Fluids at rest

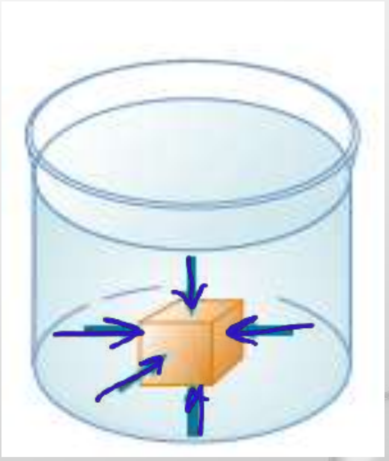
- If a fluid is **at rest** there are **No** shearing forces acting on it, and any force must be acting perpendicular to the fluid.

القوى في حالة السكون تكون قوى عمودية وليس قصية

- **Stress on an object submerged in a static fluid**

القوى دائما عمودية على السطح وعلى الجدران

- The force exerted by a static fluid on an object is always **perpendicular** to the *surfaces* of the object.
- The force exerted by the fluid on the walls of the container is **perpendicular** to the *walls* at all points.



$P = \frac{F}{A} \Rightarrow$ الاجهاد العمودي

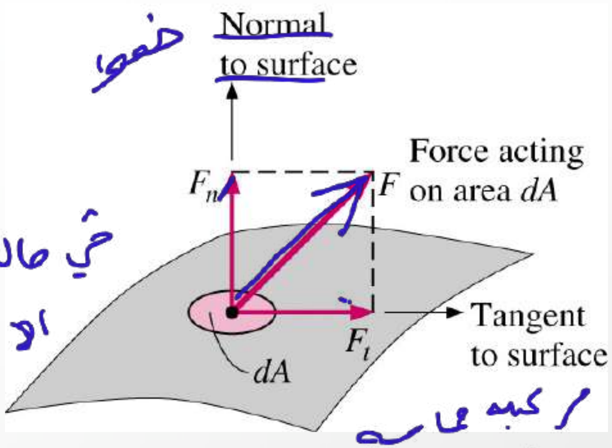
Fluid Stress

الاجهاد = الضغط

- Stress is defined as the force per unit area.
- Normal component: normal stress $\tau = \frac{F}{A}$
- In a fluid at rest, the **normal stress** is called **pressure**

في حالة الموائع الساكنة تكون الاجهاد العمودي يسمى ضغط

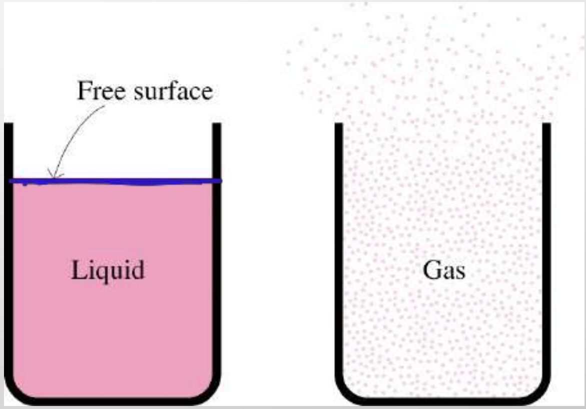
- Tangential component: **shear stress**



عمودي

المركبة المماسية اختيه

- **A liquid** takes the shape of the container it is in and **forms a free surface** in the presence of gravity
- **A gas** expands until it encounters the walls of the container and fills the entire available space. Gases cannot form a free surface
- Gas and vapor are often used as synonymous words



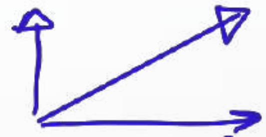
Shear stress and pressure

Consider a force, $\vec{F}$, acting on a 2D region of area A sitting on x-y plane

$$\vec{F} = F_x\,(\pm\hat{i}) + F_y\,(\pm\hat{j}) + F_z(\pm\,\hat{k})$$

قوة عمودية

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



قوة افقية

$\tau = \frac{F_x}{A}$

For simplicity, let $F_y = 0$

$$\tau = \frac{F_x}{A} \quad (shear\ stress) \qquad\qquad p = \frac{F_z}{A} \; (normal\ stress\ (pressure))$$

- **Shear stress and pressure at a point**

نقطة

$$\tau = \left(\frac{F_x}{A}\right)_{\lim A\to 0} \qquad\qquad p = \left(\frac{F_z}{A}\right)_{\lim A\to 0}$$

- **Units of stress (shear stress and pressure)**

N/m2
lb/in2
lb/ft2

N/m2

$$\frac{[F]}{[A]} = \frac{N}{m^2} = Pa\ (Pascal)\ in\ SI\ units \qquad \frac{[F]}{[A]} = \frac{lb}{in^2} = psi\ (pounds\ per\ square\ inch)\ in\ English\ units$$

$$\frac{[F]}{[A]} = \frac{lb}{ft^2} = pounds\ per\ square\ foot\ (English\ units)$$

Note

Fluids are either liquids or gases:

Liquid: A state of matter in which the molecules are relatively free to change their positions with respect to each other but restricted by cohesive forces so it can maintain a relatively fixed volume.

قيود تماسك

Gas: a state of matter in which the molecules are practically unrestricted by cohesive forces. A gas has neither definite shape nor volume.

** Fluids considered in this course move under the action of a shear stress, no matter how small that shear stress may be (unlike solids)

Continuum View of Fluids

ممكن اعتبار الموائع نظام مستمر (يتحرك ويتوزع في الوعاء)

- Convenient to assume fluids are continuously distributed throughout the region of interest. That is, the fluid is treated as a continuum

نظام مستمر

- This continuum model allows us to not have to deal with molecular interactions directly. We will account for such interactions indirectly via $\boxed{\text{viscosity}}$

يمكن فهم القوى بين الجزيئات من خلال مفهوم اللزوجة

- A good way to determine if the continuum model is acceptable is to compare a characteristic length (L) of the flow region with the $\boxed{\text{mean free path}}$ of molecules.

للتأكد ان مبدأ الاستمرارية مقبول

- If $L << \lambda$, Continuum model is valid

ممكن مقارنة تدفق طول معين L
في منطقة التدفق مع متوسط المسار الحر λ

Mean free path (λ) : $L << \lambda$ العقود الاستمرارية محفوظ

Average distance that a molecule travels before it collides with another molecule.

λ متوسط المسار الحر هو متوسط المسافة التي تقطعها الجزيئات
قبل ان تصطدم لتصادم جديد

Viscosity

اللزوجة

- Viscosity, μ, is the property of a fluid, due to cohesion and interaction between molecules, which offers resistance to shear deformation.

اللزوجة :- خاصية للمائع مرتبطة بقوى التماسك بين الجزيئات وتسبب مقاومة التشوه

- Different fluids deform at different rates under the same shear stress. The ease with which a fluid pours is an indication of its viscosity.

سهولة الجريان للمائع تدل على لزوجته

- Fluid with a high viscosity such as syrup deforms more slowly than fluid with a low viscosity such as water. The viscosity is also known as dynamic viscosity.

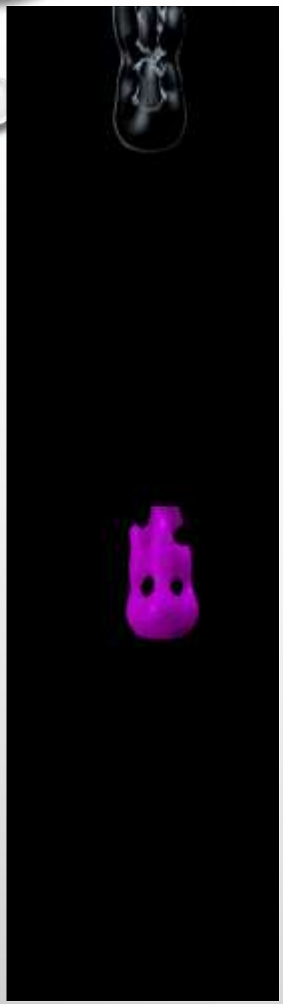
الموائع التي تتشوه بصعوبة مثل العسل لها لزوجة اكبر من الموائع التي تتشوه بسهولة

Units: **N.s/m²** **or** **kg/m/s**

Typical values:

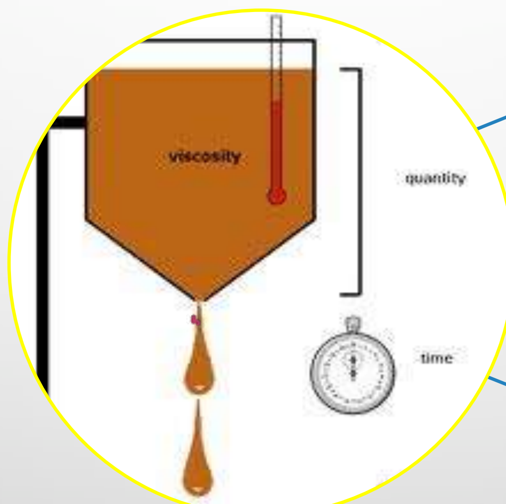
Water = 1.14 ×10^{-3} kg/m/s; **Air = 1.78 ×10^{-5} kg/m/s**

μ μ



Viscosity

- ❖ A simulation of substances with different viscosities.
- ❖ The substance above has lower viscosity than the substance below.



Dynamic μ μ

Kinematic ν ν

Dynamic viscosity, $\boxed{\mu}$

Definition

μ :- قوى القص اللازمة لكل وحدة المساحة

❖ Dynamic viscosity, μ , is defined as the ***Shear force per unit area*** (shear stress, $\boxed{\tau}$) needed to drag a layer of fluid with a unit velocity past another layer at a unit distance away from it in the fluid

τ :- القوة اللازمة لتحريك طبقة من المائع بسرعة وحدة بالنسبة لطبقة اخرى

❖ Measure of internal friction of fluid particles

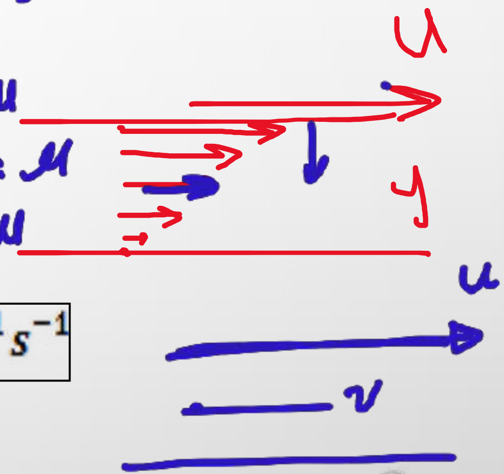
- •Molecular cohesiveness

μ :- تعبير قوى الاحتكاك

μ :- تعبير التماسك الجزيئي

- •Resistance fluid has to shear (or flow)

μ :- تعبير عن مدى مقاومة المائع للجريان



$$\mu = \frac{\tau}{\left(\frac{du}{dy}\right)}$$

Water: $1.14 \times 10^{-3}\ kgm^{-1}s^{-1}$

Air: $1.78 \times 10^{-5}\ kgm^{-1}s^{-1}$

Units: Nsm^{-2} or $kgm^{-1}s^{-1}$ or $\boxed{Pa.s}$ or poise ($10\ Poise = 1\ Nsm^{-2}$)

Kinematic viscosity, ν

Definition: is the ratio of the viscosity to the density;

$$\nu = \mu / \rho$$

$$\frac{\mu \text{ اللزوجه الديناميكيه}}{\rho \text{ الكثافه}} = \nu \text{ اللزوجه الحركيه}$$

- will be found to be important in cases in which significant viscous and gravitational forces exist.

$$\nu = \frac{1.14\times10^{-3}}{1000} = 1.14\times10^{-5}\ m^2/s$$

ν **Units:** m^2/s

Typical values:

ν Water = 1.14×10^{-6} m^2/s; ν Air = 1.46×10^{-5} m^2/s;

In general,

في السوائل

- ✓ viscosity of liquids ↓ with ↑ temperature, whereas

كلما زادت درجة الحراره قلت اللزوجه والعكس صحيح

في الغازات

- ✓ viscosity of gases ↑ with ↑ in temperature.

كلما زادت درجة الحرارة زادت اللزوجة

Viscosity in Gases & Liquids

Viscosity in gases

- Due to intermolecular collision between randomly moving particles
- For gas, temperature ↑, amount of intermolecular collision ↑, viscosity ↑

في الغازات عند زيادة درجة الحرارة تزداد التصادمات وتزداد اللزوجة

Viscosity in liquid

- Due to intermolecular collision between liquid particles
- For liquid, temperature ↑, intermolecular collision is weak, viscosity ↓

في السوائل عند زيادة درجة الحرارة تصبح التصادمات اضعف وتقل اللزوجة

Facts

اللزوجه تدل على المقاومه الداخليه للتدفق الجريان (السيولة)

- **Viscosity:** A property that represents the internal resistance of a fluid to motion or the "fluidity".

قوة السحب

- **Drag force:** The force a flowing fluid exerts on a body in the flow direction. The magnitude of this force depends, in part , in ***viscosity.***

اهمية اللزوجة

- Viscosity is important, for example,

  للتعرف على كمية المائع الذي يمكن نقله في انبوب

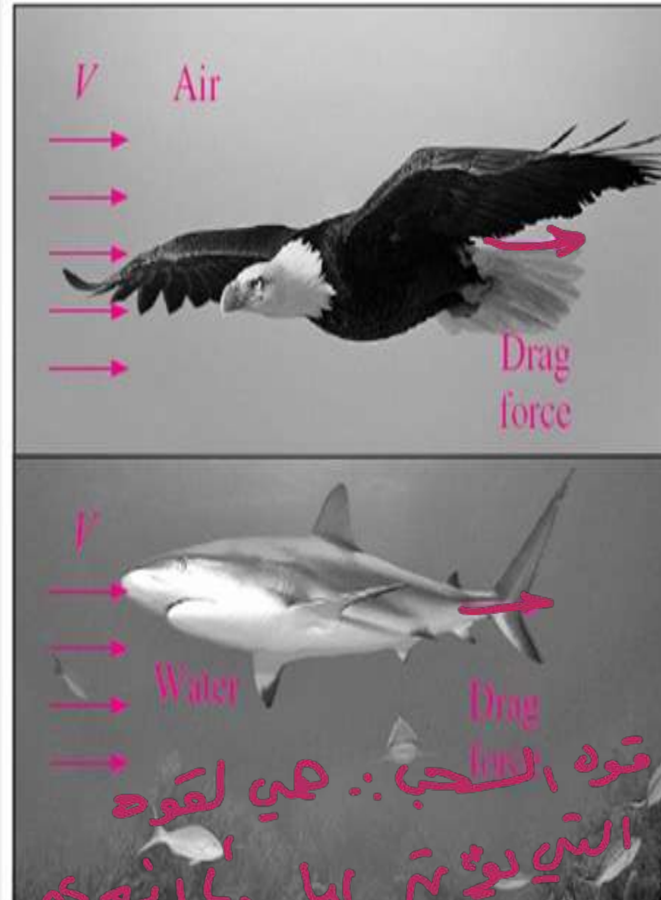
  - To determine the amount of fluids that can be transported in a pipeline during a specific period of time.

  لحساب الطاقة المفقودة عند نقل الموائع في الانابيب

  - To determine the energy losses associated with transport of fluids in ducts, channels and pipes.

- Viscosity is due to the internal frictional force that develops between different layers of fluids as they are forced to move relative to each other.

سبب اللزوجه هو قوة الاحتكاك الداخلية بين الطبقات المتحركة في المائع



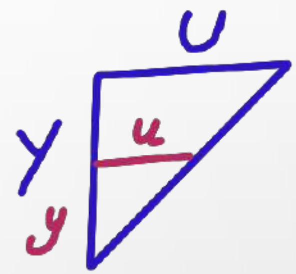
قوة السحب: هي القوة التي يؤثر بها المائع على جسم متحرك داخله وتعتمد على اللزوجه

Viscosity (μ)

No slip condition

مانع الانزلاق لصفيحه غير متحركه سرعته صفر

- Because of viscosity, at boundaries (walls) particles of fluid adhere to the walls, and so the fluid velocity is **zero** relative to the wall
- Viscosity and associated shear stress may be explained via the following: flow between no-slip parallel plates.

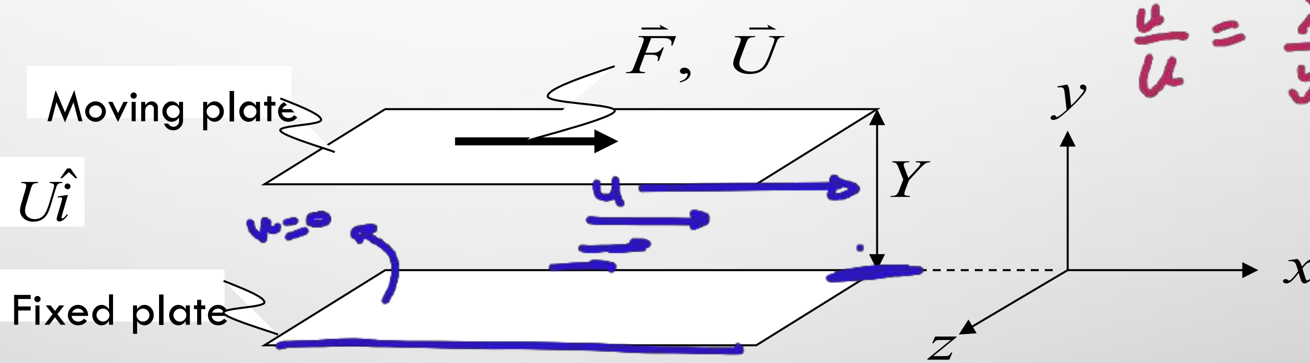


- Flow between no-slip parallel plates

each plate has area *A*

$$\frac{u}{U} = \frac{y}{Y}$$

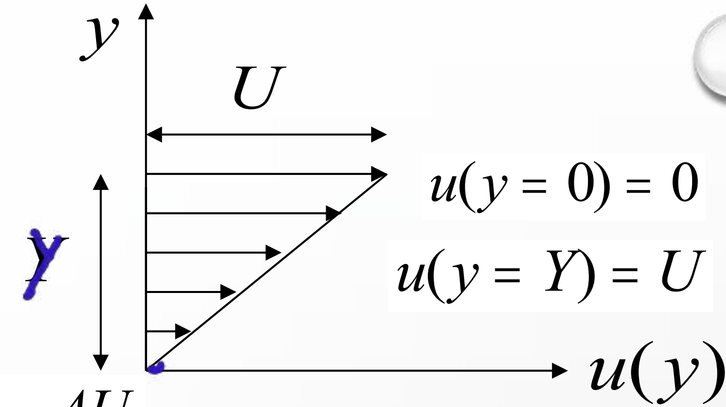
$\vec{F} = F\hat{i}$ $\quad$ $\vec{U} = U\hat{i}$



Force $\vec{F}$ induces velocity $\vec{U}$ on top plate. At top plate flow velocity is $\vec{U}$

At bottom plate velocity is zero

The velocity induced by moving top plate can be sketched as follows:



$u(y = 0) = 0$

$u(y = Y) = U$

The velocity induced by top plate is expressed as follows:

السرعه معتمده على
ارتفاع

$$u(y) = \left(\frac{U}{Y}\right) y$$

For a large class of fluids, empirically, $F \propto \frac{AU}{Y}$

More specifically, $F = \mu \frac{AU}{Y}$; μ *is coefficient of viscosity*

Shear stress induced by F is $\tau = \frac{F}{A} = \mu \frac{U}{Y}$

From previous slide, note that $\frac{du}{dy} = \frac{U}{Y}$

Thus, shear stress is $\boxed{\tau = \mu \frac{du}{dy}}$

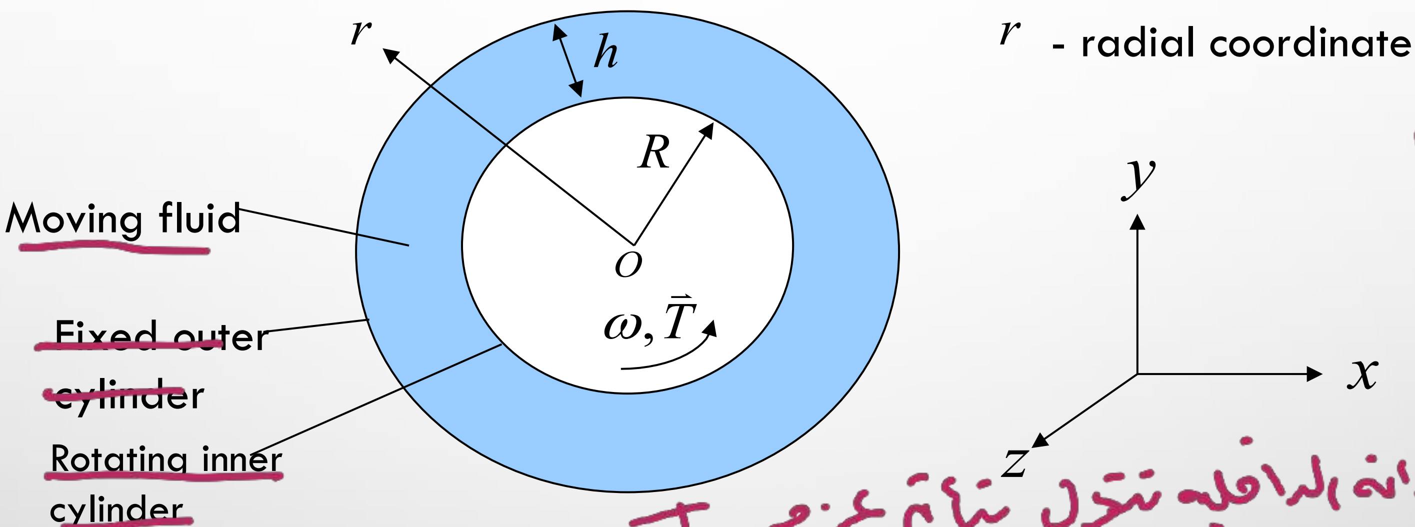
In general, we may use previous expression to find shear stress at a point inside a moving fluid. Note that if fluid is at rest this stress is zero because $\frac{du}{dy} = 0$

Viscometer

مقياس اللزوجة

Coefficient of viscosity $\boxed{\mu}$ can be measured empirically using a viscometer

Example: Flow between two concentric cylinders (viscometer) of length L

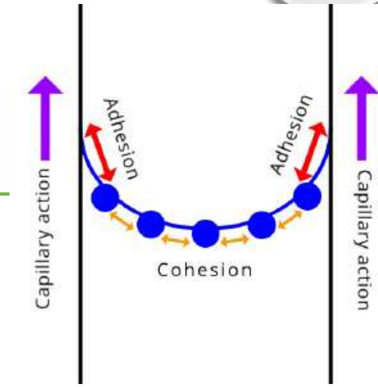


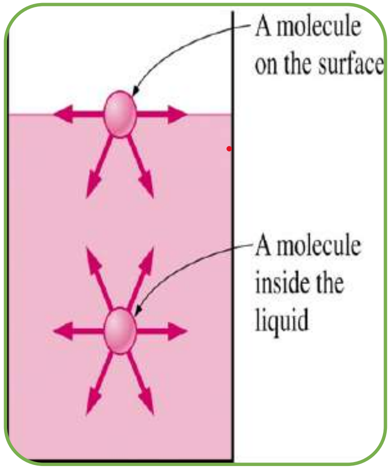
الاسطوانة الداخلية تتحرك بتأثير عزم T
الاسطوانة الخارجية ثابتة

Inner cylinder is acted upon by a torque, $\vec{T} = T\hat{k}$ causing it to rotate about point O at a constant angular velocity ω and causing fluid to flow. **Find an expression for** $\vec{T}$

التوتر السطحي

Surface Tension, $\boxed{\sigma}$



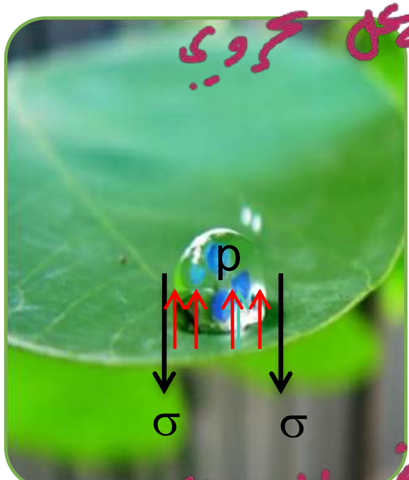


Surface tension:

- Defined as the force acting a unit length of a line drawn in the liquid surface

القوة المؤثرة على كل وحدة طول على خط مرسوم على سطح السائل

يعمل على تقليل مساحة السطح مما يجعل القطرات تأخذ شكل كروي



- Surface tension tend to reduce the surface area of a body of liquid

- The internal pressure within the droplet, p and the surface tension forces,σ must be in equilibrium.

الضغط الداخلي في القطرة P والتوتر السطحي σ تكونان في حالة اتزان

Surface tension

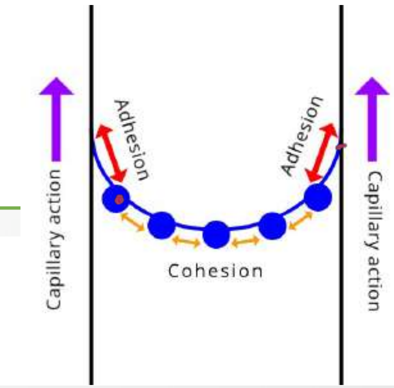
قوى التوتر السطحي تكون عمودية على القوة

- Taking vertical equilibrium of the forces acting on the droplet

ومقدارها صغير جداً

- The magnitude of surface tension forces are very small compared to other forces
- Normally are neglected

غالبيتها اهمال



- Surface tension vector (acts uniformly along contact perimeter between liquid and tube)

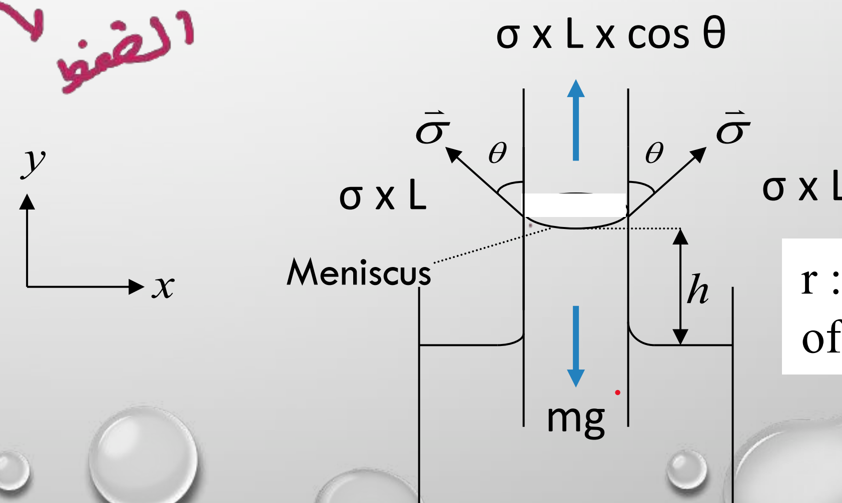
التوتر السطحي

الضغط

$$2\pi r\sigma = p\pi r^{2}$$

$$p = \frac{2\sigma}{r} \Rightarrow \sigma = \frac{pr}{2}$$

Units : N/m



r : radius of tube

تلاصق

تماسك

Adhesion of water molecules to the tube dominates over cohesion between water molecules giving rise to $\vec{\sigma}$ and causing fluid to rise within tube

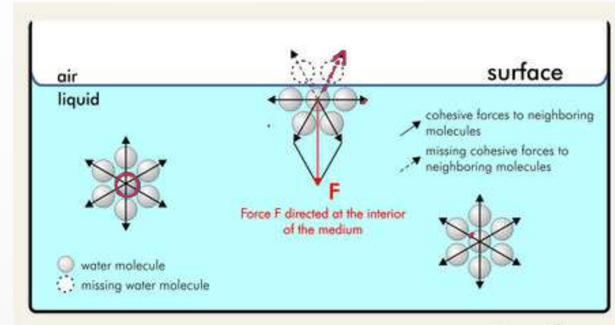
$$\boxed{\vec{\sigma} = \sigma \hat{n}}$$

- unit vector in direction of $\vec{\sigma}$

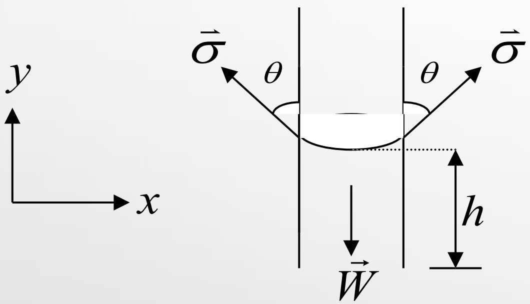
σ surface tension (magnitude of $\vec{\sigma}$)

$$\vec{\sigma} = \sigma\,[\sin\theta(\hat{i}) + \cos\theta(\hat{j})]$$

$$[\sigma] = \frac{force}{length}$$



Given conditions in previous slide, what is σ ?



$$\vec{\sigma} = \sigma\,[\sin\theta(\hat{i}) + \cos\theta(\hat{j})]$$

$$\vec{W} = W(-\hat{j}\,)$$ (weight vector of water)

σ_i: $+j$

W $-j$

Equilibrium in *y-direction* yields: $\sigma\cos\theta(2\pi r)\,(\hat{j}) + W(-\hat{j}\,) = 0\,\hat{j}$

Thus $\sigma = \dfrac{W}{2\pi r\cos\theta}$ with $W = \gamma_{water}\pi r^2 h$

Capillarity

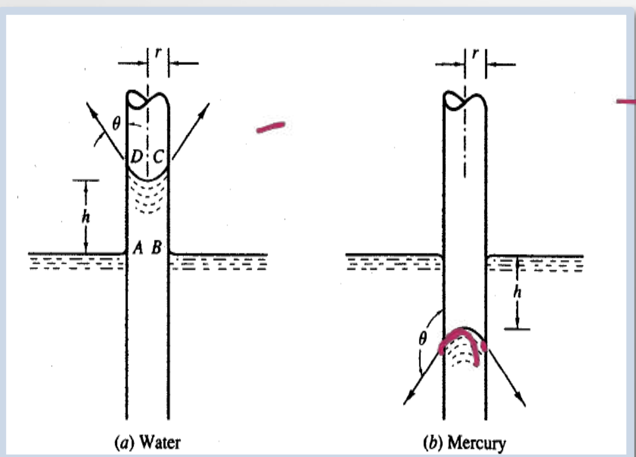
الخاصيه الشعرية

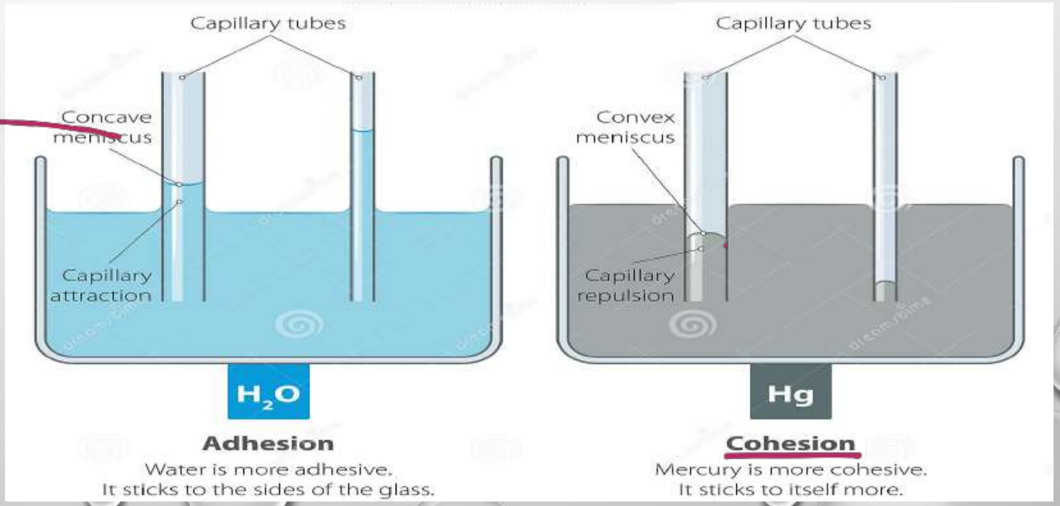
When a liquid comes into contact with a solid surface:

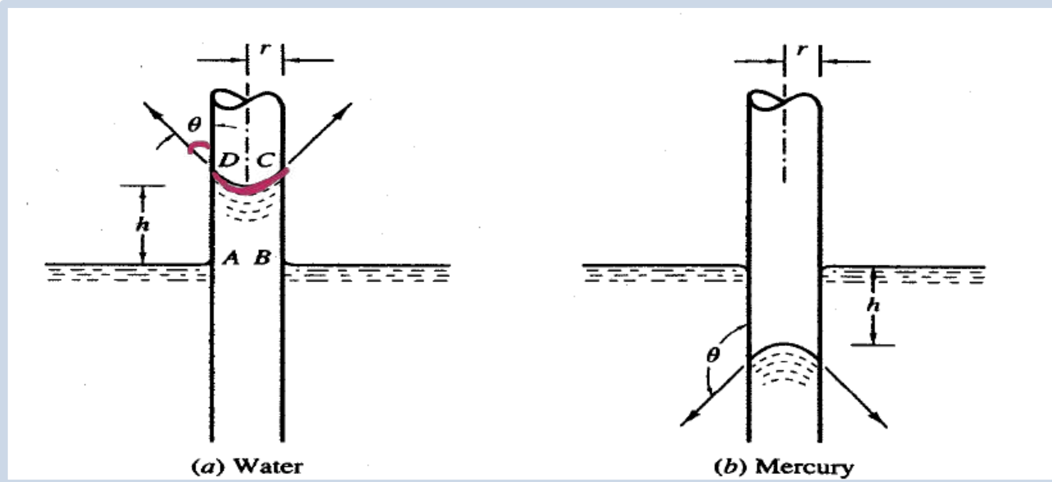
قوى التلاصق - Adhesion forces: forces between solid and liquid

قوى التماسك - Cohesion forces: forces within liquid

If cohesive forces > adhesive forces, the meniscus in a glass tube will the liquid concaves down in order to reduce contact with the surface of the wall as in figure (a). When the adhesive force of the liquid to the wall > the cohesive force of the liquid, the liquid is more attracted to the wall than its neighbors, causing the upward concavity. (b).







التأثير الشعري

Capillary effect is the rise or fall of a liquid in a small-diameter tube

التوتر السطحي الزاوية 2r

$$h = \frac{4\sigma\cos\theta}{\rho g d} \quad \textbf{Or} \quad h = \frac{4\sigma\cos\theta}{\gamma d} \quad \textbf{Or} \quad h = \frac{2\sigma\cos\theta}{\rho g r}$$

كثافة الثقل ما الوزن النوعي

Units= m or mm

where h = height of capillary rise (or depression)

σ = surface tension

θ = wetting (contact) angle زاوية التلامس

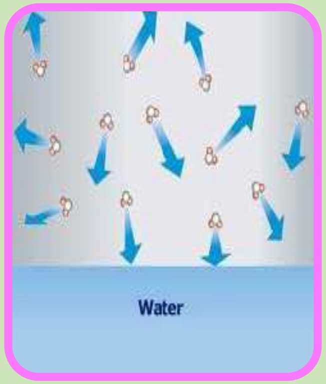
γ = specific weight of liquid

r = radius of tube

Vapor pressure, P_v

الضغط البخاري

Vapor pressure



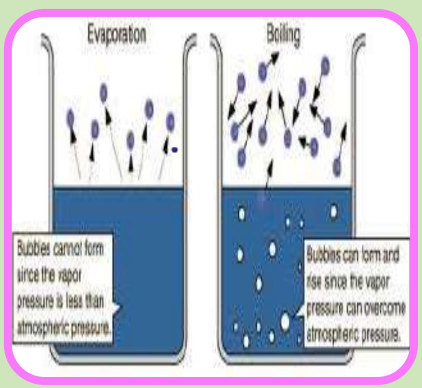
الضغط الذي يتحول فيه السائل الى بخار

- Defined as the pressure at which a liquid turns to vapor.
- The pressure exerted by its vapor in phase equilibrium with its liquid at a given temperature

ضغط البخار عندما تكون في حالة اتزان مع السائل

- The molecules which moves above the surface of the liquid exert pressure in the confined surface
- i.e. # of molecules escaping liquid surface = # of incoming molecules

حالة الاتزان عدد الجزيئات التي تغادر السطح = عدد الجزيئات التي ترجع للسطح



•Under this equilibrium we call the vapor pressure the saturation pressure

عند هذه النقطة نسمي الضغط ضغط الاشباع

•At any given temperature, if pressure on liquid surface falls below the the saturation pressure, rapid evaporation occurs **(i.e. boiling).** For a given temperature, the saturation pressure is the boiling pressure

عندما يكون الضغط اقل من ضغط الاشباع يحدث تبخر سريع (الغليان)

$$P_{vapour} = P_{saturation}$$

Units: N/m^2 or Pascal

في حساب ضغط الاشباع = الضغط البخاري عند الغليان

Compressibility

قابلية الانضغاط

الانضغاط هو التغير في الحجم بسبب الضغط و يؤدي الى زيادة الكثافة

- All fluids compress if pressure increases resulting in an increase in density

•Compressibility is the change in volume due to a change in pressure

•A good measure of compressibility is the bulk modulus (It is inversely proportional to compressibility)

$y = \frac{stress}{strain}$

حجم النوعي

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

$$B_\upsilon = -V \frac{dp}{dV}$$

$\upsilon = \frac{1}{\rho} = \frac{V}{m}$ (*specific volume*)

p is pressure

معامل التشكل الحجمي

•From previous expression we may write $\frac{(\upsilon_{final} - \upsilon_{initial})}{\upsilon_{initial}} \approx -\frac{(p_{final} - p_{initial})}{B}$

$B = 320{,}000\ psi$

$B = v \frac{dp}{dv}$

•For water at 15 *psi* and 68 degrees Fahrenheit,

•From above expression, increasing pressure by 1000 *psi* will compress the water by only 1/320 (0.3%) of its original volume

•Thus, water may be treated as incompressible (density (ρ) is constant)

عند حساب التغير في الحجم للماء كان مقداره قليل جداً ولهذا يعتبر الماء غير قابل للانضغاط

- In reality, no fluid is incompressible, but this is a good approximation for certain fluids

Types of Fluid

Fluids can be classified into five basic types. They are:

Types of Fluid

- Ideal Fluid مثالي
- Real Fluid حقيقية
- Pseudo-plastic Fluid زائفة
- Non-Newtonian Fluid غير نيوتونية
- Newtonian Fluid نيوتونية

1. Ideal Fluid:

مائع مثالي

A fluid is said to be ideal if it is assumed to be both incompressible and inviscid (non-viscous).

غير قابل للانضغاط غير لزج

- ✓ An Ideal Fluid is a fluid that has no viscosity (inviscid) and

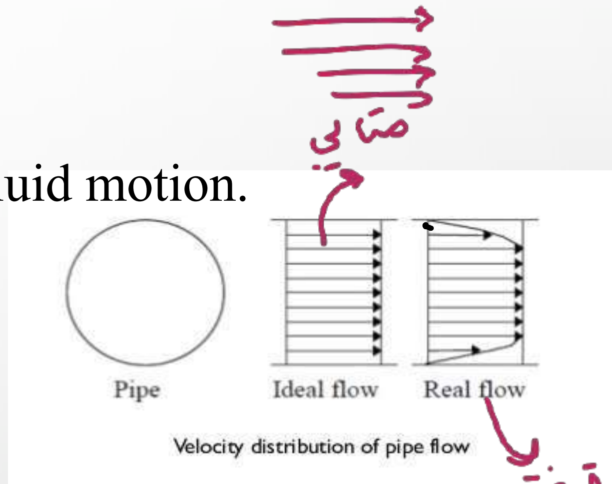
  اللزوجه صفر

  no frictional forces.

  غير قابل للانضغاط
- ✓ It is incompressible in nature.

  لا يوجد توتر سطحي
- ✓ no surface tension reset up even during the fluid motion.
- ✓ Practically, no ideal fluid exists.

  لا يوجد مائع مثالي في الطبيعه



2. Real Fluid:

المائع الحقيقي

Practical Fluid have surface tension, viscosity and compressibility.

- ✓ Real fluids are compressible in nature. They have some viscosity.

  لديها احتكاك
- ✓ Real fluids implies friction effects.

Examples: Kerosene, Petrol, Castor oil

يوجد توتر سطحي
له لزوجه
قابل للانضغاط

موائع لدنه زائفه

3 Pseudo-plastic Fluid:

- A fluid whose apparent viscosity or consistency decreases instantaneously with an increase in shear rate.
- **Examples: quick sand and ketch-up etc..** مائع تقل لزوجته واتساقه بشكل سريع عند تعرضه لاجهادات قص

ketch-up

Quick sand

موائع نيوتونيه

4 Newtonian fluid:

- Fluids that obey Newton's law of viscosity. For a Newtonian fluid,
- viscosity is entirely dependent upon the temperature and pressure of the fluid. موائع تتبع قانون نيوتن في اللزوجة تعتمد على درجة الحراره والضغط ولا تعتمد على معدل القص
- **Examples: water, air, emulsions**

Different types of Emulsions

موائع غير نيوتونيه

5 Non-Newtonian Fluids

- Fluids that do not obey Newton's law of viscosity are non-Newtonian fluids. لا تتبع قانون نيوتن
- Examples: Flubber, Oobleck (suspension of starch in water), Pastes, Gels & Polymer solutions

Gel

Tooth Paste

Newtonian and Non-Newtonian Fluid

Fluid $\xrightarrow{\text{obey}}$ Newton's law of viscosity $\xrightarrow{\text{refer}}$ Newtonian fluids

Example:
Air
Water
Oil
Gasoline
Alcohol
Kerosene
Benzene
Glycerine

امثلة عن موائع نيوتونية

Newton's' law of viscosity is given by;

$$\tau = \mu \frac{du}{dy}$$

معدل تغير الحركة

where,

τ = shear stress

μ = viscosity of fluid

du/dy = shear rate, rate of strain or velocity gradient

- **The viscosity** $\boxed{\mu}$ is a function only of the condition of the fluid, particularly its temperature.
- The magnitude of the **velocity gradient (du/dy)** has no effect on the magnitude of μ.

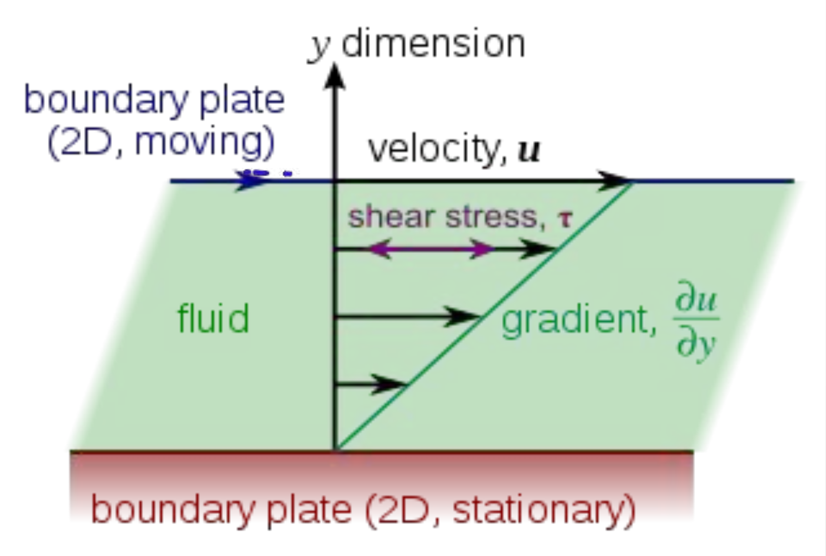
Newton's equation of viscosity

Shear stress due to viscosity at a point : $\tau = \mu \dfrac{du}{dy}$

- **Kinematic viscosity**

$$\nu = \frac{\mu}{\rho}$$

μ : viscosity (coefficient of viscosity)



Newton's Law of Viscosity is very useful to us as we can use it to evaluate the ***shear stress*** (and ultimately the shear force) exerted by moving fluid onto the fluid's boundaries.

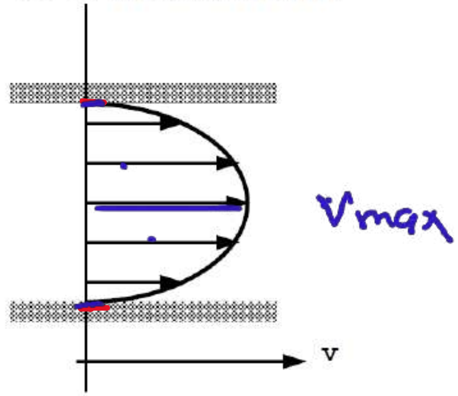
$$\tau \text{ at boundary} = \mu \left(\frac{du}{dy}\right)_{\text{at boundary}}$$

Note y is direction normal to the boundary

Velocity gradient

The fluid "*sticks*" to the wall.

Moving away from the wall velocity increases to a maximum.



Change in velocity with distance is "velocity gradient" = $\frac{du}{dy}$

Plotting the velocity across the section gives "velocity profile"

So:

Shear stress, τ, **is the force per unit area:**

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

U/y is the rate of change of velocity with distance

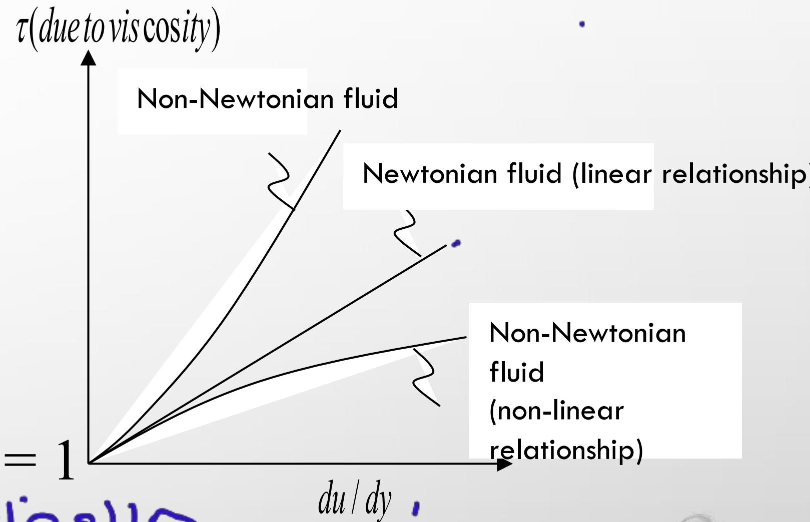
in differential form this is $\frac{du}{dy}$ **= velocity gradient.**

Non-Newtonian Fluid

بعض الموائع لديها µ غير ثابته تسمى موائع غير نيوتونيه

- Some fluids do not have constant **µ** → They don't obey Newton's Law of viscosity.

- They do obey a similar relationship and can be placed into several clear categories



The general relationship is:

$$\tau = A + B\left(\frac{du}{dy}\right)^{n}$$

where A, B and n are constants.

For Newtonian fluids A=0, B = **µ**, and n = 1

حالة خاصة إذا كانت موائع نيوتونية

$A = 0 \quad n = 1 \quad B = \mu$

In this course we will only deal with Newtonian fluids

Classification of Flows

المناطق اللزجه وغير اللزجه في التدفق

➢ Viscous vs. Inviscid Regions of Flow

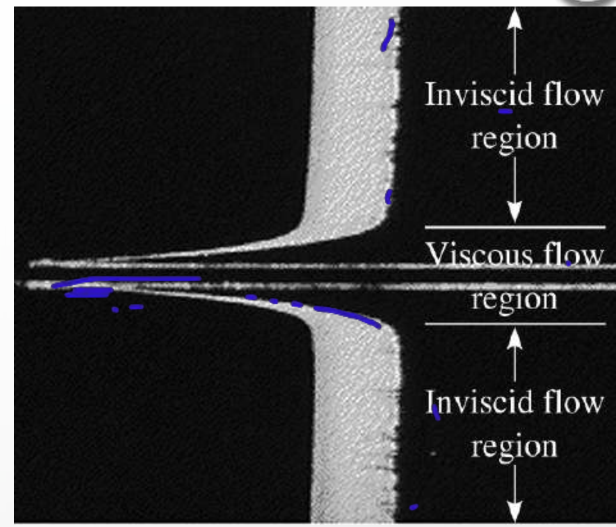
- **Viscous flows:** الاحتكاك موجود لاكن اهماله

  Flows in which the frictional effects are significant.

- **Inviscid flow regions:**

  In many flows of practical interest, there are regions (typically regions not close to solid surfaces) where viscous forces are negligibly small compared to inertial or pressure forces.

توصف الاماكن (خصوصاً بعيده عن جدا)
تكون قوى اللزوجه صغيره مقارنه مع الضغط او القوى الداخليه



The flow of an originally uniform fluid stream over a flat plate, and the regions of viscous flow (next to the plate on both sides) and inviscid flow (away from the plate).

➢ Internal vs. External Flow

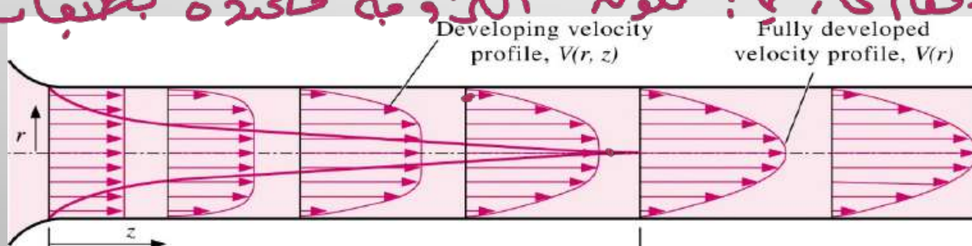
التدفق الداخلي مقابل الخارجي

- Internal flows are dominated by the influence of viscosity throughout the flow field

  التدفق الداخلي : تكون اللزوجه مسيطره على التدفق

- For external flows, viscous effects are limited to the boundary layer and wake.

  التدفق الخارجي : تكون اللزوجه محدده بطبقات الحدود



تدفق خارجي

تدفق غير انضغاطي   مقابل   تدفق انضغاطي

➢ Compressible vs. Incompressible Flow

- A flow is classified as incompressible if the density remains nearly constant.

  الكثافة تقريبا ثابته عند   غير قابل للانضغاط

- Liquid flows are typically incompressible.
- Gas flows are often compressible, especially for high speeds.

  السوائل غير قابله للانضغاط
  الغازات قابله للانضغاط خصوصا بالسرعات العاليه

- Mach number, Ma = V/c is a good indicator of whether or not compressibility effects are important.

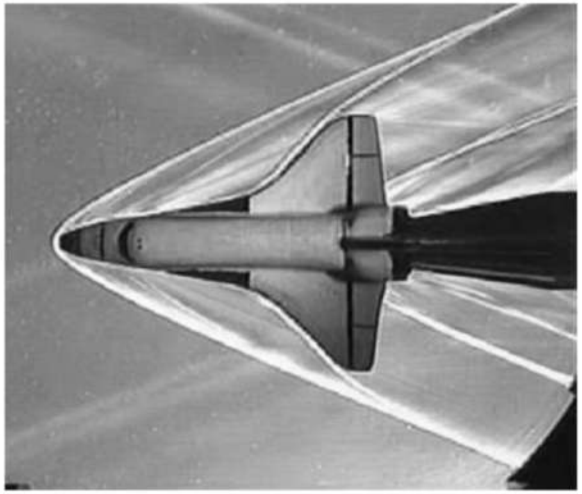
  مقياس ماخ

$$\text{Ma} = \frac{V}{c} = \frac{\text{Speed of flow}}{\text{Speed of sound}}$$

سرعة التدفق
سرعة الصوت

- Ma < 0.3 : Incompressible   غير قابل للانضغاط
- Ma < 1 : Subsonic $0.3<M<1$ تدفق انتقالي
- Ma = 1 : Sonic   تدفق صوتي
- Ma > 1 : Supersonic   تدفق فوق صوتي
- Ma >> 1 : Hypersonic   تدفق مفرط

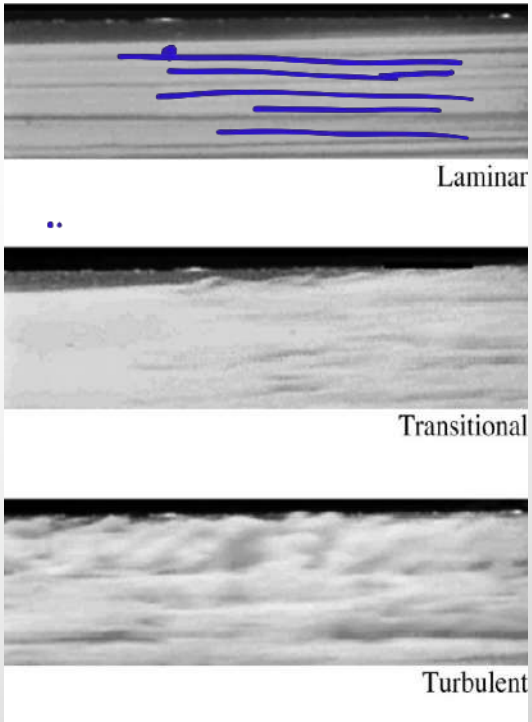
قابل للانضغاط



Schlieren image of a small model of the space shuttle orbiter being tested at Mach 3 in the supersonic wind tunnel of the Penn State Gas Dynamics Lab. Several *oblique shocks are seen in the air* surrounding the spacecraft.

جريان منتظم و مزعج اضطرابي

Laminar vs. Turbulent Flow



منتظم
- **Laminar:** highly ordered fluid motion with smooth streamlines.

خطوط جريان ملساء و متوازيه

اضطرابي
- **Turbulent:** highly disordered fluid motion characterized by velocity fluctuations and eddies.

تدفق غير منتظم عشوائي يتميز بتقلبات السرعة و الدوامات

تدفق انتقالي
- **Transitional:** flow that contains both laminar and turbulent regions

خليط بين النوعين

عدد رينولدز
- **Reynolds number**: $R_e = \rho UL/\mu$ is the key parameter in determining whether or not a flow is laminar or turbulent.

منتظم	$Re < 2000$ Laminar ,
عشوائي	$Re > 4000$ Turbulent

عدد رينولد يحدد نوع الجريان

$$Re = \frac{\rho U L}{\mu}$$

التدفق طبيعي مقابل التدفق قسري

Natural versus Forced Flow

- A fluid flow is said to be natural or forced, depending on how the fluid motion is initiated.

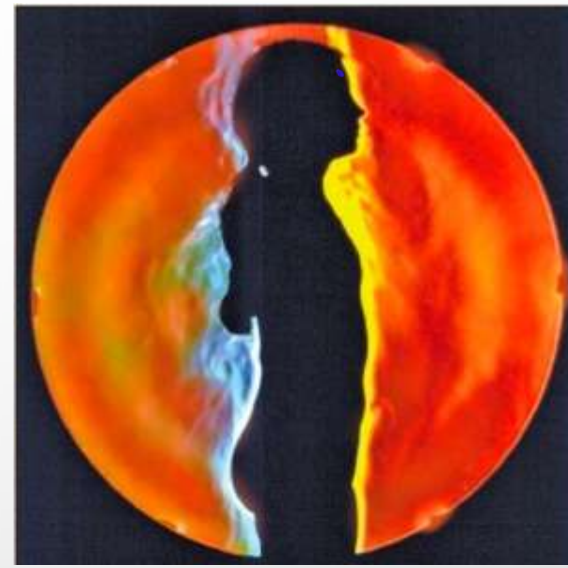
- **In forced flow** تدفق قسري

يتم اجبار ، اي المائع ان يتدفق باستخدام مضخة او مروحة

a fluid is forced to flow over a surface or in a pipe by external means such as a pump or a fan.

- **In natural flows**

any fluid motion is due to natural means such as the buoyancy effect (قوى الطفو), which manifests itself as the rise of the warmer (ساخن) (and thus lighter (اخف)) fluid and the fall of cooler (بارد) (and thus denser (اكثر كثافة)) fluid



In this schlieren image of a girl in a swimming suit, the rise of lighter, warmer air adjacent to her body indicates that humans and warm-blooded animals are surrounded by thermal plumes of rising warm air.

System and Control Volume

الانظمة والحجم الحاكم

- A system is defined as a quantity of matter or a region in space chosen for study.

النظام : اي كمية مادة او منطقة نهتم بدراستها

- **A closed system:**

(known as a control mass) consists of a fixed amount of mass.

كمية مادة ثابتة

- **An open system** or control volume:

is a properly selected region in space. It usually encloses a device that

نظام مفتوح يسمح بتبادل الكتلة مثل ضواغط و توربينات و فوهات

involves mass flow such as a compressor, turbine, or nozzle.

- In general, *any arbitrary region in space* can be selected as a control volume.

There are no concrete rules for the selection of control volumes, but the proper choice certainly makes the analysis much easier.

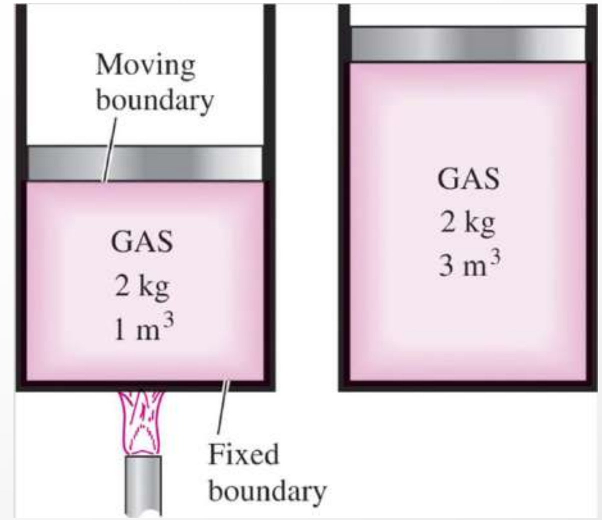
We'll discuss control volumes in more detail in the next Chapters.

System and Control Volume

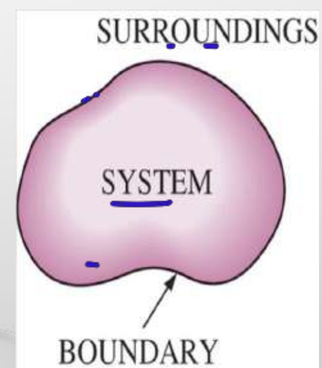
شو هو؟
- **System:**
  A quantity of matter or a region in space chosen for study.

محيط
- **Surroundings:**
  خارج النظام
  The mass or region outside the system
- The real or **Boundary:** حدود
imaginary surface that separates
 the system from its surroundings.

حد هو سطح حقيقي أو تخيلي يفصل النظام عن المحيط



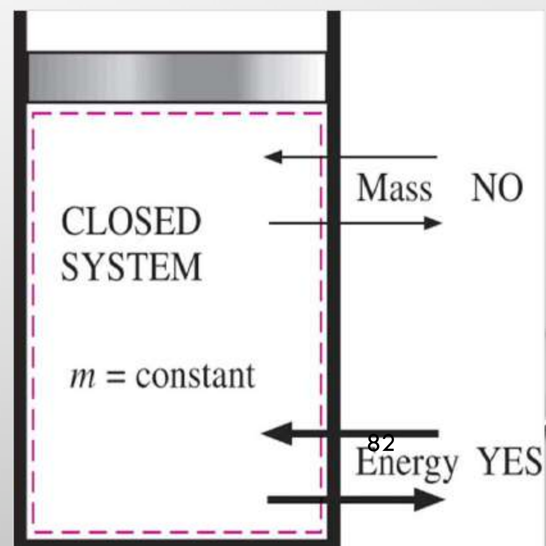
➢ **The boundary of a system can be *fixed or* movible.** Systems may be considered to be ***closed*** or ***open***.



➢ **Closed system (Control mass):**

A fixed amount of mass, and no

mass can cross its boundary.

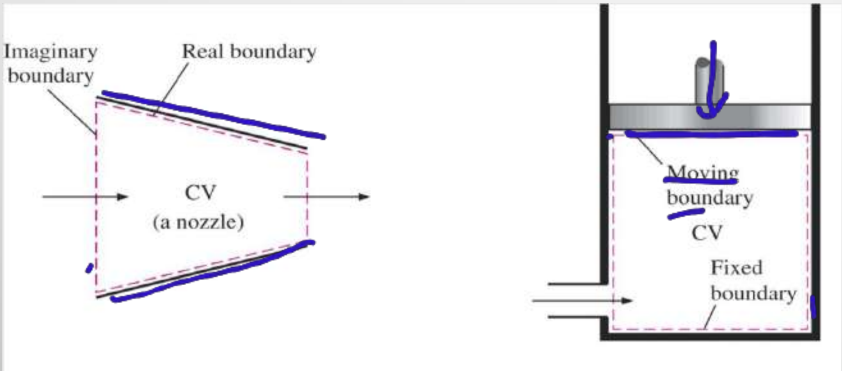


Open system (Control volume)

A properly selected region in space.

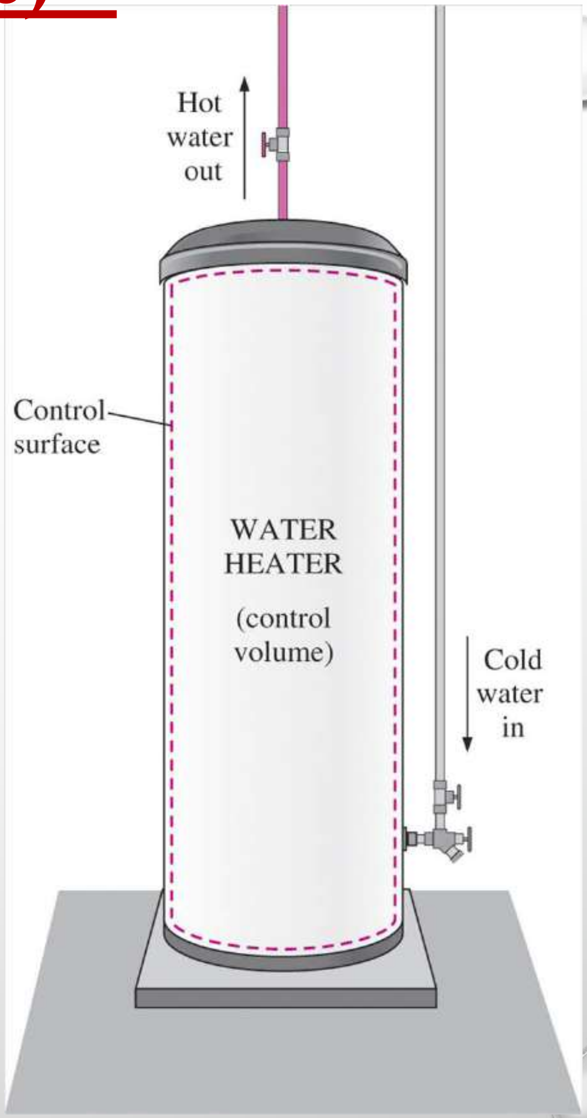
- It usually encloses a device that involves mass flow such as a compressor, turbine, or nozzle.
- Both mass and energy can cross the boundary of a control volume.
- **Control surface:**

The boundaries of a control volume. It can be real or imaginary.



(*a*) A control volume with real and imaginary boundaries

(*b*) A control volume with fixed and moving boundaries



An open system (a control volume) with one inlet and one exit.