orthodontics

conservative dentistry

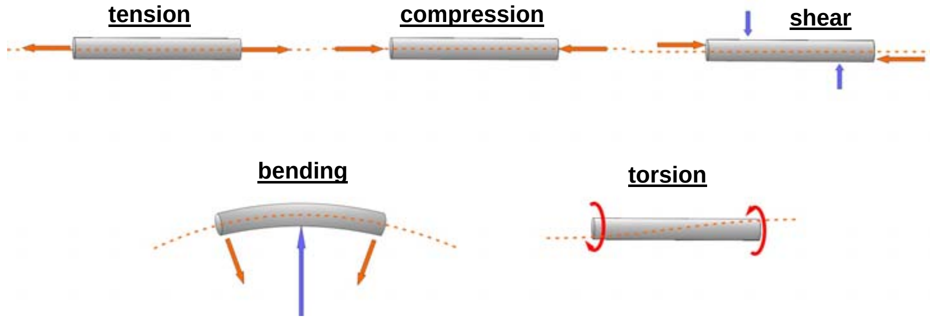
prosthetic dentistry

Physical basis of dental material science 7.

Mechanical properties 1.

Deformations (an object gets changed due to force)

force → deformation

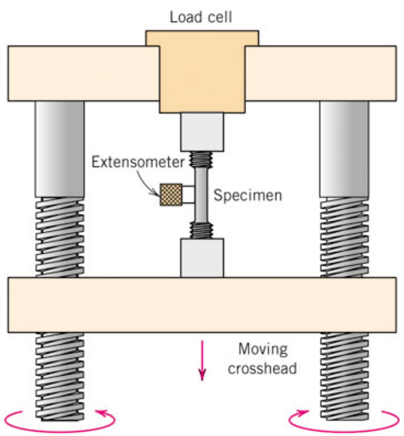


(arrows = forces – direction and magnitude)

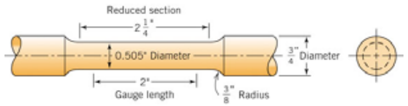
Isotrope material: properties are independent from the direction.

Test methods

tension

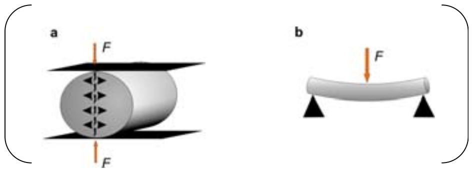


standard



diametral compression

3-point bending test



Characterization of load:

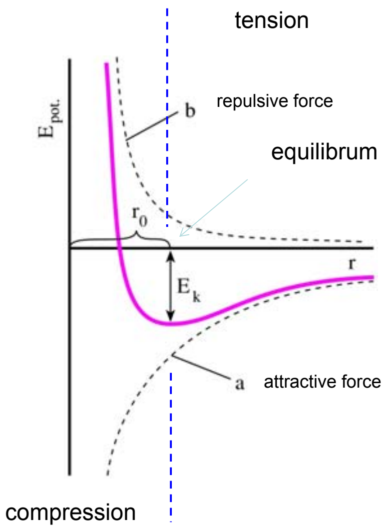
stress(σ):

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

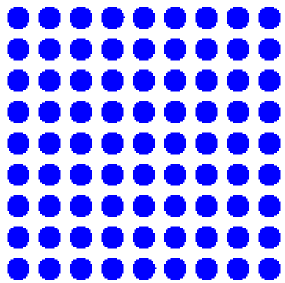
Engineering system! (no drastic change in shape, e.g. A_0 is constant)

⇒ Internal stresses

Internal forces compensate external foces



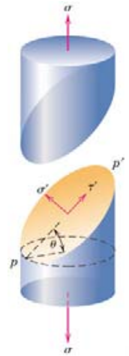
lattice

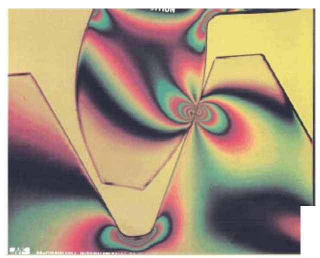


Both elongation and compression result opposite atomic forces!

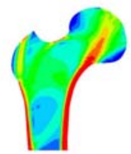
Examination of the stress distribution

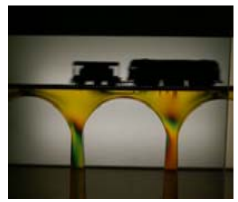
- **experimental**: optical measurments



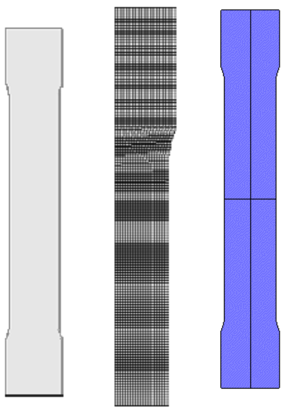


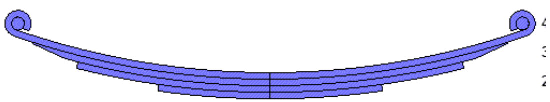
e.g. :
usage of polarized light
(observation of anistropy)





- **theoretical**:
finite element method (build up from small elementary shapes.)

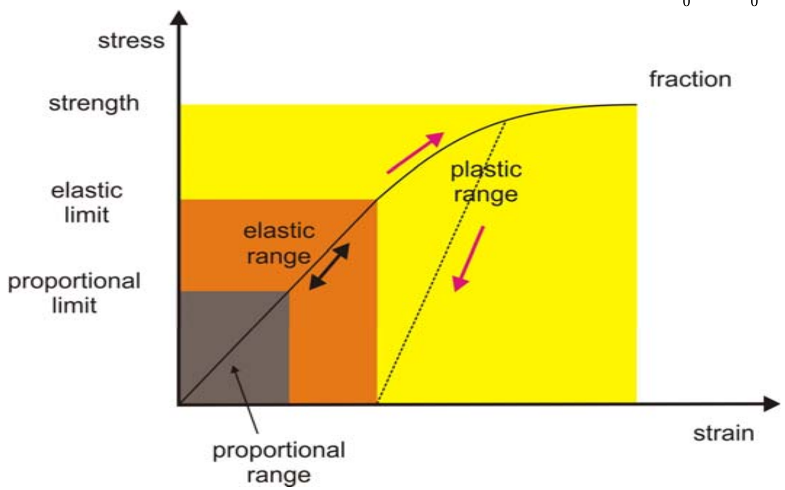




Stress-strain diagram

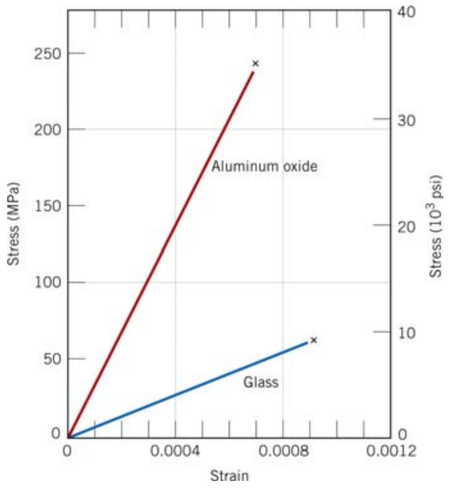
Strain: relative changing of dimensions.

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

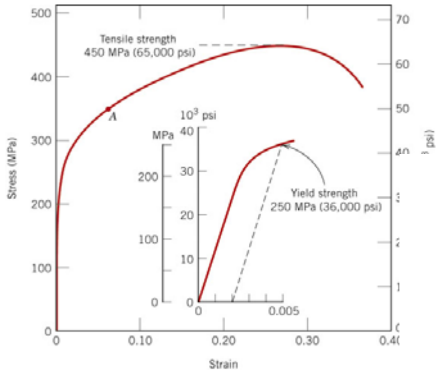


examples:

ceramics

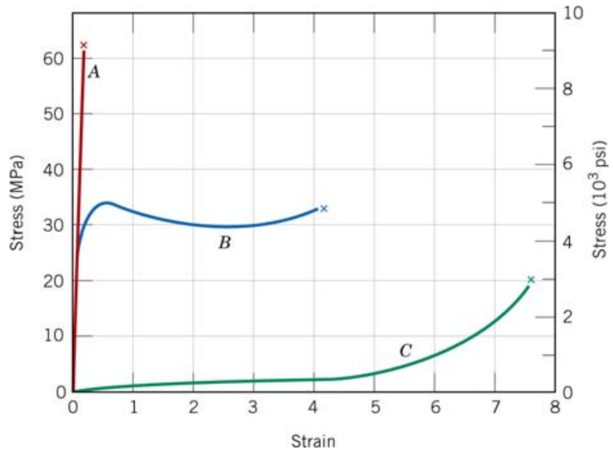


metals, e.g. brass

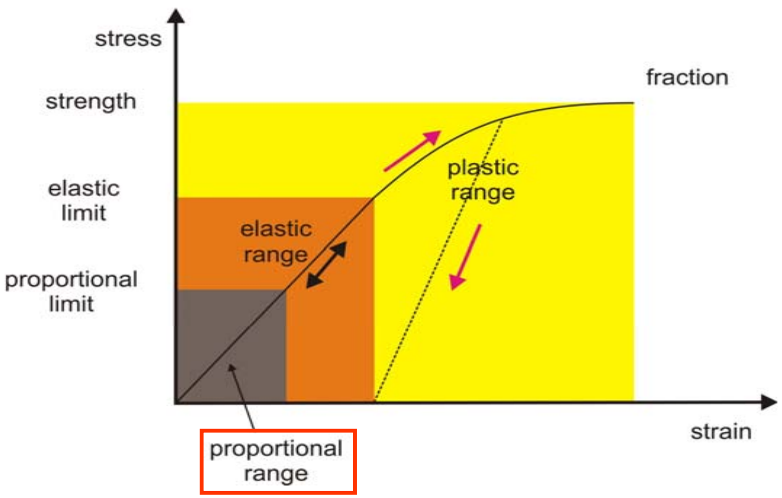


A: hard (glass -like)
B: semi-crystalline
C: rubber

polymers



Stress-strain diagram

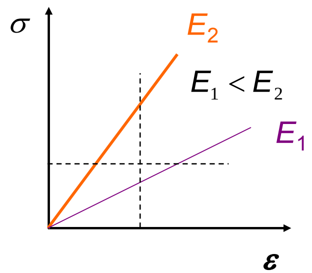


elasticity (to proportional limit)

- tension/compression

strain →
relative tension/compression (changing of the length): $\varepsilon = \frac{\Delta l}{l_0}$ $[\varepsilon] = 1$

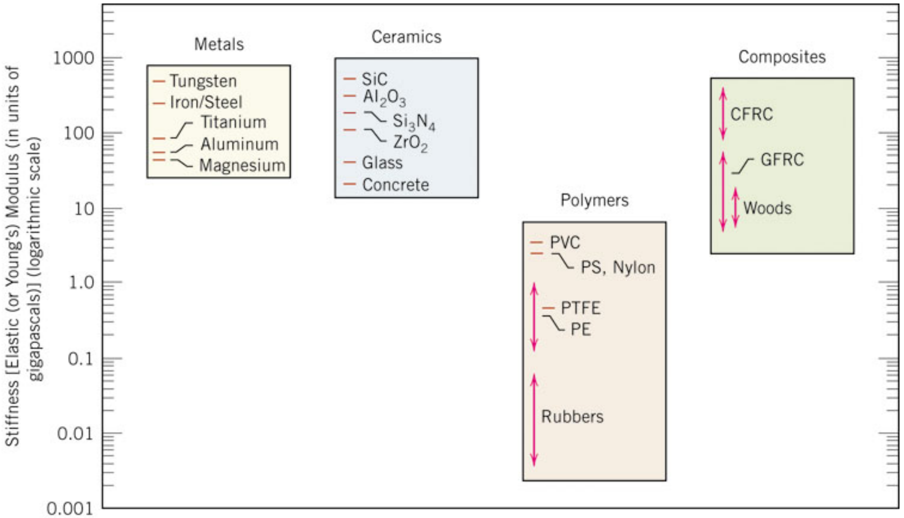
Hooke's law: $\sigma = E \cdot \varepsilon$ E — **elastic**(Young's) **modulus** $[E]$ = Pa



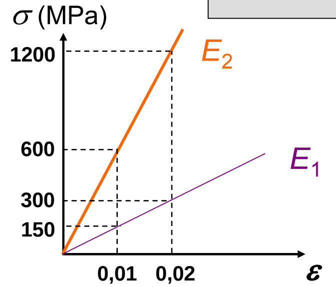
E — resistance against the tension or compression, **stiffness**

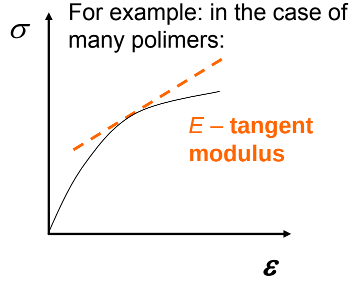
$1/E$ — propensity for tension or compression, **elasticity**

Stiffness



E.g.:



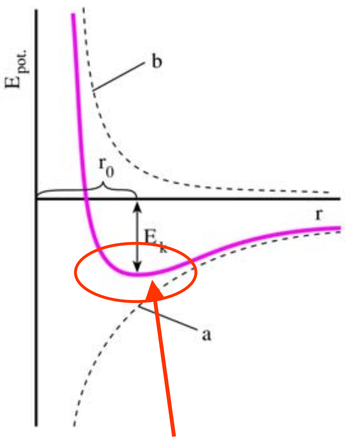


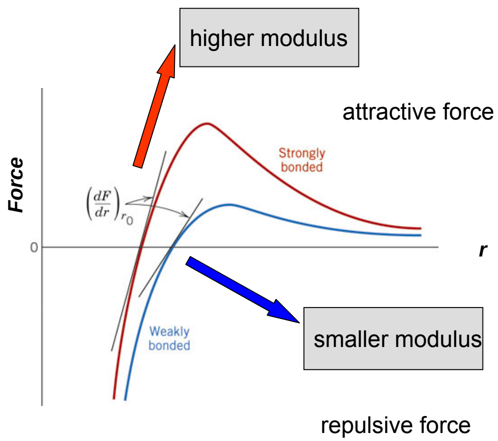
Stiffnes of a few dental materials:

anyag	*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

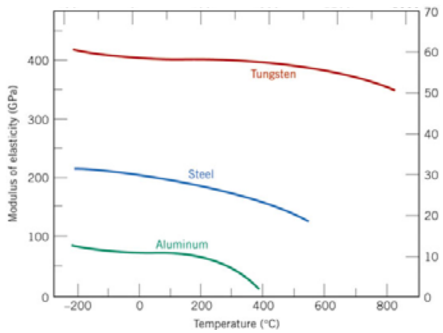




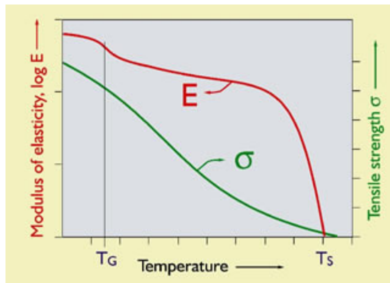
near parabolic profile → linear force law

Influence of temperature:

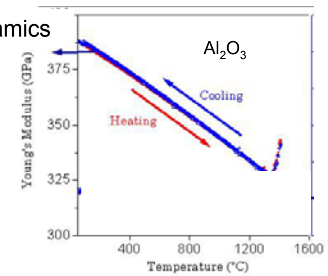
metals

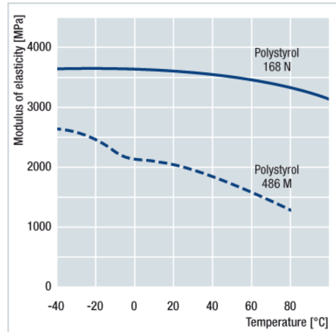


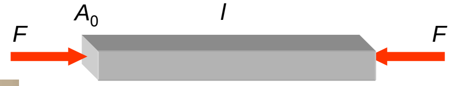
semicrystallic polimers



ceramics







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

Material parameter! **Stiffness of the material**

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

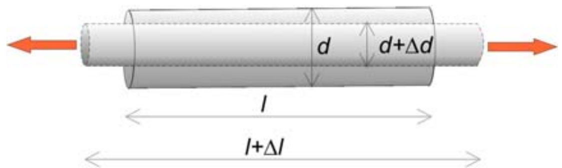
Body parameter (material + geometric factors)! **Stiffness of the body (at tension)**

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.

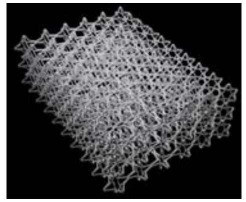
(See spring: D — spring constant)

lateral changing of the size:



Auxetic materials (negative Poisson's ratio):

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

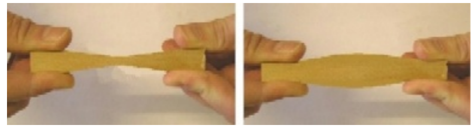


$$\frac{\Delta d}{d} = -\nu \frac{\Delta l}{l}$$

ν — **Poisson's ratio** $[\nu] = 1$

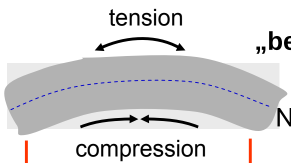
Pl.

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



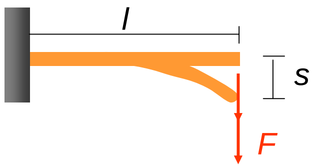
The elastic property of a homogene, isotrope material is exactly determined by E and ν.

- bending



„bending = tension + compression"

Neutral surface



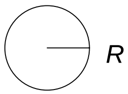
$$F = 3E \cdot \frac{\Theta}{l^3} \cdot s$$

Θ — surface moment of inertia

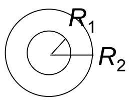
s: static deflection

Stiffness of the body (bending)

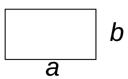
Cross-section e.g.:

circle 

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

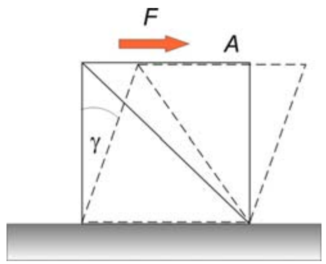
annulus 

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

rectangle 

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

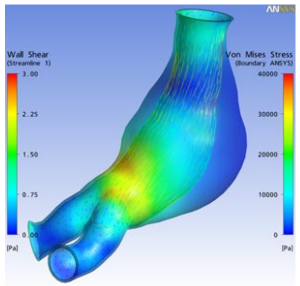
- shear

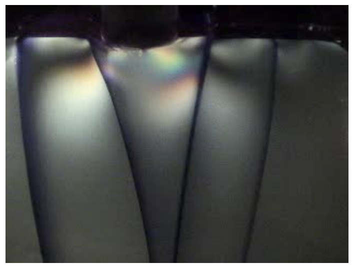


$$\sigma = G\gamma$$

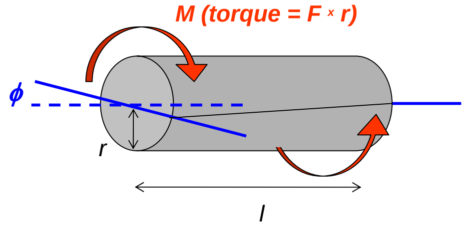
$$G = \frac{E}{2(1+\nu)}$$

shear modulus

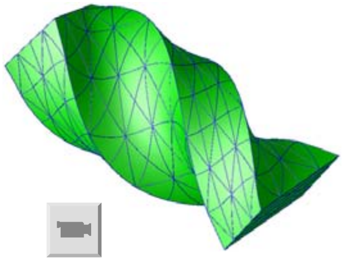


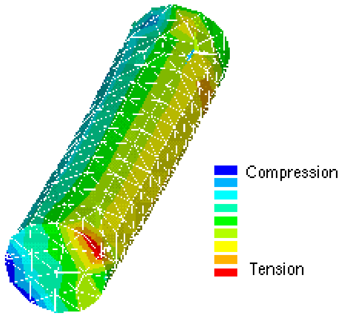


- twisting (torsion)



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





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

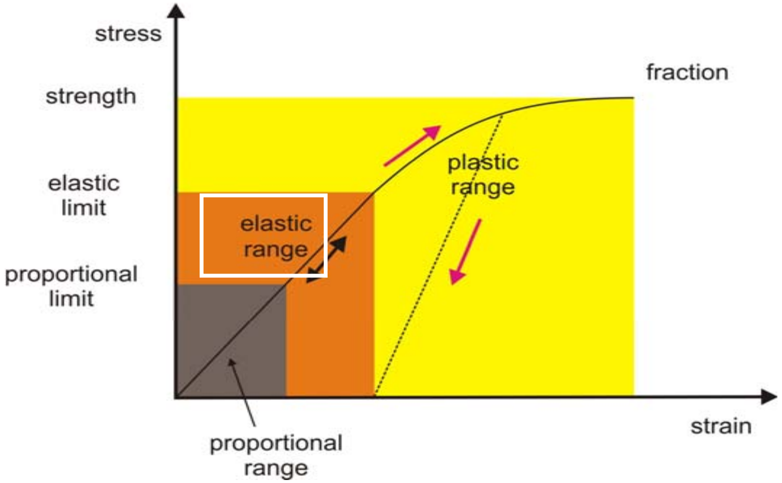
ν — Poisson's ratio [ν] = 1

G — shear modulus [G] = Pa

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

Θ — surface moment of inertia

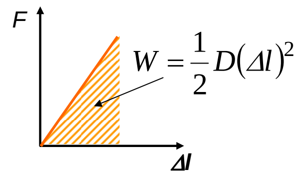
Stress-strain diagram

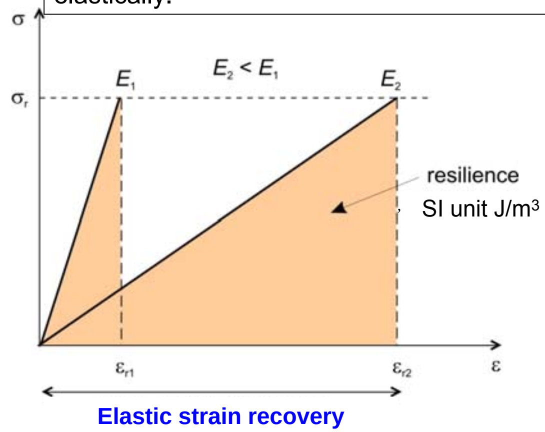


Elastic behavior (to elastic limit)

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

see: spring





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

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