KINGDOM OF SAUDI ARABIA
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ISLAMIC UNIVERSITY
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قسم الفيزياء

FLUID MECHANICS

[PHY 404]

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Physics Department

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Course Contents

Chapter 1: Fluid Mechanics Basics

Chapter 2: Kinematics ← حالة السكون

Chapter 3: Momentum and energy in inviscid flow

Chapter 4: Potential flow:

Chapter 5: Linear water waves

Text Books:

1. Introduction to Fluid Mechanics. Fox, McDonald & Pritchard, 9th Edition, Wiley.
2. Fluid Mechanics, Fundamental and Applications, 4th ed., Y.A. Cengeland J.M. Cimbala, McGraw Hill, 2017)

Learning Objectives

- Basic introduction to fluid mechanics
- To know a brief history of fluid mechanics and some of the pioneers in various aspects of fluid mechanics
- To refresh some basic knowledge of dimensions and unit conversion
- To learn about some of the properties of fluids most relevant to fluid mechanics

Learning Outcomes

By the end of this unit, Student should be able to:

- Differentiate between a fluid, a liquid and a gas.
- Describe what fluid mechanics is all about.
- Name some of the historical figures that have a huge impact on the development of fluid mechanics over their years as well as their respective contributions.
- Recognize the importance of dimensional homogeneity in engineering calculations.
- Handle unit conversions without error.
- Have a working knowledge of the basic properties of fluids relevant to physics and engineering.

Chapter 1
Fluid Mechanics Basics

1.1 Introduction to Fluids

- Flow
- Pressure
- Properties of fluids
- Viscosity.

1.2 Units and Dimension Used in Fluids

WHAT IS HYDRAULICS

- Greek word **“HUDAR”** , means – **“WATER”**

هويا

- It’s that branch of physical and engineering science deals with water (at ***rest*** or in ***motion***)
- Or its that branch of physical science which is based **on experimental observation** of water flow.

WHAT IS FLUID MECHANICS?

- Mechanics of ***fluids***

سوائل

غاز

- It’s that branch of physical science which deals with the ***behavior*** of fluid under the conditions of rest & motion

سلوك

السكون

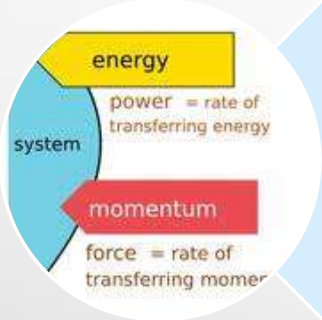
الحركة

Fluid Mechanics

موائع سكونيه

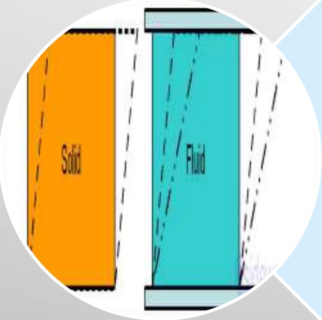
Fluid Mechanics is a study of the behavior of Fluids either at rest *(fluid statics)* or in motion *(fluid dynamics)*.

موائع حركيه



لتحليل

The analysis is → relate *continuity of mass* and *energy* with *force* and *momentum*.



تشوه

Fluid is a substance which deforms continuously under the action of *shearing force*

قوة مماسية اتجاه للامام

$P = \frac{F_{\perp}}{A}$ قوة عامودية

* A → وحدة السطح

$\tau = \frac{F_{\parallel}}{A}$ → قوة مماسية

قوى القص

What Is Fluid Mechanics?

مائع   المائع هو المادة التي تتشوه بشكل مستمر (تدفق) عند تعرضها لقوى القص

تدفق

- **Fluid:** a substance that continually deforms (flows) under applied *shear stress*

shear force بسبب

علم يدرس سلوك الاجسام عند تعرضها لقوة

ميكانيكا

- **Mechanics:** science concerned with behavior of physical bodies when subjected to forces

ميكانيكا الموائع

- **Fluid Mechanics:** the science that deals with the behavior of fluids at rest (*fluid statics*) or fluids in motion (*fluid dynamics*), and their subsequent effects on the surrounding environment

ميكانيكا الموائع: علم يدرس سلوك الموائع السكونية والموائع الحركية وتأثيرها على المحيط

APPLICATION AREAS OF FLUID MECHANICS

Natural flows and weather

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Boats

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Aircraft and spacecraft

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Power plants

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Human body

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Cars

Photo by John M. Cimbala.

Wind turbines

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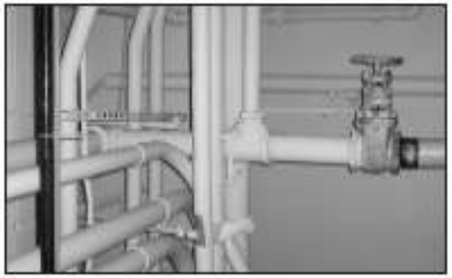


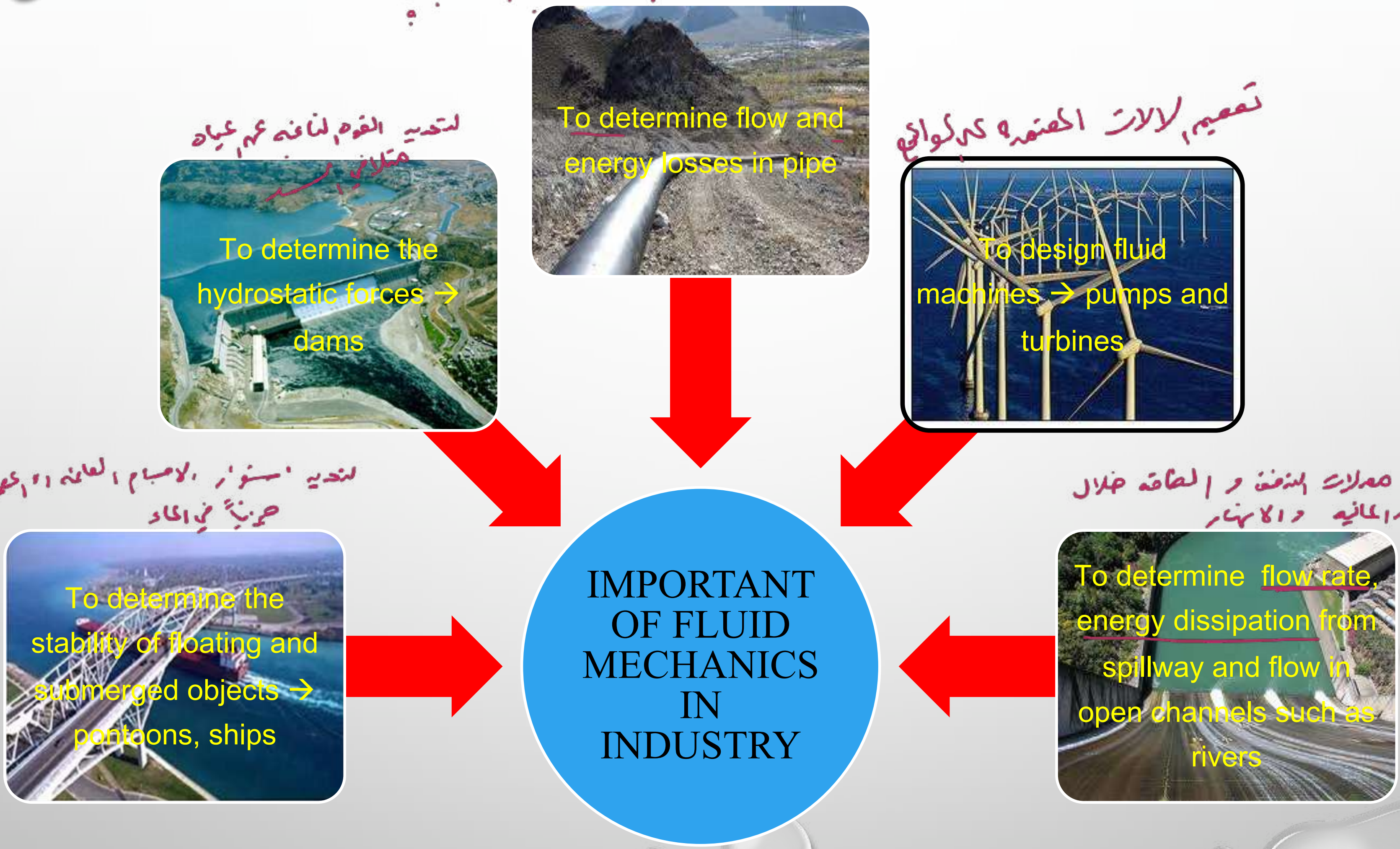
Piping and plumbing systems

Photo by John M. Cimbala.

Industrial applications

Courtesy UMDE Engineering, Contracting, and Trading. Used by permission.

Important of Fluid Mechanics



لتحديد التدفق و الطاقة في الانابيب

To determine flow and energy losses in pipe

لتحديد القوه الناتجه عن مياه متلاطمه

To determine the hydrostatic forces → dams

تصميم الالات المضخه كهروائي

To design fluid machines → pumps and turbines

لتحديد مستوى الاجسام الطافيه او المغموره جزئياً في الماء

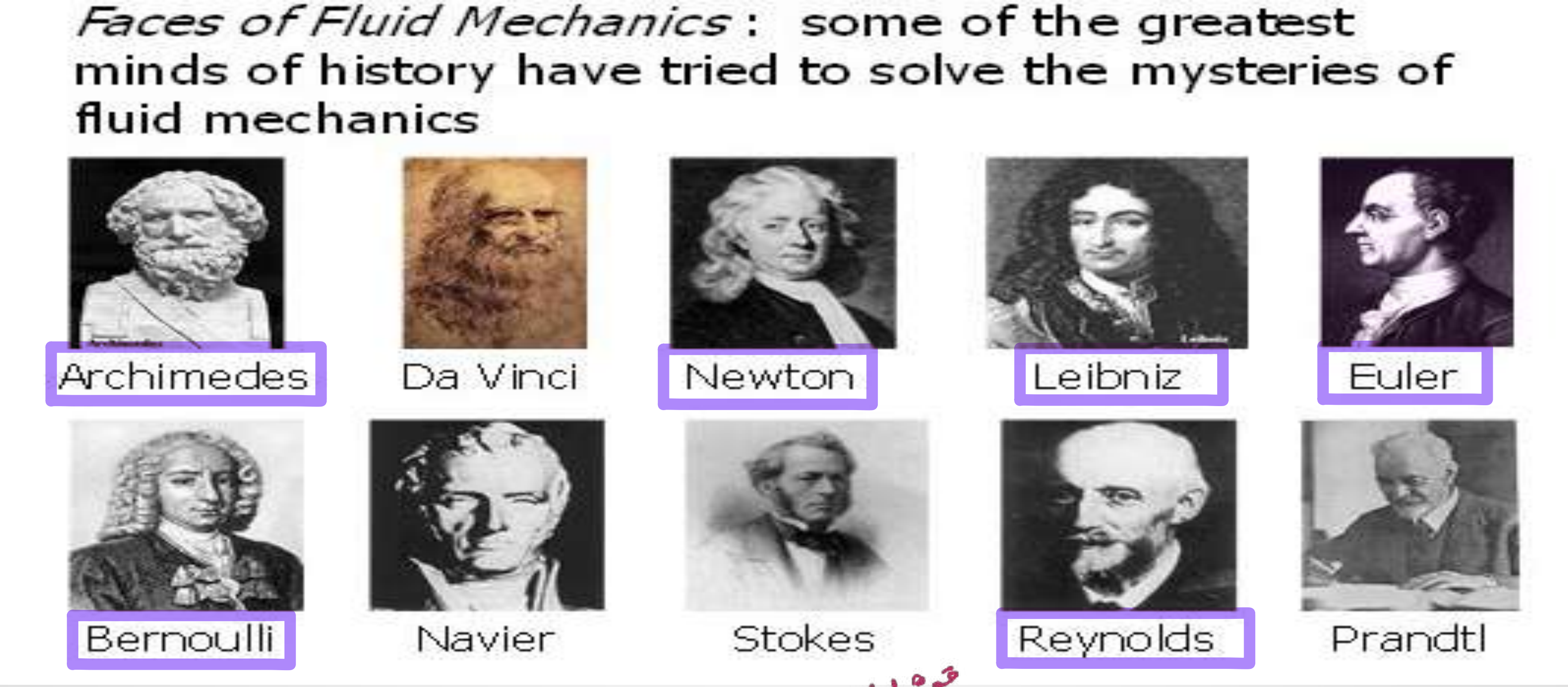
To determine the stability of floating and submerged objects → pontoons, ships

للتعرف معدلات التدفق و الطاقه خلال المنافذ المائيه و الانهار

To determine flow rate, energy dissipation from spillway and flow in open channels such as rivers

IMPORTANT OF FLUID MECHANICS IN INDUSTRY

History

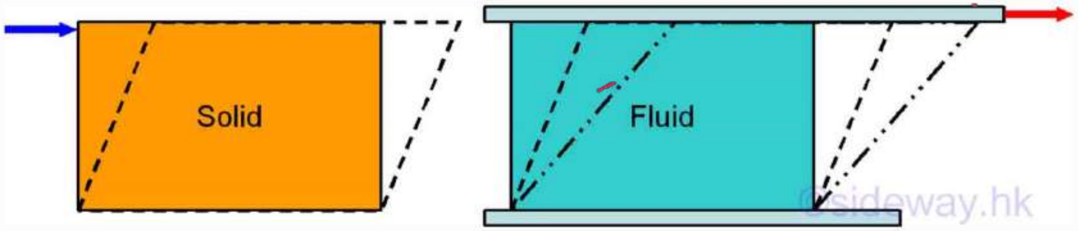


Faces of Fluid Mechanics : some of the greatest minds of history have tried to solve the mysteries of fluid mechanics

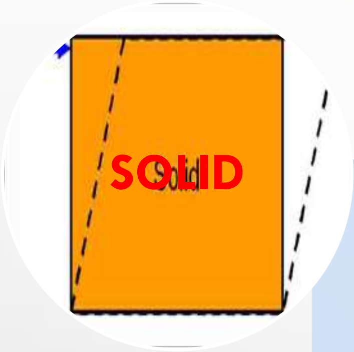
- ARCHIMEDES (285-212 BC) - BUOYANCY قوة الطفو
- BLAISE PASCAL (1623-1662) - HYDROSTATICS القوى السكونيه
- DANIEL BERNOULLI (1700-1782) – ENERGY EQUATION معادله الطاقة
- ANTONIE CHEZY (1718-1798) – VELOCITY IN CHANNEL السرعه في الانابيب
- HENRY DARCY (1803-1858) – GROUNDWATER FLOW تدفق المياه الجوفيه
- JEAN POISEUILLE (1799-1869) – LAMINAR FLOW التدفق المنتظم

اختلاف في ارتباط الجزيئات

Difference Between Solid and Fluid



الغاز و السائل



ITEM 1

صلب

- Have preferred shape

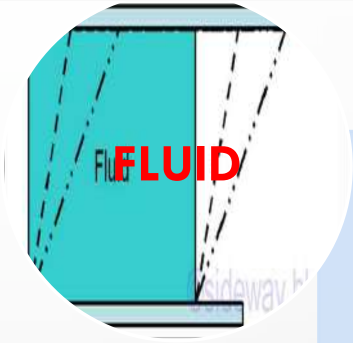
لها شكل محدد

- Hard & not easily deformed

قاسية لا تتشوه بسهولة

- Cannot deformed continuously under shear force

لا تتشوه بشكل مستمر مع قوة القص



ITEM 2

مائع

- Does not have any preferred shape

ليس لها شكل محدد

- Soft & easily deformed

لينه تتشوه بسهولة.

- Deformed continuously under shear force

تتشوه بشكل مستمر تحت قوة القص

Conditions of Fluids

موائع غير قابله للانضغاط
(كثافه ثابته)

- The study of incompressible fluid under static conditions (hydrostatics)

مائيه

موائع قابله للانضغاط

- That dealing with the compressible static gases- aerostatics

هوائيه

STATICS

ستاتيكا
سكونيه

تتعامل مع السرعه والتسارع
وانماط الحركه

- Deals with the – velocities, accelerations and pattern of flow only

وحين التغير

- Force and energy causing velocities and accelerations are not deal under this head.

KINEMATICS

حركيه

يتعامل مع الحركه والتسارع و
القوى والطاقه المسببه
لهما

- Deal with the relationship between velocities and accelerations of fluid with the FORCES @ ENERGY causing them.

العلاقه بين المسببات والنتيجة

DYNAMICS

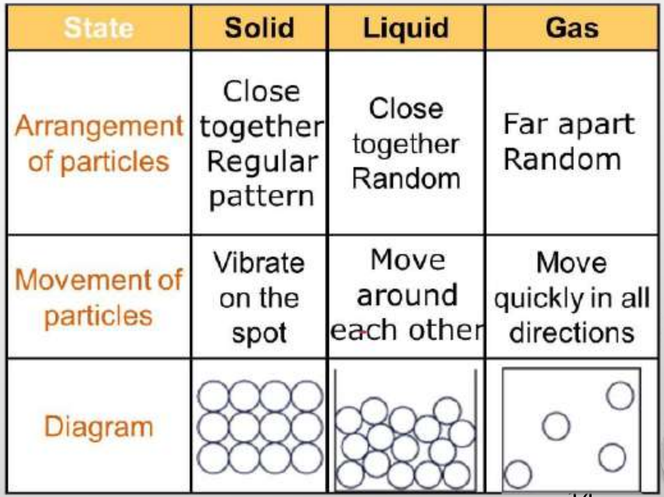
ديناميكا

k → velocity
→ تسارع
→ تشكل، مائع

D → force
energy

QUESTIONS

1. Draw molecule of solid, liquid, gas
2. Discuss in terms of arrangement, particles movement, closeness of particles.
3. Discuss shape, volume



State	Solid	Liquid	Gas
Arrangement of particles	Close together Regular pattern	Close together Random	Far apart Random
Movement of particles	Vibrate on the spot	Move around each other	Move quickly in all directions
Diagram			

State of Matter

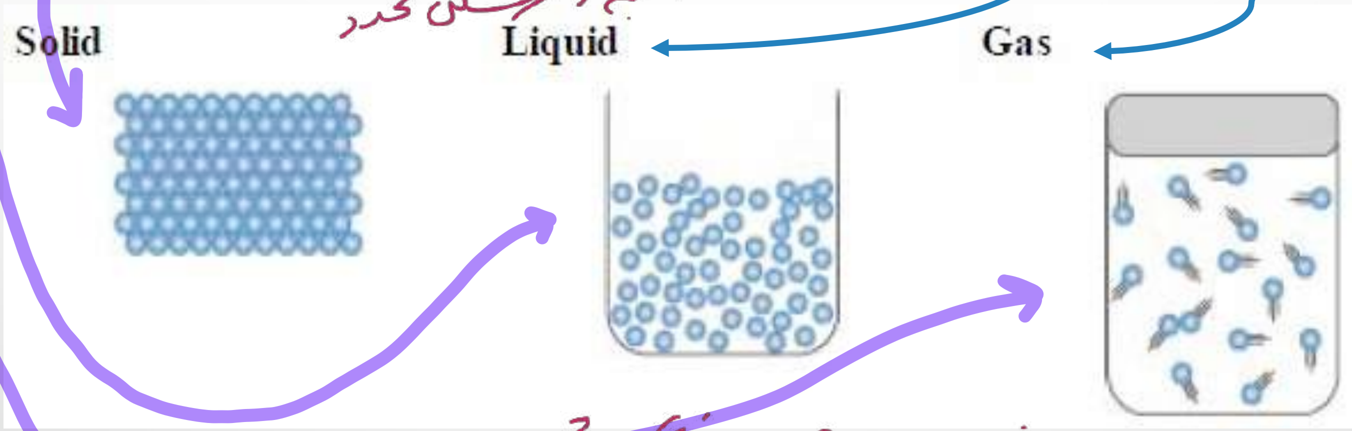
ليس لها حجم و لا شكل محدد

- **Gas:** doesn't have any definite volume or shape

حجم محدد

- **Liquid:** have definite volume at any particular temperature
- **Solid:** have definite volume and shape

حجم و شكل محدد



Fluid

الموائع : المواد القادره على التدفق وليس لها شكل محدد

- Fluid is a substance that is capable of flowing. It has no definite shape of its own. It assumes the shape of its container.

- Both liquids and gases are fluids.

Examples: Water , milk, kerosene, petrol, emulsions etc.

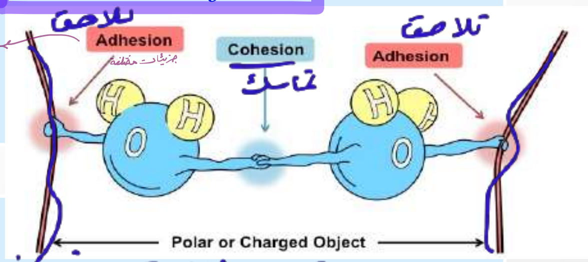
Concept of Fluid

In **Fluid**: الموائع تتحرك بحرية لكن مقيدة بقوة تجاذب بين الجزيئات (تماسك)

-The molecules can move freely but are constrained through *attraction force* called *cohesion*. قوى التماسك (بين الجزيئات المتشابهة) ← تسبب توتر سطحي

-This force is interchangeable from one molecule to another.

وهي قوى متبادلة بين الجزيئات



For **Gases:** القوى في الغازات ضعيفة جداً مما يؤدي الى تشتتها والفرار من الوعاء

- It is very weak which enables the gas to disintegrate and move away from its container.
- A *gas* is a fluid that is easily compressed (ضغط) and expands (انتشار او توسع) to fill its container.
- It fills any vessel in which it is contained. There is thus no free surface.

الغازات تنضغط وتتمدد بسهولة لتملأ الوعاء ، تملأ الوعاء بالكامل دون ترك فراغ

(free surface) غشاء مشدود

For **Liquids:**

- It is stronger which is sufficient enough to hold the molecule together and can with stand high compression, which is suitable for application as hydraulic fluid such as oil.

هناك قوة محصلة من السطح ناتجة من قوى التماسك تكون اتجاهها نحو السائل وتسبب ظهور الغشاء المشدود

- On the surface, the cohesion forms a resultant force directed into the liquid region and the combination of cohesion forces between adjacent (الجزيئات القريبة) molecules from a tensioned membrane known as *free surface*.

في السوائل القوى اكبر مما يسمح لها بالحفاظ على الجزيئات معاً وتقاوم الضغط العالي وهذا يجعلها مناسبة للتطبيقات الهيدروليكية

Important Facts

اجهاد قص يتدفق

- In fact if a shear stress is acting on a fluid it will flow and if a fluid is at rest there is no shear stress acting on it.

مائع يتدفق اجهاد قص

Fluid Flow → Shear stress – Yes ✓

مائع ساكن

Fluid Rest → Shear stress – No ✗

☐ **A fluid** is a substance that flows under the action of shearing forces قوى القص . If a fluid is at rest, we know that the forces on it are in balance.

الفرق بين الصلب والمائع هو قدرتها على مقاومة الاجهادات التي تسبب تغيير بالشكل

- Distinction between a solid and a fluid is made on the basis of the substance's ability to resist an applied shear (or tangential) stress that tends to change its shape.

تغيير تشكل الشكل

المادة، الصلبة تقاوم الاجهادات المسببة للتشوه

- A solid can resist an applied shear stress by deforming,
- a fluid deforms continuously under the influence of shear stress, no matter how small.

الموائع تتشوه بشكل مستمر مع تأثير الاجهادات مهما كانت صغيرة

في المواد الصلبة الاجهاد يتناسب طرديا مع المطاوعة

✓ In solids stress is proportional to *strain*,

في الموائع فان الاجهاد يتناسب طرديا مع معدل المطاوعة

✓ but in fluids stress is proportional to *strain rate*.

- When a constant shear force is applied, a solid eventually stops deforming, at some fixed strain angle, whereas a fluid never stops deforming and approaches a certain rate of strain.

عندما نؤثر باجهاد قص ثابت على مادة صلبة فانها تتوقف عن التشوه عند زاوية معينة لكن الموائع تستمر حتى تصل الى معدل تشوه ثابت

Fluid Deformation between Parallel Plates

Side view

Force F causes the top plate to have velocity U.
What other parameters control how much force is required to get a desired velocity? → حاكه لزوجة السطح

Distance between plates (*b*)

Area of plates (*A*)

Viscosity!

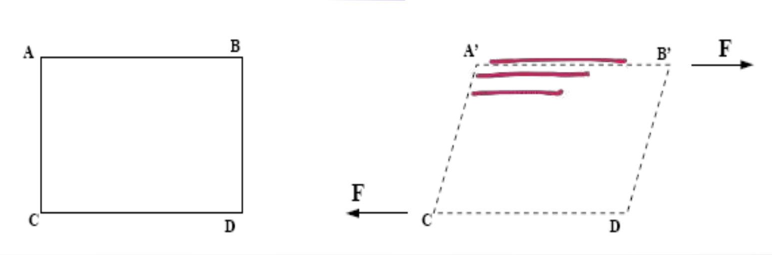
Shear stress in moving fluid

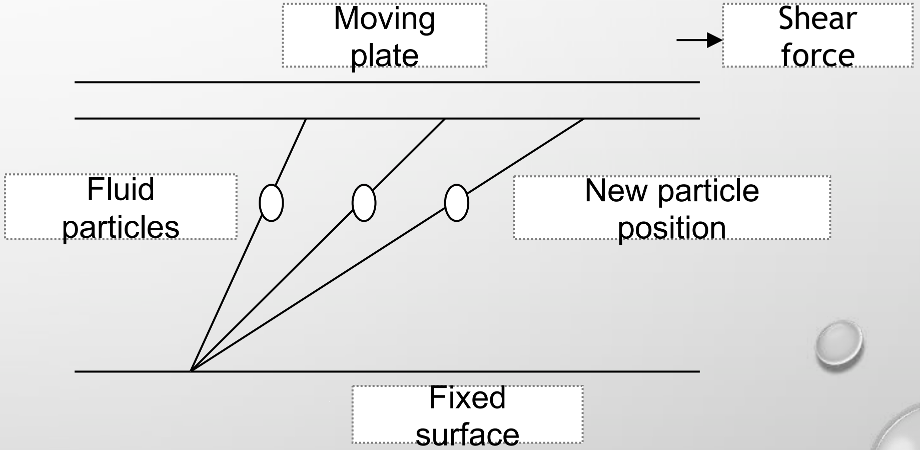
- If fluid is in motion, shear stress are developed if the particles of the fluid move relative to each other. Adjacent particles have different velocities, causing the shape of the fluid to become distorted.

- On the other hand, the velocity of the fluid is the same at every point, no shear stress will be produced, the fluid particles are at rest relative to each other.

- **Forces** acting along edges (faces), such as F, are known as **shearing forces**.

قوى





A fluid is a substance, which deforms continuously, or flows, when subjected to shearing forces

مقارنه

Comparison Between Liquids and Solids

Liquid → قابل للانضغاط مقارنة بـ solid	**solid**
✓ Liquid confirm the shape of container	✓ Do not conform the shape of container
✓ Liquid can flow	✓ Solids cannot flow
✓ Molecules of liquid are distinctly apart	✓ Molecules of solids are close to each other
✓ Liquid have relatively less molecular attraction	✓ Solids have more molecular attraction
✓ Liquid are slightly compressible	✓ Solids are highly incompressible
✓ Liquids cannot sustain shear forces	✓ Solids can sustain shear ← يقاوم ال shear forces

Distinction between solid and fluid?

- ✓ **Solid:** can resist an applied shear by deforming.

  (Stress is proportional to strain)

- ✓ **Fluid:** deforms continuously under applied shear.

  (Stress is proportional to strain rate)

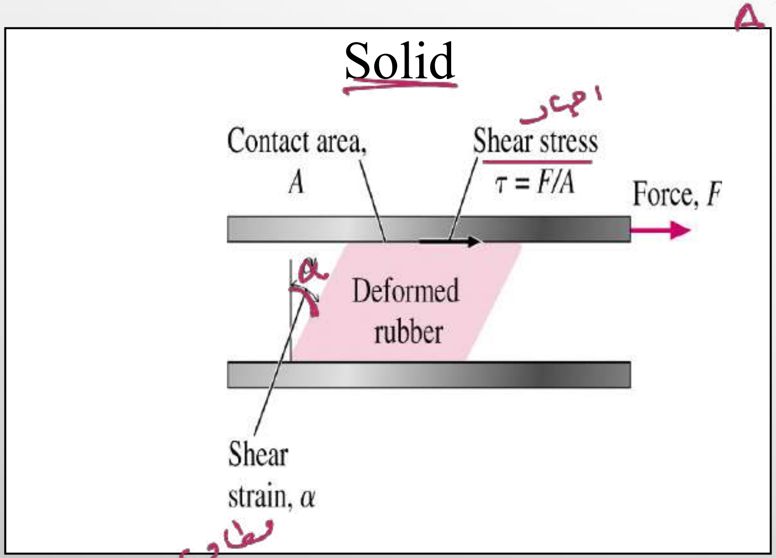
$u = V \frac{y}{h}$

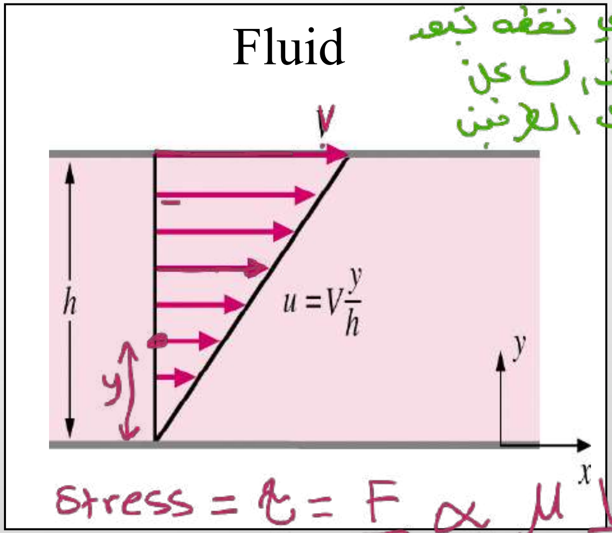
$stres = \frac{F}{A}$

V :- السرعة عند الطرف المتحرك

u :- السرعة عند اي نقطة تبعد
y عن الطرف الساكن

h :- المسافة بين الطرفين





$$\tau = \frac{F}{A} \propto \mu \frac{V}{h}$$

$Stress = \tau = \frac{F}{A} \propto \mu \frac{V}{h}$

$\boxed{\mu: \text{اللزوجة}}$

Units and Dimension Used in Fluid Mechanics

WHAT IS UNITS?

وحده

- Standardized system of measurements used to describe the magnitude of the dimension
- A properties that can be measured

WHAT IS DIMENSION?

الابعاد

- Measurable properties used to describe a body/system
- The standard element, in terms of which these dimensions can be described quantitatively & assigned numerical values.

Various System of Units

The primary quantities which are also referred to as basic dimensions, such as ***L*** for length, ***T*** for time, ***M*** for mass and ***F*** for force.

الابعاد

The various systems of units include :

1. **System International Units (SI)**
2. **English Units (EI)**

Quantity	SI Unit	English Unit
Length (L)	Meter (*m*)	Foot (*ft*)
Mass (m)	Kilogram (*kg*)	Slug (slug) = $lb*sec^2/ft$
Time (T)	Second (*s*)	Second (*sec*)
Temperature (θ)	Celcius (^oC)	Farenheit (^oF)
Force (F)	Newton *(N)* = $kg*m/s^2$	Pound (lb)

$1 m = \frac{1F}{1a}$

Units and Dimension

1 *Newton*: Force required to accelerate 1 *kg* of mass to 1 m/s^2

1 *slug*: is the mass that accelerates at 1 ft/s^2 when acted upon by a force of 1 *lb*

To remember units of a Newton use F = ma (Newton's 2nd Law)

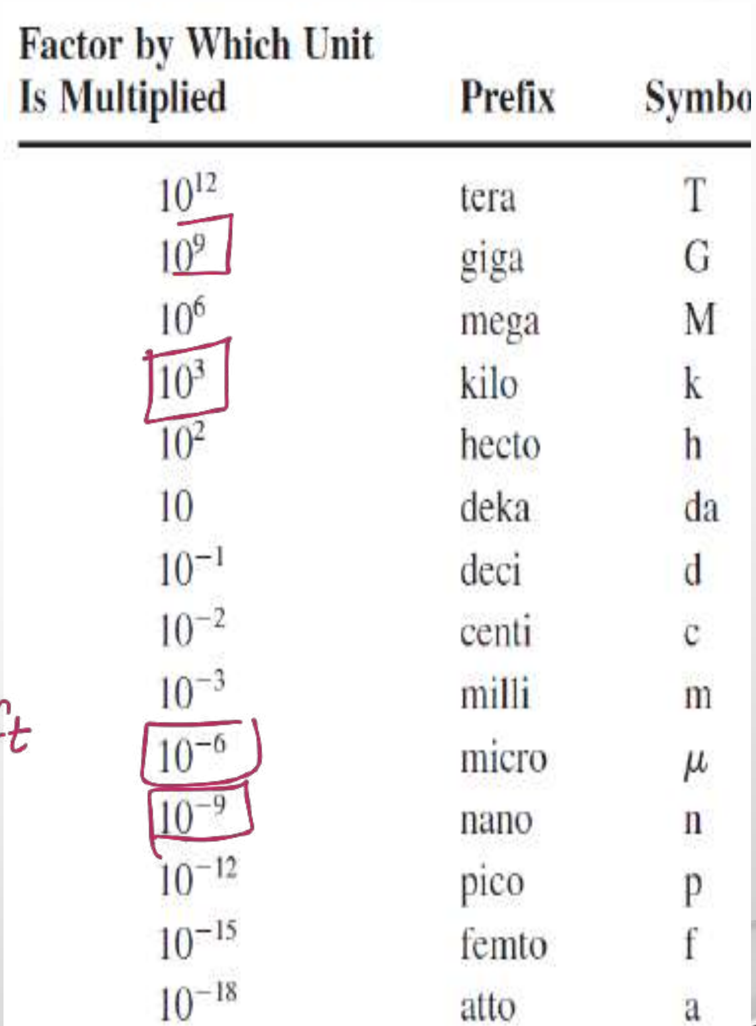
$[F] = [m][a] = kg*m/s^2 = N = kg\,m/s^2$

To remember units of a slug also use F = ma => m = F / a

$m = F/a = lb \cdot sec^2/ft$

$[m] = [F] / [a] = lb / (ft / sec^2) = lb*sec^2 / ft$

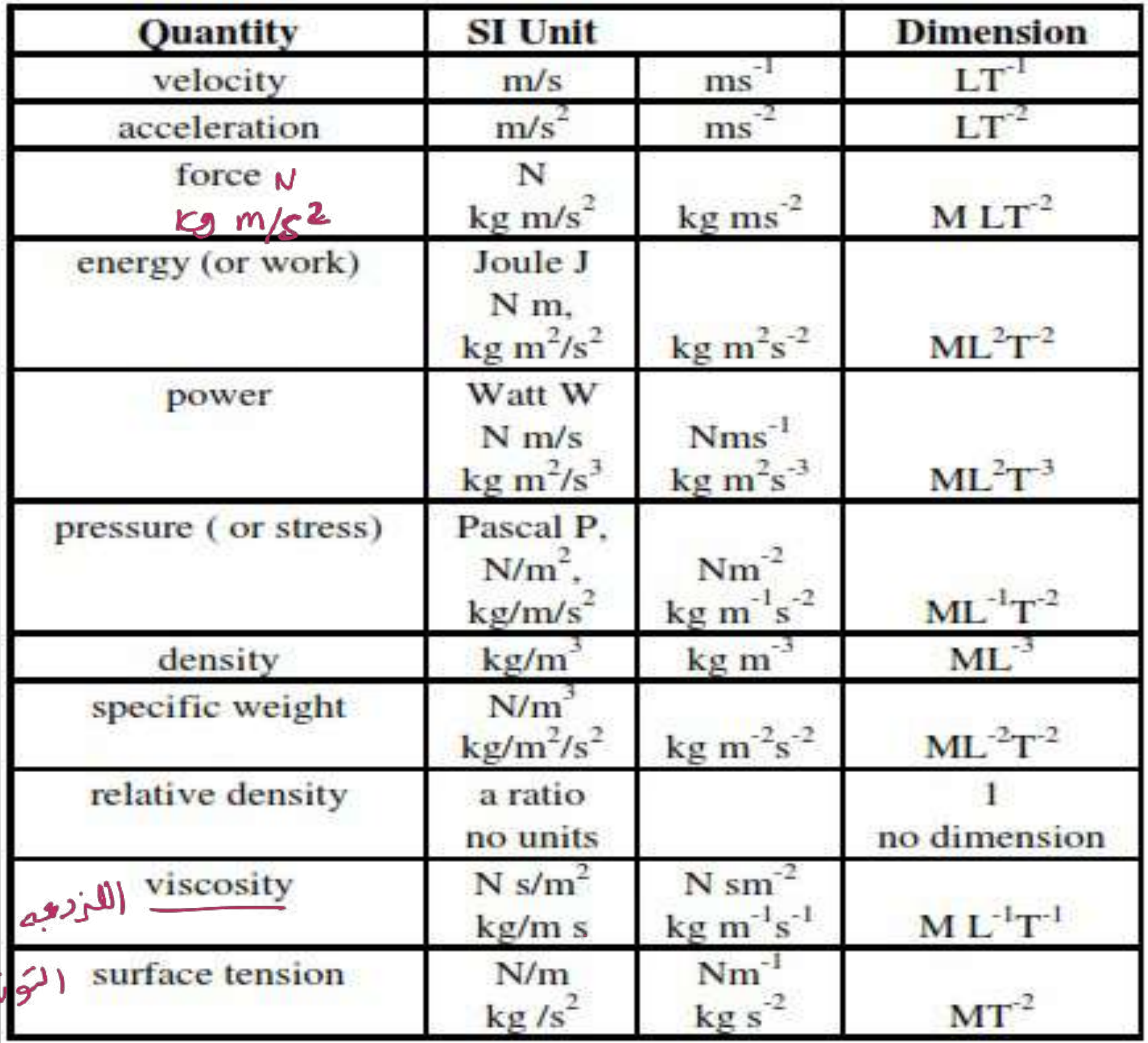
1 *lb*: is the force of gravity acting on (or weight of) a platinum standard whose mass is 0.45359243 *kg*



Factor by Which Unit Is Multiplied	Prefix	Symbo
10^{12}	tera	T
$\boxed{10^{9}}$	giga	G
10^{6}	mega	M
$\boxed{10^{3}}$	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
$\boxed{10^{-6}}$	micro	μ
$\boxed{10^{-9}}$	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Derived Units

mass M
Lengh L
Time T



Quantity	SI Unit		Dimension
velocity	m/s	ms^{-1}	LT^{-1}
acceleration	m/s^2	ms^{-2}	LT^{-2}
force N $kg\ m/s^2$	N $kg\ m/s^2$	$kg\ ms^{-2}$	$M\ LT^{-2}$
energy (or work)	Joule J N m, $kg\ m^2/s^2$	$kg\ m^2s^{-2}$	ML^2T^{-2}
power	Watt W N m/s $kg\ m^2/s^3$	Nms^{-1} $kg\ m^2s^{-3}$	ML^2T^{-3}
pressure (or stress)	Pascal P, N/m^2, $kg/m/s^2$	Nm^{-2} $kg\ m^{-1}s^{-2}$	$ML^{-1}T^{-2}$
density	kg/m^3	$kg\ m^{-3}$	ML^{-3}
specific weight	N/m^3 $kg/m^2/s^2$	$kg\ m^{-2}s^{-2}$	$ML^{-2}T^{-2}$
relative density	a ratio no units		1 no dimension
اللزوجه viscosity	$N\ s/m^2$ $kg/m\ s$	$N\ sm^{-2}$ $kg\ m^{-1}s^{-1}$	$M\ L^{-1}T^{-1}$
التوتر السطحي surface tension	N/m $kg\ /s^2$	Nm^{-1} $kg\ s^{-2}$	MT^{-2}

Physical Properties of Fluids

سوائل

غازات

Fluid properties are intimately related to fluid behavior

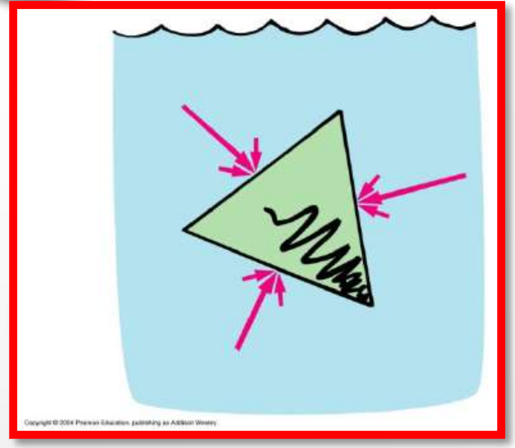
Physical Properties of Fluids

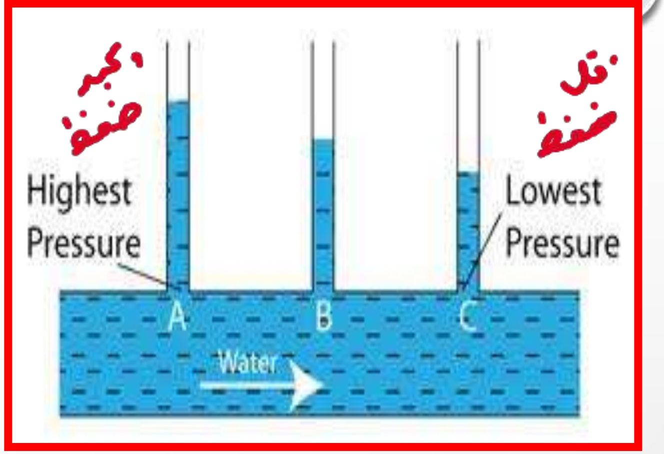
- Density
- Specific Volume
- Specific Weight
- Specific Gravity
- Compressibility
- Surface Tension
- Pressure
- Buoyancy
- Viscosity
- Surface Tension
- Capillarity

Pressure

$P=\frac{5}{1}=5\,N/m^2=5Pa$

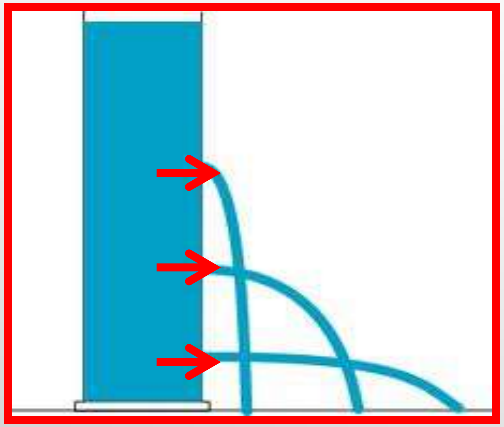
الضغط = القوه / المساحة



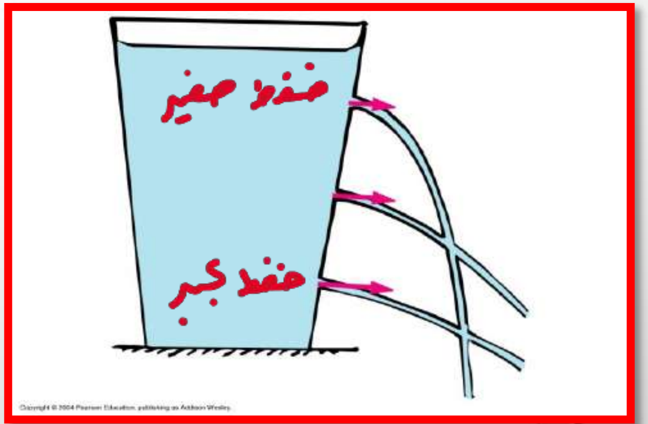


Pressure acts perpendicular to the surface and increases at greater depth.

كلما زاد العمق زاد الضغط



$$pressure=\frac{force}{area}$$



القوه عموديه على المساحة

✓ *Pressure* is the force per unit area, where the force is perpendicular to the area.

- A measure of the amount of force exerted on a surface area

Density

$\rho = \frac{m}{V}$

كثافة اكبر

Regardless of form (solid, liquid, gas) we can define how much mass is squeezed into a particular space

الكثافة:- كمية المادة في وحدة الحجوم = $\frac{m\ \text{كتلة}}{V\ \text{حجم}}$

Density of a material is defined by the amount of matter per unit volume.

Density of material may be referred to in many ways.

Mass Density, $\boxed{\rho}$

$\rightarrow$ kg/m³
$\rightarrow$ g/cm³
1000 ÷

Definition

Density of a fluid, ρ, is defined as the ***mass per unit volume***

- It is denoted by the Greek symbol, ρ.

$$\rho = \frac{m}{V}$$

kgm^{-3} — kg — m^3

$$\rho = \frac{mass}{volume}$$

ρ_{water} = 1000 kgm^{-3}

ρ_{air} =1.23 kgm^{-3}

الغازات بشكل عام قابلة للانضغاط
اذا الكثافة تكون متغيرة

- ➢ If the density is constant (most liquids), the fluid is *incompressible*.

عندما تكون السوائل غير قابلة للانضغاط اذا تكون الكثافة ثابتة

- ➢ If the density varies significantly (e.g. some gas fluids), the fluids is *compressible*.

اذا كانت الكثافة غير ثابتة متغيرة اذا المائع
تكون قابل للانضغاط

(Although gases are easy to compress, the flow may be treated as incompressible if there are no large pressure fluctuations).

تقريبا اذا لم يكن هناك اختلافات كبيرة في الضغط اذا المادة تكون غير قابلة للانضغاط

$\rho = \frac{m}{V}$ $V = \frac{m}{\rho}$ $m = \rho V$

Example:

A tank is filled with oil whose density is $\boldsymbol{\rho} = 850$ kg/m^3. If the volume of the tank is $V = 2$ m^3, determine the amount of mass m in the tank.

$m = \rho V$
$= 850 \times 2 = 1700$ kg

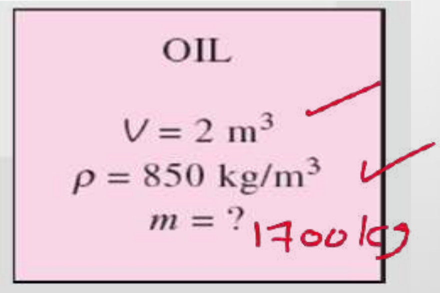
Solution:

Oil is a nearly incompressible substance and thus its density is constant.

$$m = \boldsymbol{\rho} V$$

Thus,

$$m = (850 \text{kg/m}^3)(2\text{m}) = 1700 \text{ kg}$$



SG الكثافة النسبية

Relative Density at Specific Gravity, $\boxed{SG}$

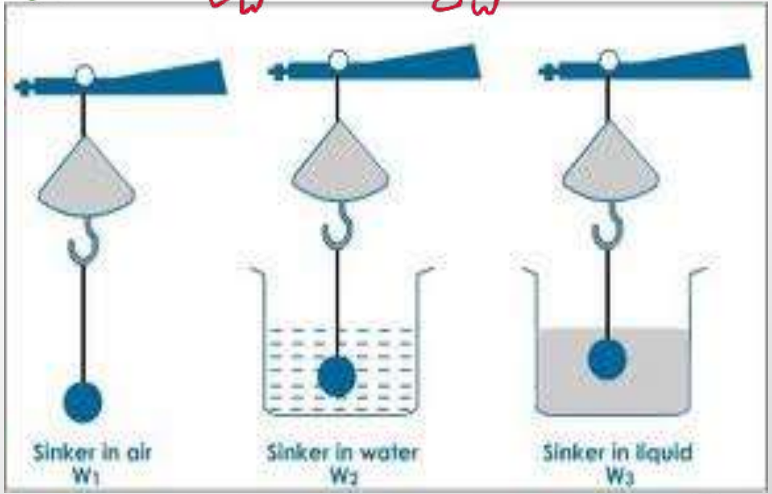
Definition

SG نسبه بين الجذب النوعي لمادة الى الوزن النوعي للماء عند درجه 4C°

❖A ratio of the specific weight of a substance to the specific weight of water at standard temperature (4°C) and atmospheric pressure.

$$SG = \frac{\text{كثافة مادة}}{\text{كثافة الماء}} = \frac{\rho_s}{\rho_w} = \frac{\gamma_s}{\gamma_w}$$

$$SG = \frac{\rho_s}{\rho_{w@4°C}} = \frac{\gamma_s}{\gamma_{w@4°C}}$$



Units: dimensionless

SG ليس لها وحدة

❖Unit is none, since ratio is a pure number. *SG* is a dimensionless quantity

الوزن النوعي γ

Specific Weight, γ

Definition

- ❖Specific weight of a fluid, γ , is defined as the weight of the fluid per unit volume .

وزن الجسم لكل وحدة حجم

- ❖Force exerted by gravity, g, upon unit volume of substance

$$\gamma = \frac{\overset{mg}{W}}{V} = \boxed{\rho g}$$

وزن / حجم

ρ = the density of the material (kgm^{-3})
g = acceleration due to gravity (ms^{-2})

الوزن النوعي = الكثافة x تسارع الجاذبية

Units: N/m^3

$\gamma_{Water} = 9.81 \times 10^3\ N/m^3$

الحجم النوعي :: الحجم لكل وحدة كتلة

$v = \frac{V}{m}$ (معكوس الكثافة)

Specific Volume: Represents the volume per unit mass of fluid.

Specific Volume is the inverse of the mass density. v = V/m or v =1/ρ

$$v = \frac{V}{m} = \frac{1}{\rho}$$

Exercises:

A reservoir of oil has a mass of $\overset{m}{825}$ kg. The reservoir has a volume of $\overset{V}{0.917}$ m^3. Compute the $\underset{\rho}{\text{density}}$, $\underset{\gamma}{\text{specific weight}}$, and $\underset{SG}{\text{specific gravity}}$ of the oil.

$$\rho = \frac{m}{V} = \frac{825}{0.917} = 900\ kg/m^3$$

Solution:

$$\rho_{oil} = \frac{mass}{volume} = \frac{m}{\forall} = \frac{825}{0.917} = 900 kg/m^3$$

$$\gamma = \rho g = 900 \times 9.81$$
$$= 8829\ N/m^3$$

$$\gamma_{oil} = \frac{\text{weight}}{\text{volume}} = \frac{\text{mg}}{\forall} = \rho\text{g} = 900\text{x}9.81 = 8829\text{N}/\text{m}^3$$

$$SG = \frac{900}{1000} = 0.9$$

$$\text{SG}_{\text{oil}} = \frac{\rho_{\text{oil}}}{\rho_{\text{w@4°C}}} = \frac{900}{1000} = 0.9$$

Density, Specific Gravity, and Mass of Air in a room

Example:

نحل السؤال باعتبار ان الهواء غاز مثالي

Determine the density, specific gravity, and mass of the air in a room whose dimensions are 4 m × 5 m × 6 m at 100 kPa and 25 ^{0}C.

$PV = mRT$ $\boxed{P = \rho RT}$

Solution: The density, specific gravity, and mass of the air in a room are to be determined.

Assumptions: At specific conditions, air can be treated as an ideal gas.

Properties: The gas constant of air is R = 0.287 kPa. m^3/ kg. K.

Analysis: The density of the air is determined from the ideal-gas relation:

$$P = \rho RT$$

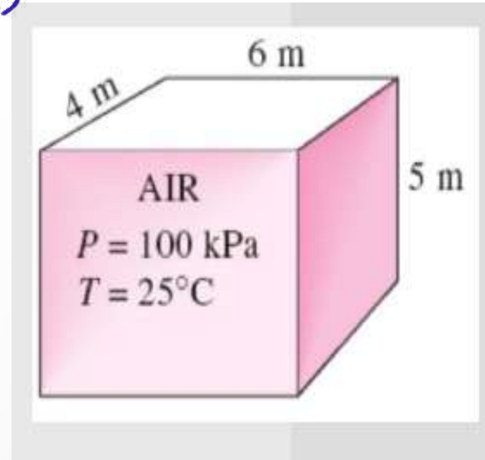
➢ Solution:

$$P=\frac{\rho}{RT}=\frac{100}{0.287\times(25+273.15)}=1.17\ kg/m^3$$

➢ Density of Air in a room

$$\rho=\frac{P}{RT}=\frac{100kPa}{(0.287kPa.m^3/kg.K)(25+273.15)K}$$

$$\rho=1.17kg/m^3$$



- Then the specific gravity of the air:

$$SG=\frac{\rho_{air}}{\rho_{w}}=\frac{1.17}{1000}$$

$$=0.00117$$

$$SG=\frac{\rho_{air}}{\rho_{water}}=\frac{1.17kg/m^3}{1000kg/m^3}=0.00117$$

- Finally, the volume and the mass of the air in the room are:

$$\rho=\frac{m}{V}$$

$$m=\rho\times V$$

Volume: V = (4 m) (5 m)(6 m) = 120 m^3

mass: $m = \rho V = (1.17\ kg/m^3)(120\ m^3) = 140$ kg.

$$=1.17\times4\times5\times6$$

$$=140\ kg$$

Gases: ”Boyle’s Law”

قانونه بويل

- The primary difference between a liquid and a gas is the distance between the molecules.
- In a gas, the molecules are so widely separated, that there is little interaction between the individual molecules.
- IDEAL GAS. الغاز المثالي
- Independent of what the molecules are.

ثبوت

➢ Boyle’s Law

قانونه بويل

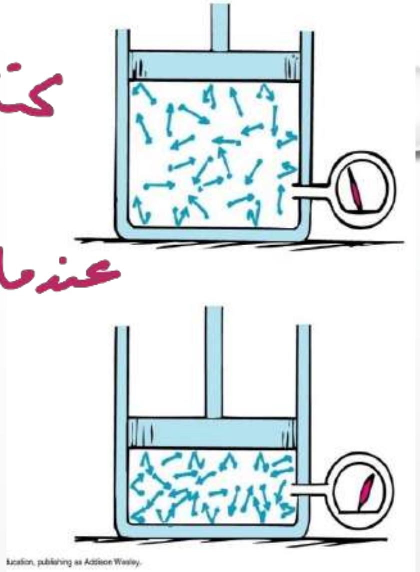
V P T

- Pressure depends on density of the gas.
- Pressure is just the force per unit area exerted by the molecules as they collide with the walls of the container.

عند مضاعفة الكثافة فان التصادمات تتضاعف و ايضا الضغط على جدران الوعاء يتضاعف

- Double the density, double the number of collisions with the wall and this doubles the pressure.

Boyle's Law



Education, publishing as Addison Wesley.

كثافه

كثافه = كتله / حجم

- **Density** is mass divided by volume.

عندما ينقص الحجم للنصف يزداد الكثافه ويزداد الضغط

- Halve the volume and you double the density and thus the pressure.

P V

Boyle's Law: is the Pressure -Volume Relationship

حراره معينة

- At a given temperature for a given quantity of gas, the product of the pressure and the volume is a constant.

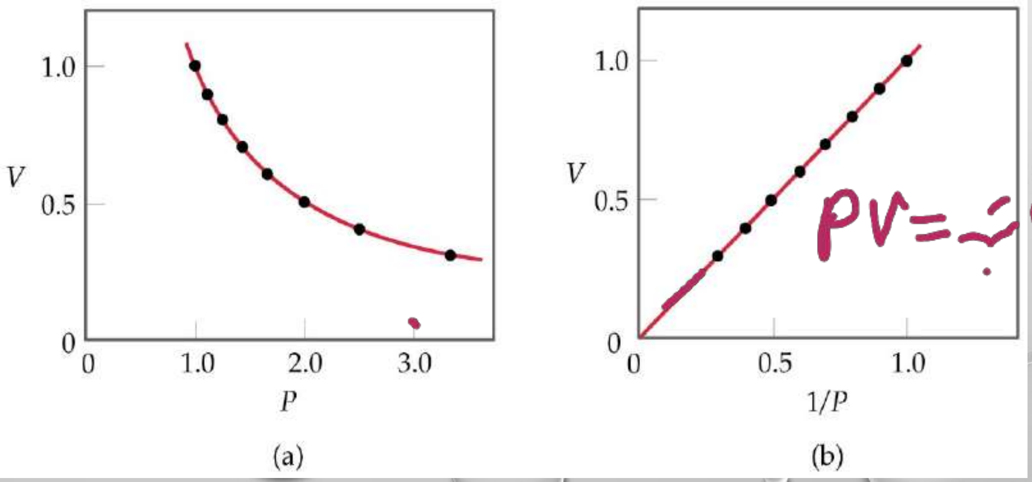
PV = ثابت

التناسب عكسي بين P و V

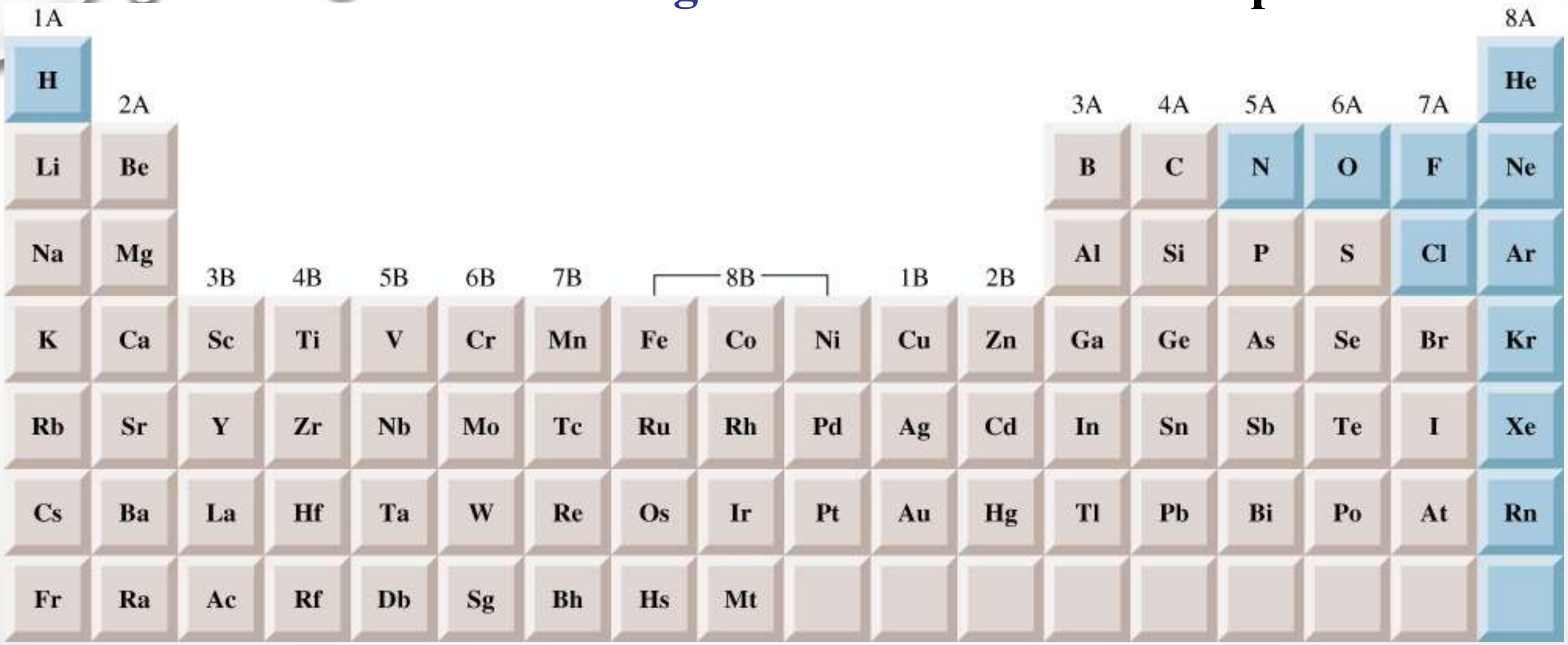
$$P \alpha 1/V$$

$$P x. V = constant$$

$$\boxed{P_1 \cdot V_1 = P_2 \cdot V_2}$$



Elements that exist as gases at 25^0C and 1 atmosphere



1A	2A	3B	4B	5B	6B	7B	8B			1B	2B	3A	4A	5A	6A	7A	8A
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt									

Example

A sample of gas contained in a flask with a volume of $\overset{V_1}{\underline{1.53}}$ L and kept at a pressure of $\overset{P_1}{\underline{5.6\times10^3\ \text{Pa}}}$. If the pressure is changed to $\overset{P_2}{\underline{1.5\times10^4}}$ Pa at $\underline{\text{constant temperature}}$, what

V_2 will be the new volume?

$$V_2 = \frac{P_1V_1}{P_2} = \frac{5.6\times10^3 \times 1.53}{1.5\times10^4} = 0.57\ L$$

Example:

$V_1 = 946$ $V_2 = 154$

$P_1 = 720$ $P_2 =$

V_1 P_1 V_2

A sample of chlorine gas occupies a volume of 946 mL at a pressure of 726 mmHg. What is the pressure of the gas (in mmHg) if the volume is reduced at constant temperature to 154 mL?

$$P_2 = \frac{V_1 P_1}{V_2}$$

$$P_1 \text{ x } V_1 = P_2 \text{ x } V_2$$

$$= \frac{946 \text{x } 726}{154}$$

$P_1 = 726$ mmHg $P_2 = ?$

$V_1 = 946$ mL $V_2 = 154$ mL $= 4460$

$$P_2 = \frac{P_1 \text{ x } V_1}{V_2} = \frac{726 \text{ mmHg x } 946 \text{ m}\cancel{\text{L}}}{154 \text{ m}\cancel{\text{L}}} = 4460 \text{ mmHg}$$

قانون الغاز المثالي

Ideal Gas Law

ضغط
حجم
درجة حرارة
كمية مادة

- Gases are highly compressible in comparison to liquids, with changes in gas density directly related to changes in pressure and temperature through the equation:

ضغط ← $$\boxed{P = \rho RT}$$ → كثافة → درجة الحرارة (K) → ثابت الغاز

Where, P is the absolute pressure, ρ is the gas density, R is the gas constant, T is the **absolute temperature**.

- SI unit of the temperature is the Kelvin scale.

$$T(K) = T(^0C) + 273$$

$$P = \rho RT$$

$$P = \frac{nM}{V} RT$$

$$PV = nRT$$

- **General gas Law:**

$\boxed{PV= n\ RT}$, n = m/MM , (MM: molecular mass)

$\to$ Pa $\Rightarrow$ R = 8.314
$\to$ atm $\Rightarrow$ R = 0.0821

Many gases can be treated as ideal gases :

•Air – nitrogen, oxygen, hydrogen, helium, argon, neon, krypton and carbon dioxide.

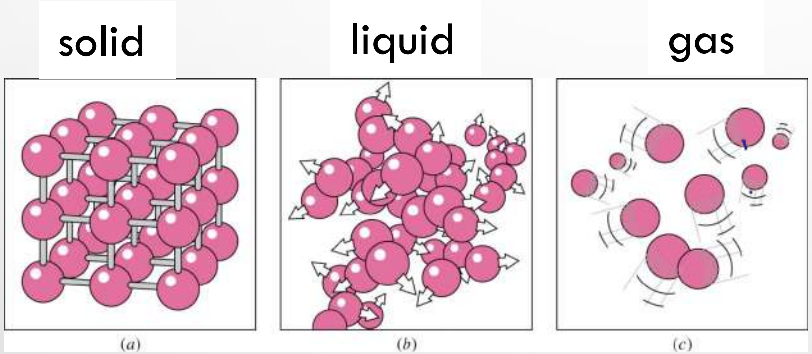
Pressure

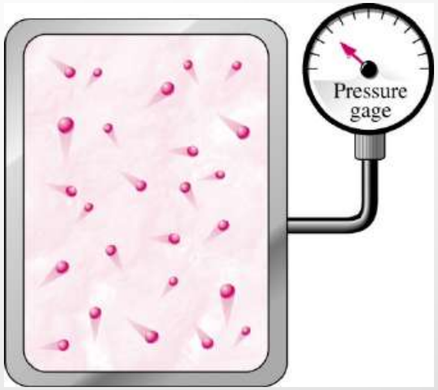
On a microscopic scale, pressure is determined by the interaction of individual gas molecules

الضغط :- التجاذب بين الجزيئات

- Intermolecular bonds are strongest in solids and weakest in gases.

Where molecules in solids are closely packed together, whereas in gases they are separated by relatively large distances





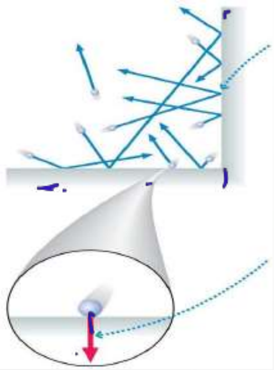
The arrangement of atoms in different phases:

a) Molecules are at relatively fixes positions in a solid

b) Groups of molecules move about each other in the liquid phase

c) Individual molecules move about at random in the gas phase.

Pressure is due to the net force of the molecules in a fluid colliding with the walls. الضغط القوه المحصله الناتجه م تصادم الجزيئات بالجدار



- ✓ A very large number of collisions happen each second.
- ✓ Each collision exerts a tiny net force on the wall.
- A fluid in a container presses with an outward force against the walls of that container.

Pressure is defined as the ratio of the force to the area, where the force is perpendicular to the area.

الضغط = القوه / المساحه = $\frac{F}{A}$

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

N

m²

Nm⁻² (Pa)

The SI units of pressure are N/m², also defined as the pascal, where 1 pascal = 1 Pa = 1 N/m².
Other units:

1 atm= 1.01×10⁵ Pa 1.0125×10^5
1 mmHg = 133 Pa
1 kPa = 10³ Pa
1 psi = 6890 Pa

$\frac{N}{m^2} = Pa$

- ➢ This is the ***Absolute pressure***, the pressure compared to **a vacuum.**

الضغط المطلق

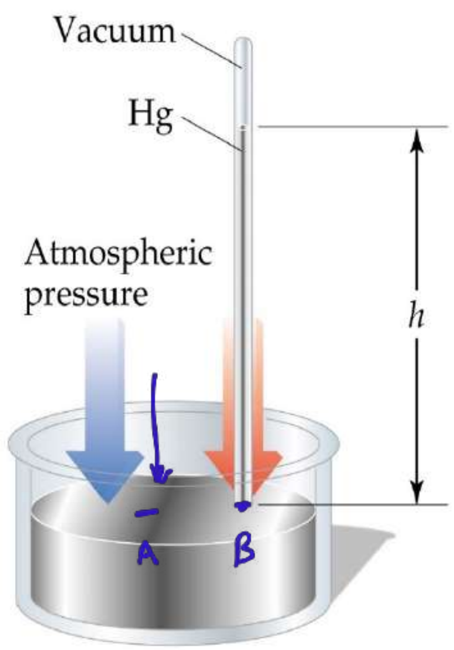
الضغط المطلق :- الضغط نسبه الى الفراغ

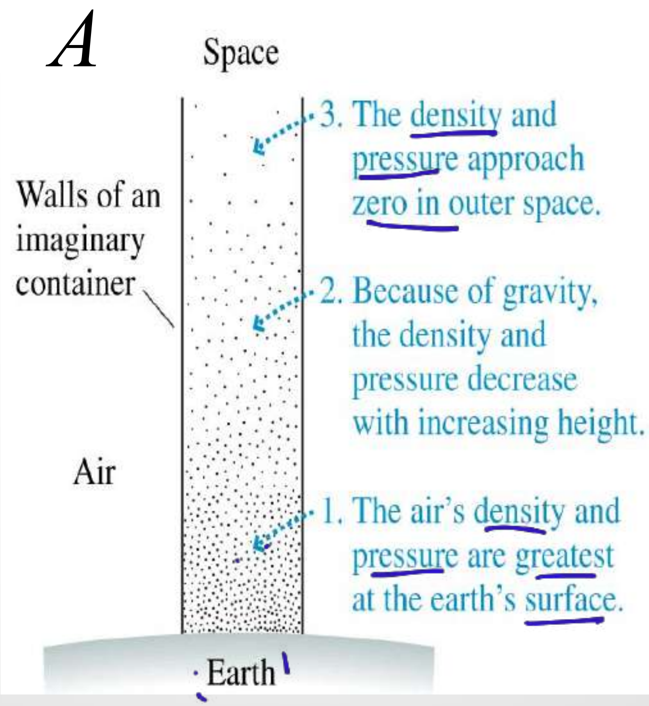
Atmosphere Pressure

عند الارتفاع للاعلى تقل الضغط و الكثافة

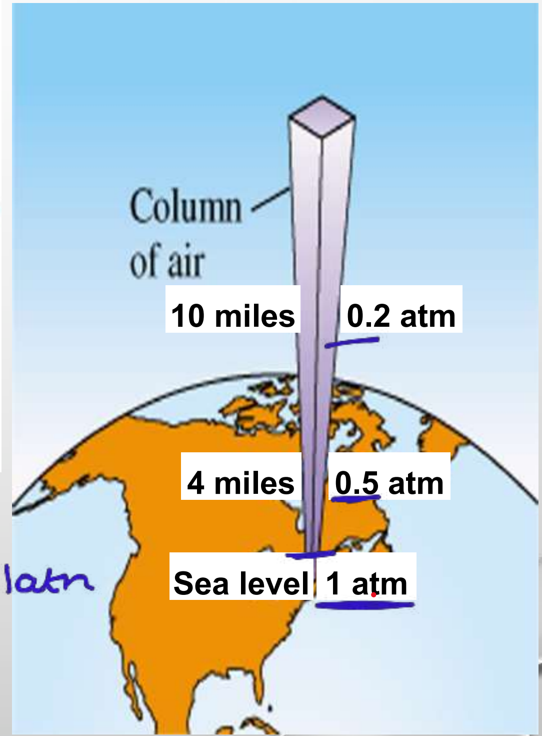
The pressure and density decrease with increasing height in the atmosphere

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





The global average sea-level pressure is 1 atm



Par

- Standard atmospheric pressure = 760 mm of Hg = 1atm

- 1 atm = 760 mmHg = 760 torr = 101.325 kPa.

6

1.01×10^5

قيمة الضغط الجوي عند سطح البحر

الضغط المعياري

Gauges Pressure

Pressure gauges: such as tire gauges and blood pressure monitors, measure not the actual or absolute pressure p but what is called **gauge pressure** p_g.

ضغط قياسي يقيس الضغط
مثل ضغط الاطار، أو ضغط
الدم وليس الضغط الكلي

where 1 atm = 1.01×10^5 Pa.

- i.e "120 over 80" means the maximum gauge pressure in your arteries is 120 mmHg or 1.6×10^4 Pa.

120 mmHg
$120 \times 1.01 \times 10^5 = 1.6 \times 10^4$

$P = 1.6 \times 10^4 + 1.01 \times 10^5$

- The actual, or "absolute" pressure in your arteries has a maximum of

$$p = p_g + 1\text{atm}$$

$$= 1.6 \times 10^4 + 1.01 \times 10^5 \text{ Pa} = 1.17 \times 10^5 \text{ Pa}$$

$P = P_g + P_{atm}$

الضغط = الضغط المعياري + الضغط الجوي
مطلق

الضغط المطلق

Absolute Pressure

الضغط الكلي (مطلق) = الضغط العياري + الضغط الجوي

Pressure measured above a perfect vacuum (zero) is known as absolute pressure

$P = P_g + P_{atm}$

Absolute pressure is P_g

$$p_{absolute} = \rho g h + p_{atmospheric}$$

ضغط داخل غاز سائل ساكن

Absolute pressure = Gauge pressure + Atmospheric

ضغط عياري

جوي

الضغط يتناسب مع العمق

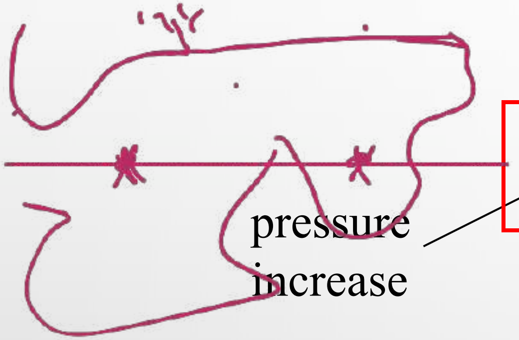
Variation of Pressure with depth

الضغط في الموائع يؤثر بشكل متساوي في جميع الاتجاهات

Pressure in a fluid acts equally in all directions

يزداد الضغط خطياً مع العمق

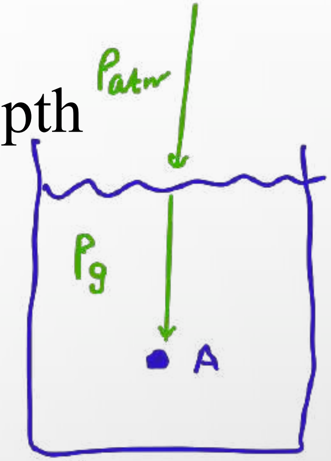
Pressure in a static liquid increases linearly with depth



$$\boxed{\Delta p = \rho g \, \Delta h}$$

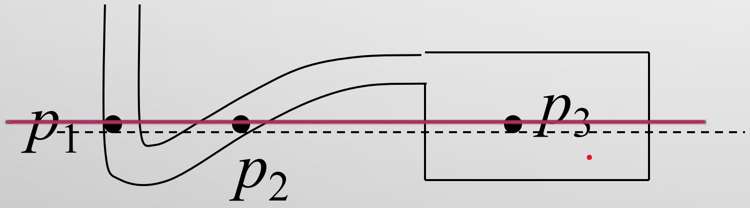
pressure increase

increase in depth (m)



$P_g = \rho g h$

The pressure at a given depth in a continuous, static body of liquid is constant.



$p_1 = p_2 = p_3$

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

الضغط عند نفس العمق متساوي

Example: (a) What are the absolute pressure and (b) the total force on the bottom of a swimming pool 22.0 m by 8.5 m whose uniform depth is 2.0 m? (c) What will be the pressure against the *side* of the pool near the bottom?

The absolute pressure is given by $P=P_0+\rho gh$, and the total force is the absolute pressure times the area of the bottom of the pool.

$P = P_g + P_{atm} = \rho gh + 1.01\times10^5$

(a) $$P = P_0 + \rho gh = 1.013\times10^5\ \mathrm{N/m^2} + \left(1.00\times10^3\ \mathrm{kg/m^3}\right)\left(9.80\ \mathrm{m/s^2}\right)\left(2.0\ \mathrm{m}\right)$$

$$= \boxed{1.21\times10^5\ \mathrm{N/m^2}}$$

a) $P = 1000 \times 9.8 \times 2 + 1.013\times10^5 = 1.21 \times 10^5$ pa N/m^2

(b) $$F = PA = \left(1.21\times10^5\ \mathrm{N/m^2}\right)\left(22.0\ \mathrm{m}\right)\left(8.5\ \mathrm{m}\right) = \boxed{2.3\times10^7\ \mathrm{N}}$$

b) $F = PA = 1.21 \times 10^5 \times 8.5\times22 = 2.3\times10^7$ N

(c) The pressure against the side of the pool, near the bottom, will be the same as the pressure at the bottom,

1.21×10^5 p

$$P = \boxed{1.21\times10^5\ \mathrm{N/m^2}}$$