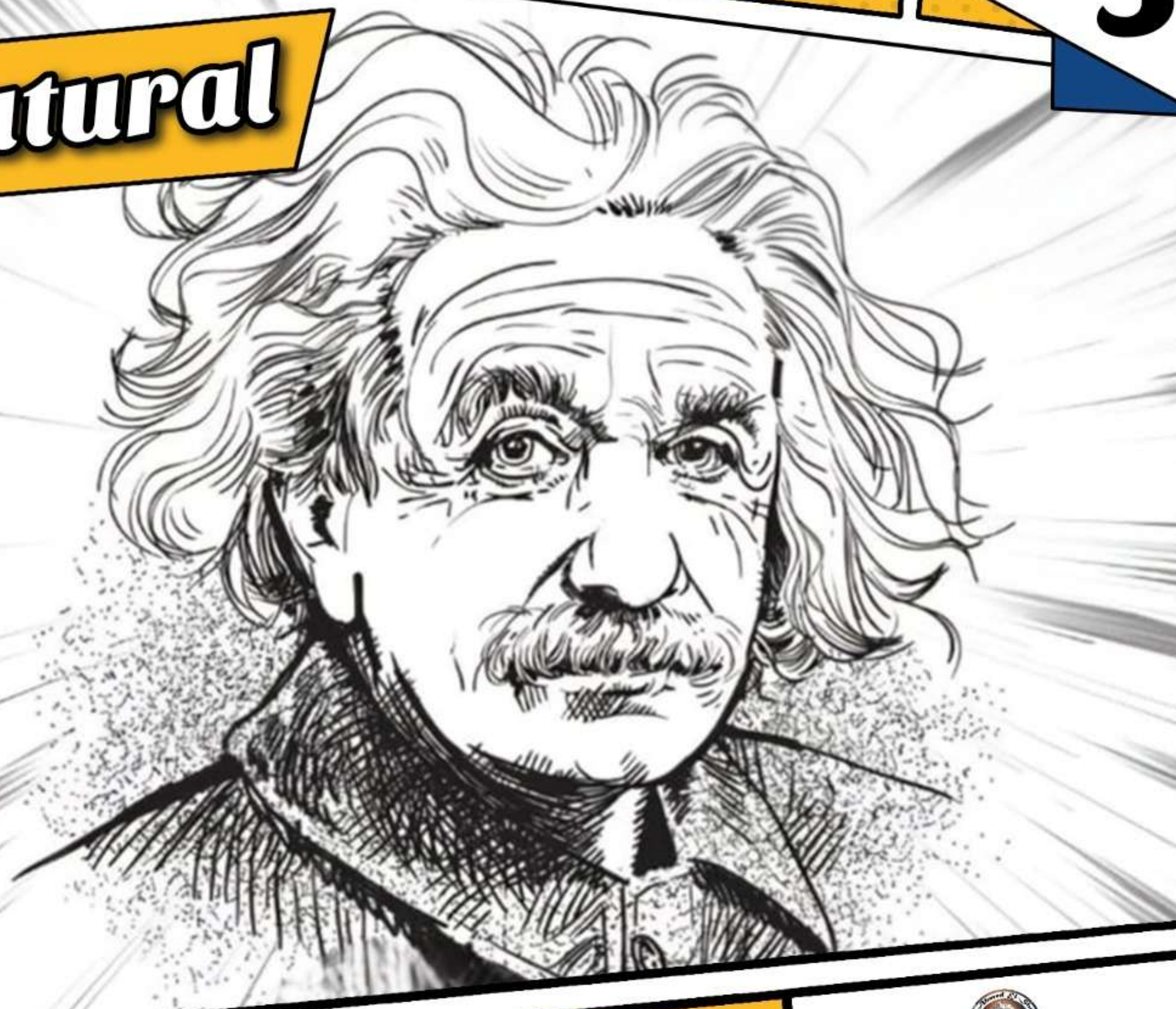
Dr/A.ElShabasy physics

2025

NO 3

Natural



Properties of Matter (Static Fluid and Surface Tension)

Physics 1 Dr.Elsahbasy

WhatsApp group

Fluids

Fluids

Any matter that can flow is considered as fluid (Liquids – Gases)

Fluids we study

1. Statics

- ☞ fluids at rest or steady, or laminar
- ☞ density- relative density- pressure-surface tension

2. Dynamic

- ☞ dynamics when the fluid is in motion
- ☞ Bernoulli – viscosity

① Statics fluid

Density ρ

- ✶ it is the mass per unit volume and depends on the nature of the material
- ✶ All objects made of a given material have the same density, regardless their size or mass.

$$\rho = \frac{m}{V} \text{ , unit is } \frac{Kg}{m^3}$$

`

$$\rho_{water} = 1000 \frac{Kg}{m^3} = 1 \frac{g}{cm^3}$$

Relative Density ρ_S/ρ_W

- ✶ Density of substance over density of water
- ✶ unit less

$$\boxed{\frac{\rho_S}{\rho_W}}$$

$$\boxed{Relative\ density\ for\ water = 1 = \frac{1000}{1000}}$$

Example 1

Two objects of equal volume are mixed together. The density of object X is $2000kg/m^3$, and the density of object Y is $8000kg/m^3$. What is the density of the mixture?

Answer

Example 2

What mass of a material with density ρ is required to make a hollow spherical shell having inner radius r_1 and outer radius r_2 .

Answer

$$\rho = \frac{m}{V} \qquad \rightarrow \quad mass = \rho \times V$$

$$mass = \rho \times \left[\frac{4}{3}\pi r_2^3 - \frac{4}{3}\pi r_1^3\right]$$

Example 3

Two spheres are cut from a certain uniform rock. One has radius 4.50 cm. The mass of the other is five times greater. Find its radius.

Answer

$$m_2 = 5\, m_1$$

$$\frac{m_1}{\frac{4}{3}\pi r_1^3} = \frac{m_2}{\frac{3}{4}\pi r_2^3}$$

$$\frac{m_1}{\frac{4}{3}\pi r_1^3} = \frac{5\, m_1}{\frac{3}{4}\pi r_2^3}$$

$$r_2 = r_1 \sqrt[3]{5} = 7.69cm$$

Pressure:

✶ The force F acting perpendicular to a surface divided by the area A

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

Units

☞ $\frac{N}{m^2} = Pascal$
☞ torr
☞ 1 bar = $10^5 \frac{N}{m^2} = 10^5\ Pa$
☞ The British unit ***pounds per square inch*** ($\frac{lb}{in^2}$, or psi)
☞ Another unit of pressure is the ***atmosphere***

الضغط الجوي

هو وزن عمود الهواء الساقط من الغلاف على الارض

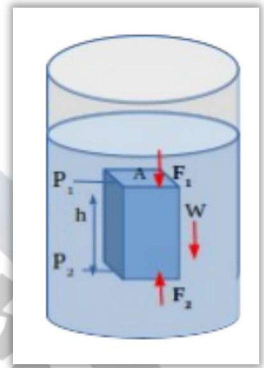
☞ $1\ atm = 1.013x10^5\ Pa = 14.7\ psi = 1.013\ bars$

Pressure with depth "h"

- Consider a certain liquid of density

There are two external force act on fluid

1. **gravitational force** that is the weight of the fluid. (Downward)



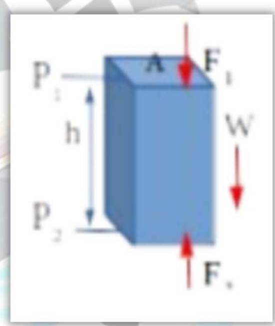
$$W = mg = \rho V g = \rho A h g$$

Where:

$$V = Ah$$

2. **collisional force** that is responsible for fluid pressure.

- horizontal forces cancel each other
- Vertical forces



$\boldsymbol{F_1}$: force at the upper surface (downward) $\boldsymbol{F_1 = P_1 A}$

$\boldsymbol{F_2}$: force at the lower surface (upward) $\boldsymbol{F_2 = P_2 A}$

بما ان النقطة ثابتة مش بتتحرك يبقى مجموع القوة عليها بصفر

$$-W - F_1 + F_2 = 0$$

$$F_2 - F_1 = W$$

$$P_2 A - P_1 A = \rho A h g$$

$$P_2 - P_1 = \rho h g$$

$$P_2 = P_1 + \rho h g$$

☞ **If P_1 at the surface**

$$P_1 = P_{atm}$$
$$P_2 = P_{atm} + \rho g h$$

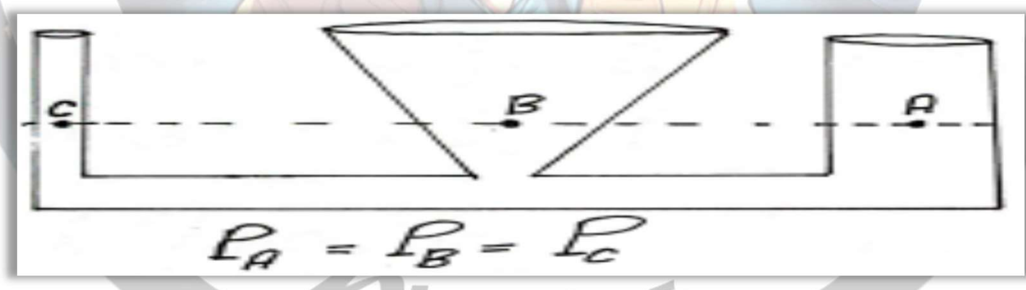
✶ The difference between an absolute pressure(الضغط الكلى) and an atmospheric pressure (الضغط الجوى) is called **gauge pressure**

(Gauge Pressure) الضغط المقاس

هو الضغط الذي يتم قياسه باستخدام أجهزة قياس الضغط مثل أجهزة قياس ضغط الإطارات أو الغلايات. وهو يعبر عن الفرق بين الضغط الفعلي في نظام ما والضغط الجوي المحيط.

$$P - P_{atm} = P_{Gauge} = \rho g h$$

all horizontal points that in same level have same pressure



Example

The swimming hole that located at a distance of $h = 5.50\ m$ below the surface of the water. Find the pressure at each of these two points. Where The pressure acting on the surface of the water is the atmospheric pressure of 1.01×10^5 Pa.

Answer

$$P_2 = p_1 + \rho g h = 1.01 \times 10^5 + (1000 \times 9.8 \times 5.5) = 1.54 \times 10^5$$

Example

A submarine is located at a depth of $h = 20m$ below the surface of the sea. The atmospheric pressure at the surface of the sea is $1.01 \times 10^5 pa$. Find the pressure acting on the submarine. (The density of seawater $\rho = 1025 kg/m^3$).

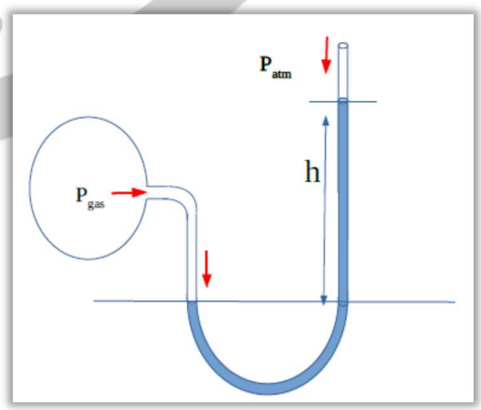
Answer

Gauge pressure

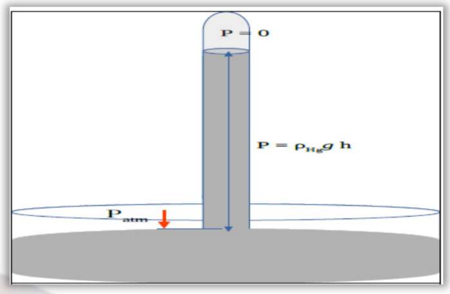
① Manometer

$$P_{gas} = P_{Hg} + P_{atm}$$

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



② Mercury barometer



is used to measure **the atmospheric pressure.**

It consists of a glass tube filled with mercury and closed at one end

$$p_a = (\rho\ g\ h)_{Hg} = 13600\,\frac{Kg}{m^3} \times 9.8\,\frac{m}{s^2} \times 0.76\,m$$

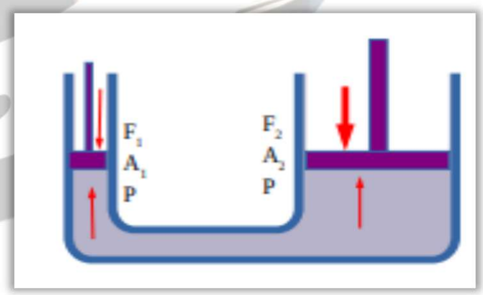
$$p_a = (\rho\ g\ h)_{Hg} = 13600\,\frac{Kg}{m^3} \times 9.8\,\frac{m}{s^2} \times 0.76\,m$$

$$= 1.013 \times 10^5\ \frac{N}{m^2}$$

Density of mercury equal 13- times density of water

Pascal's law

If a pressure is applied to an enclosed fluid, this pressure is transmitted undiminished to every part of the fluid and the walls of the containing vessel



إذا تم تطبيق ضغط على سائل محصور، فإن هذا الضغط ينتقل بالكامل ودون نقصان إلى جميع أجزاء السائل وجدران الحاوية.

☞ Hydraulic piston

$$P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

☞ Mechanical advantage

معناه انا هدى قوة صغيرة قد ايه علشان اخد قوة كبير

$$M = \frac{F_2}{F_1} = \frac{A_2}{A_1} > 1$$

خلى بالك لازم تكون المساحه فى القانون المساحة الكبيرة على المساحة الصغيرة ده الشرط علشان اما تيجى تحل

Example

You have a hydraulic piston with a small piston area of $0.01m^2$ and a large piston area of $0.1m^2$. If a force of $50N$ is applied to the small piston, what is the output force on the large piston?

Answer

1. Calculate the pressure on the small piston:

$$P = \frac{F_1}{A_2} = \frac{50N}{0.01m^2} = 5000 \text{ Pa}$$

2. The pressure remains the same on the large piston:

$$P = \frac{F_2}{A_2}$$

$$F_2 = P \times A_2 = 5000\ Pa \times 0.1m^2 = 500\ N$$

Example

Calculating Required Area If you want to lift a weight of 1000 N using a hydraulic piston, and you wish to operate at a pressure of 2000 Pa, what is the required area for the large piston?

Answer

Example

A hydraulic lift has two pistons with areas in the ratio of 1:3. If a force of 200 N is applied to the smaller piston, what is the force exerted by the larger piston?

Answer

$$\frac{A_1}{A_2} = \frac{1}{3}$$

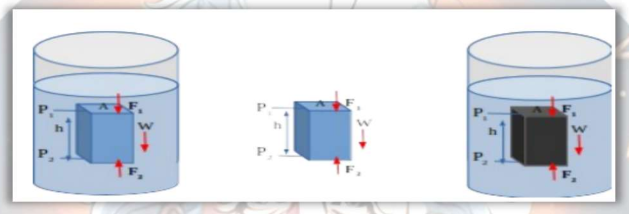
The force exerted by the larger piston (F_2) can be found using:

$$MA = \frac{F_2}{F_1} \Rightarrow F_2 = MA \times F_1 = 3 \times 200 = 600N$$

Archimedes

When a completely or partially immersed object in a fluid, the fluid exerts an upward force on the object equal to the weight of the fluid that is displaced completely or partially by the object.

عندما يكون جسم مغمورًا بالكامل أو جزئيًا في سائل، فإن السائل يمارس قوة دفع لأعلى على الجسم تعادل وزن السائل الذي تم إزاحته.



$$F_B = F_2 - F_1 = mg = \rho_L V g$$

Where:

F_b: **buoyant force** on the solid object and depends on the liquid density and the displaced liquid volume.

القوة الطافية

هي القوة التي تدفع الجسم إلى الأعلى عندما يكون مغمورًا في سائل.

$$F_B = \rho_l gV$$

☞ ***The total force affected the solid object is***

$$F_t = F_B - W = \rho_l gV - \rho_s gV$$

Example

A block of wood with a density of $600\ kg/m^3$ is floating on water (density of water = $1000\ kg/m^3$). If the volume of the block is $0.05\ m^3$,calculate the buoyant force acting on the block.

Answer

$$F_B = \rho_l \,.\, g \,.\, V$$

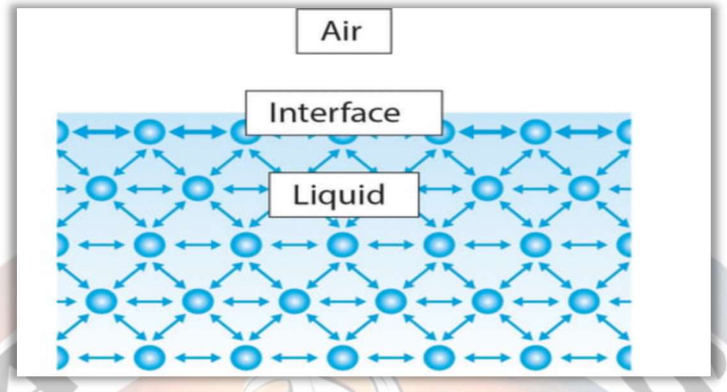
$$F_B = 1000 \,.\, 9.8 \,.\, 0.05 = 400\ N$$

Example

A metal cube with a volume of $0.02\ m^3$ and density $8000\ kg/m^3$ is completely submerged in a tank of oil with a density of $900\ kg/m^3$. Calculate the net force acting on the cube (ignore air buoyancy).

Answer

Surface tension



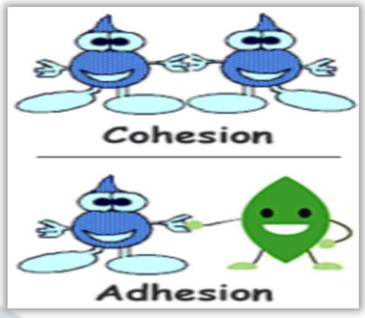
- The surface tension appears as the water molecules attract.
- The surface molecules attract with those on a molecule below the surface but not to the overlying air.
- But for molecule inside the liquid are equally attracted in all directions with their neighbor molecules.

التوتر السطحي

هو خاصية فيزيائية تظهر على سطح السوائل، تجعل السطح يتصرف وكأنه غشاء مرن مشدود. ينتج التوتر السطحي عن قوى التجاذب بين جزيئات السائل، حيث تكون جزيئات السطح معرضة لقوى جذب غير متساوية مقارنة بالجزيئات الموجودة داخل السائل.

تفسير التوتر السطحي:

- **داخل السائل** :كل جزيء يتعرض لقوى تجاذب متساوية من جميع الاتجاهات من الجزيئات المحيطة به.
- **على السطح** :الجزيئات الموجودة على سطح السائل تتعرض لقوى جذب فقط من الجزيئات المجاورة لها داخل السائل، وليست هناك قوى جذب من الأعلى (الهواء مثلاً). هذا يؤدي إلى تكوين طبقة مشدودة على السطح.



☞ **cohesive forces:** are forces appear between molecules of the same substance.

☞ **Adhesive forces:** force appear between molecules of two different adjacent materials

Surface tension

$$\gamma = \frac{F}{d}$$

Where:

d: The length over which the force is applied, often referring to the length of the surface in contact with the liquid.

Units

✶ (N/m) but the CGS unit of dyne per centimeter (dyn/cm)

✶ **In the case of the sliding wire, $d = 2L$**

✶ **In the case of capillary tube, d = $2\pi r$**

In Bubble and Drop

$$p - p_{atm} = \frac{2\gamma}{R_d} \ for\ droplets$$

$$p - p_{atm} = \frac{4\gamma}{R_b} \ for\ bubbles$$

p: is Pressure inside the bubble or drop

R: is Radius of the bubble or drop

- ★ الفقاعة لها سطحين، لذلك فرق الضغط فيها أكبر.
- ★ القطرة لها سطح واحد، لذلك فرق الضغط فيها أقل

The prove

The force on the semi bubble

$$F\gamma = \gamma L = 2\pi R\gamma$$

There are two surfaces inside and outside then

$$F\gamma = 2 \times 2\pi R\gamma = 4\pi R\gamma$$

This force is equal to the forces of the pressure difference between inside and outside the bubble

$$P_{in} - P_{out}$$

$$F_p = (P_{in} - P_{out}) A = (P_{in} - P_{out}) \times \pi R^2$$

therefore:

$$\left(P_{in} - P_{out}\right) \times \pi R^2 = 4\pi R\gamma$$

since $P_{in} = P$ and $P_{out} = P_{atm}$

then

$$P - P_{atm} = 4\gamma / R$$

Example

A capillary tube with a radius of $0.15\ cm$ is dipped vertically into a liquid. If $0.08\ g$ of the liquid is raised inside the capillary, what is the surface tension of the liquid? Assume $g = 9.8\ m/s^2$.

Answer

$$\gamma = \frac{F}{2\pi r} = \frac{w_g}{2\pi r}$$

$$\gamma = \frac{0.08 \times 10^{-3} \times 9.8}{2\pi \times 0.0015} \approx 0.083\ N/m$$

Example

If the bubble has a radius $R_b = 2\ cm$, what is the radius R_d of the drop if the pressure difference between the bubble and the drop is the same?

Answer

1. Using the relationship:

$$R_d = \frac{R_b}{2}$$

$$R_d = \frac{2\ cm}{2} = 1\ cm$$

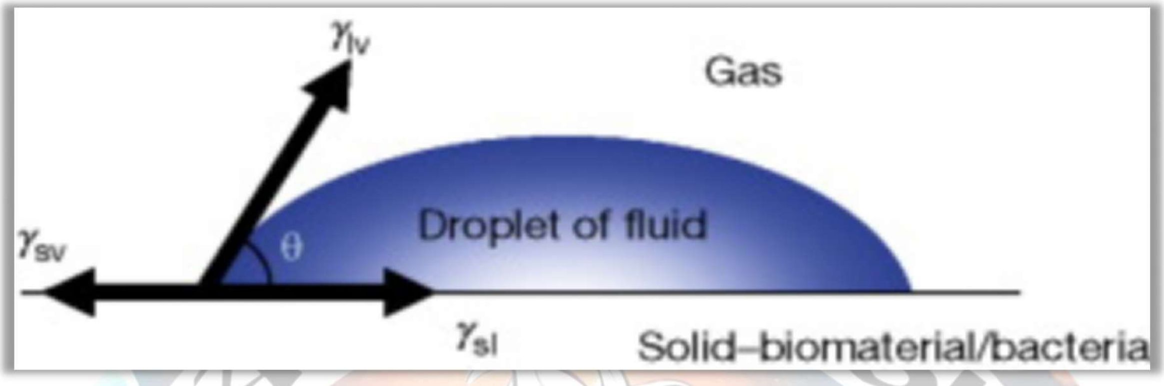
Example

If the bubble has a radius $R_b = 4\ cm$ what is the radius R_d of the drop if the pressure difference between the bubble and the drop is the same?

Answer

☞ *Mercury does not wet glass??*

Contact angle



☞ The contact angle θ , is defined as the angle between the tangent to the liquid and the solid surface at the point of contact

هي الزاوية التي تتكون بين سطح السائل وسطح الجسم الصلب عند نقطة التلامس.

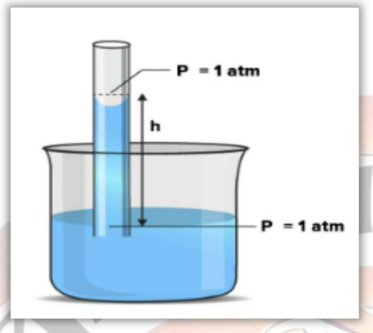
1) Water in glass

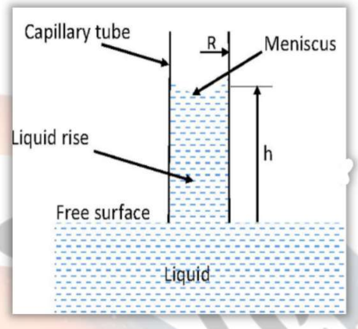
- The **adhesive** forces between water-glass molecules are greater than the **cohesive** force between water – water molecules

2) Mercury in glass

- The **cohesive** forces between mercury – mercury molecules are greater than the **adhesive** forces between mercury – glass

Rise of liquid in a capillary tube





$$\gamma = \frac{rgh\rho}{2\cos\theta}$$

Example

In a capillary tube, if $r = 0.2cm$, $\rho = 0.6\ g/cm^3$, $h = 3cm$, and $\theta = 15°$, calculate the liquid surface tension. Use $g = 9.8\ m/s^2$.

Answer

$$\gamma = \frac{0.002 \times 9.8 \times 600 \times 0.03}{0.9659 \times 2} = \frac{0.35328}{1.9318}$$

"النجاح لا يأتي لمن ينتظر، بل لمن يعمل بجد ويثابر على تحقيق أحلامه."