orthodontics

conservative dentistry

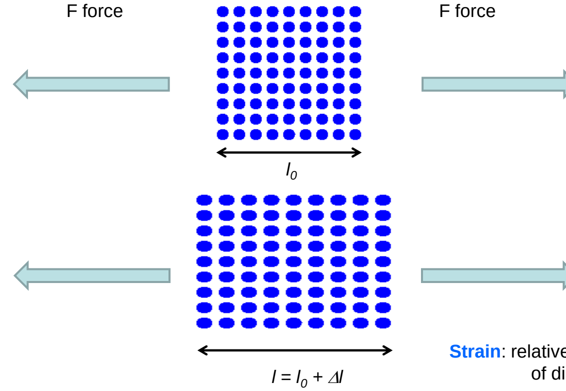
prosthetic dentistry

Physical basis of dental material science 7.

Mechanical properties 1.

1

crystal



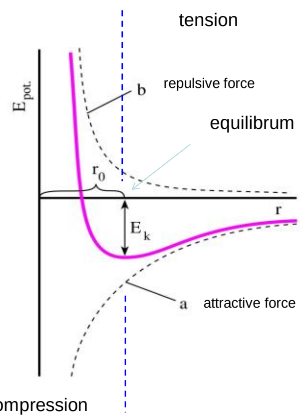
Strain: relative changing of dimensions.

The integrity of the object doesn't change!
Only the size changes!

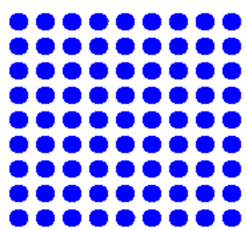
$$\varepsilon = \frac{\Delta l}{l_0} = \frac{l - l_0}{l_0}$$

2

Internal forces compensate external foces



lattice



Both elongation and compression result opposite atomic forces!

3

Characterization of the load:

stress(σ):

$$\sigma = \frac{F}{A_0} \qquad [\sigma] = \frac{\mathrm{N}}{\mathrm{m}^2} = \mathrm{Pa}$$

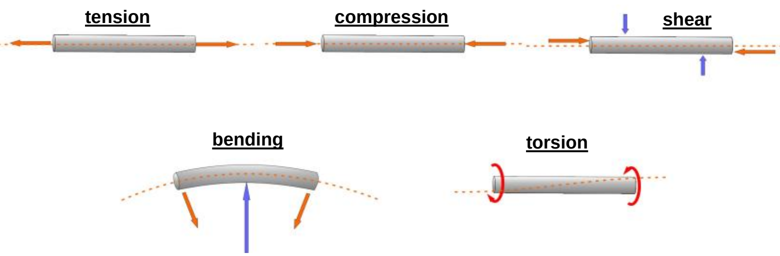
Engineering system! (No drastic change in shape, e.g. A_0 is constant!)

⇨ Internal stresses

4

Deformations (an object gets changed due to force)

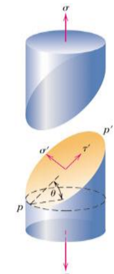
force → deformation



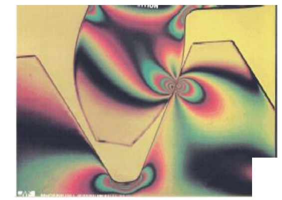
Isotrope material: properties are independent from the direction.

(arrows = forces – direction and magnitude)

Examination of the stress distribution

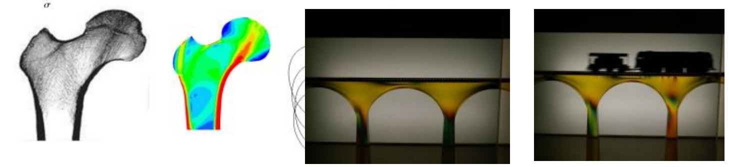


- **Experimental methods**: optical measurments

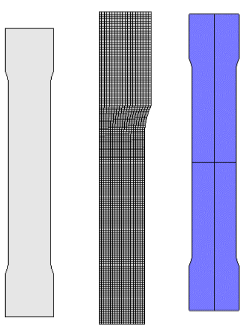


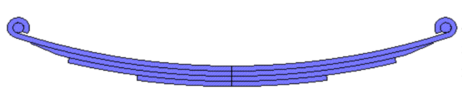
e.g. :
usage of polarized light

(observation of anistropy produced by the force)



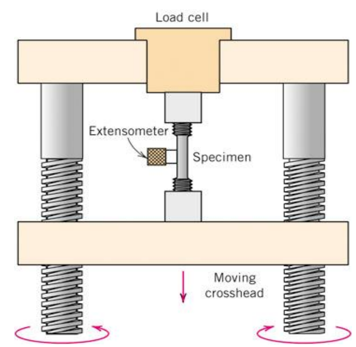
- **Theoretical method**:
Finite Element Method
(computer builds up the body from small elementary shapes.)



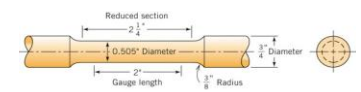


Physical test methods

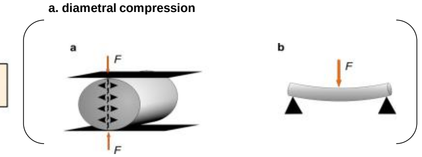
1. tension test



standard body



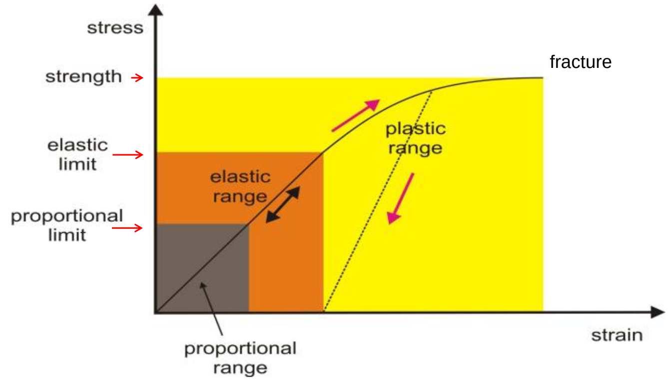
a. diametral compression



b. 3-point bending test

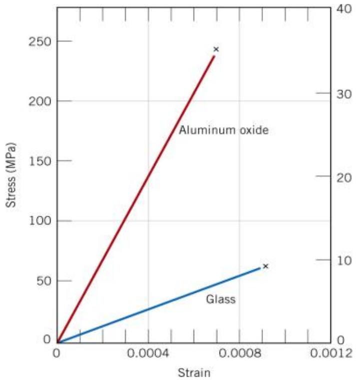
Stress-strain diagram

strength: maximum of the stress
elastic limit: maximum stress in elastic range
proportional limit: maximum stress in the proportional range



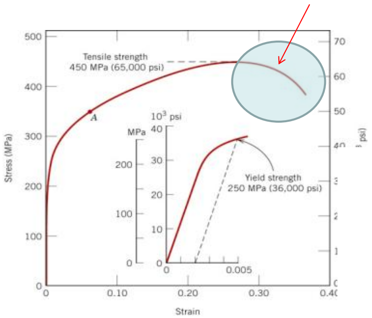
examples:

ceramics



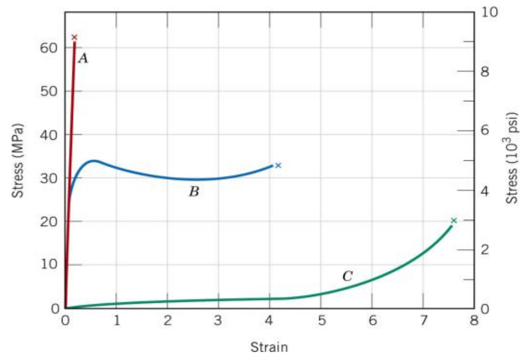
metals, e.g. brass

???

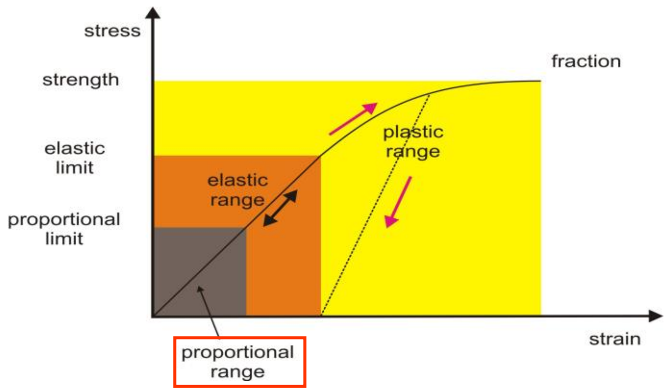


A: hard (glass -like)
B: semi-crystalline
C: rubber

polymers



Stress-strain diagram



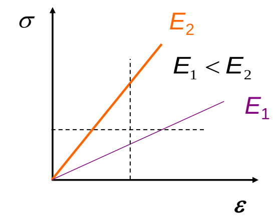
Elasticity (to the proportional limit)

- tension/compression

strain →
relative tension/compression (changing of the length):

$\varepsilon = \frac{\Delta l}{l_0}$ $[\varepsilon] = \text{no unit}$

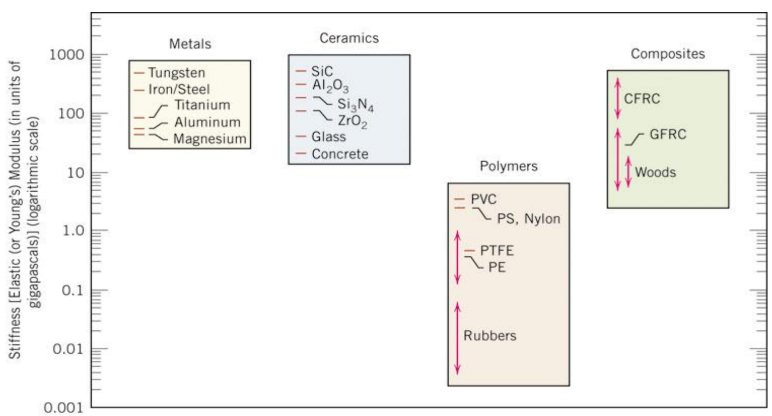
Hooke's law: $\sigma = E \cdot \varepsilon$ E — **elastic**(Young's) **modulus** $[E]$ = Pa



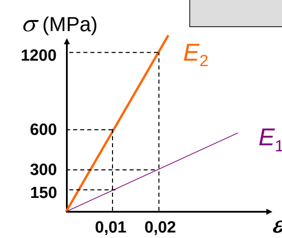
E — resistance against the tension or compression, **stiffness**

$1/E$ — propensity for tension or compression, **elasticity**

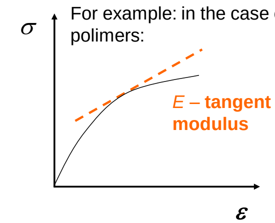
Stiffness of different materials



E.g.:



For example: in the case of many polimers:

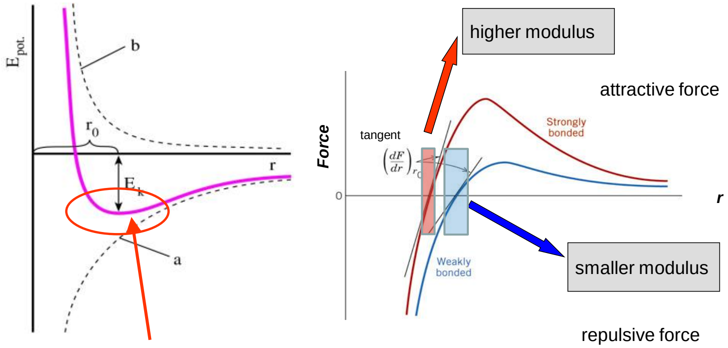


Stiffnes of a few dental materials:

material	E (GPa)
Enamel of the teeth	≈ 100
dentin	≈ 15
steel	200-230
Amalgam	50-60
gold	79
Gold alloys	75-110
Pd-Ag alloys	100-120
Co-Cr alloys	120-220
Ni-Cr alloys	140-190
glass	60-90
ceramics	60-130
Porcelain	60-110
PMMA (polimetilmetacrylate)	2,4-3,8
silicon	≈ 0,0003

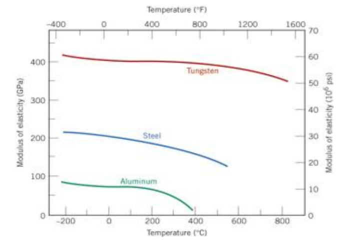
reminder:

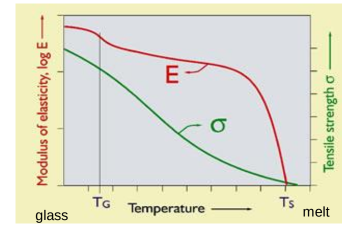
atomic interactions

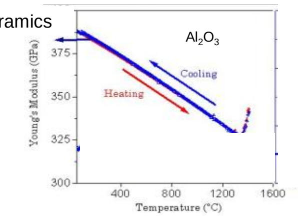


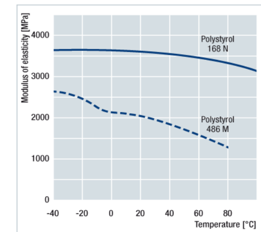
near parabolic profile → it is characteristic for a linear force law.

Influence of the temperature:









$$\sigma = E \cdot \varepsilon$$

Material parameter! **Stiffness of the material**

$$F = E \cdot \frac{A_0}{l_0} \Delta l = D \Delta l$$

$$\sigma = \frac{F}{A_0}, \quad \varepsilon = \frac{\Delta l}{l_0}$$

Body parameter (material + geometric factors)! **Stiffness of the body (at tension)**

Stiffness of the material: stress that is necessary for unit strain.

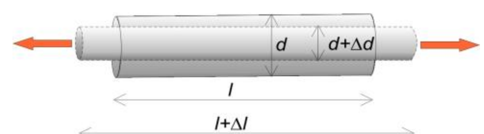
Stiffness of the body: force that is necessary for unit changing of the length.

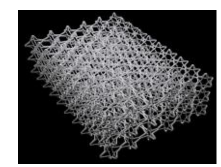
(See spring: D — spring constant)

lateral changing of the size:

Auxetic materials (negative Poisson's ratio):

(e.g.: special foams, variants of Polytetrafluoroethylene)





$$\frac{\Delta d}{d} = -\nu \frac{\Delta l}{l}$$

ν — **Poisson's ratio (no unit)**

e.g.

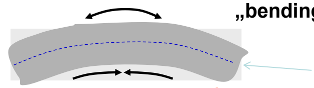
material	ν
Enamel	0.33
Dentin	0.31
amalgam	0.31
PDL	0.45
polimers	0.40–0.50

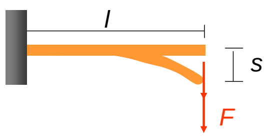
(„normal material")

The elastic property of a homogene, isotrope material is exactly determined by E and ν.

- **bending**

„bending = tension + compression"





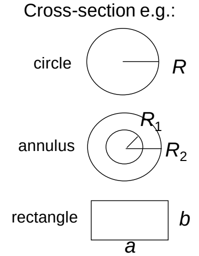
$$F = 3E \cdot \frac{\Theta}{l^3} \cdot s$$

Θ — surface moment of inertia

s: static deflection

Stiffness of the body (bending)

Cross-section e.g.:

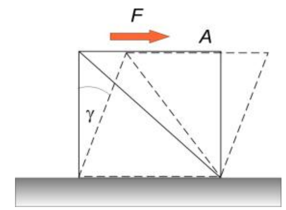


circle: $\Theta = \frac{\pi}{4} \cdot R^4$

annulus: $\Theta = \frac{\pi}{4} \cdot \left(R_2^4 - R_1^4\right)$

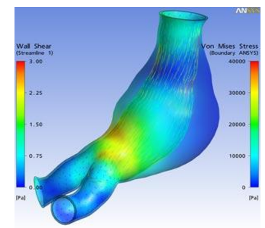
rectangle: $\Theta = \frac{1}{12} ab^3$

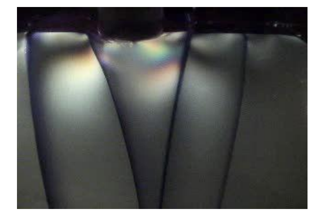
- **shearing**



$$\sigma = G\gamma$$

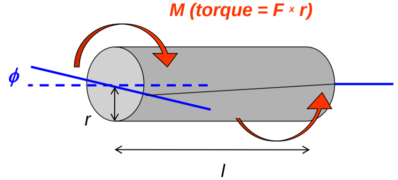
$$G = \frac{E}{2(1+\nu)}$$ shear modulus



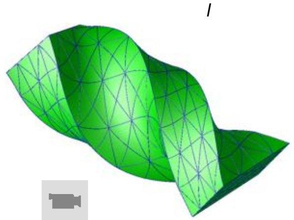


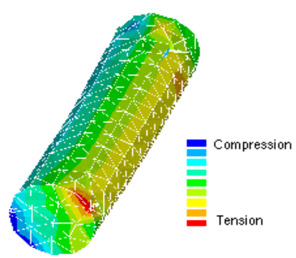
- **twisting (torsion)**

M (torque = F × r)



$$M = G \frac{r^4 \pi}{2l} \phi$$





Summary:

Hooke's law:

	for material	for body
tension/compression	$\sigma = E \cdot \varepsilon$	$F = E \cdot \frac{A}{l} \Delta l$
shear	$\sigma = G\gamma$	$F = 2G \cdot \frac{A}{L^3} \cdot \Delta L$
bending		$F = 3E \cdot \frac{\Theta}{l^3} \cdot s$
twisting (torsion)		$M = G \frac{r^4 \pi}{2l} \phi$

E — elastic (Young's) modulus [E] = Pa

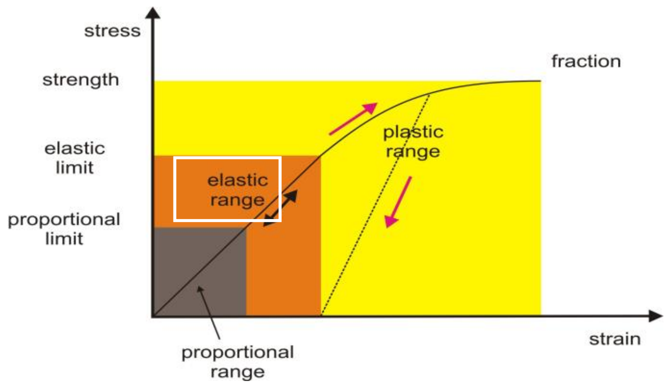
ν — Poisson's ratio [ν] = 1

G — shear modulus [G] = Pa

Θ — surface moment of inertia

$$G = \frac{E}{2(1+\nu)}$$

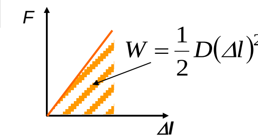
Stress-strain diagram

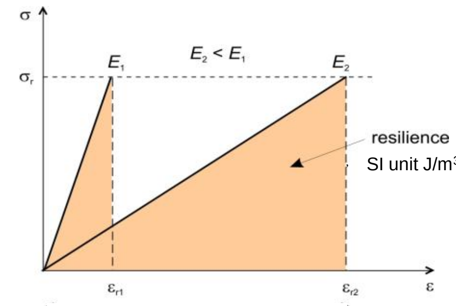


Elastic behavior (to elastic limit)

resilience **(w_r):** property of a material to absorb energy when it is deformed elastically.

see: spring





Elastic strain recovery (maximum elastic strain)

$$w_r \approx \frac{1}{2}\sigma_r \varepsilon_r = $$

$$= \frac{1}{2} E \varepsilon_r^2 = \frac{1}{2E}\sigma_r^2$$

elastic energy:

	for material	for body
• tension/compression	$w_r = \frac{1}{2} E \cdot \varepsilon^2$	$W_r = \frac{1}{2} E \cdot \frac{A}{l} \Delta l^2$
• bending		$W_r = \frac{1}{2} 3E \cdot \frac{\Theta}{l^3} \cdot s^2$

remark: „elastic" =

- small E (large $1/E$)
- large elastic strain recovery
- large resilience