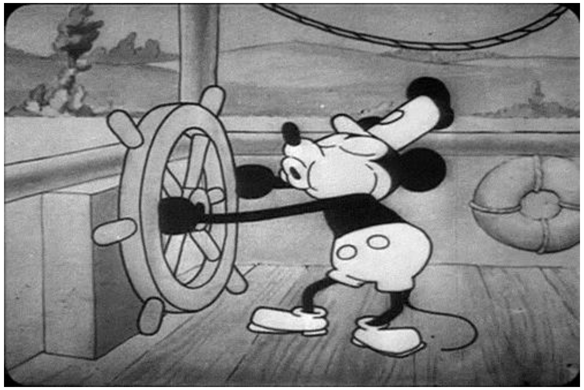
WORCESTER POLYTECHNIC INSTITUTE
MECHANICAL ENGINEERING DEPARTMENT

STRESS ANALYSIS
ES-2502, D'2020

We will get started soon...



03 April 2020

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Lecture 06:
Unit 5: Strain: definition of normal strain and shear strain

03 April 2020

General information

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Design of simple connections

Allowable stress: safety factor (SF)

$$SF = \frac{F_{fail}}{F_{allow}}$$

In terms of forces

or

$$SF = \frac{\sigma_{fail}}{\sigma_{allow}}$$

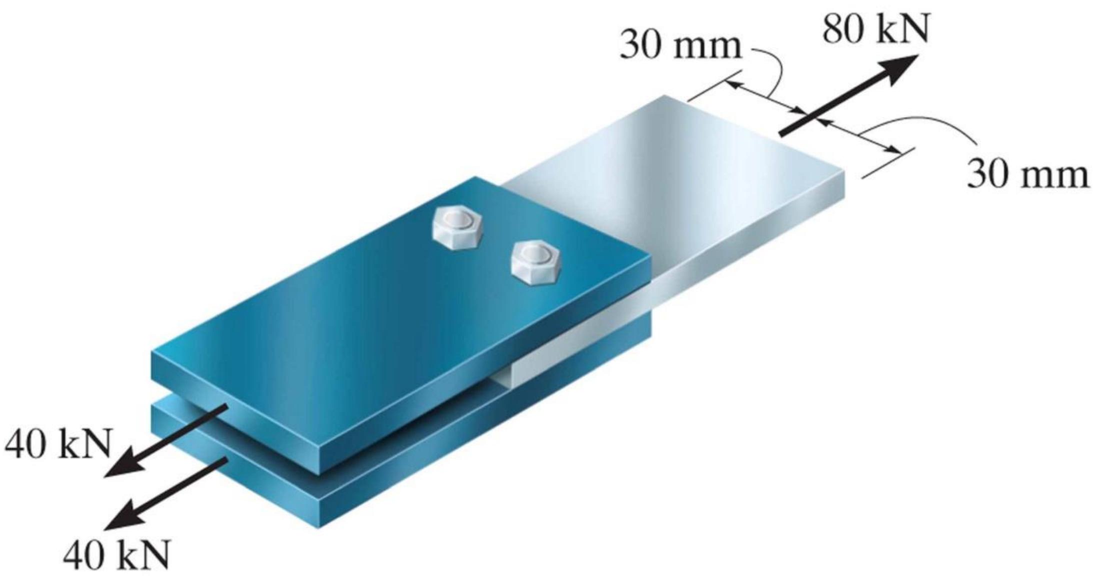
In terms of normal stresses

$$SF = \frac{\tau_{fail}}{\tau_{allow}}$$

In terms of shear stresses

Design of simple connections: example D

The joint is fastened together using two bolts. Determine the required diameter of the bolts if the failure shear stress for the bolts is $\tau_{fail} = 350\ MPa$. Apply a safety factor for shear of 2.5.

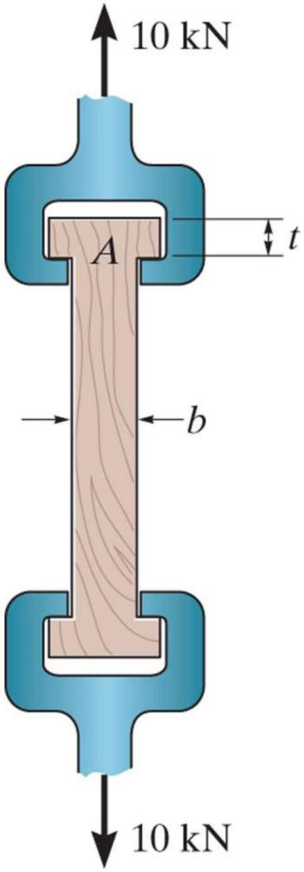


Approach:

1) Define free-body diagrams
2) Determine internal loadings
3) Use safety factor
4) Compute diameter

Design of simple connections: example E

The wood specimen is subjected to the pull of $10\ kN$ in a tension testing machine. If the allowable normal stress for the wood is $\sigma_{allow} = 12\ MPa$ and the allowable shear stress is $\tau_{allow} = 1.2\ MPa$ determine the required dimensions b and t so that the specimen reaches these stresses simultaneously. The specimen has a depth of 25 mm.



Approach:

1) Define free-body diagrams
2) Determine internal loadings
3) Compute b and t using stress equations

Strain

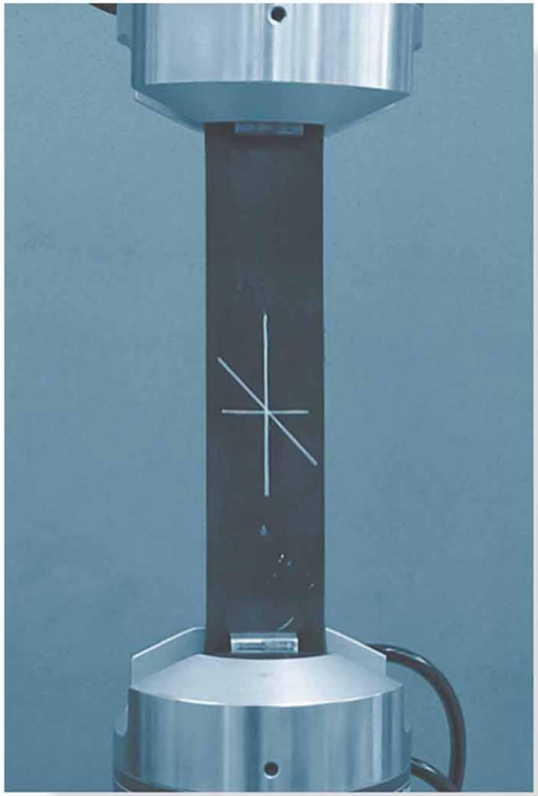


Figure: 02-01-A-UN

Note the before and after positions of three different line segments on this rubber membrane which is subjected to tension.The vertical line is lengthened, the horizontal line is shortened, and the inclined line changes its length and rotates.

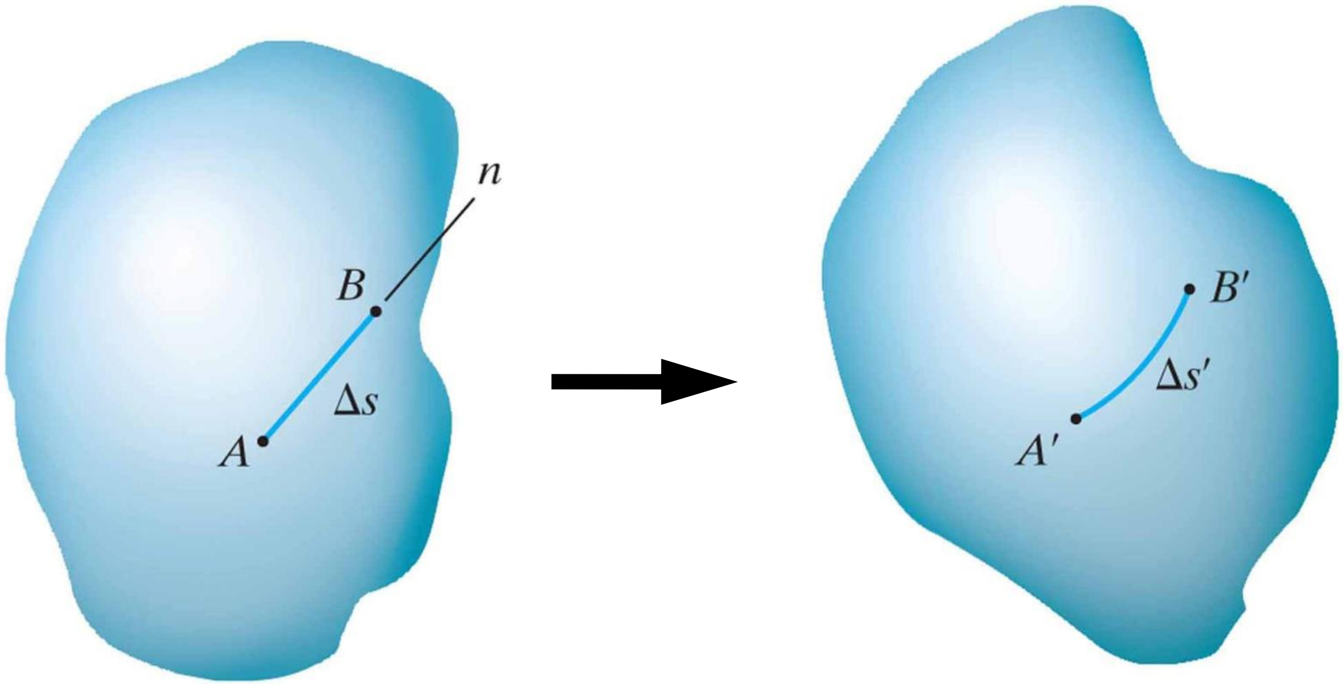
Observe what happened to the white line segments in this tensile test experiment

Figure: 02-01-B-UN

Note the before and after positions of three different line segments on this rubber membrane which is subjected to tension.The vertical line is lengthened, the horizontal line is shortened, and the inclined line changes its length and rotates.

<u>Strain</u>: definition: change in length per unit length

Normal strain

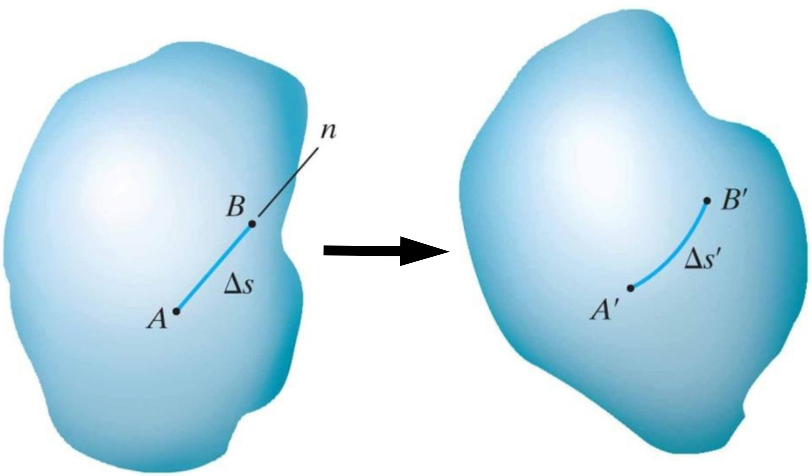


Undeformed body
(a)

Deformed body
(b)

Strain: definition: change in length per unit length

Normal strain



Undeformed body
(a)

Deformed body
(b)

Average normal strain:

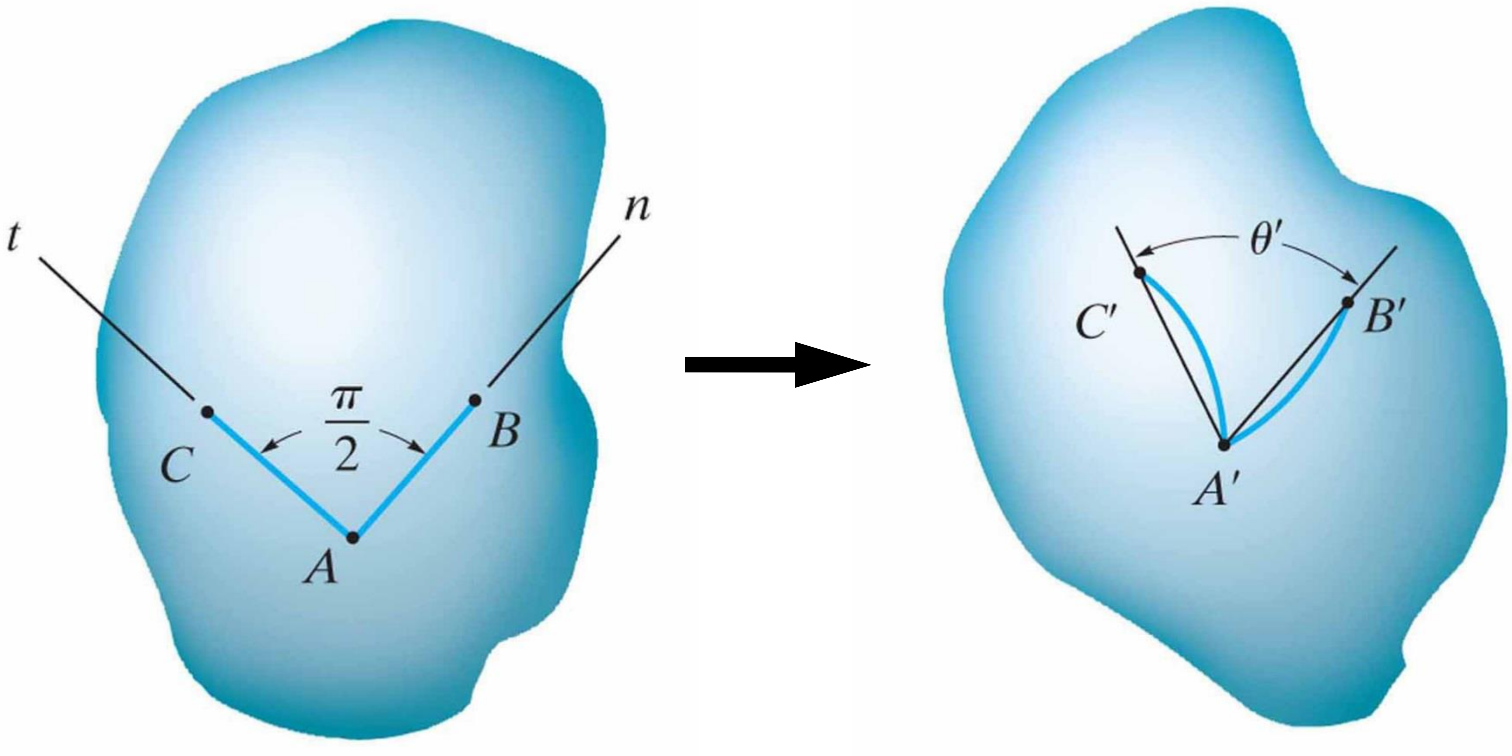
$$\varepsilon_{avg} = \frac{\Delta s' - \Delta s}{\Delta s}$$

Normal strain:

$$\varepsilon = \lim_{B \to A \ along \ n} \frac{\Delta s' - \Delta s}{\Delta s}$$

<u>Strain</u>: definition: change in length per unit length

Shear strain

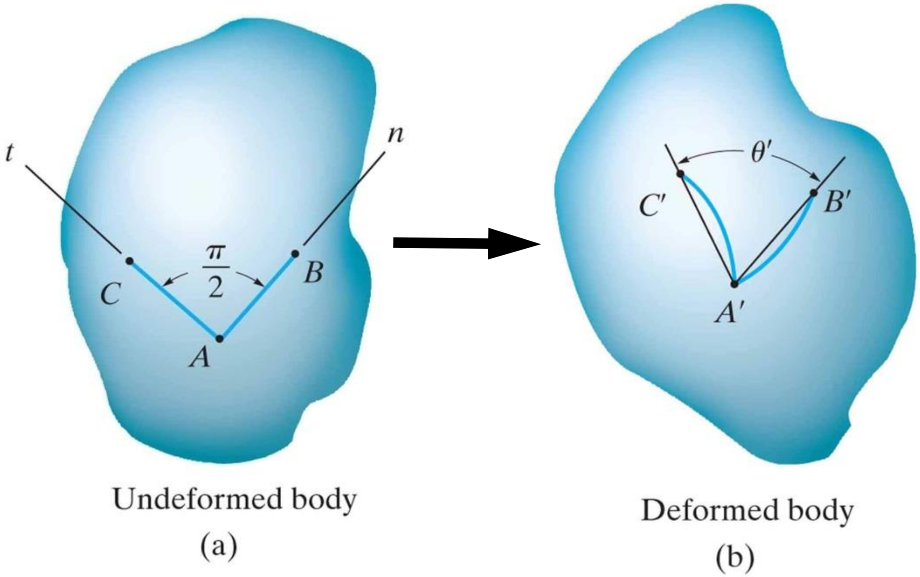


Undeformed body
(a)

Deformed body
(b)

Strain: definition: change in length per unit length

Shear strain



Shear strain:

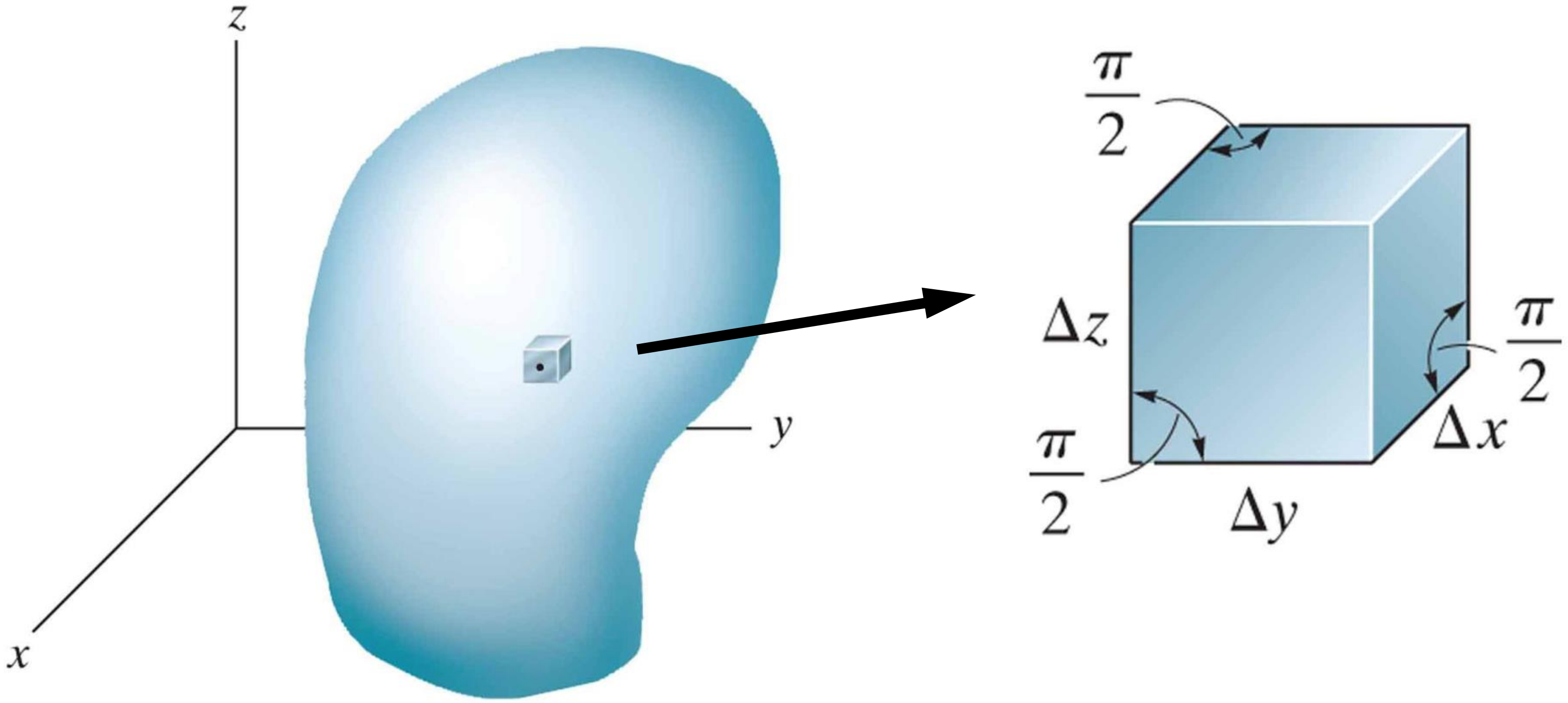
$$\gamma_{nt} = \frac{\pi}{2} - \lim_{\substack{B \to A \text{ along } n \\ C \to A \text{ along } t}} \theta'$$

Cartesian strain components

Before deformations

Differential element or cube (undeformed)

Dimensions: Δx, Δy, Δz



Cartesian strain components

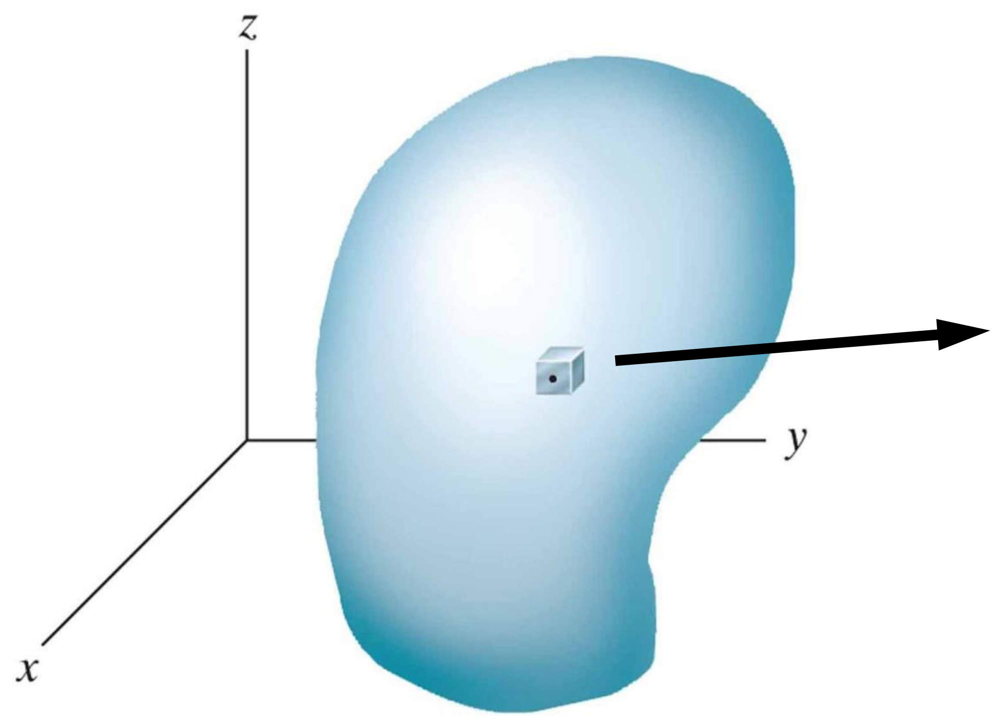
After deformations

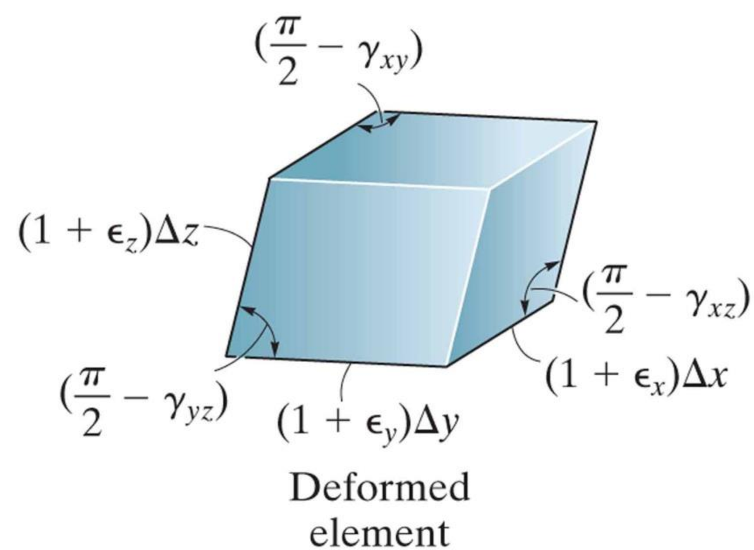
Differential element or cube (deformed)

New dimensions: $\Delta x + \varepsilon_x(\Delta x)$

$\Delta y + \varepsilon_y(\Delta y)$

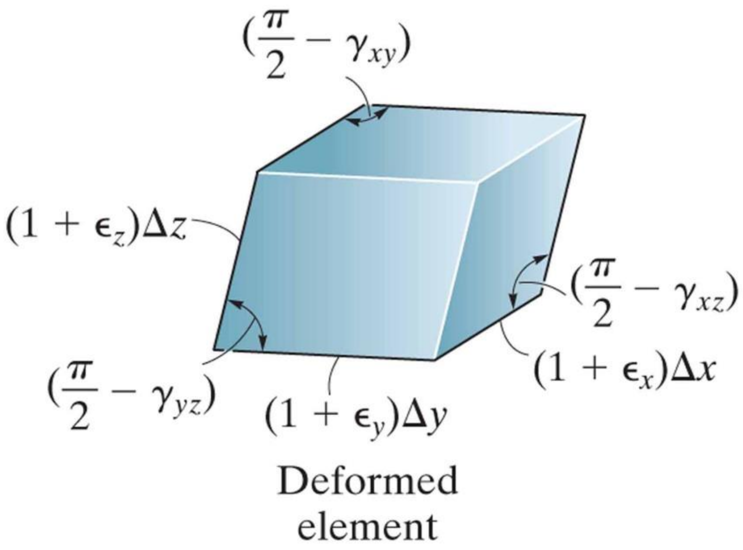
$\Delta z + \varepsilon_z(\Delta z)$





Cartesian strain components

Differential element or cube (deformed)



Original dimensions

Elongations

New dimensions:

$$\Delta x + \varepsilon_x(\Delta x)$$
$$\Delta y + \varepsilon_y(\Delta y)$$
$$\Delta z + \varepsilon_z(\Delta z)$$

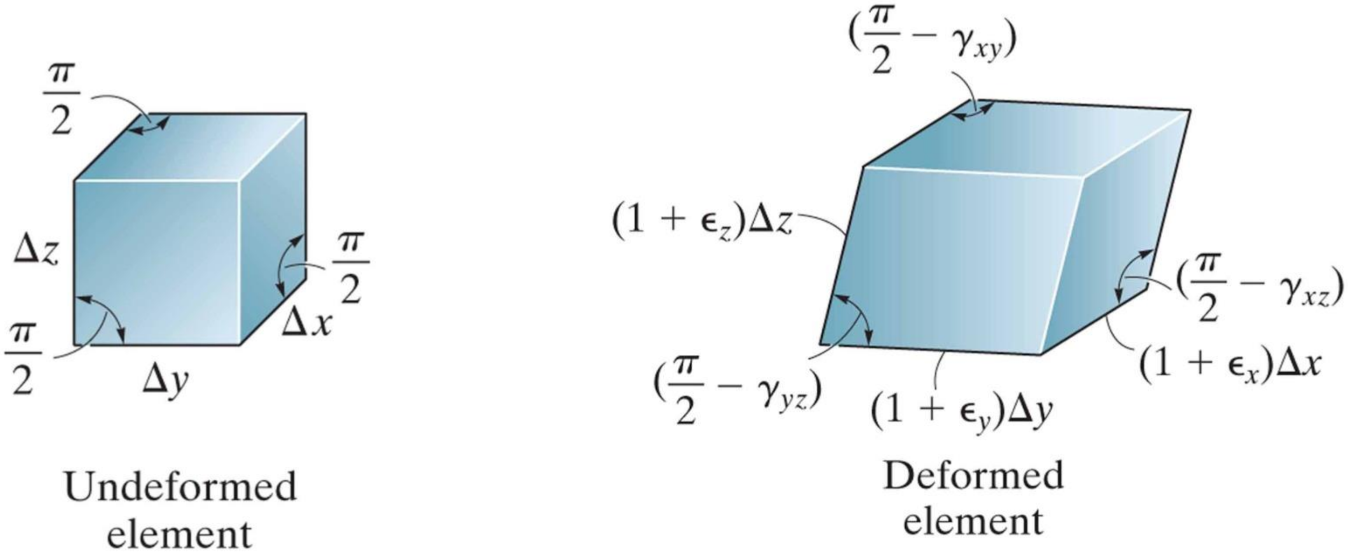
Approximate angles between sides:

$$\frac{\pi}{2} - \gamma_{xy} \ , \quad \frac{\pi}{2} - \gamma_{yz} \ , \quad \frac{\pi}{2} - \gamma_{xz}$$

Cartesian strain components

1) Normal strains cause a change in volume of the element
2) Shear strains cause a change in its shape
3) Normal and shear strains occurs simultaneously during deformation
4) State of strain at a point on a body requires: ε_x, ε_y, ε_z, and

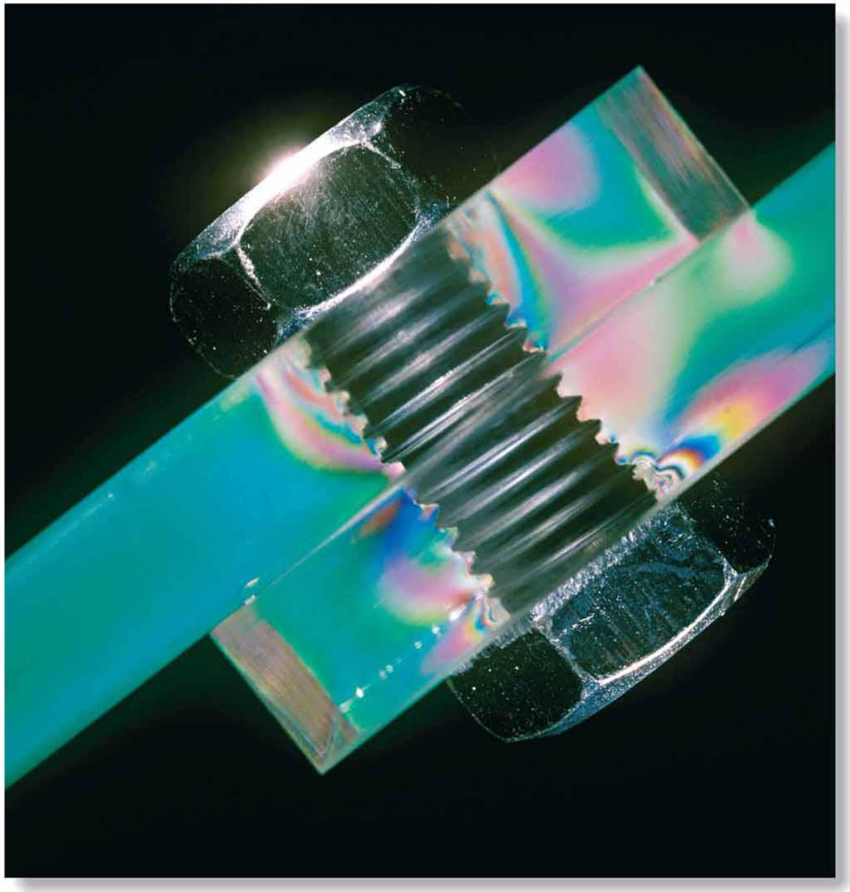
γ_{xy}, γ_{yz}, γ_{xz}



Typical strain distributions generated inside a bolted assembly

Polarized light used in experiment shown: bolted assembly

Strains are related to stresses in the materials

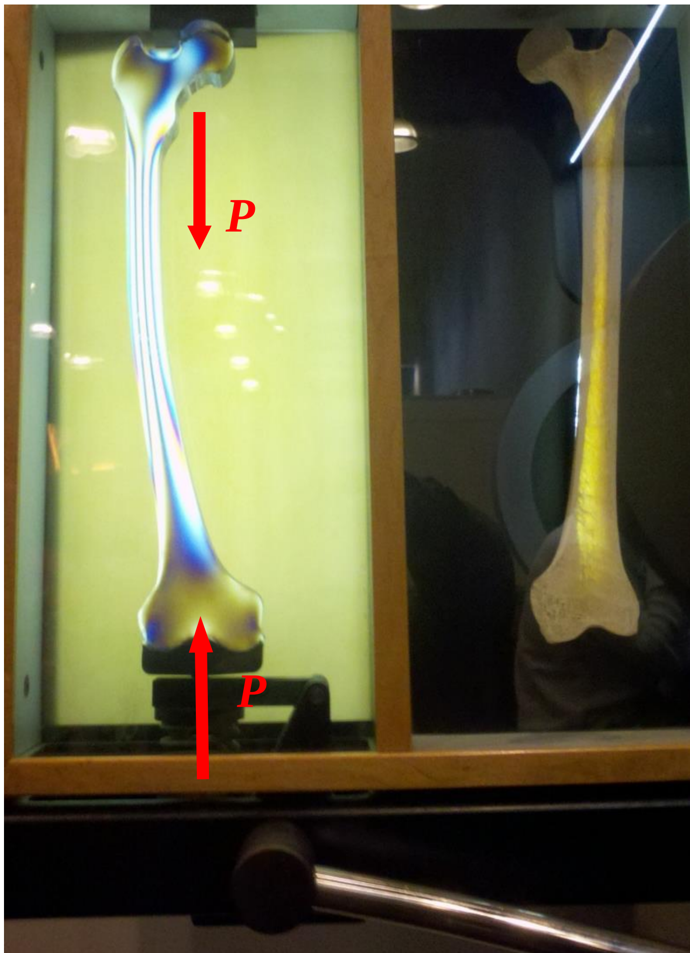


Strains can be measured and stresses estimated from strains

Typical strain distributions generated inside a bolted assembly

Polarized light used in experiment shown: component in compression

Strains are related to stresses in the materials



Strains can be measured and stresses estimated from strains

Reading assignment

- Chapter 1 of textbook
- Review notes and text: ES2001, ES2501

Homework assignment

- As indicated on webpage of our course