SOFT MATTER PHYSICS 2007

Soft Matter Physics HT07 - Contact information

Lectures:

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Applied Physics
S2046 (Soliden)
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- Overview of Soft Matter
- Glasses
- Colloids
- Experimental methods
- Self assembly
- Gels

Johan Hedström
Applied Physics
S1008 (Soliden)
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tel: 3369

- Phase transitions
- Polymers
- Polymer solutions
- Problem solving class

Soft Matter Physics HT07 - Literature

Course book:
Richard A. L. Jones - *Soft Condensed Matter*
Oxford University Press 2002

Extra material, ppt-presentations and seminar slides will be available on the homepage in connection to each lecture.

Other recommended books:
Hamley - *Introduction to Soft Matter*
Daoud & Williams - *Soft Matter Physics*
Kleman & Lavrentovich - *Soft Matter Physics (e-book)*
Poon & Andelman - Soft Condensed Matter Physics in Molecular and Cell biology (*e-book*)

Soft Matter Physics HT07 - Homepage

http://fy.chalmers.se/~matic/cfsm/smp_course.html

Centre for Functional Soft Matter 08/30/2007 01:34 PM

Centre for Functional Soft Matter

Contact information

- SMP-course home
- News
- Work program
- Seminars
- Literature
- Projects
- Links

Soft Matter Physics HT07

New course starts Monday 4th September 2007, 13:15 in room N6115

Soft Matter Physics is a course given within the masters programs *Applied Physics* and *Physics of Matter, Material and Biological Systems*. It is open for students from Chalmers, Göteborg University or graduate students. If you are interested in the physics of matter all around us and how the macroscopic properties can be tuned, this is the place to be. For more information about the course please contact:

Aleksandar Matic	Johan Hedström
tel: 5176	tel: 3369
room: S2046	room: S1011

Soft Matter Physics HT07 - Work program

4/9 N6115	13.00	Introduction to soft matter: Concepts, statistical physics, … (AM) Chap. 1.1-1.2, 2.1-2.3 A.1-A-4
6/9 N6115	8.00	Phase transitions (JH) Chap. 3.1-3.4
11/9 N6115	13.00	Polymers I (JH) Chap. 5.1-5.5, B.1-B.2 + extra material
13/9 N6115	8.00	Glasses: Glass transition and glass structure (AM) Chap. 2.4 + extra material
18/9 N6115	13.00	Problem solving class I (JH)

….

Soft Matter Physics HT07 - Seminars

24/9 12:00 Johan Bergenholtz, Department of Chemistry, GU
Rheology of Colloidal Dispersions

9/10 13-15 Per Rudquist, MC2
Liquid Crystals & liquid crystal displays

12/10 12:00 Maud Langton, Swedish Institute for Food and Biotechnology

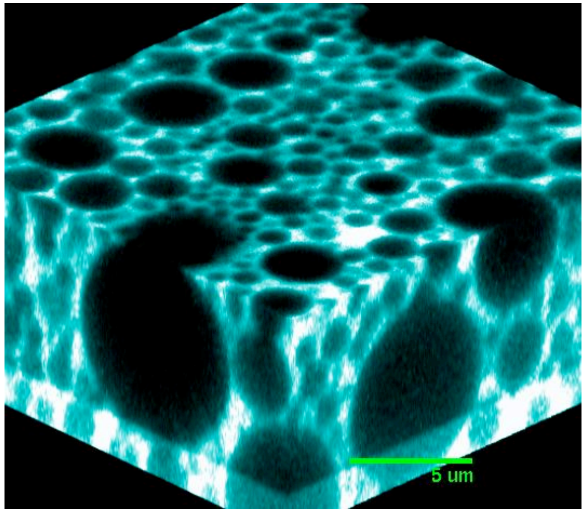
16/10 12:00 Linda Gunnarsson, Bio-nano-photonics group, Applied Physics Chalmers
Metal nano-particles for bioimaging, bio-sensing and medical applications

Lunch-sandwich will be served!
(if you cannot attend let me know)

Soft Matter Physics HT07 - Projects

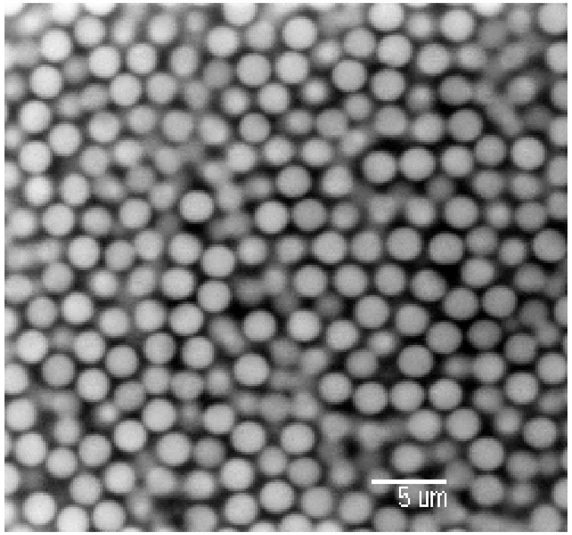
- Individual project work part of the examination
- Select a topic of your interest (material, technique, phenomena, application…) - no later than 18/9!
- Tutorial 1/2h (v.38) + 1/2 (v.40-41) sign up in advance
- Written report 2-4 pages, hand in 18/10

Soft Matter



3D image of a compressed emulsion

www.deas.harvard.edu



Colloidal glas, www.deas.harvard.edu

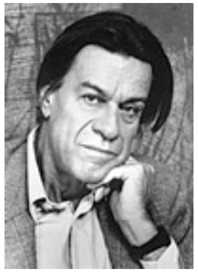
Silica-gel, KMF

i) What is Soft Matter?

ii) Why soft?

iii) What's special?

Soft Matter



Pierre-Gilles de Gennes

SOFT MATTER

Nobel Lecture, December 9, 1991

by

PIERRE-GILLES DE GENNES

College de France, Paris, France

What do we mean by soft matter? Americans prefer to call it "complex fluids". This is a rather ugly name, which tends to discourage the young students. But it does indeed bring in two of the major features:

1) Complexity. We may, in a certain primitive sense, say that modern biology has proceeded from studies on simple model systems (bacterias) to complex multicellular organisms (plants, invertebrates, vertebrates...). Similarly, from the explosion of atomic physics in the first half of this century, one of the outgrowths is soft matter, based on polymers, surfactants, liquid crystals, and also on colloidal grains.

2) Flexibility. I like to explain this through one early polymer experiment, which has been initiated by the Indians of the Amazon basin: they collected the sap from the hevea tree, put it on their foot, let it "dry" for a short time. And, behold, they have a *boot*. From a microscopic point of view, the starting point is a set of independent, flexible polymer chains. The oxygen from the air builds in a few bridges between the chains, and this brings in a spectacular change: we shift from a liquid to a network structure which can resist tension - what we now call a *rubber* (in French: caoutchouc, a direct transcription of the Indian word). What is striking in this experiment, is the

http://nobelprize.org/physics/laureates/1991/index.html

Overview of Soft Materials

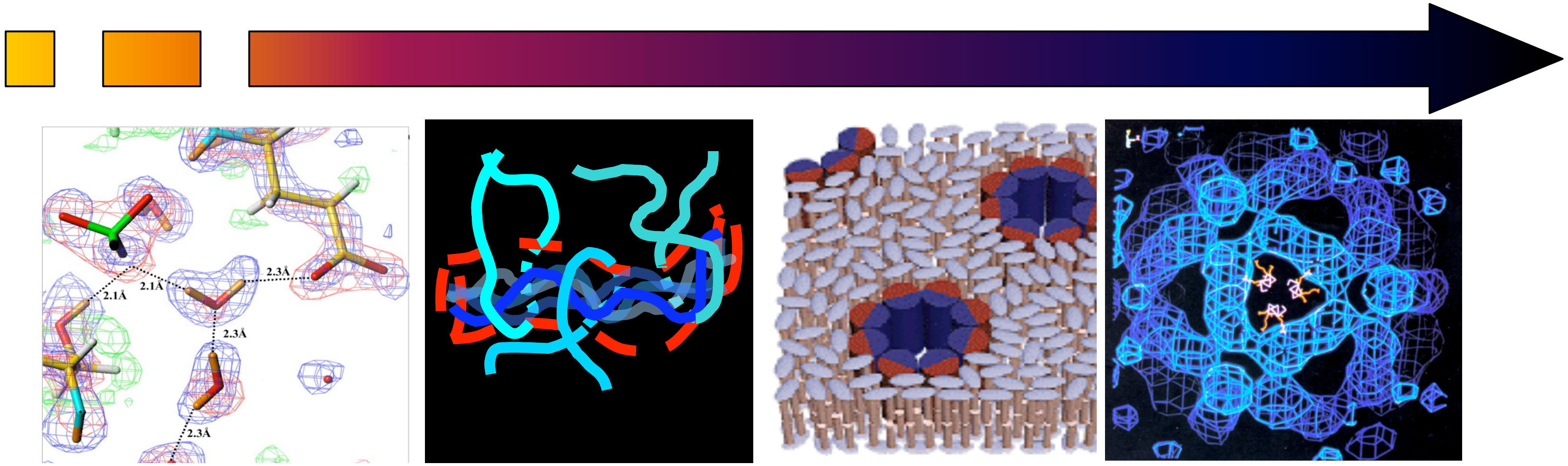
Polymers	Gels	Colloids	Pastes	Surfactants	Liquid crystals	Glasses
-Synthetic		- Sols				-organic
-Bio-polymers		- Emulsions				- metallic
		- Micelles				- inorganic
Plastics		*Food*	*Pharmaceuticals*		*Displays*	
Rubber						*“Godis”*
Fabric		*Papermaking & pulp*				*Fibres*
		Paint				*Windows*
						Art
Volvo		ARLA, GB	ASTRA			Karamellkungen
		SIK	SCA, Mölnlycke			Orrefors

Length scales in Soft Matter

Structures on length scales of ≈1-1000 nm are important for the properties of soft matter ⇒
atomic length scale can be "ignored" (coarse grained view of world)

Length scale in nm

0.01 0.1 0.3 1.0 3.0 10 30 100



atomic structures ***organic molecules*** ***surfaces and multilayers***

pharmaceuticals

micelles

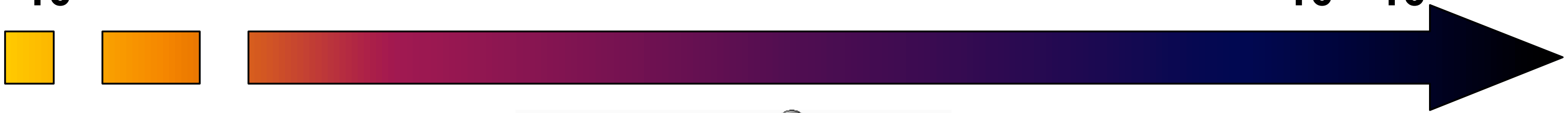
polymers ***proteins***

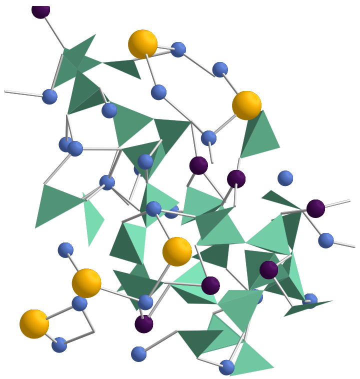
supermolecules

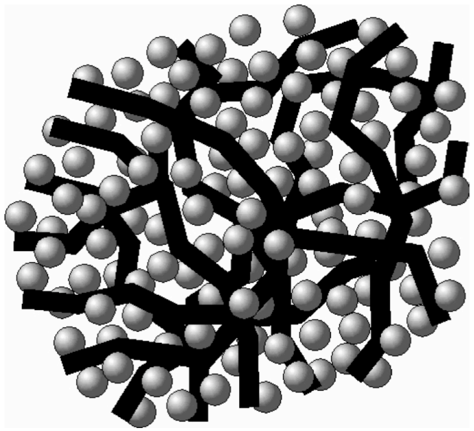
Time and energy scales:

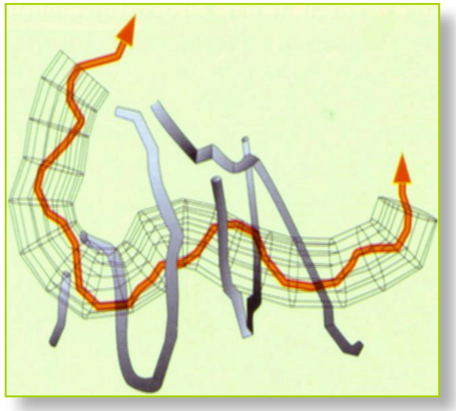
Time scale (seconds)

10^{-13} **10^{-7}-10^{3}**









elementary excitations

tunneling

diffusion

molecular excitations

polymer reptation

glassy dynamics

libration

- Dynamics in soft matter span an enormous time-scale

- Slow dynamics in non-equilibrium configurations

Interactions

Thermal energy kT≈ $0.4 \cdot 10^{-20}$ J around room temperature (300 K)

i) Covalent bonds

Strong bonds:

≈ 30-100 $\cdot 10^{-20}$J -> 10-250 kT

ii) Ionic interactions

Strong bonds:

≈100 $\cdot 10^{-20}$J -> 250 KT

(but often screened in solution)

iii) van der Waals interactions

Weak interaction:

0.1-1 $\cdot 10^{-20}$J -> 0.2-2 kT

iv) hydrogen bonds

Relatively weak:

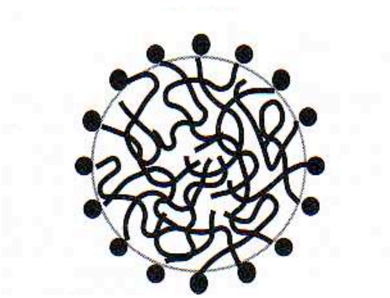
2-6 $\cdot 10^{-20}$J -> 5-15 kT

Self assembly and hierarchical structures

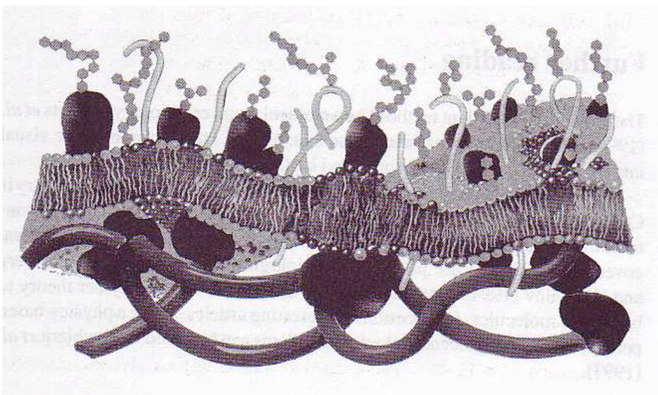
energy vs entropy

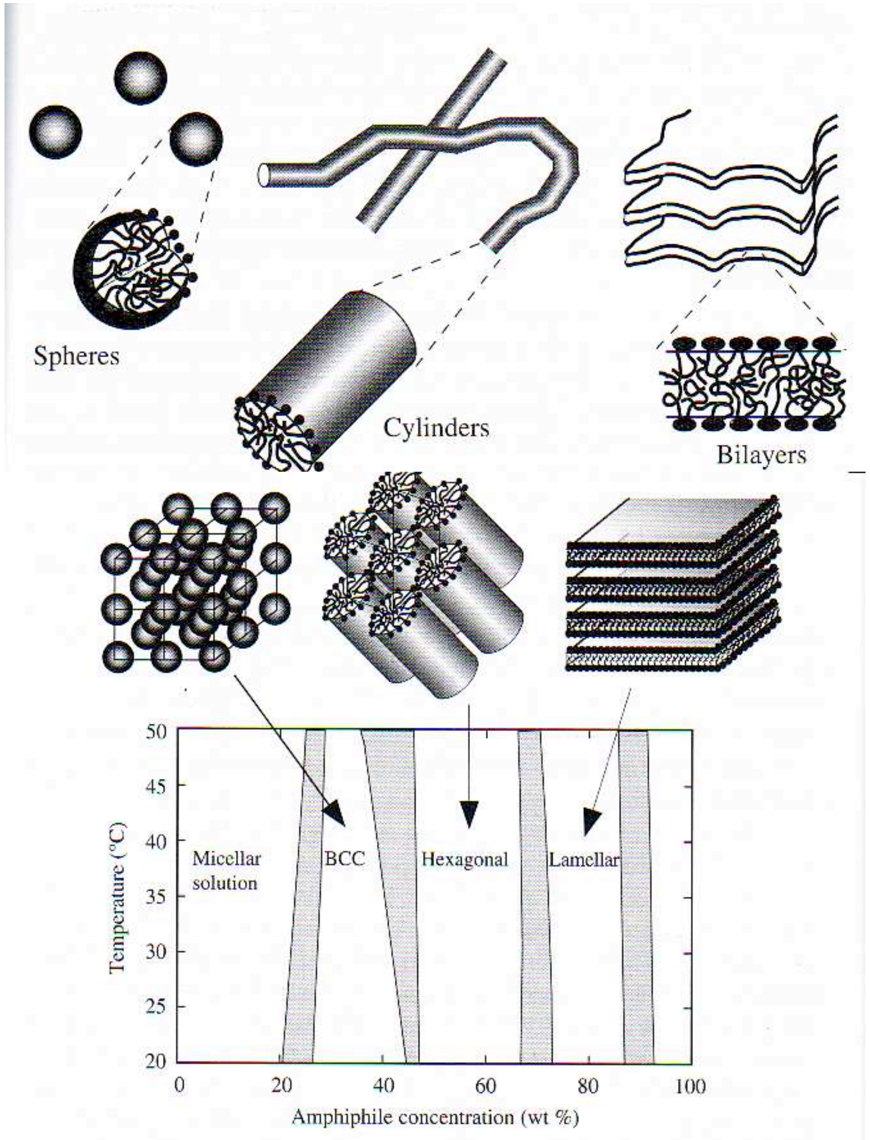
Structures built up of smaller building blocks

- micelles



- membranes





4 Characteristics of Soft Matter

i) Length scales:

- Structures of ≈10-1000 nm determine the properties

ii) Time scales: processes from 10^{-12} - 10^{3} s

- Dynamics processes over a wide time scales 10^{-12} - 10^{3} s

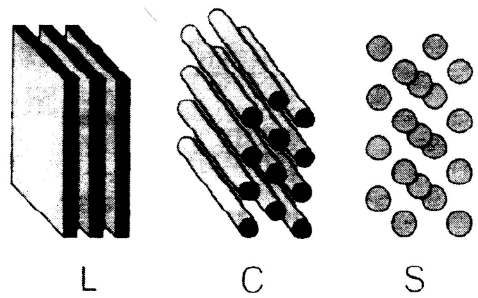
- Very slow processes in non-equilibrium configurations

iii) Weak interactions

- Interactions between molecules and molecular structures ≈ kT

iv) Self assembly

- Hierarchical arrangement of structures.



- Competition between interaction energy and entropy

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Rubber						*"Godis"*
Fabric		*Papermaking & pulp*				*Fibres*
		Paint				*Windows*
						Art
Volvo		ARLA, GB	ASTRA			Karamellkungen
		SIK	SCA, Mölnlycke			Orrefors

- macroscopically soft
- not liquids, not solids
- variety of forms & morphology
- complex systems, many d.o.f, disorder
- out of equilibrium structures
- self assembly
- interaction energy - entropy balance

4 Characteristics of soft matter

1) Length scales 10-1000 nm of important
2) Time scales: processes from 10^{-12} - 10^{3} s
3) Weak interactions (kT)
4) Self assembly properties

Mechanical properties

gas ⟶ liquid ⟶ solid (P,T)

Traditional condensed matter physics!

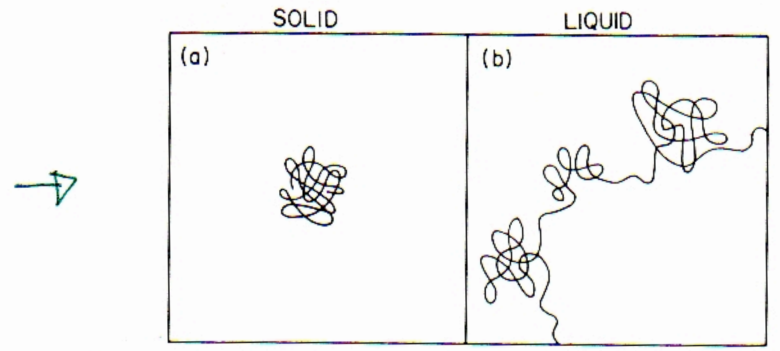
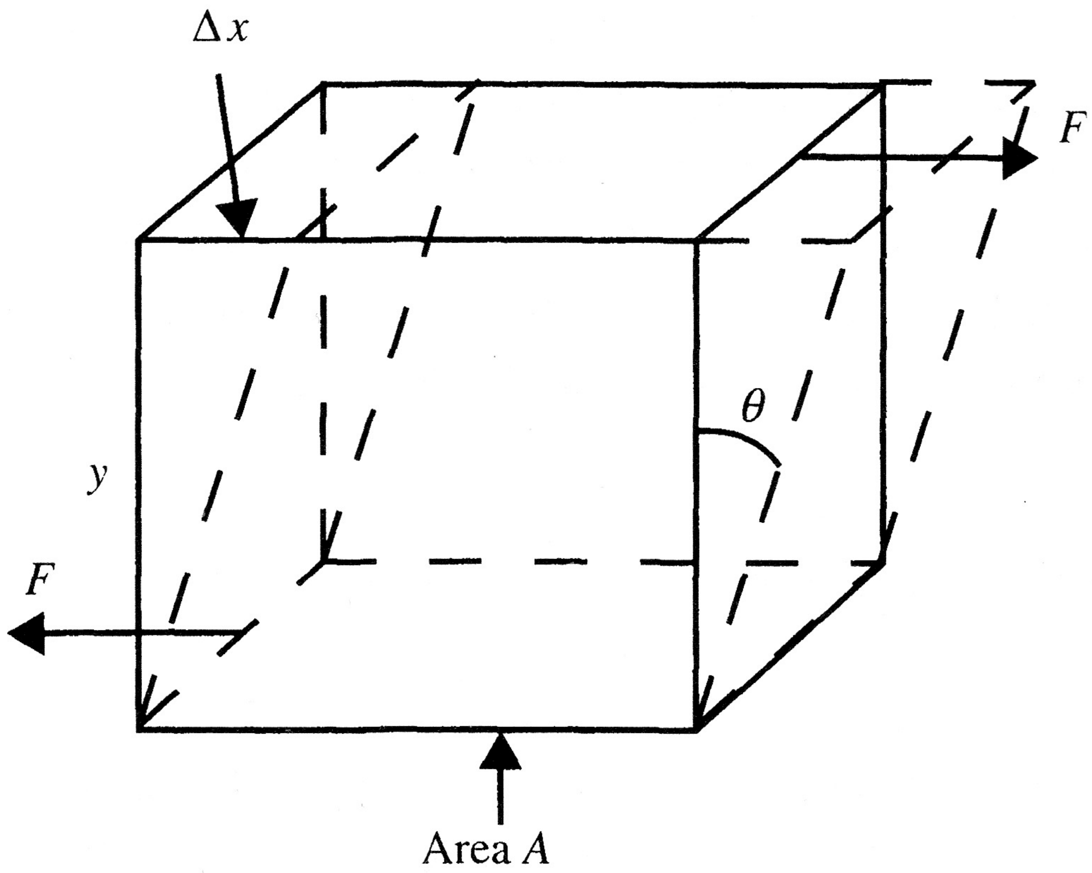


Figure 1.7 Sketches of the state of atomic motion (*a*) in a solid and (*b*) in a liquid.

Solid - sustains shear stress without yielding

Liquid- flows as a response to shear stress

Shear stress and strain



$$\sigma = \frac{F}{A}$$ shear stress

$$e = \frac{\Delta x}{y}$$ shear strain

Ideal solids and liquids

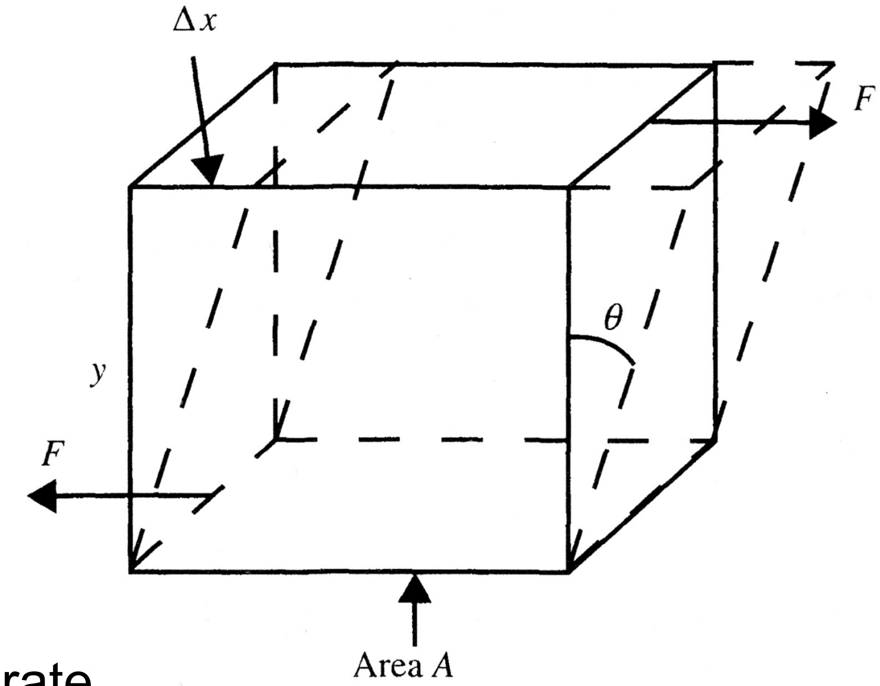
Hookean solid:

Ideal elastic response

Shear stress ⇒ constant shear strain

$$\sigma = G \cdot e$$

shear modulus



Newtonian liquid:

Shear stress results in flow

Shear stress ⇒ constant shear strain rate

$$\sigma = \eta \cdot \dot{e} \qquad F = A\eta \frac{v}{y}$$

force acting by two plates moving at relative velocity *v*

shear viscosity

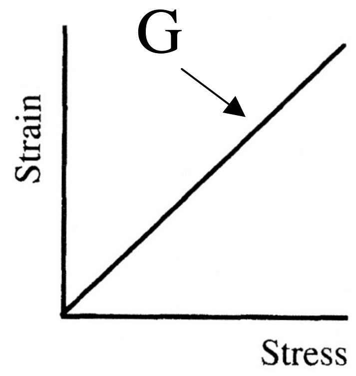
η - [$kgm^{-1}s^{-1}$, Pa S, Poise]

Ideal solids and liquids

Hookean solid:
Ideal elastic response
Shear stress ⇒ constant shear strain

$$\sigma = G \cdot e$$

shear modulus



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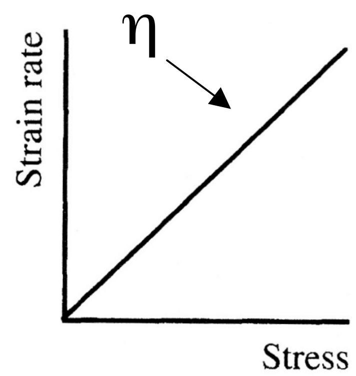
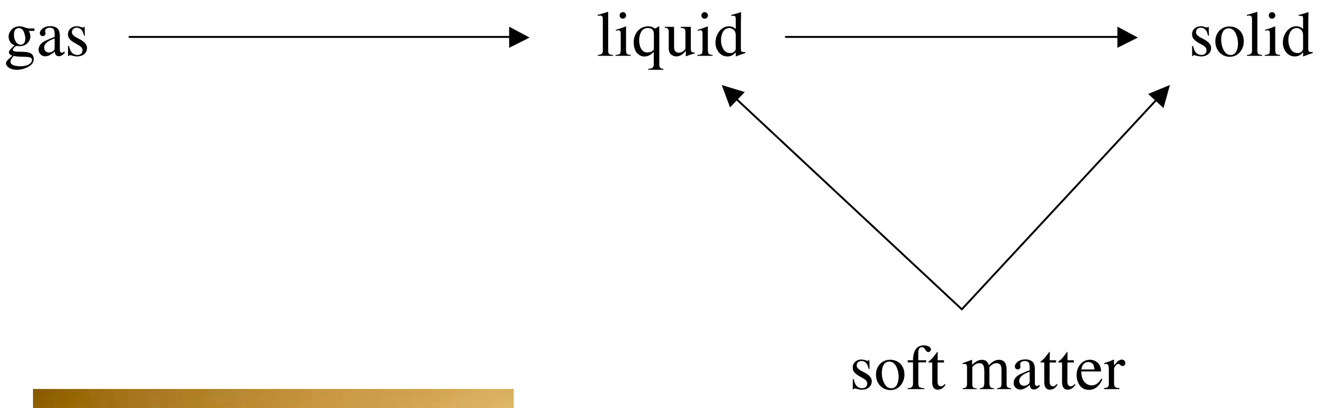


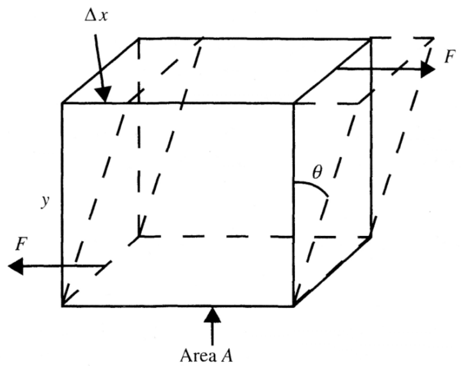
Mechanical properties

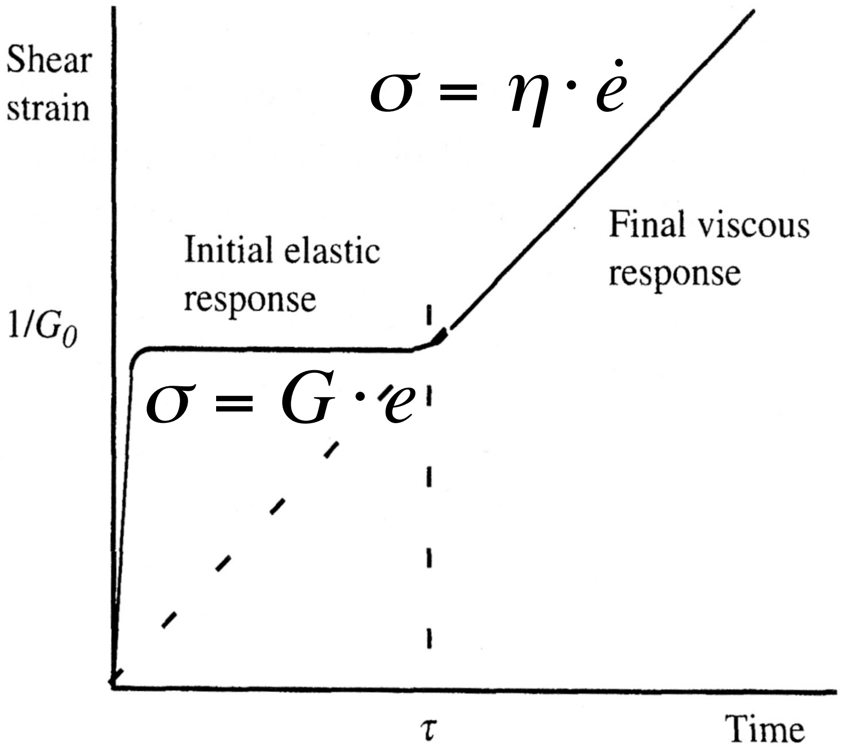


Liquid or solid?

⇒ Depends on the conditions - not only P,T

Viscoelastic response





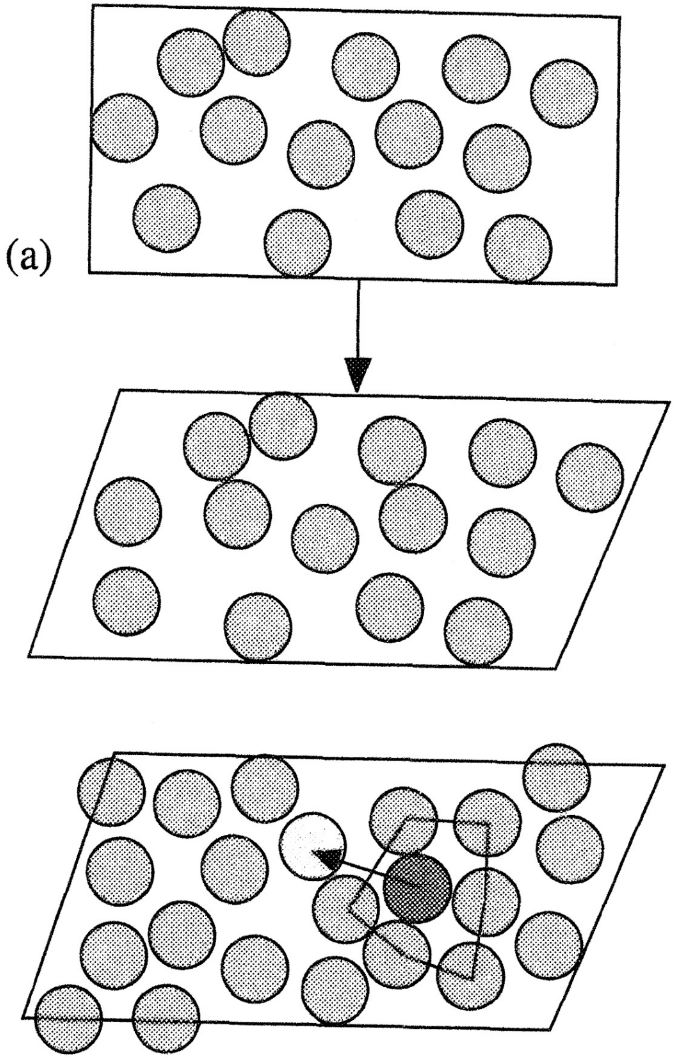
Time dependent shear strain:
Short time ($t<\tau$) - elastic
Long times ($t>\tau$) - viscous

τ - relaxation time of the system

G_0 - instant shear modulus ($t<<\tau$)

$$\eta \approx G_0 \tau$$

Relaxation time

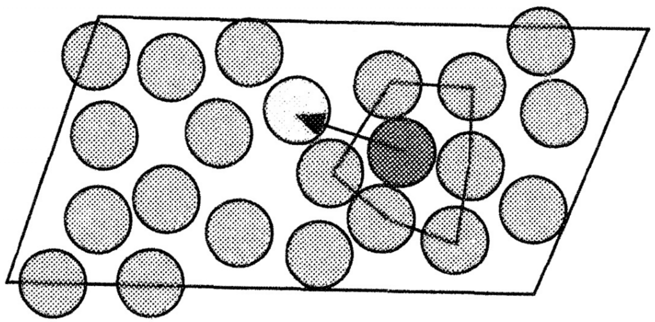


Solid - cannot relax stress, no rearrangement of atoms

Liquid - stress can be relaxed by local rearrangement of the structure:
- jumps to new sites
- reorientation

Relaxation time *(τ)* $\Rightarrow$
characteristic time of the local rearrangement of the structure

Relaxation time

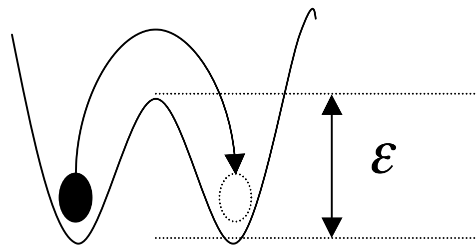


Relaxation in simple liquid

Potential to escape from local neighbourhood - ε

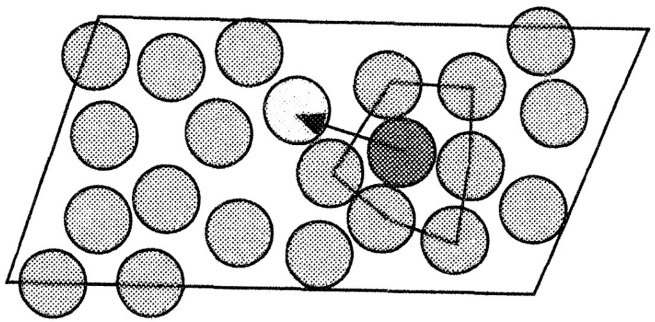
Thermally activated process - Boltzman distribution of probability

$$\Rightarrow \quad \tau^{-1} \sim \nu e^{-\frac{\varepsilon}{k_B T}}$$



ν - vibrational frequency

Viscosity of simple liquid



Relaxation in simple liquid $\Rightarrow$ viscosity of simple liquid

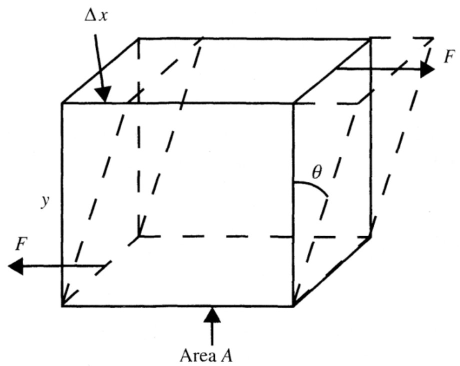
$$\tau^{-1} \sim \nu e^{-\frac{\varepsilon}{k_B T}}$$

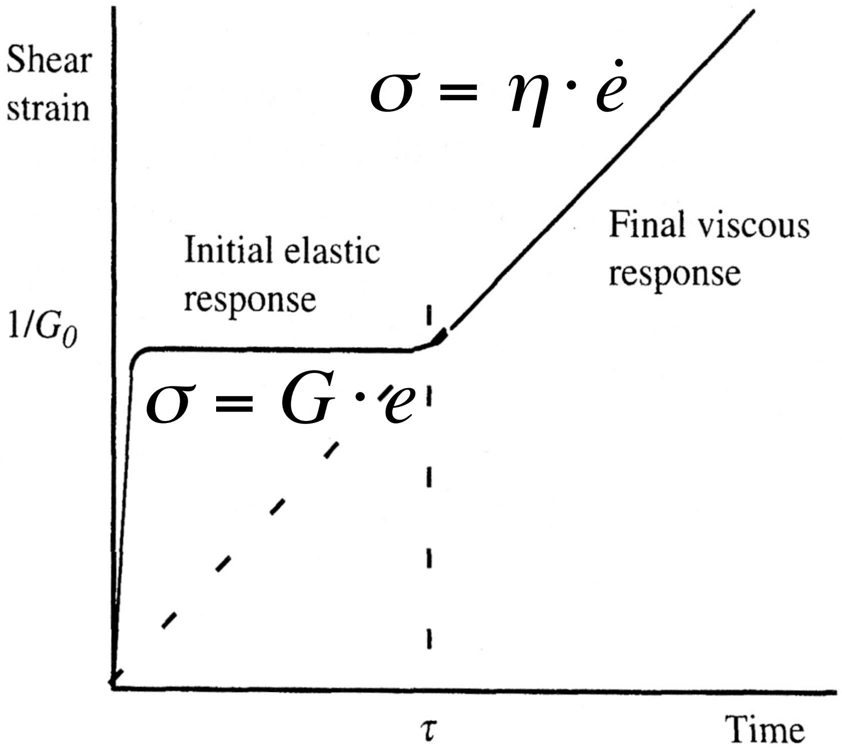
$$\eta \approx G_o \tau$$

$$\Rightarrow \quad \eta = \frac{G_o}{\nu} e^{\frac{\varepsilon}{k_B T}}$$

Arrhenius dependence of viscosity for a simple liquid!

Viscoelastic response





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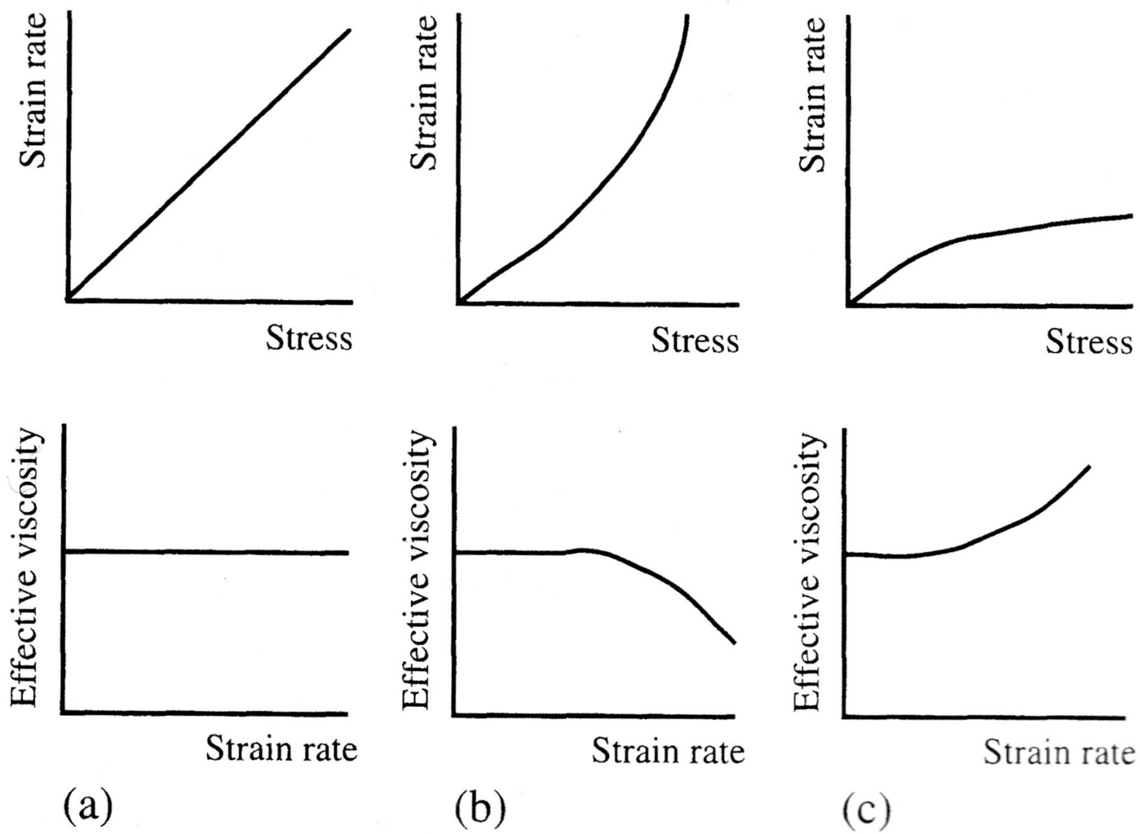
$$\eta \approx G_0 \tau$$

All liquids show viscoelastic response if observation time (or frequency) is short (high) enough!

Non-newtonian fluids

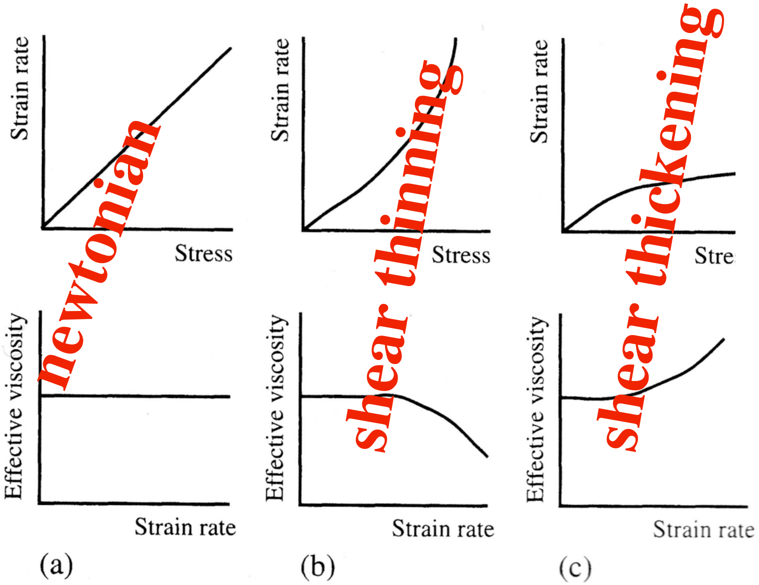
Strain rate dependent viscosity $\sigma = \eta(\dot{e})\dot{e}$

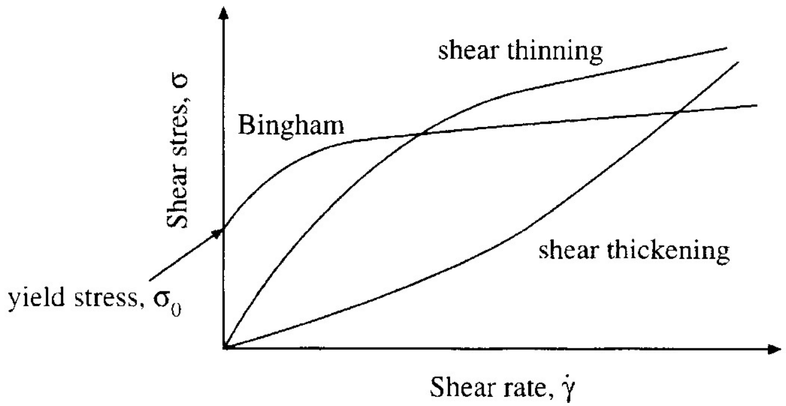


newtonian **shear thinning** **shear thickening**

Rheology

Science of deformation and flow of matter



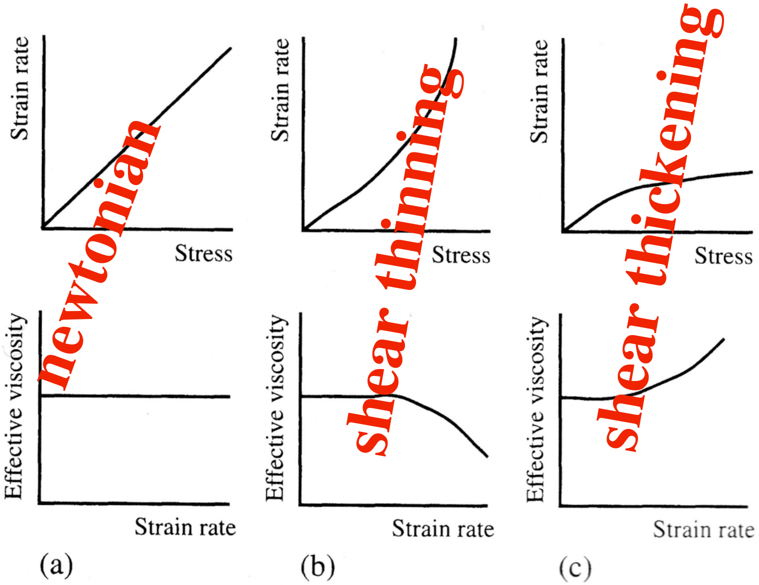


Bingham fluid $\sigma = \eta(\dot{e})\dot{e} + \sigma_0$

- does not flow until a certain yield stress

Rheology

More on rheology 28/9 12-13 seminar by Johan Bergenholtz, Göteborg University



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