PHYSICS CLUB

STEM ASYUT

Grade 10

PHYSICS LO.09

. Leader: Marven Waheed

. Co-Leader: Jomana Mohamed

Fluids Dynamics

-**Matter** is normally classified into 3 states: solid, liquid or gas. Often it includes the fourth state: plasma.

So that, the **fluid** is any substance that can flow, including liquid, gases and plasma and it has the ability to take the shape of their container.

When can I say that this substance is fluid?!!!

when it:

1- **non viscous**: means no friction force between adjacent layers and there is no resistance to the particles.

2- **incompressible**: when fluid at rest the ideal fluid is incompressible as it has constant density **and uniform volume**.

3-**its motion is steady**: means that the velocity, density and pressure are constant at any point.

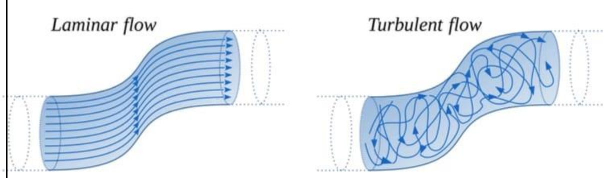
4-**moves without turbulence**: the particles has zero angular motion or rotational motion and no eddy current.

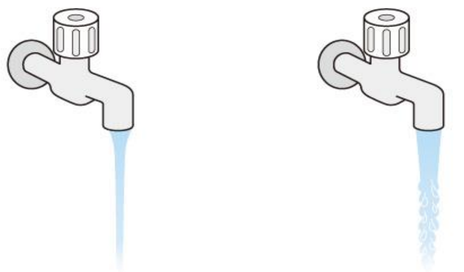
If the substance has these characteristics, it is an ideal fluid.

➢ The fluids dynamics (in motion):

The flow of fluids have two types: 1- Laminar.
2- Turbulent.

-Laminar(streamline): flow is the flow of the particles with fixed velocity at any point and doesn’t change and moves along the same smooth path. In contrast the **turbulent** flow is the irregular flow of the particles when any conditions cause abrupt changes in velocity, in conclusion the flow changes from steady to non-steady.





(a) Laminar flow (b) Turbulent flow

➢ **Reynold's number: -**

-The Reynolds number (Re) is a dimensionless quantity used in fluid mechanics to predict Flow patterns in different fluid flow situations. It helps determine whether a flow will be laminar (smooth and orderly) or turbulent (chaotic and irregular).

Formula:

$$\mathrm{Re}_D = \frac{\rho V D}{\mu} = \frac{VD}{\nu}$$

where:

- ρ = fluid density (kg/m³)
- V = fluid velocity (m/s)
- D = characteristic length (m) (for pipe flow, this is the diameter)
- μ = dynamic viscosity (Pa·s or N·s/m²)
- ν = kinematic viscosity (m²/s) (where $\nu=\mu/\rho$)

Flow Regimes Based on Reynolds Number:

- **Re < 2000 → Laminar flow** (smooth, orderly layers)
- **2000 < Re < 4000 → Transitional flow** (mixture of laminar and turbulent)
- **Re > 4000 → Turbulent flow** (chaotic and irregular)

➢ **Volume Flow Rate (Q): -**

Volume flow rate is the amount of fluid volume passing through a given surface per unit time. It is commonly used in fluid mechanics and engineering applications.

Formula:

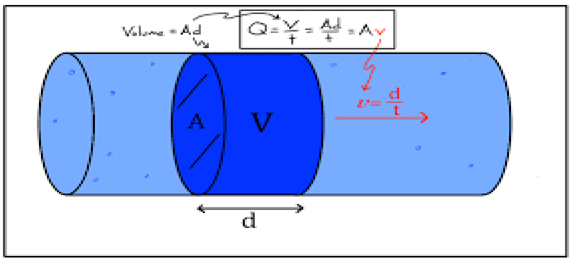
$$Q=VA$$

or

$$Q=\dot{m}\rho$$

where:

- Q = volume flow rate (m³/s)
- V = fluid velocity (m/s)
- A = cross-sectional area of the flow (m²)
- $\dot{m}$ = mass flow rate (kg/s)
- ρ = fluid density (kg/m³)



➢ Mass flow rate: -

The mass flowing in the pipe equals.

$$\dot{m}=\rho VA$$

or

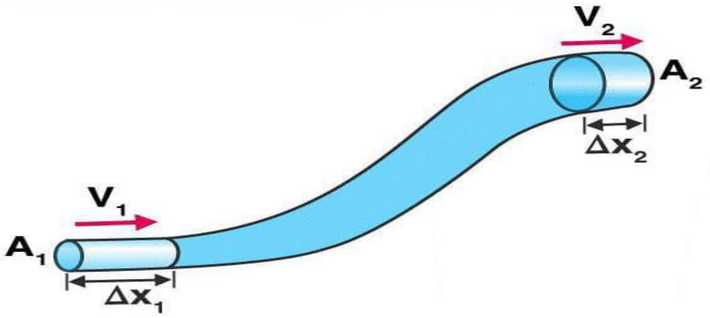
$$\dot{m}=\frac{Q\rho}{v}$$

where:

- $\dot{m}$ = mass flow rate (kg/s)
- ρ = fluid density (kg/m^3)
- V = velocity of the fluid (m/s)
- A = cross-sectional area of the flow (m^2)
- Q = volumetric flow rate (m^3/s)
- v = specific volume (m^3/kg) (inverse of density)

➢ The equation of continuity: -

If the particles of the fluid flow through the opposite pipe (if the pipe is uniform in diameter at both ends but it has a constriction between the ends called a venturi tube). We notice that the fluid entering the bottom end of the pipe moves distance x1 and v1 is the speed of the fluid at that location. If A1 is the cross-sectional area in this region. Then the fluid that moves out of the upper end of the pipe passing by x2 with cross-sectional area A2 and speed v2 .



where

M1=density1 *(A1*x1) = density1*A1*(v *t) and

M2=density2 *(A*x2) =density2*A2*(v*t)

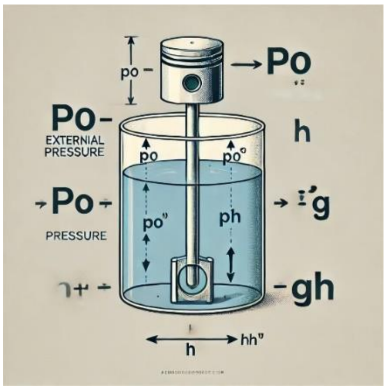
-And according to the law of conservation of mass we know that the entering mass equals the exterior one. So that, M1=M2 and by reducing the equation we get that:

$$A_1v_1 = A_2v_2$$

From this result we see that **the product of cross-sectional area of the pipe and the fluid speed is constant**.

➢ Pascal's principle: -

-When pressure is applied to an incompressible liquid enclosed in a container, it is transmitted to all parts of the liquid as well as the walls of the container imagine a container of liquid with a piston on top



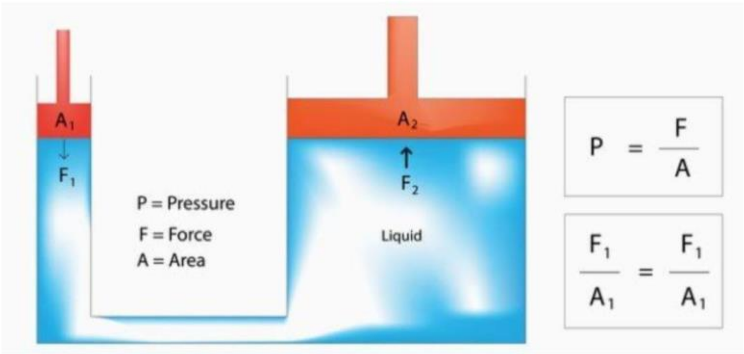
$$\mathbf{p = p_0 + p.g.}$$

➢ Hydraulic press & lift (applications of pascal principle):-

-It is a mechanism that helps lift heavy stuff, when the pressure is equal at the two sides.

-When the smaller press gets a force applied to it, the bigger press will face a higher force in the opposite direction of the smaller force.

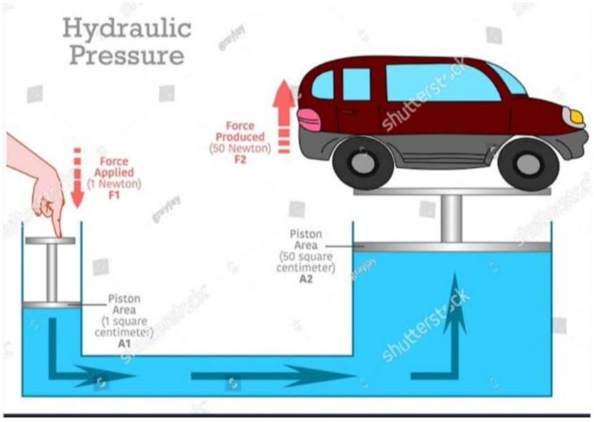
- **If the two pistons are at the same level:**



$$p_1 = p_2$$

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

- **If the level of piston1 is not the same level as piston2:**



$$\frac{F_1}{A_1} = \frac{F_2}{A_2} + pgh$$

➢ Mechanical advantage of hydraulic lift: -

According to the law of conservation of energy:
The work done on the small piston = the work gained from large piston.

$$(\mathbf{Work})_{\mathbf{in}} = (\mathbf{Work})_{\mathbf{out}}$$

$$\mathbf{F.y_2 = f.Y_1}$$

Y_1:is the distance moved by small piston
y_2:is the distance moved by large piston
So, the mechanical advantage:

$$= \frac{F}{f} = \frac{A}{a} = \frac{R^2}{r^2} = \frac{Y_1}{y_2}$$

Pdv=Work

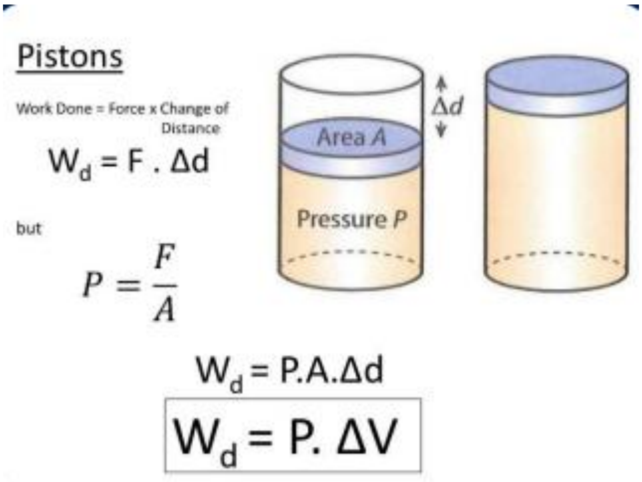
-Work: is the energy required to move something against a force.

W=F.Δx

Δx: displacement

➢ **Pressure as Energy Density:**

-Pressure in a fluid may be considered to be a measure of energy per unit volume or energy density.
For a force exerted on a fluid, this can be seen from the definition of pressure:



$$P = \frac{Force}{Area} = \frac{F}{A} = \frac{F.d}{A.d} = \frac{W}{V} = \frac{Energy}{Volume}$$

As:

$$W = F.\Delta x \ (1)$$
$$V = A.\Delta x$$
$$P = \frac{F}{A}$$
$$\text{So: } \Delta \mathbf{x} = \frac{V}{A}$$

By compensation in (1):

$$\mathbf{F} \times \frac{V}{A} = \mathbf{P\Delta V}$$

So:

$$\mathbf{W=PV}$$

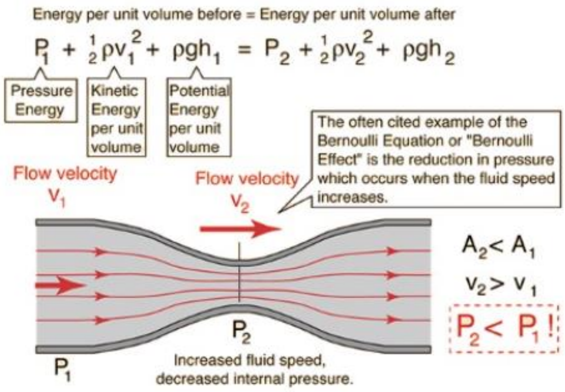
- If the work was dependent on the velocity, it would be kinetic energy.
- If the work was dependent on the hight it would potential energy.

➢ **Fluid Kinetic Energy:-**

-Kinetic energy: is an expression of the fact that a moving object can do work on anything it hits; it quantifies the amount of work the object could do because of its motion.

$$\mathbf{P.E = mgh}$$
$$\mathbf{K.E} = \frac{1}{2}\, mv^2$$

➢ Bernoulli's Equation:-



➢ Derivation of Bernoulli's Equation: -

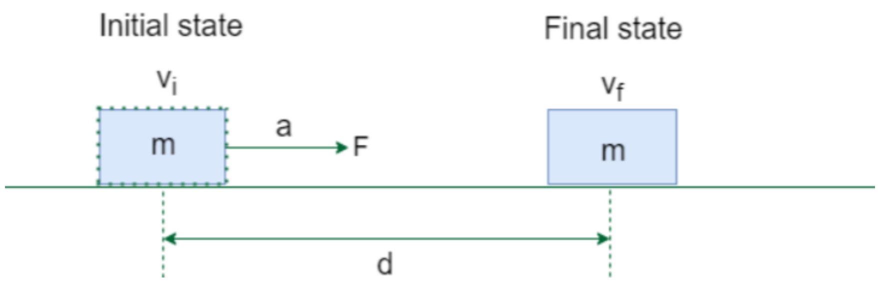
▪ Work-Energy Theorem: -

-Consider a small fluid element of cross-sectional area A and length ds. The forces acting on the element are:

- The pressure force at the inlet: P1AP_1 AP1A
- The pressure force at the outlet: P2AP_2 AP2A

The net work done by pressure forces is:

Work=(P1−P2)Ads



Net work done on a system is equal to the change in its kinetic energy

W=K2−K1

➢ Work-energy principle: -

- **Work Done by Gravity (Wg):**

Wg=−Δm·g·(y2−y1)
Wg = -Δm ·g · (y_2 - y_1)

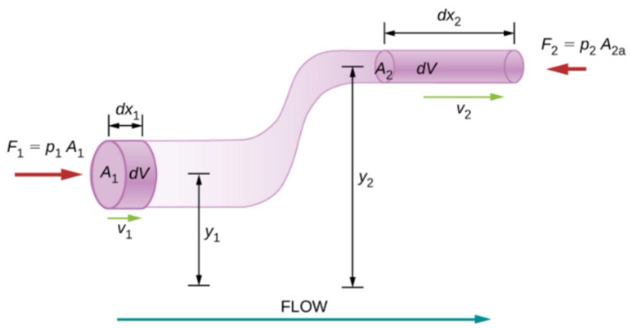
Since mass can be written in terms of density and volume,

Δm=ρΔVΔm

So,

Wg=−ρgΔV(y2−y1)

This work is **negative** because the gravitational force acts **downward**, while the displacement maybe **upward**.



(2) Work Done by Pressure Forces (Wp): -

Work is also done due to **pressure differences** at the inlet and outlet. The work done on the system at the entry is:

$$W_{in} = p_1 \Delta V$$

And the work done **by** the system at the exit is:

$$W_{out} = -p_2 \Delta V$$

The net pressure work is:

$$W_p = -p_2 \Delta V + p_1 \Delta V = (p_1 - p_2) \Delta V$$

• The work–kinetic energy theorem of Eq. 1,2 becomes **The NET WORK** done by gravity and the water
acting on itself.
The **work-energy theorem** states that the total work done on a fluid element is equal to its change in kinetic energy:

$$W = W_g + W_p = \Delta K$$

where:

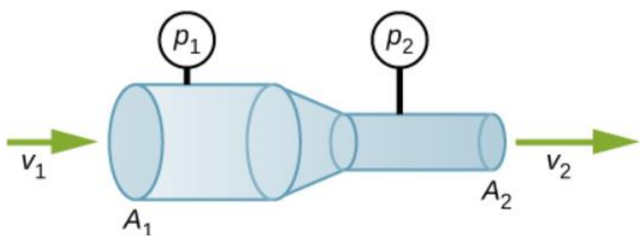
- Wg is the **work done by gravity**,
- Wp is the **work done by pressure forces**.

Special Case: Constant Elevation (y = 0)

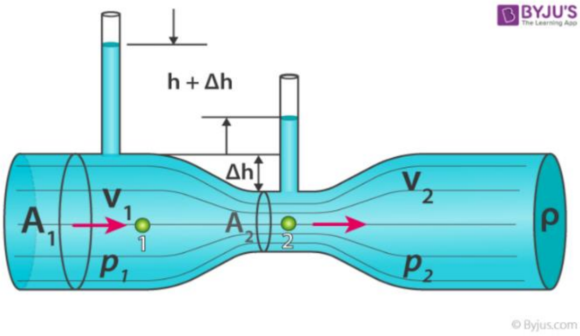
If the fluid **flows at the same height** (y1=y2), the gravitational potential energy term cancels out:

$$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$$

This means that in **horizontal flow**, an increase in velocity (v) leads to a decrease in pressure (p), which is a key concept in **aerodynamics**



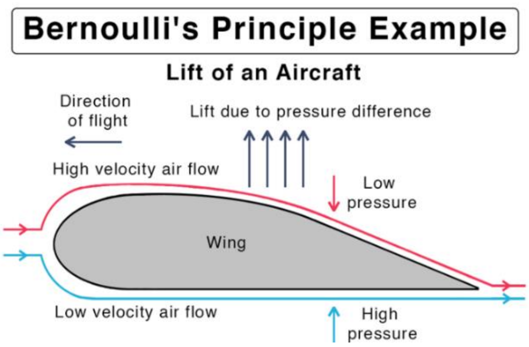
- **<u>Venturi meter</u>:** It is a device that is based on Bernoulli's theorem and is used for measuring the rate of flow of liquid through the pipes. Using Bernoulli's theorem, Venturi meter formula is given as:

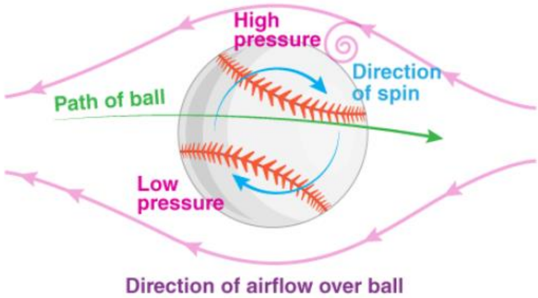


➢ <u>Bernoulli's Principle (Statement): -</u>

-If the speed of a fluid increases, its pressure decreases.

➢ <u>Applications on Bernoulli's equation in daily life:</u>





Laws of lo.09

Reynold's number	$Re_D = \frac{\rho VD}{\mu} = \frac{VD}{\nu}$
Volume Flow Rate	Q=VA Q=m˙ρ
Mass flow rate	**m˙=ρVA m˙=$\frac{Q\rho}{v}$**
Equation of contin	**A1V1=A2V**
Pascal's principle If the two pistons are at the same level	$\frac{F_1}{F_2} = \frac{A_1}{A_2}$
Pascal's principle If the level of piston1 is not the same level as piston2	$\frac{F_1}{A_1} = \frac{F_2}{A_2} + pgh$
Mechanical advantage of hydraulic lift	$= \frac{F}{f} = \frac{A}{a} = \frac{R^2}{r^2} = \frac{Y_1}{y_2}$
Work done by pressure	**W= PΔV**
Potential energy	$\mathbf{P.E = mgh}$
Kinetic energy	**K.E =** $\frac{1}{2} mv^2$
Bernoulli's Equation	$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$
Work Done by Gravity	**Wg=−ρgΔV(y2−y1)**
Work Done by Pressure Forces	**Wp=−p2ΔV+p1ΔV=(p1−p2)ΔV**

Note: This page is to help summarize most of the most important laws as a quick review of this lo.