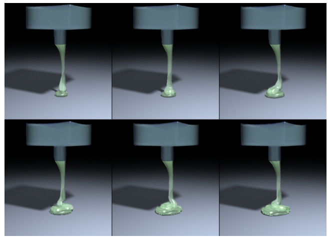

Physical Foundations of dental materials science 9.

Viscoelasticity

Keynotes:
- *Viscoelastic behavior*
- Viscoelastic models
- Viscoelastic phenomena

E-book chapter: 18

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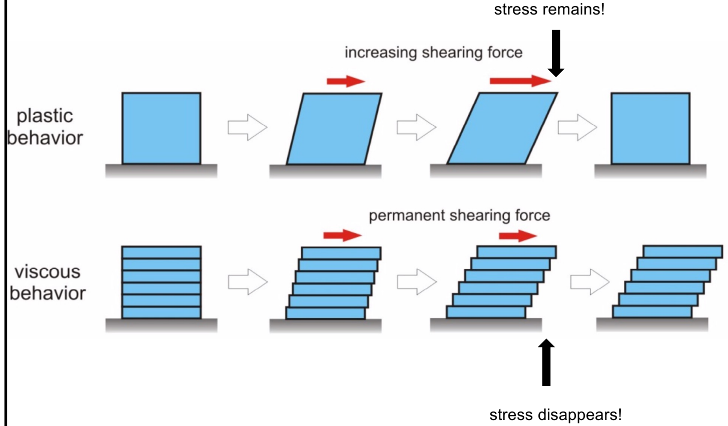
Comparing elastic and viscous behavior:



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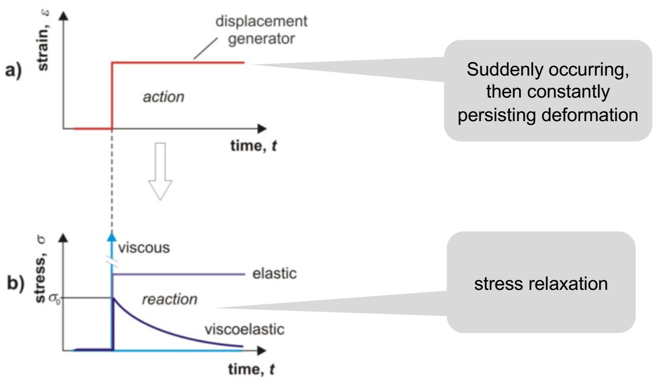
Viscoelasticity



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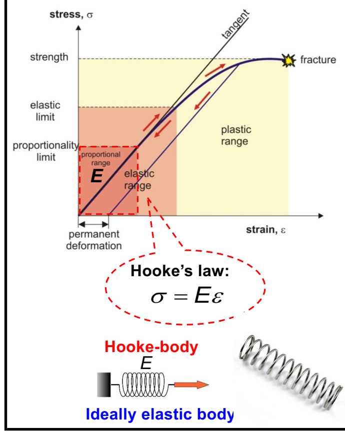
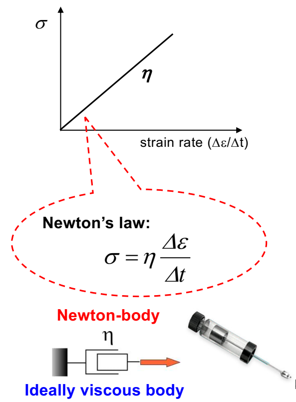
Reminder:

Elastic behavior:
- sudden
- force is required to maintain strain



Viscous behavior
- time dependent
- force is required to maintain stress rate



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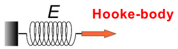
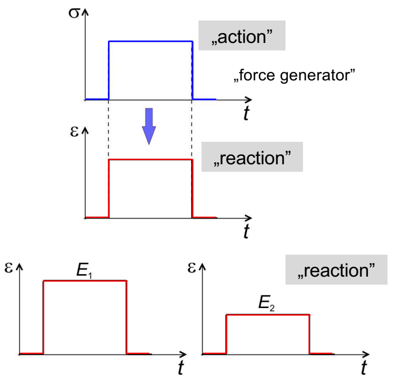
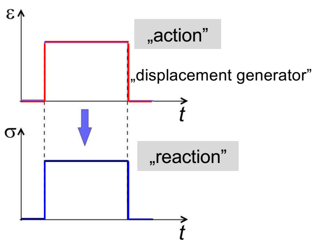
Ideal elastic behavior



How would strain change in case of constant stress?

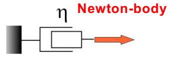


How would stress change in case of constant strain?

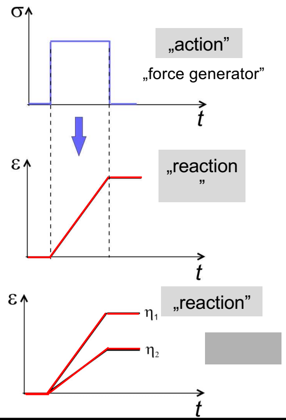


stress is constant
(no stress relaxation)

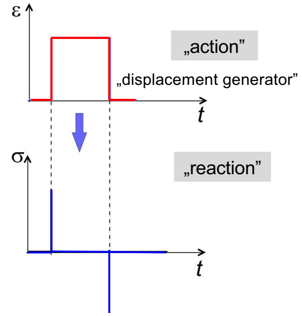
Behavior of an ideally viscous body



How would strain change in case of constant stress?

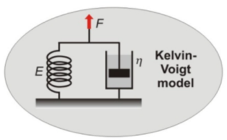


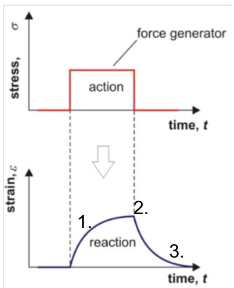
How would stress change in case of constant strain?



sudden stress
relaxation

Viscoelasticity
(mechanical model)





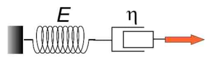
Viscoelasticity means the co-appearance of viscous and elastic behavior.
model: parallel connection of spring and dashpot (Kelvin-Voight model)

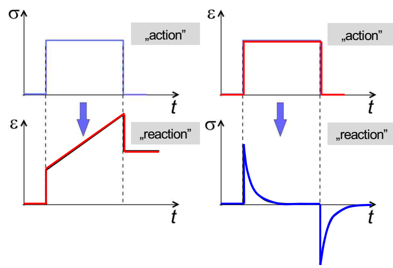
Spring: ideal elastic (Hooke) body
Dashpot: ideal viscous (Newton) body

1. Upon stretch, the extension of the spring is slowed down by the dashpot.
2. Extension stops when the elastic spring force equals the external force.
3. When the external force is quenched, the contraction of the spring is slowed down by the dashpot.

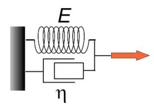
Viscoelastic models

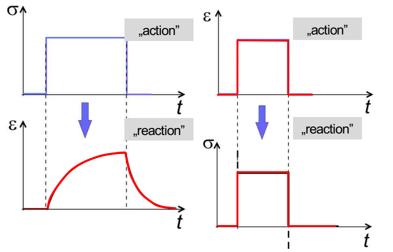
Maxwell-model

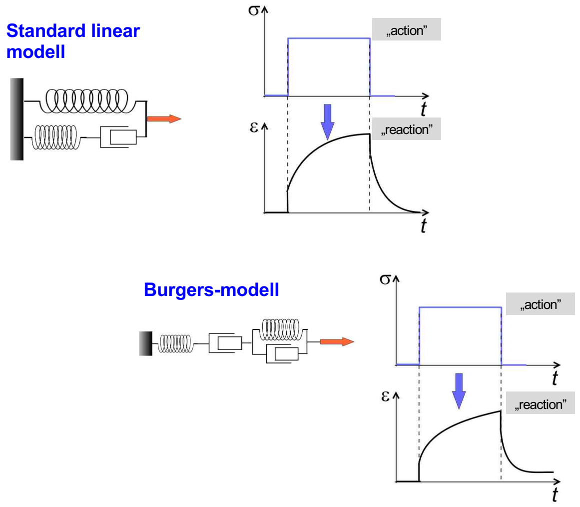




Kelvin-Voigt-model







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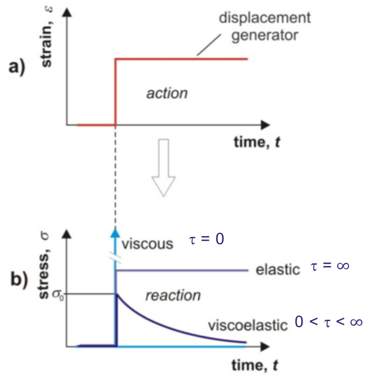
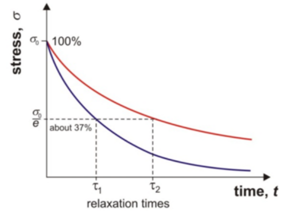
1./a Stress-relaxation in viscoelastic system

Decrease in stress while strain remains constant

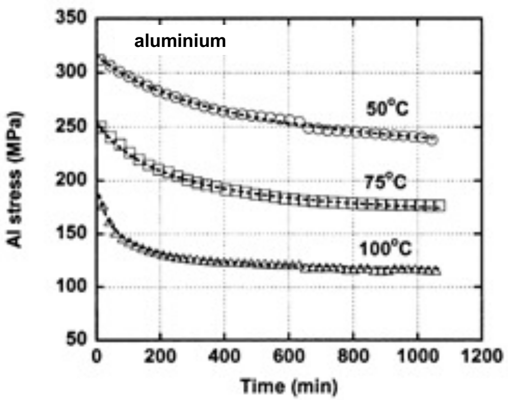




$$\sigma = \sigma_0 \cdot e^{-\frac{t}{\tau}}$$

$$\tau = \frac{\eta}{G} \qquad G = \frac{E}{2(1+\mu)}$$

10



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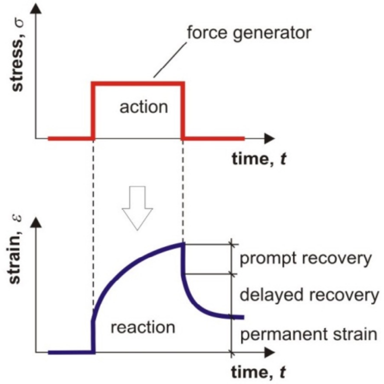
1./b Shape relaxation (recovery)

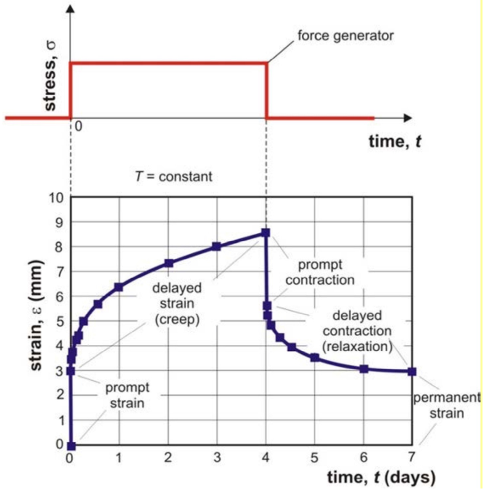
Recovery of shape after the stress is quenched.



12

12

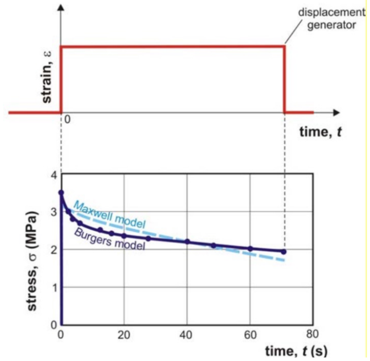
bone cement



13

13

film made of miofibrillar proteins:

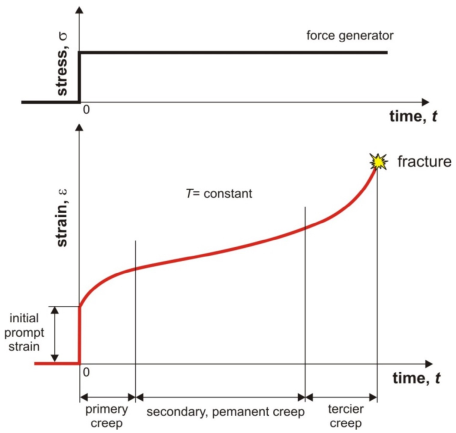


14

14

2. Creep

Continuously increasing strain upon constant long-time stress.



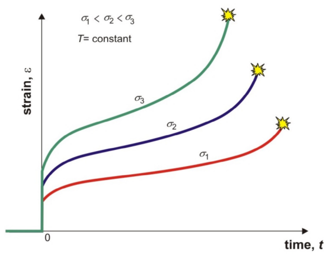
Modell: ? — Maxwell

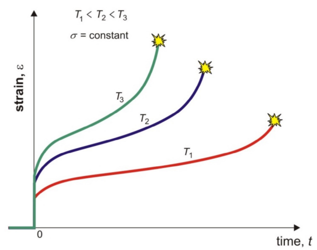
— Burgers

$1–10^7$ s **!!**

15

15





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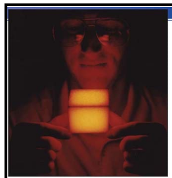



Physical foundations of dental materials 10.

Thermal and electric properties

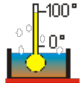
e-book chapter.: 19

17

17

Thermal properties

- **temperature**
- **heat uptake/release**



heat capacity (C): $C = \frac{\Delta Q}{\Delta T}$

molar heat capacity (c_ν): $c_\nu = \frac{C}{\nu}$

specific heat capacity (c): $c = \frac{C}{m}$

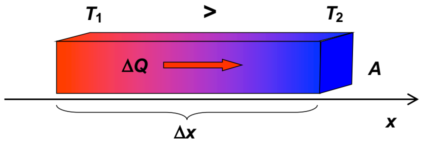
specific heat of dental materials:

material	c (J/(kg·K))
enamel	750
dentine	1260
water	4190
amalgam	210
gold	126
porcelain	1100
glass	800
PMMA	1460
zinc-phosphate	500

18

18

- **heat conduction**
  - lattice vibrations
  - free electrons



$$\frac{\Delta Q}{\Delta t} = -\lambda A \frac{\Delta T}{\Delta x}$$ **Fourier's law**

λ — **thermal conductivity**
J/(s·m²·K/m) = W/(m·K)

used in case of stationary conditions

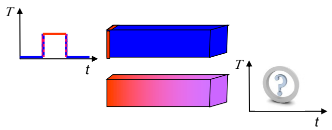
thermal conductivity of dental materials

material	λ (W/(mK))
enamel	0,9
dentine	0,6
water	0,44
amalgam	23
gold	300
porcelain	1
water	0,6-1,4
acrylate	0,2
PMMA	0,2-0,3
zinc-phosphate	1,2

19

19

non-stationary conditions:



$$D = \frac{\lambda}{c \cdot \rho}$$

D — **thermal diffusivity** (m²/s)

thermal diffusivity of dental materials

material	λ (W/(mK))	D (10^{-6} m²/s)
enamel	0,9	0,5
dentine	0,6	0,2
water	0,44	0,14
amalgam	23	9,6
gold	300	118
porcelain	1	0,4
water	0,6-1,4	0,3-0,7
acrylate	0,2	0,1
PMMA	0,2-0,3	0,12
zinc-phosphate	1,2	0,3

20

20

• thermal expansion

Linear thermal expansion:

$$\frac{\Delta l}{l} = \alpha \, \Delta T$$

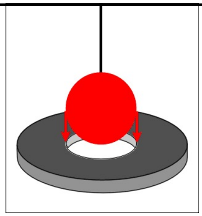
α — **coefficient of thermal expansion** (1/K)

Volumetric thermal expansion

$$\frac{\Delta V}{V} = \beta \, \Delta T$$

β — **volumetric thermal expansion coefficient** (1/K)

$$\beta = 3\alpha$$



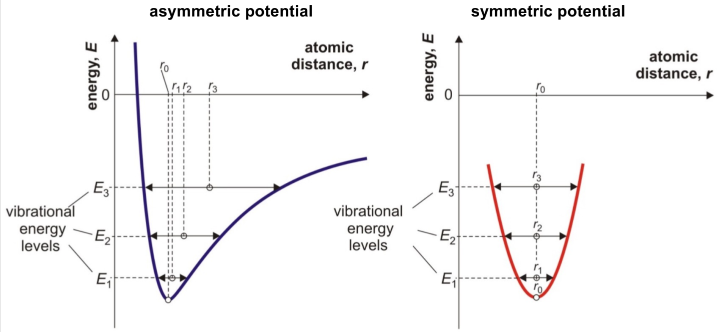
thermal expansion coefficient of dental materials:

anyag	$\alpha\,(10^{-6}$ 1/K)
enamel	11,4
dentine	8,3
gold	14,2
gold alloys	11-16
amalgam	≈ 25
porcelain	4-16
acrylate	90
glass	8
PMMA	90-160
silicone	100-200
gypsum	15-20
wax	300-500

21

21

thermal expansion



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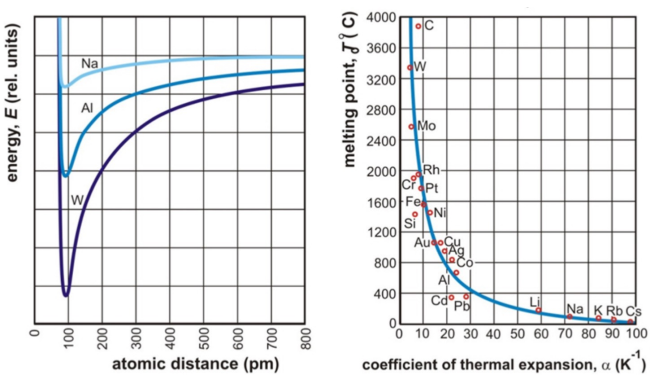

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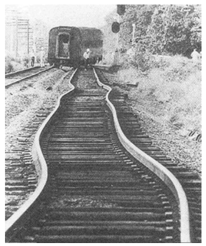
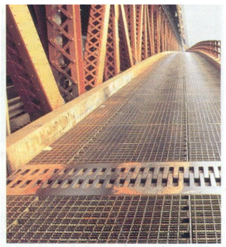
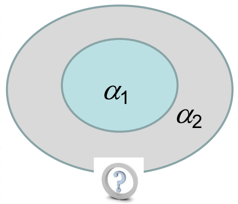
Consequences of heat expansion:

various heat expansions ⟹ stress (σ) !







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24

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Please prepare your phones to scan the QR code

25

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26