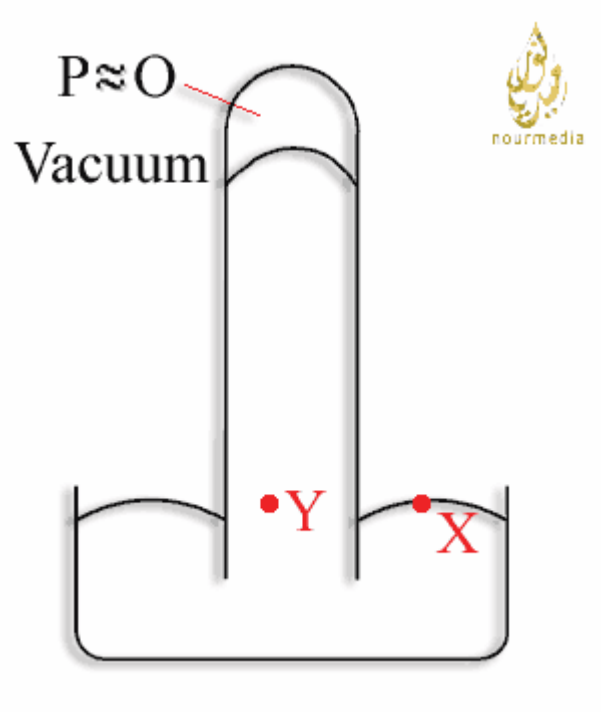
The scientific idea depends on : -

All points in the same horizontal plane in the same liquid have the same pressure.

- It is a device to measure atmospheric pressure

It consists of a long glass tube (1 meter length) filled completely with mercury (Hg) , inverted in a basin containing (Hg) .

The (Hg) surface falls to a certain level inside the tube , the space over the column is called Torricelli's vacuum which contain a small amount of Hg vapor .



•Definition of P_a: -

It is equivalent to the pressure produced by a column of Hg of height 0.76 m and across sectional area ($1m^2$) at (0°c) from the sea level.

•Estimation of P_a: -

We take 2 points (X) and (Y) at the same horizontal level (X) at the surface of Hg in the basin and
(Y) inside the tube .

$P_{at\ point\ Y} = P_{at\ point\ X}$

$r\ g\ h + P_{vacuum} = P_a$

$P_a = r\ g\ h + 0$

$P_a = r\ g\ h$

$P_a = 13595 \times 9.81 \times 0.76$

$= 1.013 \times 10^5\ N / m^2$

Where 13595 Kg/ m3 is the density of Hg at 0°c.

Notes: -

1- the height of 76 cm Hg indicate normal P_a

2- P_a acts from all directions .

3- Total pressure at a point inside a liquid is :

$P_T = P_a + r\ g\ h$

When the surface of the liquid is exposed to air ,we have:

4- P_a decreases at the top of a mountain and vice versa.

5-The shape or the inclination of the barometer tube does not affect the height of Hg.

6-The cross - sectional area of the tube, does not affect the height of Hg.

G . R: -

Mercury barometer is preferred to water barometer.

Answer

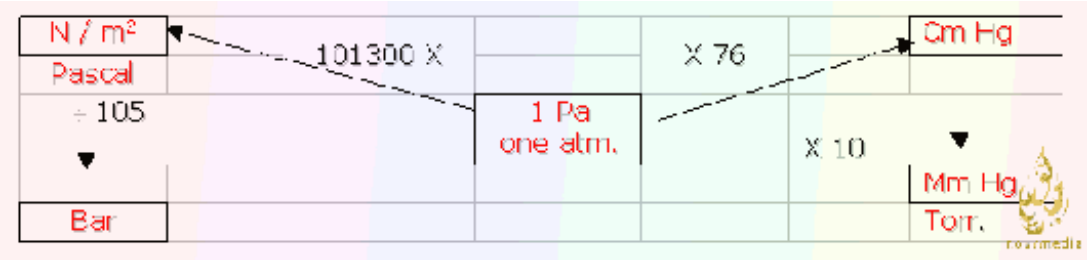
Because Hg is denser than water and occupies a short " h" that can be easily measured.

Hg does not evaporate at room temp.

$$\text{h of water} = \frac{1.013 \times 10^5}{1000 \times 9.8} = 10.33 \text{ m}$$

length of the tube must be long

Units of pressure



1 Pa = 0.76 m Hg
= 76 cm .Hg
one atm.= 760 Torr. mm Hg
} Length Hg

= 1.013 x 10^5 N / m^2

= 1.013 x 10^5 Pascal

= 1.013 bar

Pascal = 10^{-5} bar

* The manometer

The scientific idea depends on :-

All points in the same horizontal plane in the same liquid have the same pressure.

It is a device used to measure: -

1- The absolute pressure of fluids.

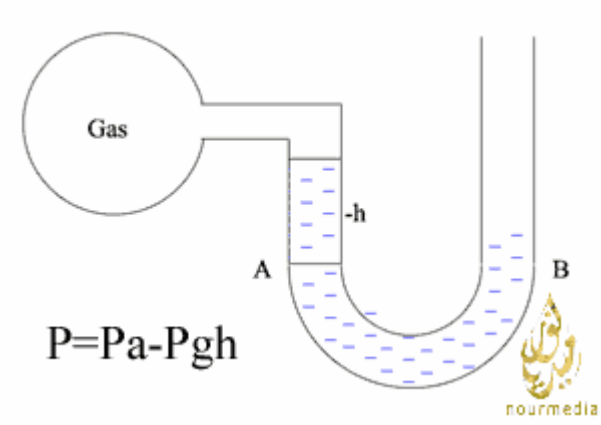
2- The difference in pressure of the fluid and the atmosphere .

Structure : -

It consists of a U shaped tube containing a suitable amount of liquid with known density. One branch of the tube is connected to the pressure source required to be measured and the other is open to the atmosphere (free branch)

Main cases

1-When pressure of the gas is equal to that of the atmosphere, the two surfaces of the liquid are in the same horizontal plane.

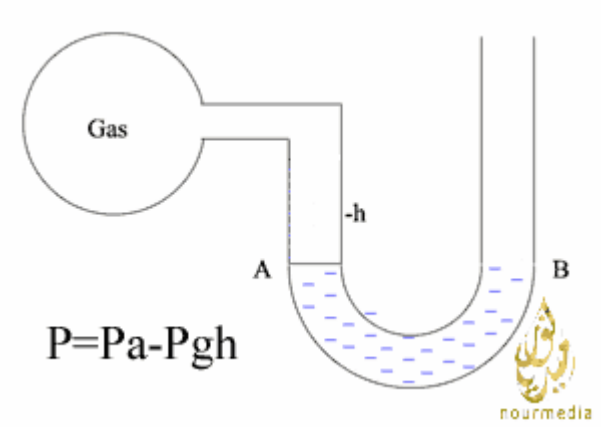


P gas = Pa

Δ P = 0

Δ h = 0

2- When pressure of the gas (absolute pressure) is greater than that of the atmosphere.



The liquid is depressed in the side attached to the gas bulb.

$P_{absolute} = P_a + \rho g h$ (in Pascal)

$= P_a + \Delta P$ (any unit)

$= P_a + h$ (in cm Hg)

$\Delta P = \rho \; g \; h \Longrightarrow N / m^2$

$Kg / m^3 \quad m / s^2 \quad m$

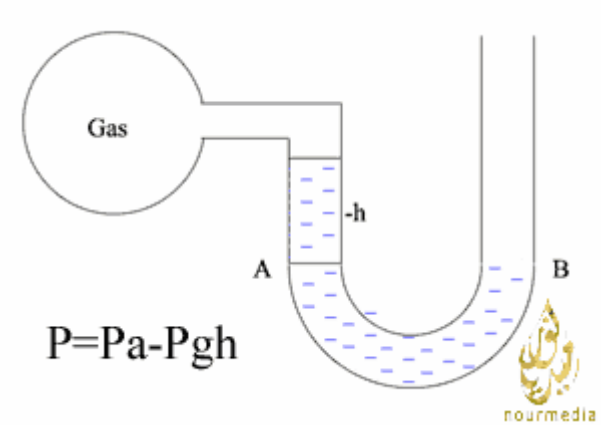
$\Delta P = h$ (in length Hg)

3- When pressure of the gas is less than that of atmosphere, the surface of the liquid will fall in the free branch.

$P_{gas} = P_a - \rho h g$ (Pascal)

$= P_a - h$ (length Hg)

$= P_a - \Delta P$ (any unit)



G . R: -

1- The water manometer is preferred to mercury manometer for measuring small difference in pressure.

Answer

Because density of water is less than that of mercury.

$$h_{H2O} > h_{Hg}$$

$$\frac{r_{Hg}}{r_{H_2O}} = \frac{h_{H_2O}}{h_{Hg}} = \frac{13600}{1000}$$

$$\frac{h_{H_2O}}{h_{Hg}} = \frac{13.6}{1}$$

2- The mercury barometer is preferred to water barometer.

Answer

$P_a = r\ g\ h_{Hg} = r_{H2O}\ g\ h_{H2O}$

$13600 \times 9.8 \times 0.76 = 1000 \times 9.8 \times h_{H2O}$

$h_{H2O} = 10.336$ m

It needs a very long tube

The evaporation temperature of water is relatively low.

Examples
(pressure-barometer-manometer)

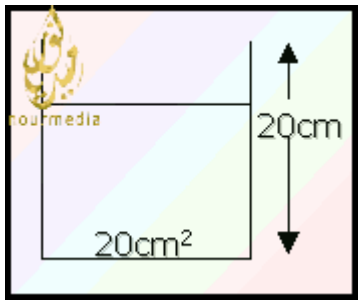
1- A cylindrical container contains mercury(density 13600 Kg / m^3)and height of 20 cm (base area 20 cm^2)

Find the force that affects the base of the container when: -

1- The container is open.

2- The surface of mercury is not exposed to atmospheric pressure

(P_a = 1.013 x 10^5 N /m^2) (g = 9.8 m / sec^2)



Solution

1- when the surface of Hg is exposed to atmosphere

$P = P_a + \rho g h$

$= (1.013 \times 10^5) + (13600 \times 9.8 \times 0.2)$

$= 127956$ N / m^2

$$P = \frac{F}{A} \longrightarrow F = P A$$

$F = 127956 \times 20 \times 10^{-4}$

$= 255.912$ Newton

2- When the surface of Hg is not exposed to atmospheric pressure: -

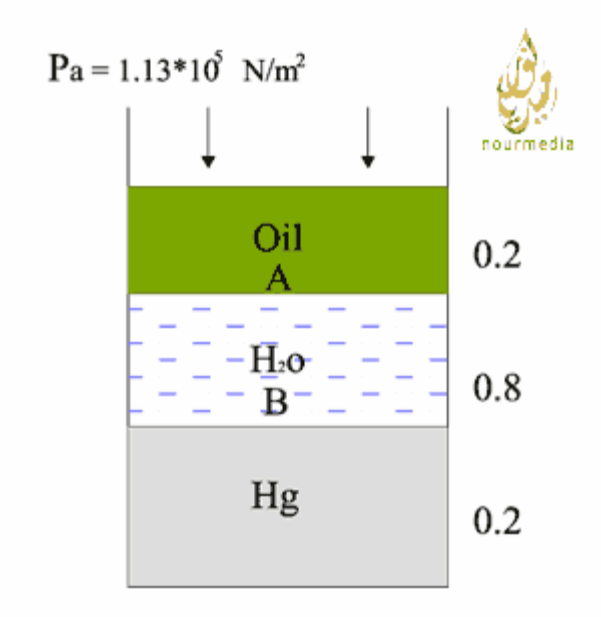
$P = r\ g\ h$

$= 13600 \times 9.8 \times 0.2$

$= 26656\ N / m^2$

$F = P\ A = 26656 \times 20 \times 10^{-4}$

$= 53.312$ Newton



$P_{oil} = 800\ Kg / m^3$

$P_{H2O} = 1000\ Kg / m^3$

$P_{Hg} = 13600\ Kg / m^3$

Find : -

1- The difference in pressure between A , B .

2- The force that affects the base of the container the area of which is 30 cm^2

Solution

1- $P_A = P_a + (r\ g\ h)_{oil}$

$$P_B = P_a + (\rho\ g\ h)_{oil} + (\rho\ g\ h)_{H2O}$$

$$\Delta P = (\rho\ g\ h)_{H2O} = 1000 \times 9.8 \times 0.8$$

$$= 7840\ N/m^2$$

2- The total pressure at the bottom

$$P = P_a + (\rho\ g\ h)_{oil} + (\rho\ g\ h)_{H2O} + (\rho\ g\ h)_{Hg}$$

$$= (1.013 \times 10^5) + (800 \times 9.8 \times 0.2) + (1000 \times 9.8 \times 0.8) + (13600 \times 9.8 \times 0.2) = 137364$$

$$F = P_A$$

$$= 137364 \times 30 \times 10^{-4} = 412.092 \text{ Newton}$$

3- A field of natural gas has an absolute pressure of 3×10^6 N / m^2 Find the height of the soil required to prevent the leakage of the gas if the atmospheric pressure is 1.013×1^5 N /m^2 , the free fall acceleration equals 9.8 m / s^2 and density of the soil equals 200 Kg / m^3.

Solution

$$P_{gas} = P_a + (\rho\ g\ h)_{soil} .$$

$$3 \times 10^6 = 1.013 \times 10^5 + 200 \times 9.8\ h$$

$$h = \frac{3 \times 10^6 - 1.013 \times 10^5}{200 \times 9.8}$$

$$= 147.89286 \text{ meter.}$$

4- A vertical plate whose dimensions are 30 and 20 cm, is placed vertically in water with density 1000 Kg / m^3, so its upper horizontal edge will be at depth of 185 cm.

1- find the force that affects the plate from one side

2- the net horizontal force that affects the plate

(P_a =1.013 x 10^5 N / m^2)

Solution

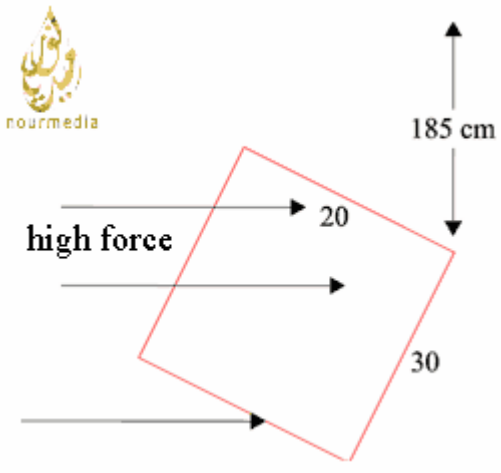
1- F = P A

F = (P a + r g h) A

F = 1.013 x 10^5 + 1000 x 9.8 x 2

= 7254 Newton

2- net force = 0



5- A submarine at depth 30 m from the surface of sea level. Find the force that affects the door of the cabinet, if its radius equals

35 cm and the sea water has density equals 1030 Kg/m^3

(g = 9.8 m / sec^2)

Solution

P = r g h

F = P A = r g h A

= 1030 x 9.8 x 30 x 2 p $(0.35)^2$

= 233077.59 N

Submarine has atmospheric pressure from inside.

6- Find the maximum height of water in the pipe of a house if the pressure in the ground floor equals 300 Kpa.

Solution

$\Delta P = P - Pa = \rho g h$

$= 300 \times 10^3 - 1.013 \times 10^5 = 1000 \times 9.8 \times h$

$$h = \frac{300 \times 10^3 - 1.013 \times 10^5}{10^3 \times 9.8}$$

$= 20.275$ m

7- Find the force that affects each side of the cube and the upper and lower sides

Solution

1- The force that affects the lower base

$F_1 = (P_a + \rho g h) A$

$= (1.013 \times 10^5 + 1000 \times 9.8 \times 9) 16$

$= 3032000$ N

2- The force that affects the sides

$F_2 = (P_a + \rho g h') A$

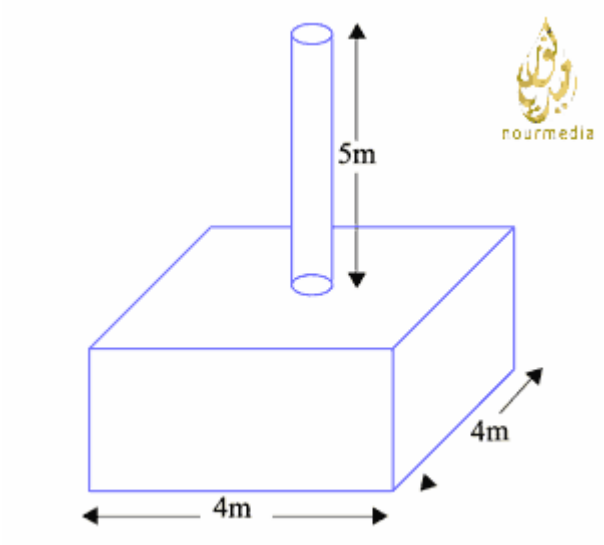
$= (1.013 \times 10^5 + 1000 \times 9.8 \times 7) 16 = 2718400$

3- The force that affects the upper base

$F_3 = (Pa + \rho g h` ) A`$

$= (1.013 \times 10^5 + 1000 \times 9.8 \times 5)(16 - 35 \times 10^{-4})$

$= 2404274$ N



8- U shaped tube contains water oil of density 800 Kg/m³ is poured in one branch to depress the surface of water 10 cm. Find: -

1- Height of water above the separating surface.

2- The height of oil.

ρ_{H_2O} = 1000 Kg / m^3

Solution

1- The height of water = 20 cm

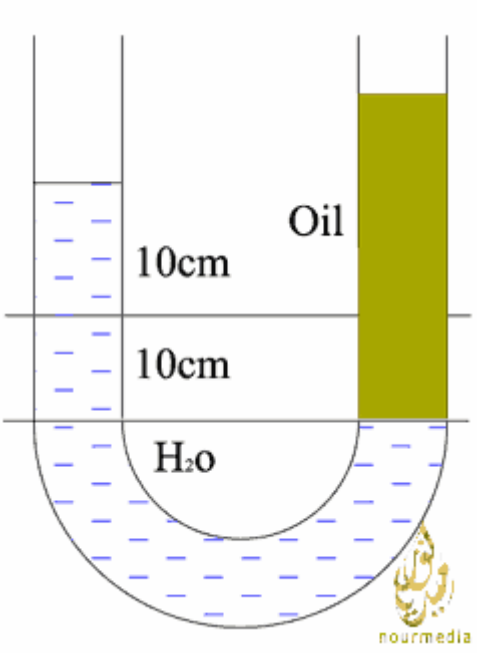
2- $P_A = P_B$

$Pa + (r\ g\ h)_{H2O} = Pa + (r\ g\ h)_{oil}$

$r_{H2O}\ h_{H2O} = r_{oil}\ h_{oil}$

$1000 \times 0.2 = 800\ h_{oil}$

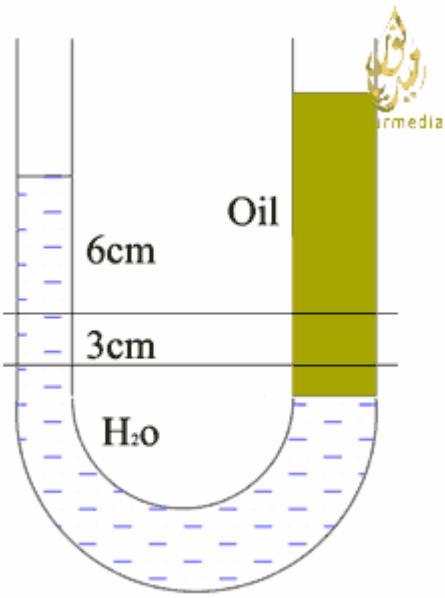
$$h_{oil} = \frac{1000 \times 0.2}{800} = 0.25\ m$$



9 - U shaped tube contains water. One of its branches has a cross - sectional area equals 4 cm^2 and the other equals 2 cm^2. Oil is poured in the wide branch to depress surface of water 3 cm.

Find the height of oil if its density equals 800 Kg /m^3

Solution



h_{H2O} = 9 cm

$(\rho\ g\ h)_{oil} = (\rho\ g\ h)_{H2O}$

$800\ h_{oil} = 1000 \times 0.09$

$$h_{oil} = \frac{1000 \times 0.9}{800} = 0.1125 \text{ m}$$

10- U shaped tube of height 20 cm is filled to its half with water kerosene is poured in one branch to fill the tube completely. Find the height of kerosene if its density is 820 Kg / m^3

ρ_{H_2O} = 1000 Kg / m^3

Solution

$(\rho\ h)_K = (\rho\ h)^{H_2O}$

$820\ (10 + X) = 1000 \times 2\ X$

$82\ (10 + X) = 200\ X$

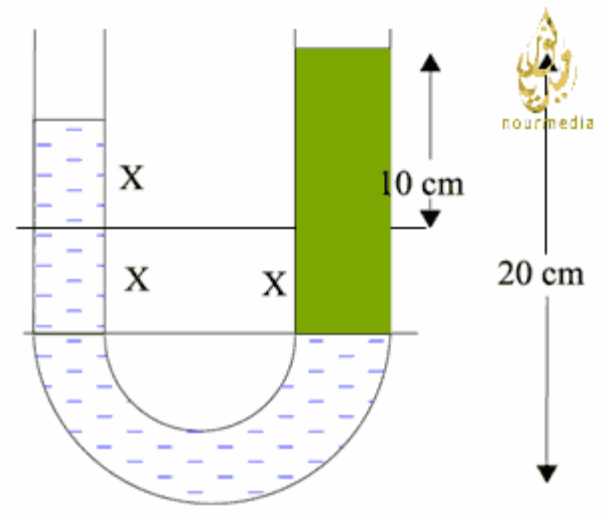
$820 + 82\ X = 200\ X$

$820 = 200X - 82X$

$$X = \frac{820}{118} = 6.949 \text{ cm}$$

$h_K = 10 + X = 10 + 6.949$

$= 16.949$ cm



11- The reading of a barometer at the ground floor is 76 cm Hg and its reading above the top of the building is 74cm Hg

Find the height of the building if the average density of air is 1.25 Kg / m^3

r_{Hg} = **13600 Kg / m^3**

Solution

$(r\ g\ \Delta\ h)_{Hg} = (r\ g\ \Delta h)_{air}$

Δ h = 76 - 74 = 2 cm Hg

13600 x 0.02 = 1.25 Δh

Height of the building = $\frac{13600 \times 0.02}{1.25}$

= 217.6 m

12- Find the reading of the barometer above the surface of a building if the height of the building is 200 m, the average density of air is

1.25 Kg / m^3 and the reading of the barometer at the ground floor equals 76 cm Hg.

r_{Hg} = 13600 Kg / m^3

Solution

$$(\rho g \Delta h)_{Hg} = (\rho g \Delta h)_{air}$$

13600 x (0.76 - h`) = 1.25 x 200

$$0.76 - h` = \frac{1.25 \times 200}{13600}$$

$$h` = 0.76 - \frac{1.25 \times 200}{13600}$$

= 0.7416 meter

= 74.16 cm Hg

13- the difference in pressure between the terminals of a water pipe equals 1.5 x 10^5 Pascal. The cross - sectional area of the pipe equals 0.25 m^2 and its length is 30 m.

Find the work done to move this volume of water.

Solution

$$\Delta P = \frac{W}{V}$$

Work = Δ P x Volume

= 1.5 x 105 x 0.25 x 30

= 1125 Kilo Joule

14 - A manometer is connected to a source of gas so mercury is raised in the free branch 50 cm.

Find pressure of the gas in: -

1- Cm Hg 2- Pascal 3- Atm.

r_{Hg} = 13600 Kg / m^2

Solution

1- In Cm Hg : -

$P_{gas} = P_a + h$

$= 76 + 50 = 126$ Cm Hg

2- In atm : -

$P_{gas} = P_a + \Delta P$

$= 1 \text{ atm.} + \frac{50}{76}$

$= 1.65789$ atm.

3- In Pascal : -

$P_{gas} = Pa + r\ g\ h$

$= 1.013 \times 10^5 + 13600 \times 9.8 \times 0.5$

$= 167940$ Pascal

15 - From the table: 1 - draw the graphic relation between mass (on the ordinate) and volume. (on the (X) axis).

Mass in gm	4	6	8	X	12	18
Volume in cm^3	0.909	1.36	1.818	2.5	2.72	Y

From the graph find: -

1- Density of the material used.

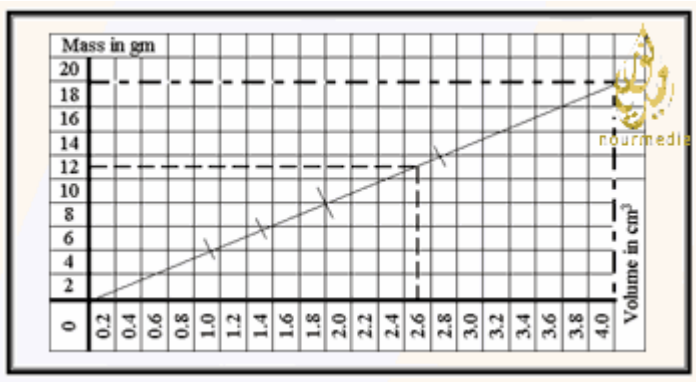
2- The value of (X) and (Y).

Solution

X = 11 gm

Y = 4.5 cm^3

$$\rho = \text{Slope} = \frac{\Delta m}{\Delta V} = \frac{(12 - 4) \times 10^{-3}}{(2.72 - 0.909) \times 10^{-6}} = 4417 \text{ Kg}$$



16- Draw the graphic relation between mass and volume. From the graph find: -

1- Density of the substance.

2- The mass (X) in gram.

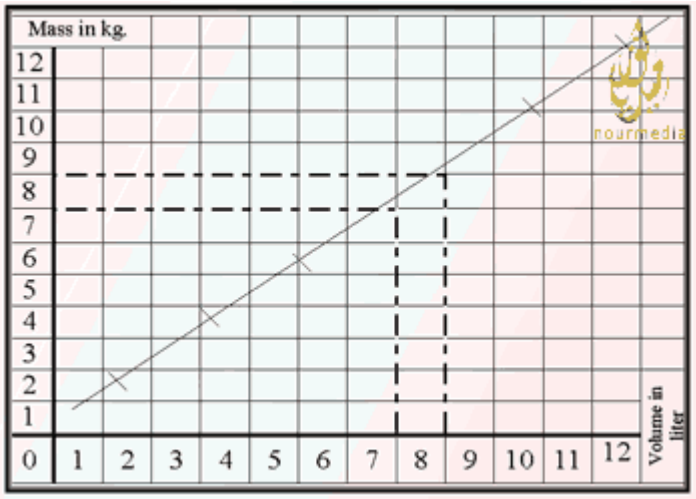
3- The volume (Y) in m^3.

mass	1 Kg	3	5	X	8	10	12 Kg
Volume	1	3 Liter	5	7	Y	10	12 liter

$X = 7 \times 10^3 = 7000$ gm

$Y = 8 \times 10^{-3} = 0.008\ m^3$

$$r = \text{Slope} = \frac{12 - 1}{12 - 1 \times 10^{-3}} = 1000 \text{ Kg / } m^3$$



17 -

Pressure bar	1.1	1.2	1.3	1.4	1.6
Depth meter	1	2	3	4	6

Draw the graphic relation between pressure and depth.
From the graph find: -

1- The density of the liquid g = 10 m/sec^2
2- The pressure at depth 20 meter
3- The atmospheric pressure

Solution

1- Slope = $\frac{\Delta p}{\Delta h} = \frac{\rho g \Delta h}{\Delta h}$ = ρg

Slope = 10 ρ

$\frac{(1.6 - 1.1) \times 10^5}{6 - 1}$ = 10 ρ

$\frac{0.5}{5} \times 10^5 = 10\ \rho$

$10^4 = 10\ \rho$

$\rho = 1000\ Kg / m^3$

3- Pa = 1 bar at depth = 0

2- P at 20 m depth = Pa + ρ g h

$= 10^5 + 10^3 \times 10 \times 20$

$= 3 \times 10^5\ N / m^2$