Mechanical Principles

Lecture 2

The physical properties of a material can be expressed in terms of four fundamental quantities: *mass*, *length*, *time*, and *charge*.

For our purposes we can ig**n**ore the quantity charge,which describes the electromagnetic interaction of particles. It plays a role, however, when we try to understand the behavior of materials at the atomic scale.

Two different system of measurement are commonly used in English-speaking countries one ,the so-called absolute System International (SI) or C.G.S system, The units of length, mass, and time are centimeters (c), grams (g)and the second (s), respectively. and force by dynes.
the other the English or Engineers system. The units are length(feet or inches), mass(pounds),time(seconds),and force(poundal).
Pound=0.454 kg.

In practice, force is often expressed in terms of grams or grams per square centimeter(or kilograms, that is thousands of grams, per square centimeter or in pounds or pounds per square inch.

TABLE 3.2 UNITS OF STRESS AND THEIR CONVERSIONS

	bar	dynes/cm^2	atmosphere	kg/cm^2	pascal (Pa)	pounds/in^2 (psi)
bar		10^6	0.987	1.0197	10^5	14.503
dynes/cm^2	10^{-6}		0.987×10^{-6}	1.919×19^{-6}	0.1	14.503×10^{-6}
atmosphere	1.013	1.013×10^6		1.033	1.013×10^5	14.695
kg/cm^2	0.981	0.981×10^6	0.968		0.981×10^5	14.223
pascal (Pa)	10^{-5}	10	0.987×10^{-5}	1.0197×10^{-5}		14.503×10^{-5}
pounds/in^2 (psi)	6.895×10^{-2}	6.895×10^4	6.81×10^{-2}	7.03×10^{-2}	6.895×10^3	

To use this table start in the left-hand column and read along the row to the column for which a conversion is required. For example, 1 bar = 10^5 Pa or 1 Pa = 14.5×10^{-5} psi.

FORCE

Force is a definable vector quantity that change or tends to produce a change in the shape or /and motion of a body .

Fore is defined by its magnitude and direction, hence it may be expressed by an arrow . 

Length of arrow is magnitude and arrow points in direction

An unbalanced force is one that cause a change in the motion of body.

The acceleration force is[a] is the rate of change of velocity,

The symbol mass is [*m*], for length [*l*] , and for time [*t*]. Velocity[*v*].

[a] = velocity/ time

V=l/t

$[a]=l/t^2$ or l/t^{-2} (ms^{-2})

التعجيل=السرعة \الزمن

السرعة= المسافة\الزمن

التعجيل = المسافة\الزمن^2

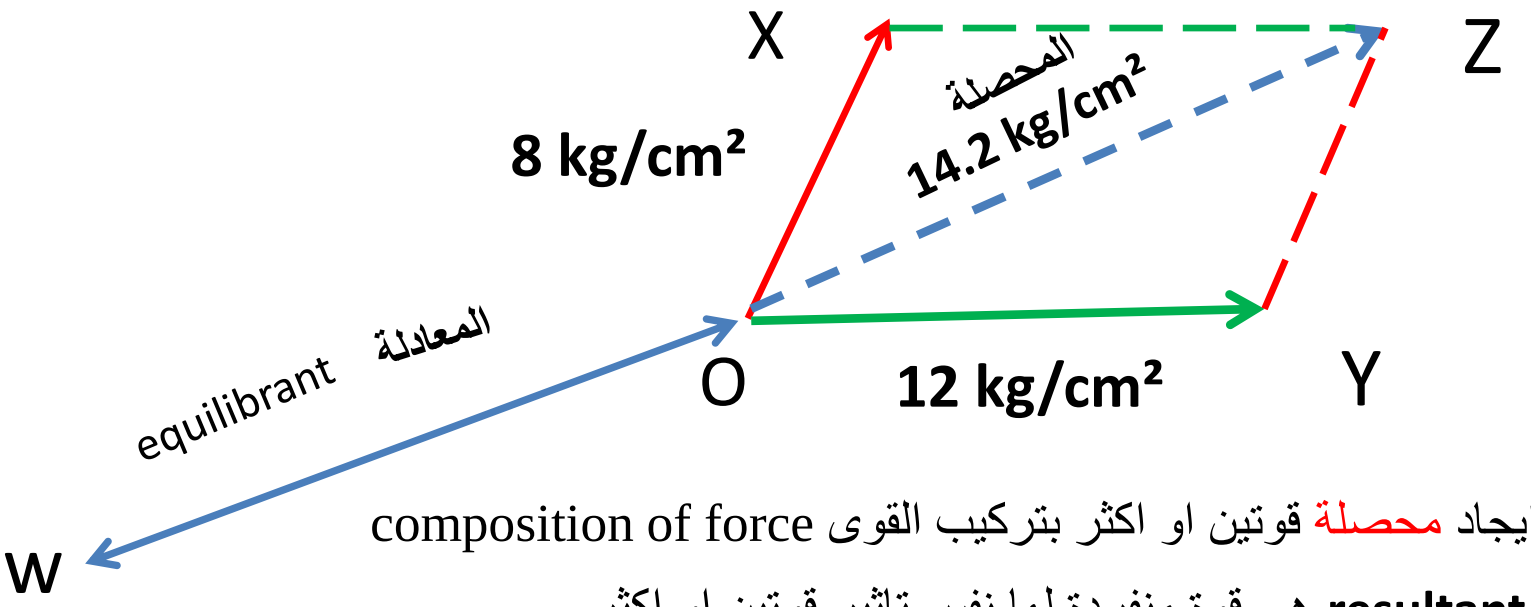
وحدة التعجيل هي م \ثانية^2

The unit of acceleration ,therefore , is m/s^2

Composition and Resolution of Force

Force may be represented by a vector, that is a line oriented In the direction in which the force is operating and proportional in length to the intensity of the force.

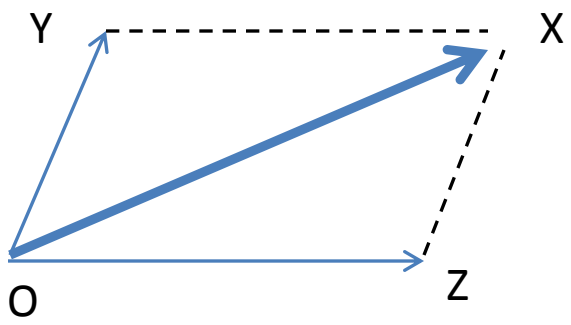
Two or more forces may act in different direction at a point as in the figure below.



تسمى عملية ايجاد محصلة قوتين او اكثر بتركيب القوى composition of force

المحصلة **resultant** هي قوة منفردة لها نفس تاثير قوتين او اكثر

Conversely, the effect of a single force may be considered in term of two or more forces that would produce the same result.

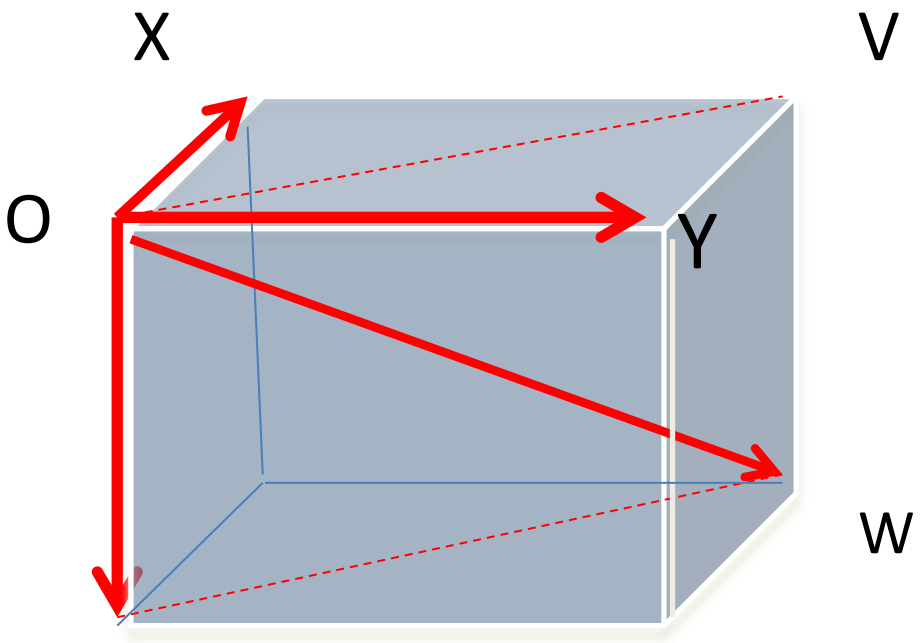


A single force may thus be resolved into two component , acting in defined direction,by Constructing a parallelogram . the diagonal of which represent the given force.

The process of finding the component of a single force is called the **resolution of force.**

The preceding discussion of composition and resolution of force has been confined to two dimension. But geology is concerned with three dimension.

يهتم الجيولوجي بالابعاد الثلاثة (xyz) لذلك يجب تحليل القوة في ثلاث ابعاد كما في الشكل



القوة الرئيسية OW

وتقع في المستوي OVWZ

يمكن تحليلها الى مركبتين احدهما عمودية OZ والاخرى OV

وتقع في المستوي الافقي OXVY

هذة القوة يمكن تحليلها الى OY and OX

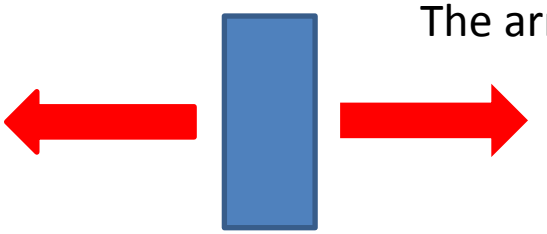
وهكذا فأن اي قوة بغض النظر عن مقدارها وزاوية ميلها يمكن تحليلها بطريقة مشابهة الى ثلاث مركبات موازية للمحاور الثلاث المتعامدة

X Y Z

Differential Force

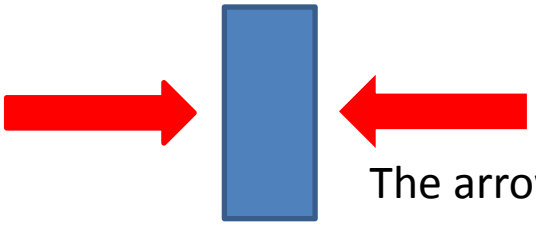
In many instance the force acting on a body are not equal on all sides.

A body is said to under **Tension** when it is subjected to external force that tend to pull it apart.



The arrow on the same straight line represent the tension forces.

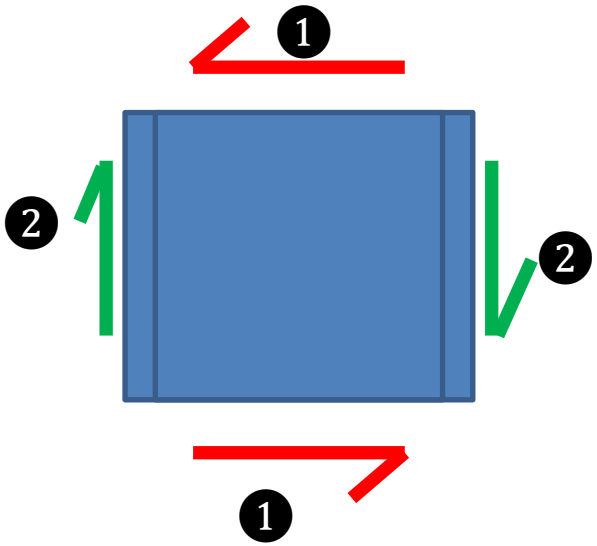
A body is said to be under **Compression** when it is subjected to external forces that tend to compress it.



The arrow on the same straight line represent the compression forces.

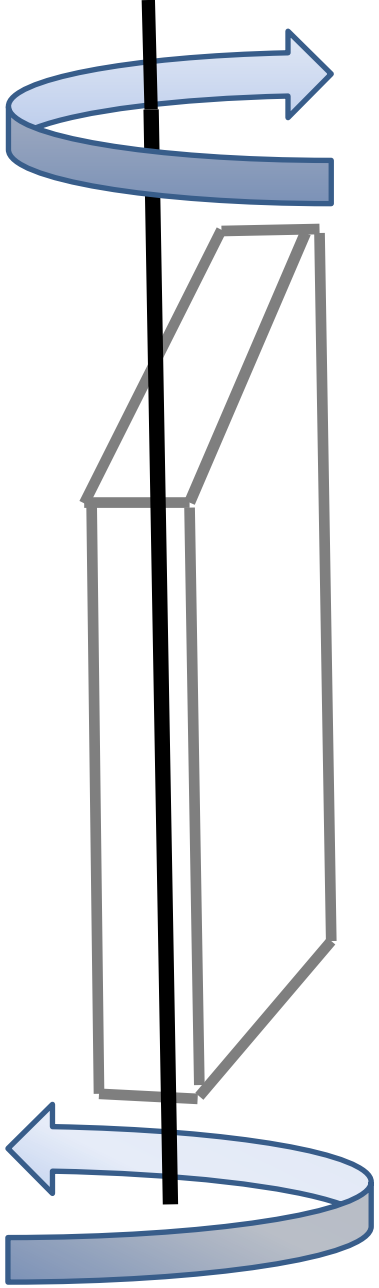
اما عندما يقع الجسم تحت تأثير قوتين متساويتين تعملان بأتجاهين متعاكسين في مستوٍ واحد وليستا على استقامة واحدة عنئذ يقال الجسم واقع تحت تاثير القوى المزدوجة Couple كما في الشكل ..(ولمنع الدوران فان مزدوجة ثانية تكون ضرورية)

A Couple consist of two equal forces that act in opposite directions in the same plane, but not along the same line

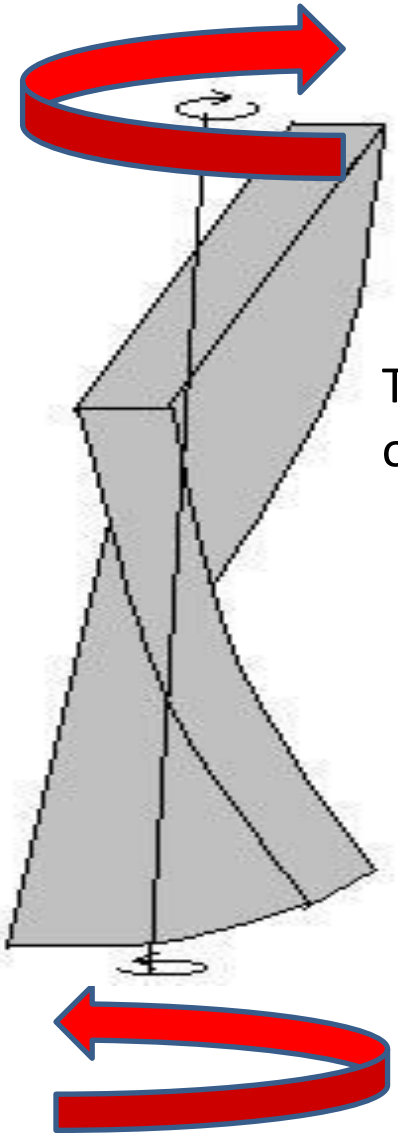


Couple

Torsion Force



A



B

Torsion result from twisting , if the two ends of a rod are turned in opposite directions.

اما قوى اللَي او الفتل

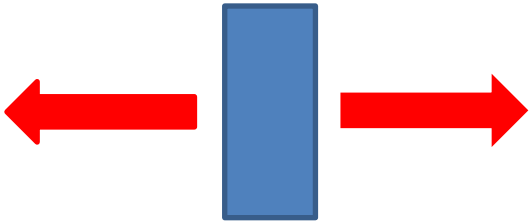
فانها تطلق على القوى التي تدوّر نهايتي جسم في اتجاهين متعاكسين.

كما في الشكل . A

حيث يعاني الجسم ليا كما في الشكل B

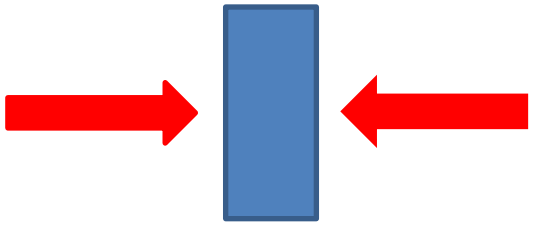
It is clear from the above that there are four types of force that affect the bodies.

Tension



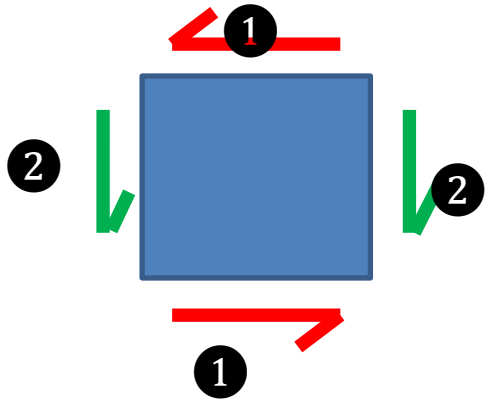
قوى الشد

Compression



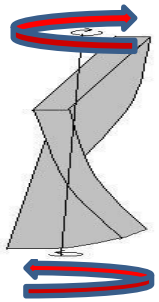
قوى الكبس او الضغط

Couple



قوى المزدوجة

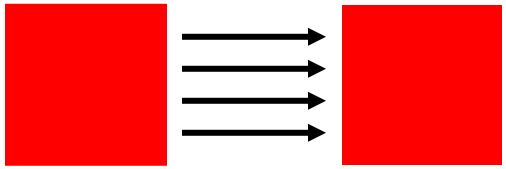
Torsion



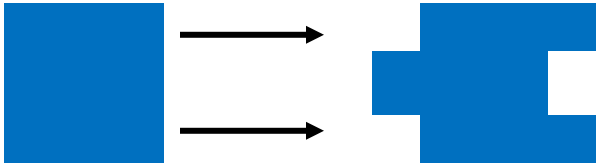
قوى اللي او الفتل

Force that act on a body may change the velocity of (that is , accelerate) the body , and/or may result in a shape change of the body , meaning there is acceleration of one part the body with respect to another part.

ان القوة العاملة على جسم ما تغير من سرعتة (التعجيل) و أو تغير من شكله , وهذا يعني ان التعجيل غير متساوي في جميع اجزاء الجسم .



affect whole body



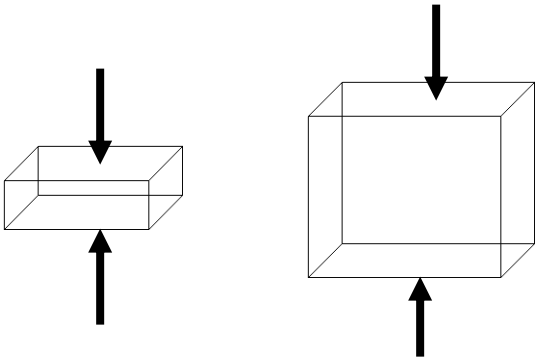
affect only part of the body

لذلك وبالرغم من ان القوة تَعد من المفاهيم المهمة الا انها لاتمكننا من ان نميز بين تأثيرها على اجزاء جسم ما ذو كتلة معينة اذا تغير شكل ذلك الجسم بصورة غير متساوية.

although force is critical concept, it cannot be used to distinguish its effects on bodies of equal mass but different shapes

Consider hitting a rock with a pointed or a flat hammer using the same force . the rock cracks more easily with the pointed hammer than with flat-head hammer

Also what do you notice when shedding an equal amount of forces on boxes of different size?



same force applied to different size boxes will not have same effect (force more "concentrated" on little box)

These examples of the intensity of force lead us into the topic of

Stress.

- Force
  - that which changes the state of rest or the state of motion of a body
    F=ma
- Stress
  - force applied to an area
    σ=F/A

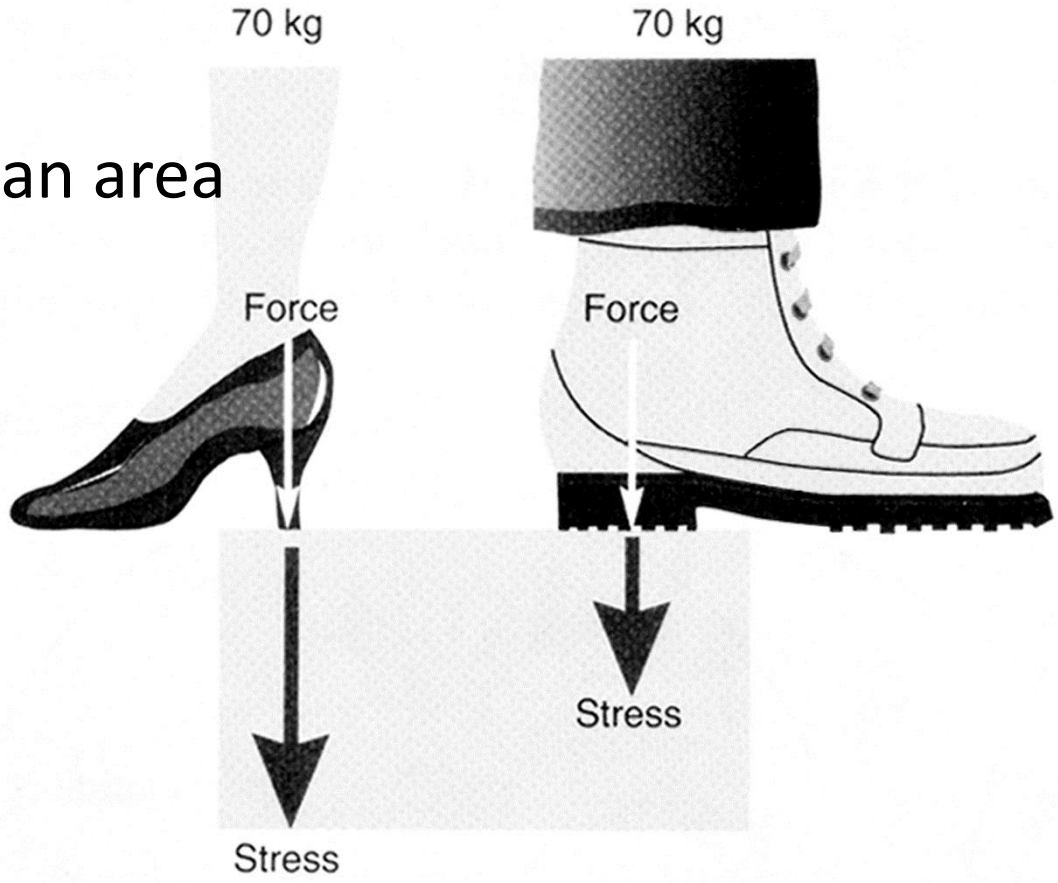
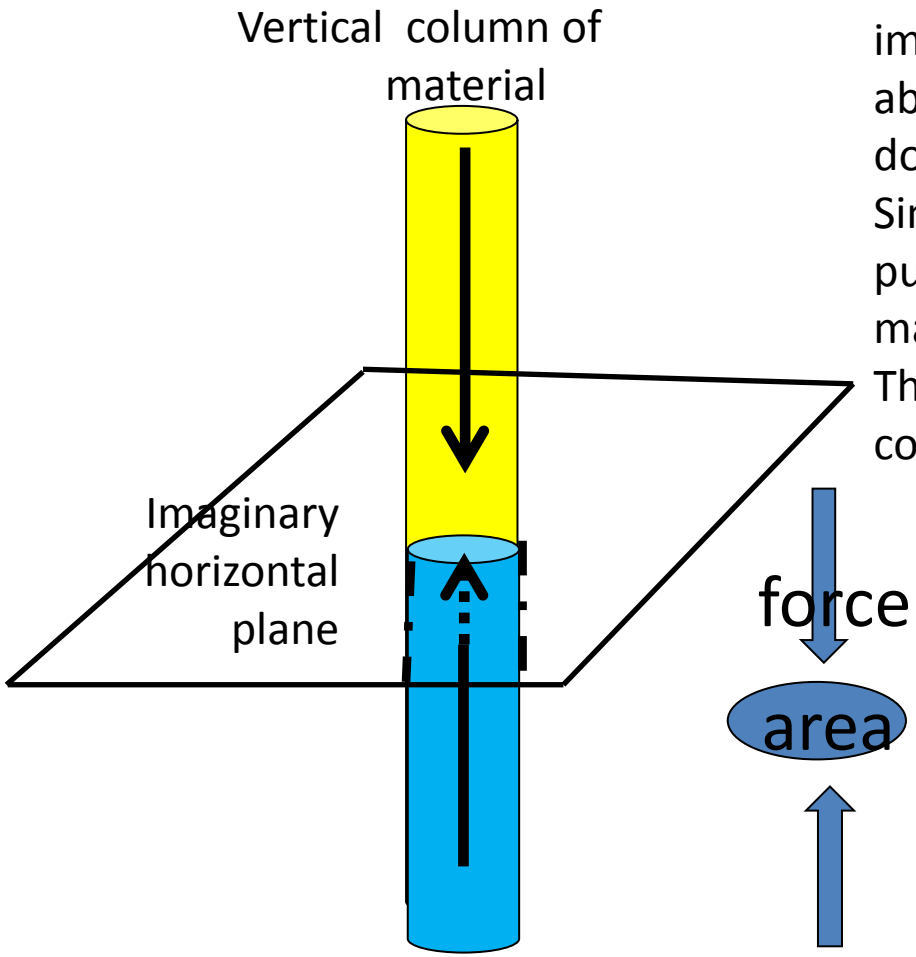


FIGURE 3–2

Stress Concept مفهوم الاجهاد



Imagine a vertical column of material. Along any imaginary plane within the column , the material above the plane , because , of its weight, pushes downward on the material below the plane . Similarly ,the part of the column below the plane pushes upward with an equal force on the material above the plane.
The mutual action and reaction along a surface constitutes a stress.

Moreover, along any imaginary plane within the column there are similar action and reaction

This concept applies to any plane whether horizontal or inclined at any angle

Two- Dimensional Stress

Normal stress
Shear stress

Stress acting on a plane is a vector quantity , meaning that it has both
Magnitude and direction; it is sometimes called traction.
Stress on an arbitrarily oriented plane, however, is not necessarily perpendicular to that plane,
But like a vector , it can be resolved into component normal to the plane and parallel to the plan

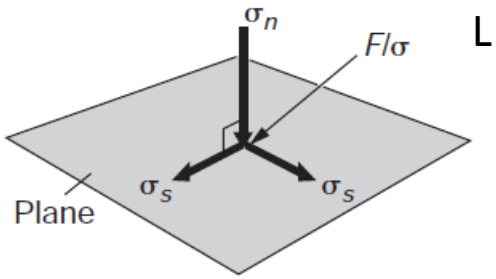
The vector component normal to the plane is called the <u>normal stress</u>
For which we use the symbol δn (some time just the symbol δ is used)

The vector component along the plane is the shear stress and has the symbol δs
(some time the symbol τ tau is used)

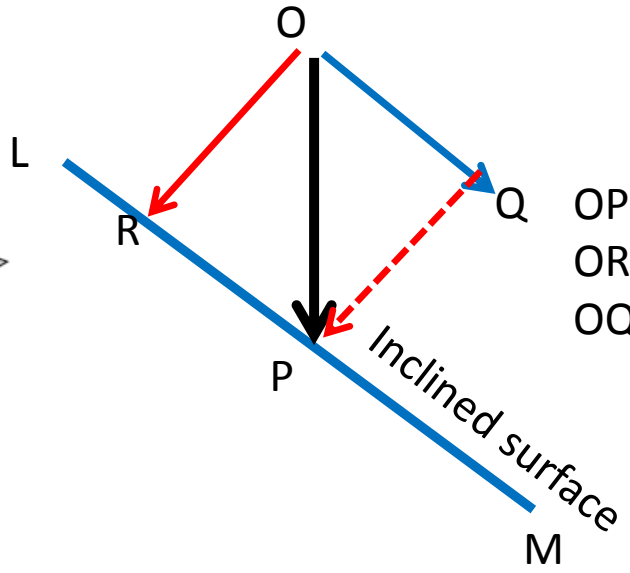
الاجهاد في بعدين

ان الاجهاد من الكميات الاتجاهية (Vector quantities) يعنى لها قيمة (magnitude) واتجاه (direction)
ويمكن ان يعمل بمختلف الاتجاهات .وبما انه متجهة اي يمكن تحليلة
الى مركبتين احدهما عمودية على المستوي (Normal Component) والاخرى موازية له(parallel) .

يطلق على المركبة العمودية بالاجهاد العمودي (Normal Stress) ويرمز له δn او δ
وعلى المركبة الموازية (اجهاد القص)(Shear Stress) ويرمز له δs واحيانا يدعى δτ (tau)



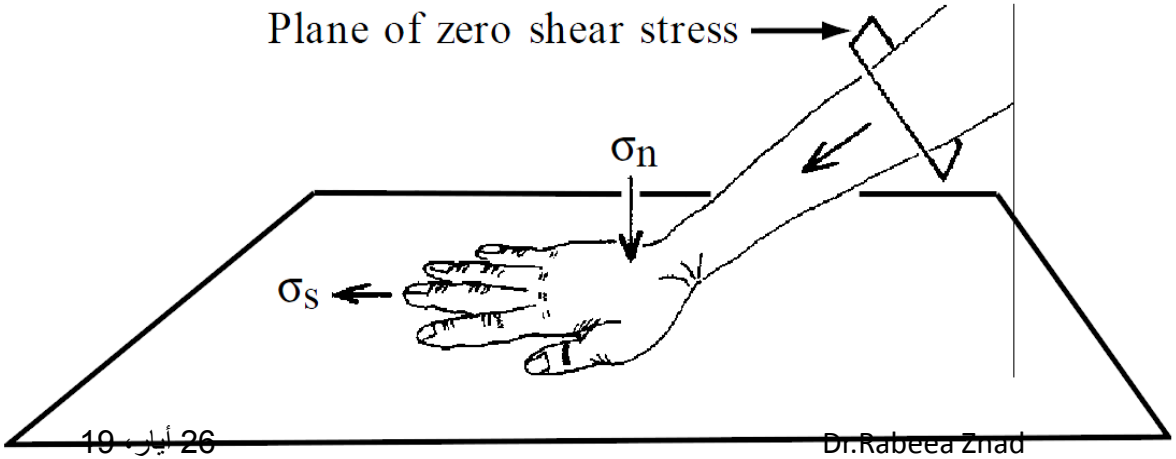
σ_n is normal stress
σ_s is shear stress
F is force; σ is stress



OP (vertical direct stress)
OR(QP) compressive stress(normal)
OQ(RP) shear stress (tangential)

The normal component is a compressive stress if tend to push together the material on opposite side of the plane. also the normal component is a tensile stress if it tend to pull a part the material on opposite sides of the plane . The tangential component is generally called a shearing stress or shear.

المركبة العمودية تمثل اجهاد كابس(Compressive Stress) اذا حاولت دفع المادة على جانبين متقابلين للمستوى.
وتمثل اجها داً ساحباً (Tension Stress) االحاولت سحب المادة على جانبين متعاكسين للمستوي. في حين تسمى المركبة المماسية بصورة عامة اجهاد القص(Shear Stress) او القص (Shear).



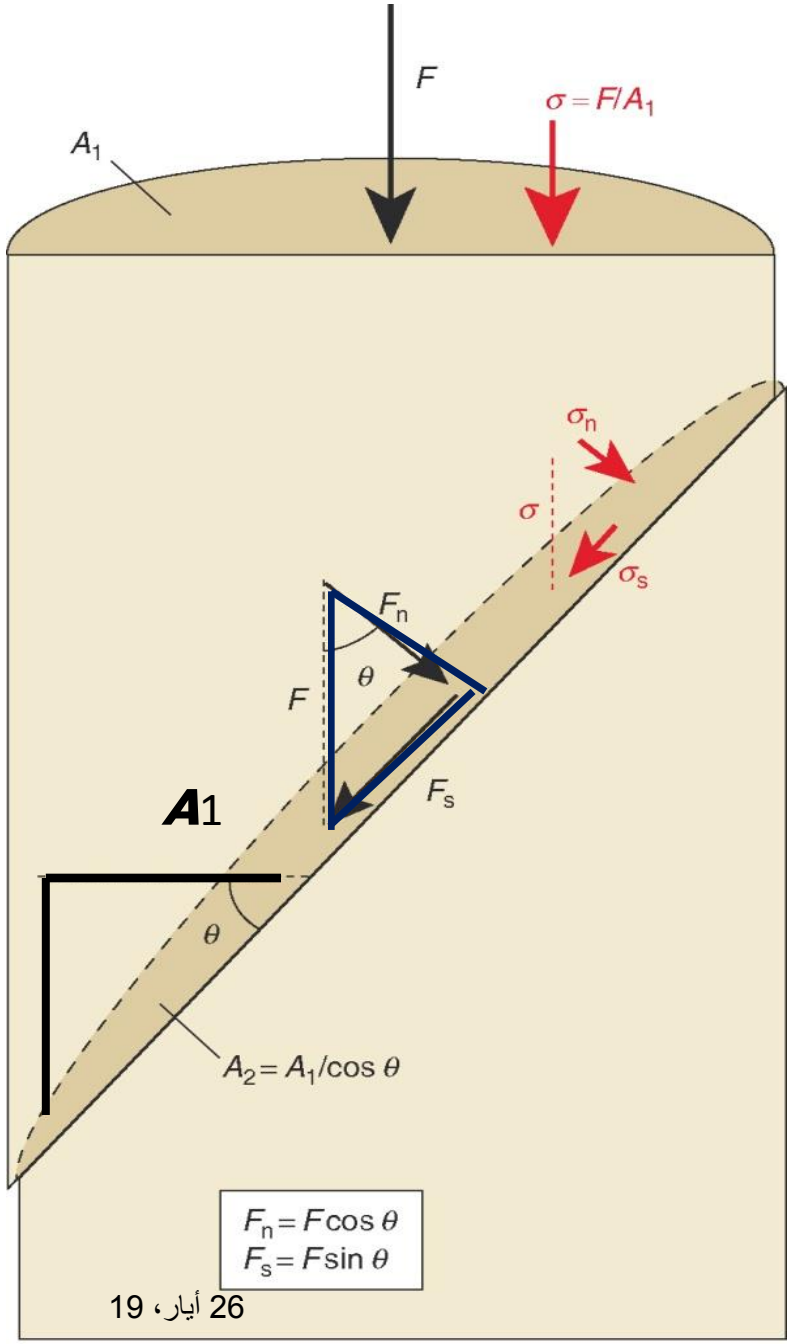
ان العلاقة بين الاجهاد العمودي والاجهاد القصي هي تعامد اي بينهما زاوية 90 درجة.

تحليل القوة والاجهاد في بعدين

Resolution of stress in two dimension

In contrast to the resolution of force , the resolution of stress into its components is not straightforward , because the area changes as a function of the orientation of the plane with respect to the stress vector.

ان تحليل مركبات الاجهاد تختلف عن تحليل مركبات القوة حيث ان مركبات الاجهاد ليست مباشرة straightforward وذلك لان المساحة العاملة عليها القوة تتغير مع تغير اتجاه المستوي وبالتالي تغير في متجة الاجهاد ومركباته.



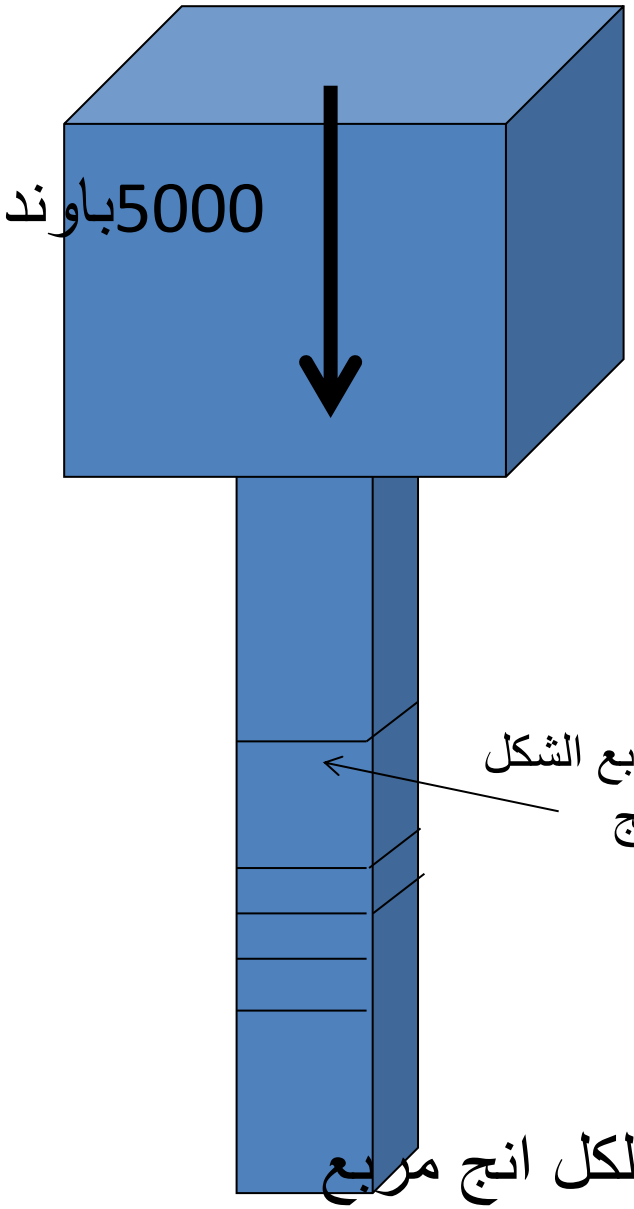
$$F_n = F\cos\theta$$
$$F_s = F\sin\theta$$

$A_2 = A_1/\cos\vartheta$

$$\sigma_n = F_n/A_2 = F\cos\theta/A_2 = F\cos^2\theta/A_1 = \sigma\cos^2\theta$$
$$\sigma_s = F_s/A_2 = F\sin\theta/(A_1/\cos\theta)$$
$$= F\sin\theta\cos\theta/A_1 = \sigma\sin\theta\cos\theta$$

what is the difference between force component and stress component

Calculation Of Stress حساب الجهد



There is no direct way to measure the stress in a body , but they may be calculated if the external forces are known . If a body is compressed or stretched, the stress is referred to a plane perpendicular to the direction in which the external forces are acting.

If a vertical column 10 inches on a side support a load 5000 pound,

Every plane in the column is subjected to a compressive force of 5000 pond. To calculate stress:-

مساحة مقطع الدعامة= طول الضلع *نفسه

10*10= 100 انج مربع

الجهد= الوزن(القوة)/المساحة

50=100/5000

الجهد= (50باوند على الانج المربع)

دعامة ذات مقطع مربع الشكل

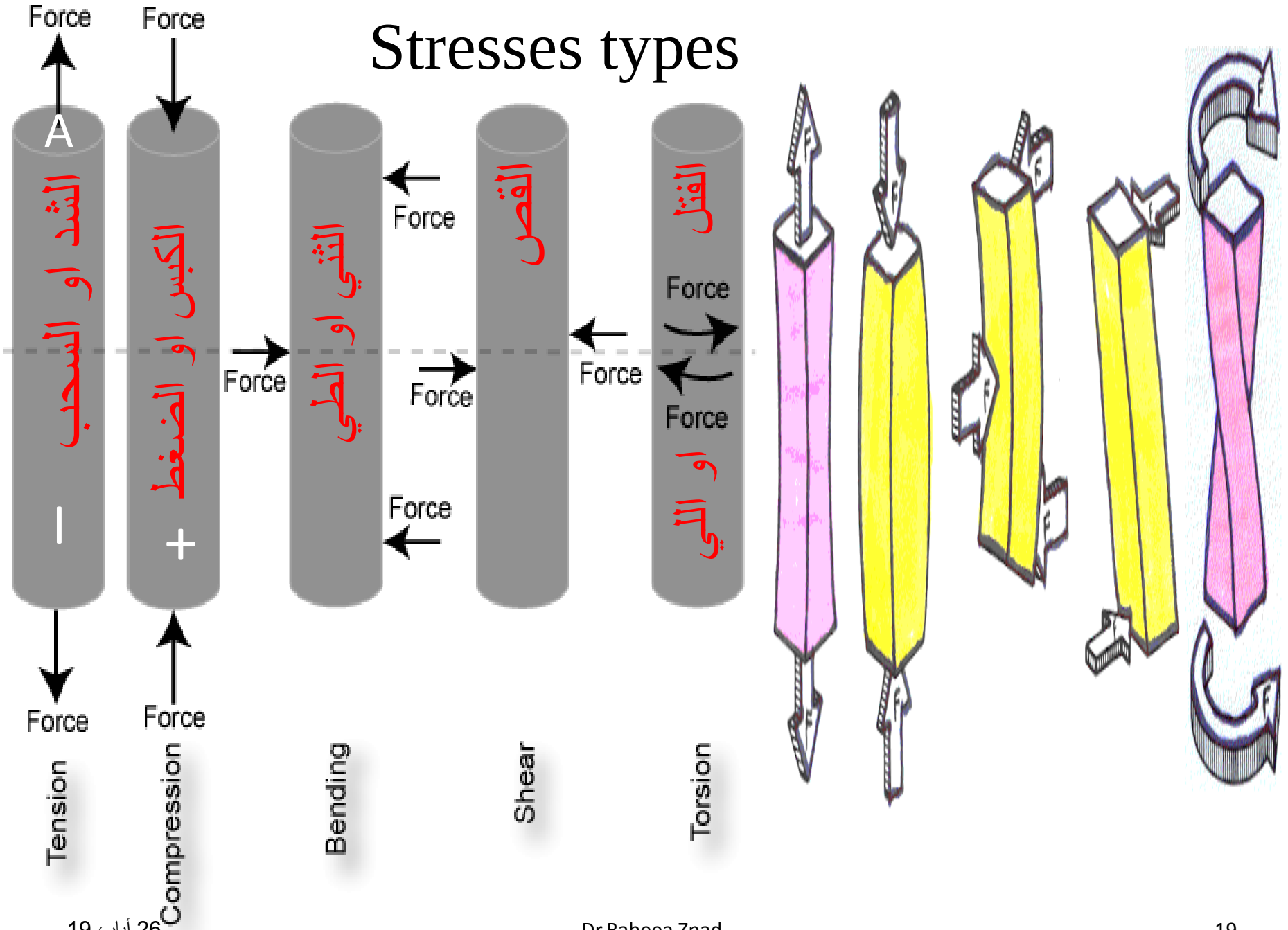
طول ضلعها 10 انج

اي ان كل انج مربع من هذة المستويات الافقية يسند ثقلا مقداره

50 Pound

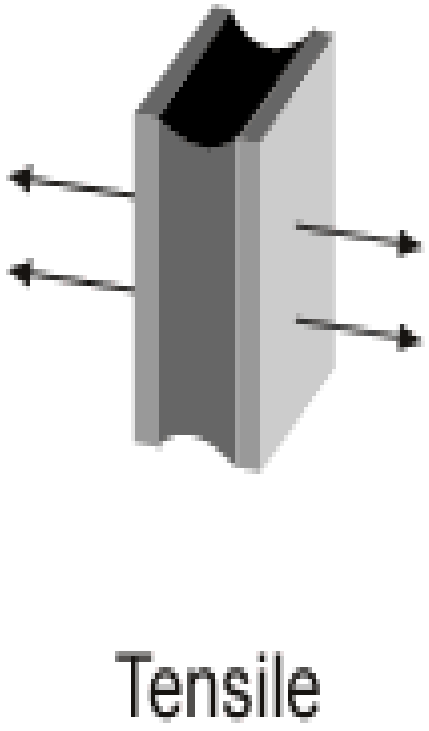
ويقال ان الاجهاد الكابس او العمودي يبلغ 50 باوند لكل انج مربع

Stresses types

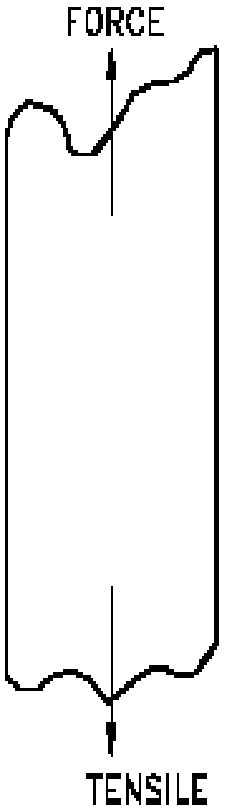


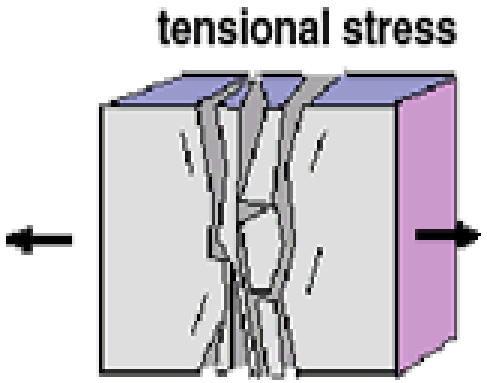
Tensile stress is the ratio of the tensile load **F** applied to the specimen to its original cross-sectional area **A**

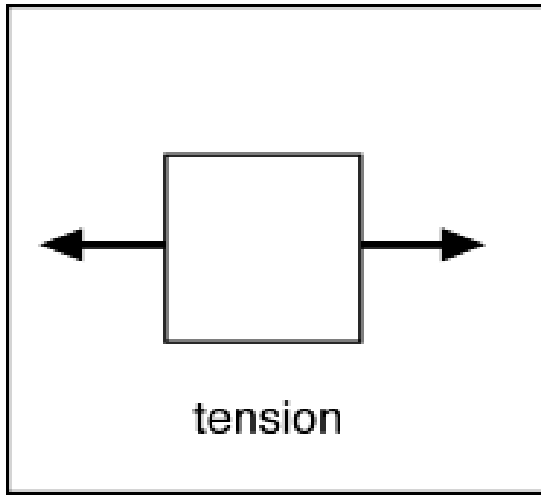
$$S = F / A$$



Tensile

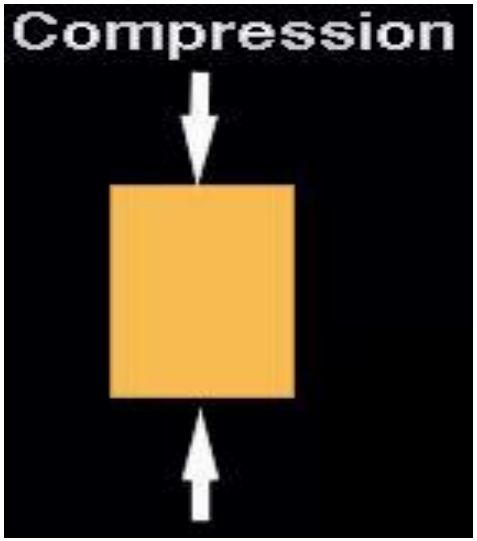


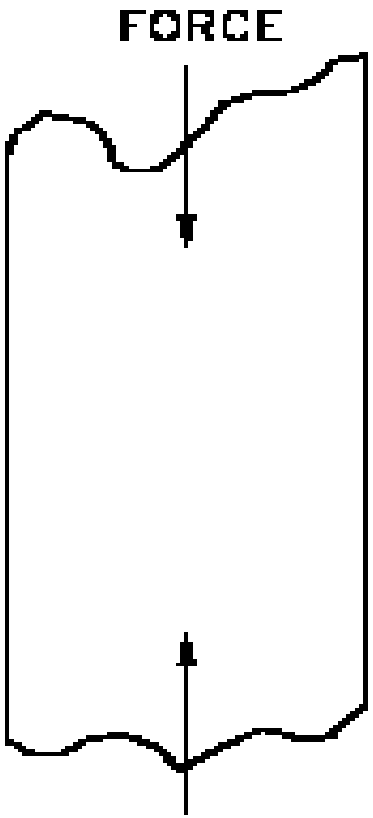


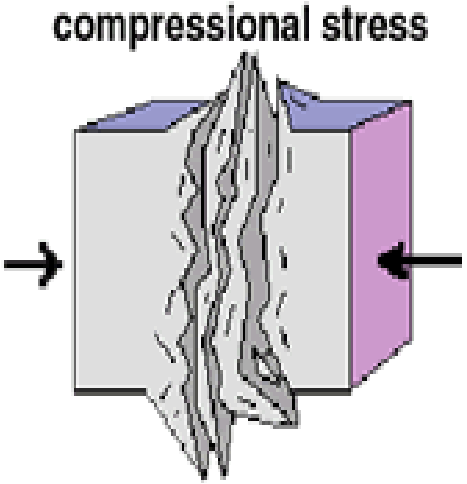


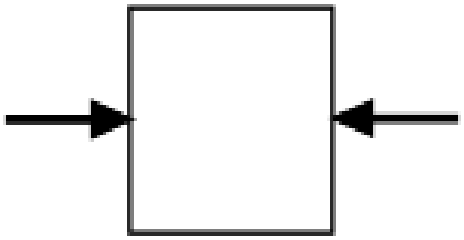
Compressional stress is the ratio of the compression load **F** applied to the specimen to its original cross-sectional area **A**

$$S = F / A$$



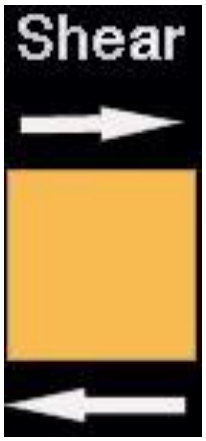


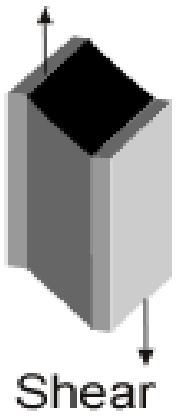


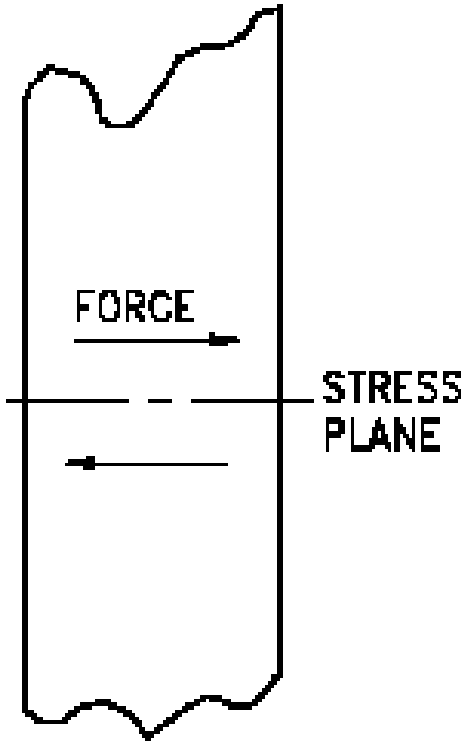


Shear stress is the ratio of the force **F** applied to the specimen to its original cross-sectional area **A**

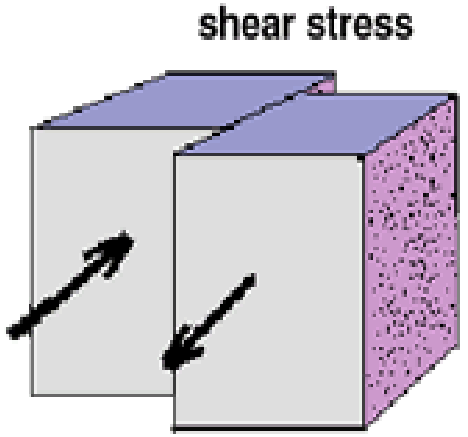
$$S = F / A$$

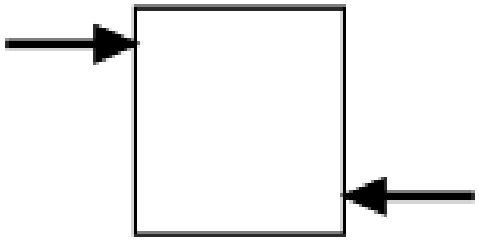






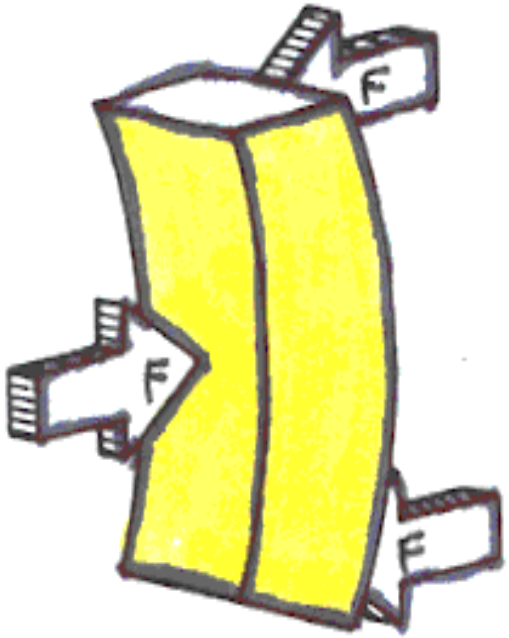
SHEAR



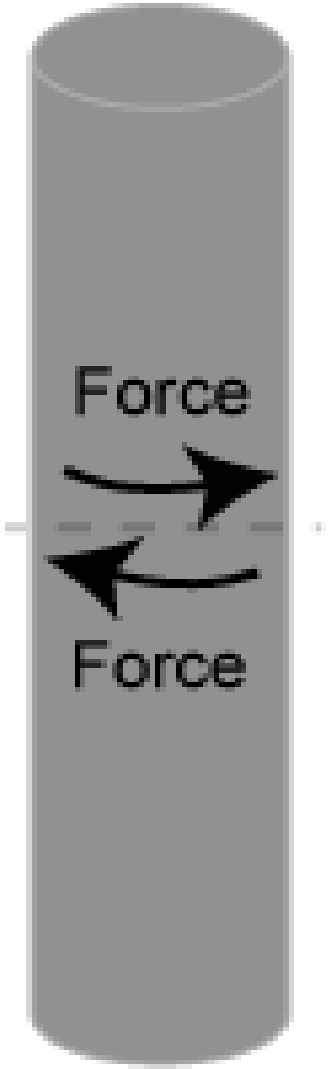


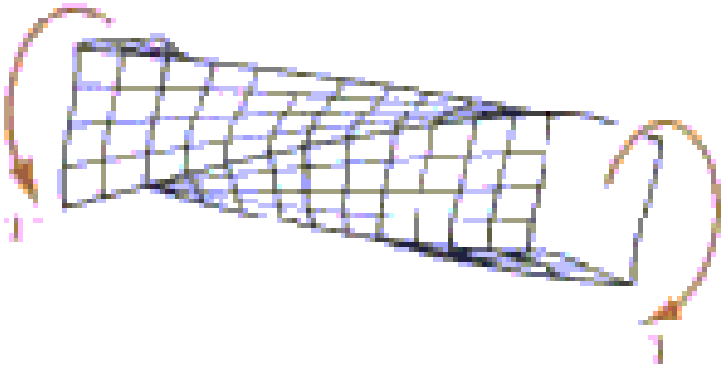
shearing

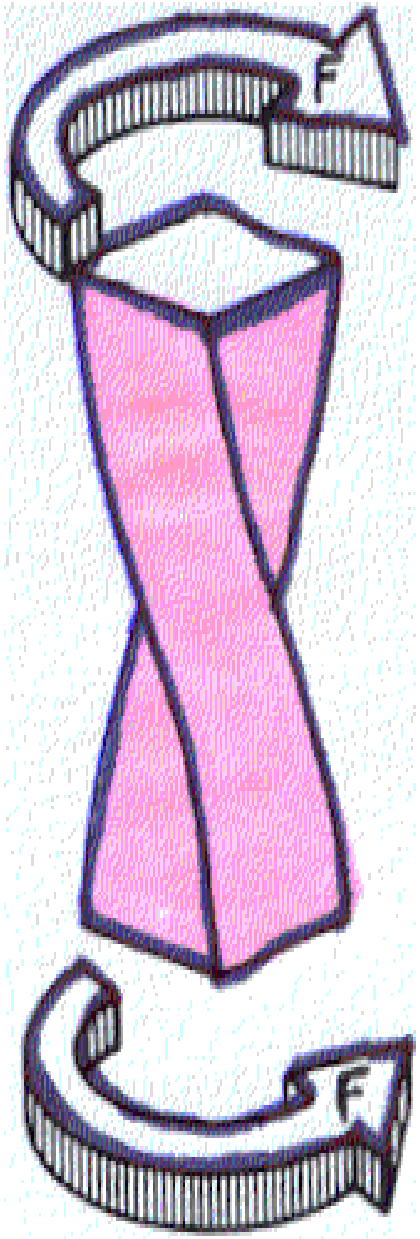
Bending is a combination of tension and compression.
Consider the bending of an object such as a piece of tubing.
The upper portion stretches (tension) and the lower portion crushes together (compression).

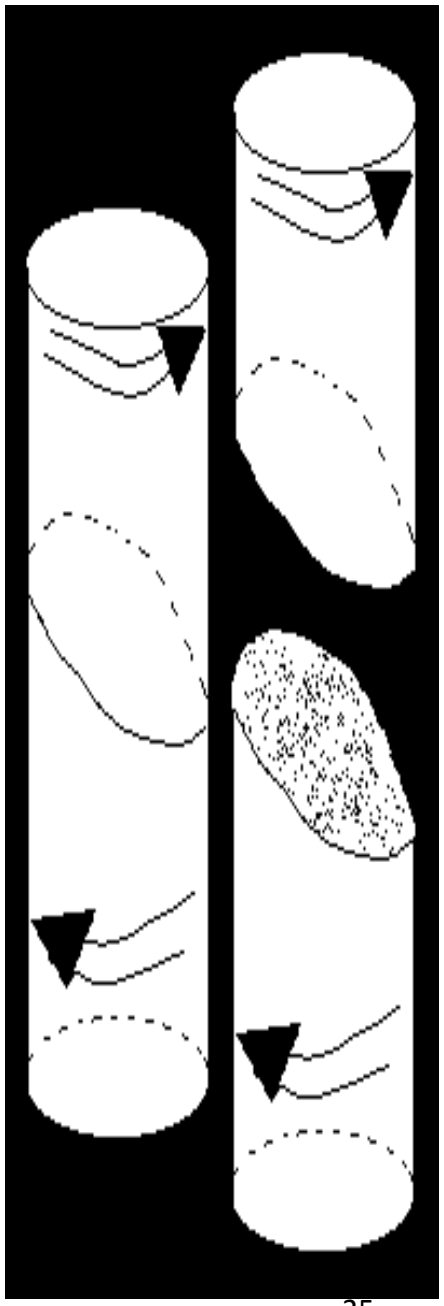


Torsional stresses are the result of a twisting force. When you wring out a chamois skin, you are putting it under torsion..






F
F



Deformation and Strain

Deformation and strain are closely related terms that are sometimes used as synonyms But they are not the same.

Component of deformation

deformation describes the complete transformation from the initial to the final geometry of a body. This change can include a (deformation components):-

Translation (movement from one place to the other)

Rotation(spin around an axis)

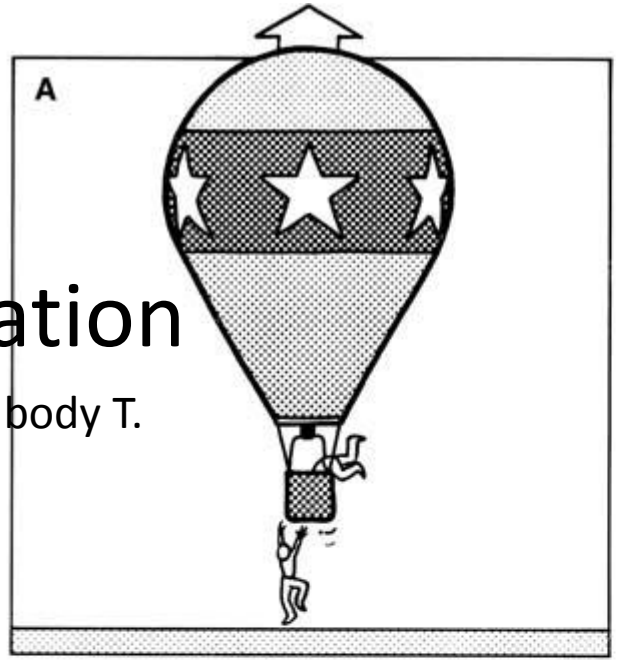
Distortion(change in shape)

Dilation or Dilataion(change in area or volume positive or negative)

another definition

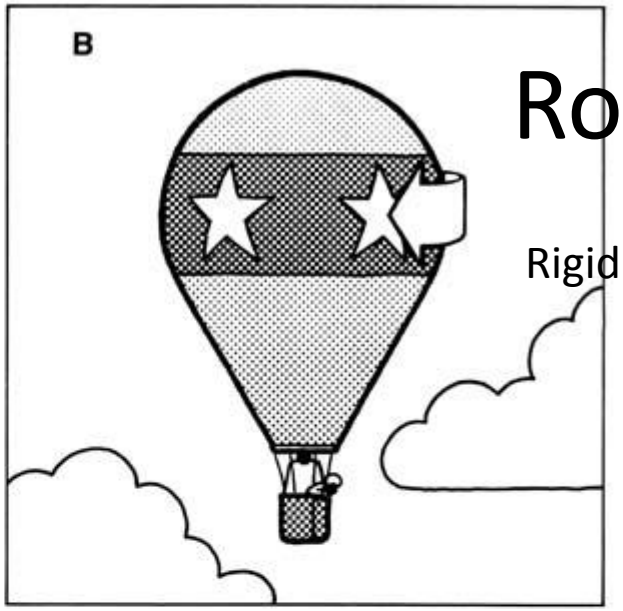
Deformation refer to changes in shape ,position , or orientation of a body resulting from the application of a differential stress
(i.e.,a state in which the magnitude of stress is not the same in all directions)

COMPONENT OF DEFORMATION



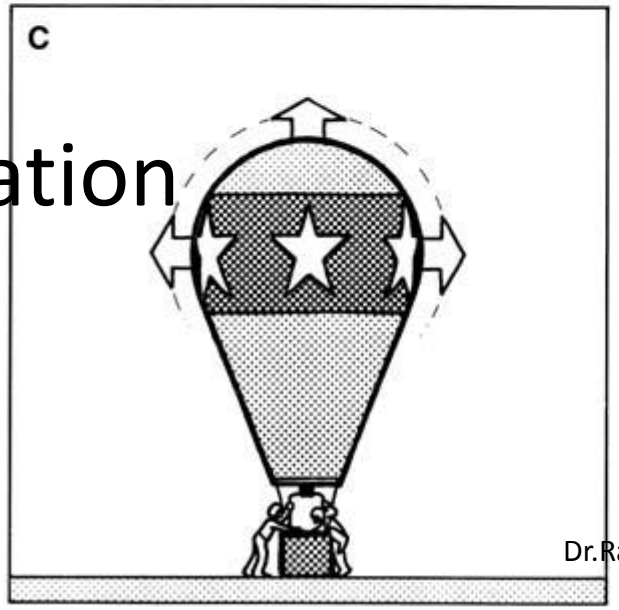
Translation

Rigid body T.

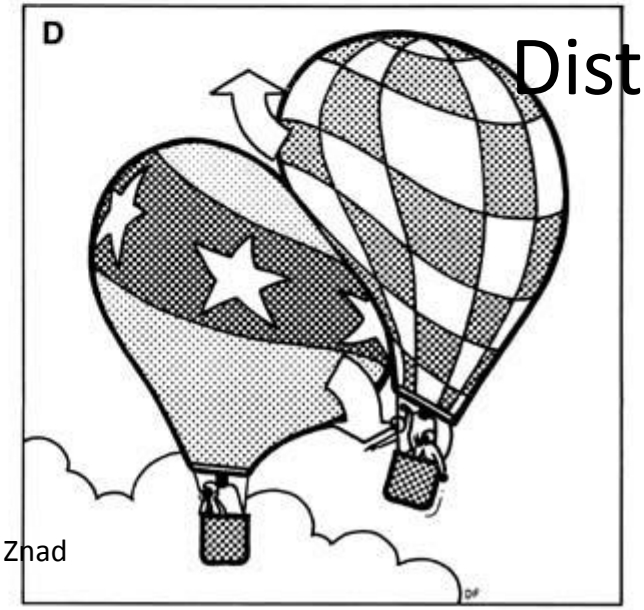


Rotation

Rigid body R.



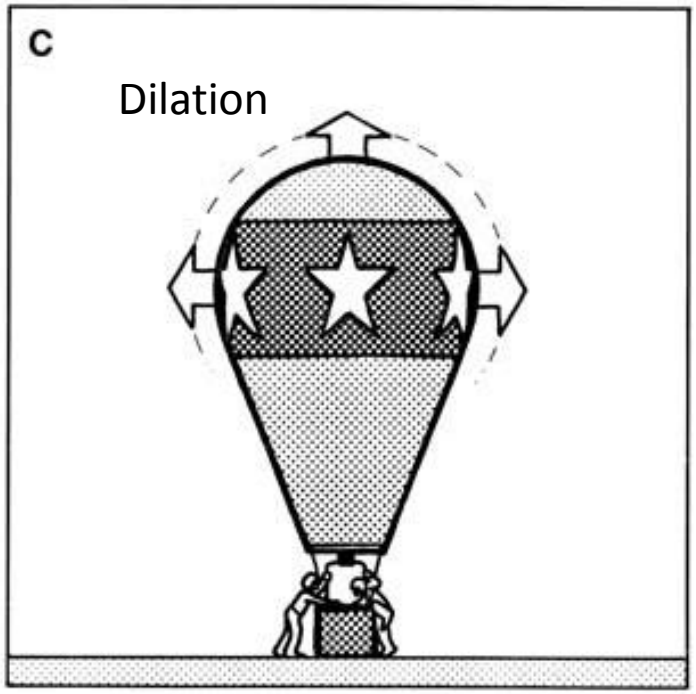
Dilation

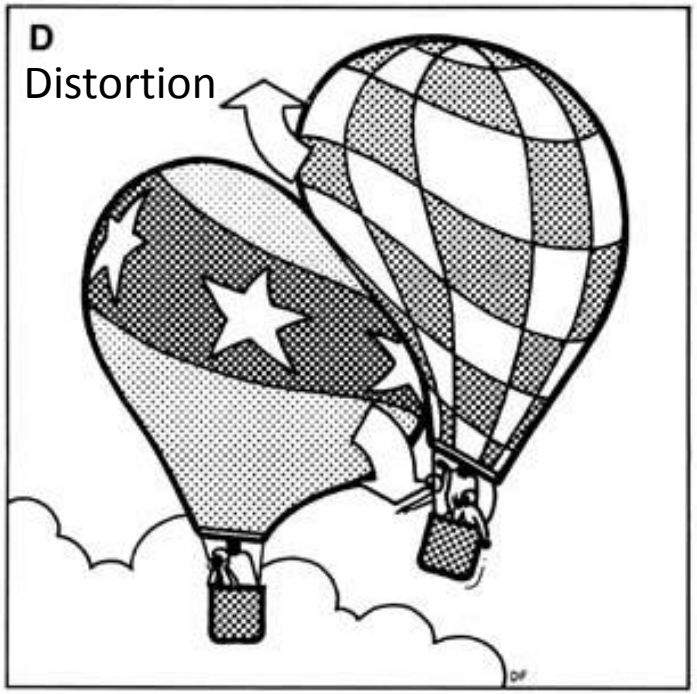


Distortion

Strain: any change in shape , with or with out change in volume ,is referred to as strain ,so, it describes the distortion of a body

الانفعال Strain هو ايضا التحريف الناتج عن الاجهاد ولكنة يصف التحولات(الانفعال) التي تطرأ داخل الجسم نفسة المتضمنة التغير في الحجم Dilation او الشكل Distortion او كلاهما.



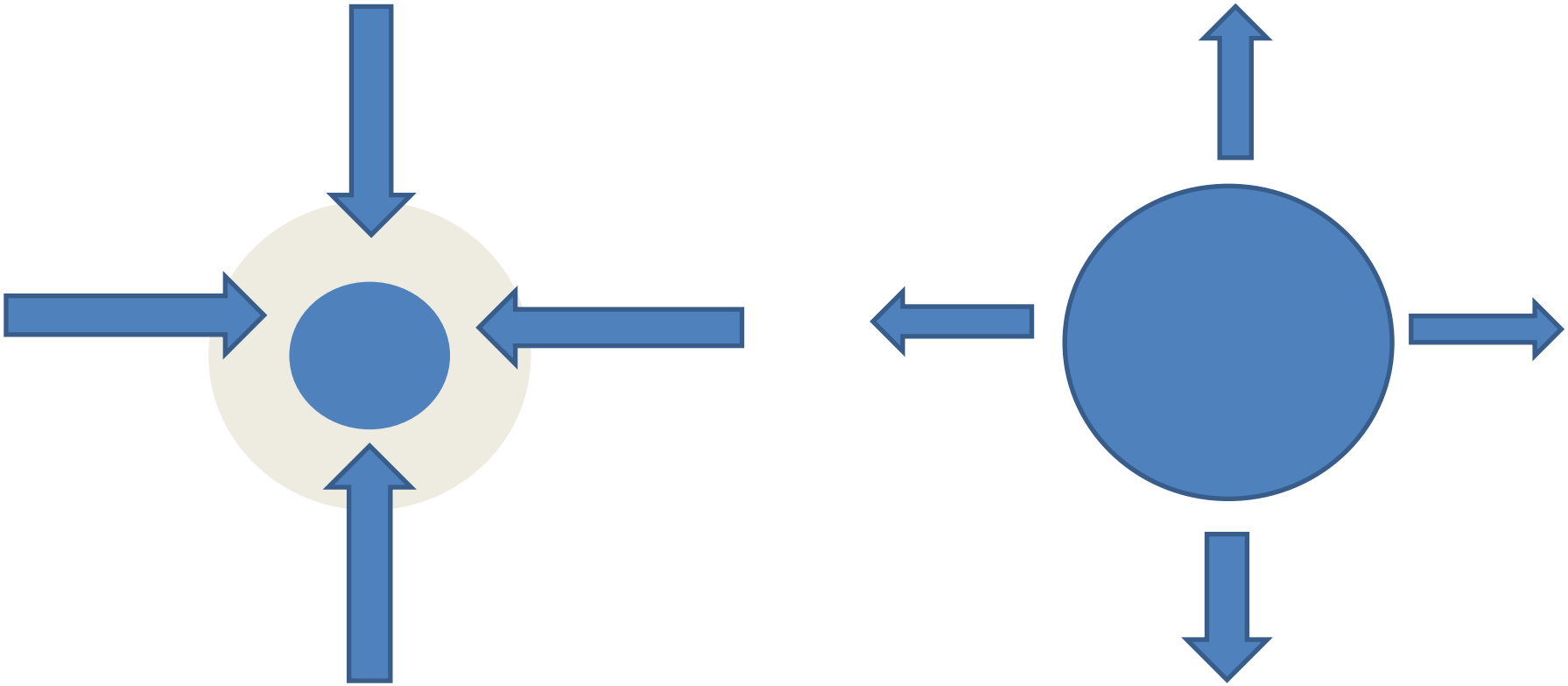


In other word: strain represent one of deformation component

بكلمة اخرى ان الانفعال Strain يمثل احد مكونات التحريف Deformation

مثال على الـ Dilation :

عندما يسلط ضغط حاصر Confining Pressure على جسم موحد الصفات Isotropic body فان هذا الجسم سوف يتغير حجمه. فإذا زاد الضغط قل حجم الجسم .أما إذا قل الضغط فان الحجم سوف يزداد، أي أن العلاقة عكسية.



مثال على التشوه :Distortion

إن الجهد بأسلوب التشوه **Distortion**
هو حالة عامة ويحدث تحت تأثير القوى الموجهة ، فمثلاً سحب جسم معدني سوف يغير من شكله وأحياناً حجمه أيضاً. (شرح على الرسم أدناه)

مساحة المقطع 1
انج مربع

الطول 10 انجات قبل تسليط القوة

قوة الشد 20.000 باوند ستمط القضيب 0.007 من الانج

اذن الاجهاد هو 20.000 باوند على الانج المربع

اما مقدار الانفعال= مقدار الزيادة/الطول الاصلي

0.0007 = 0.007/10 انج لكل انج