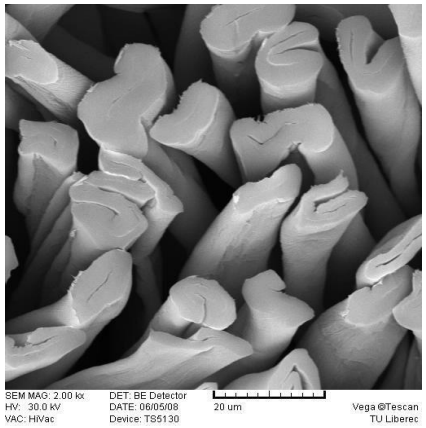
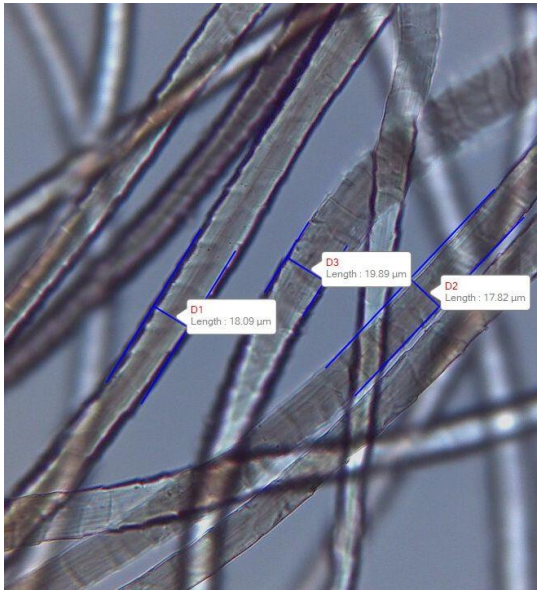
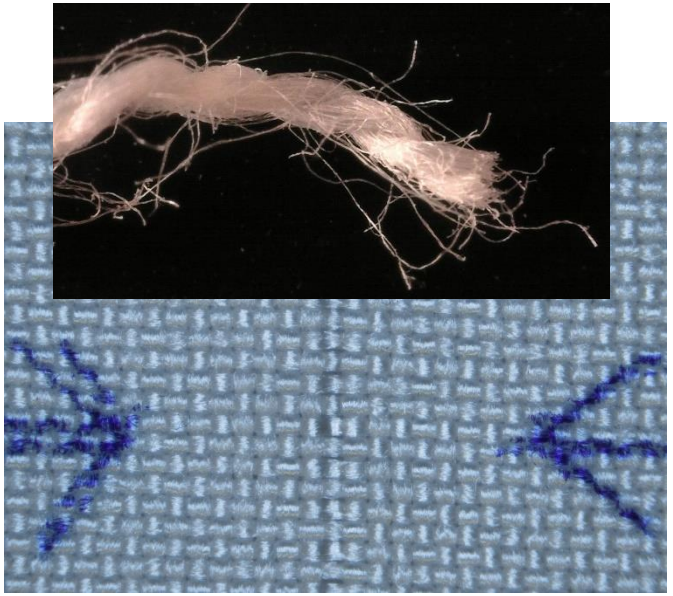
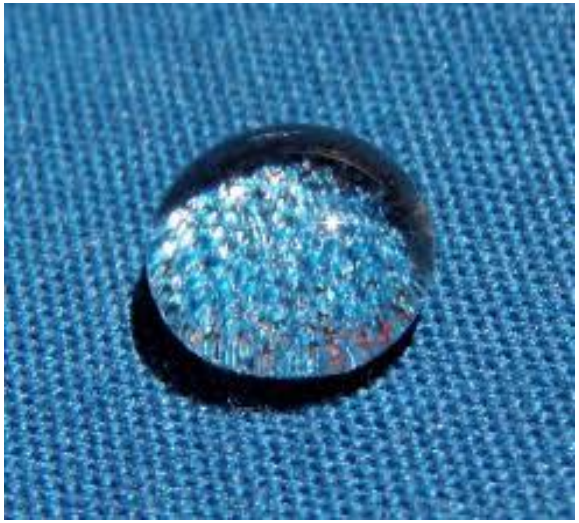


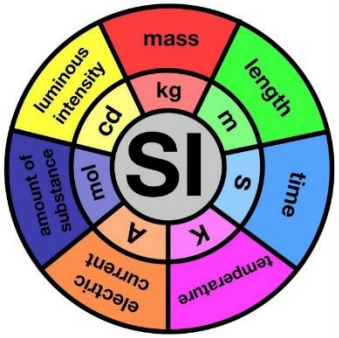


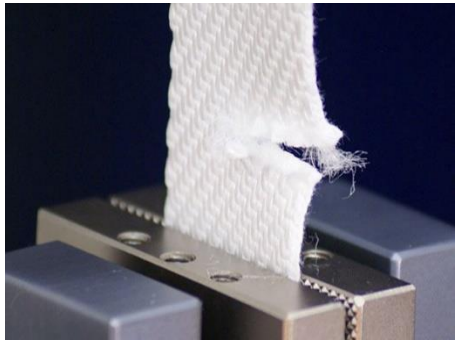


Introduction to textile metrology

Basic terms and definitions



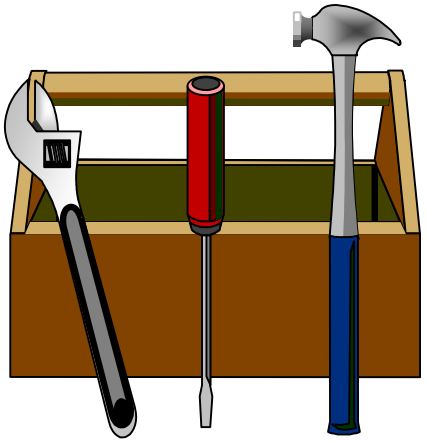




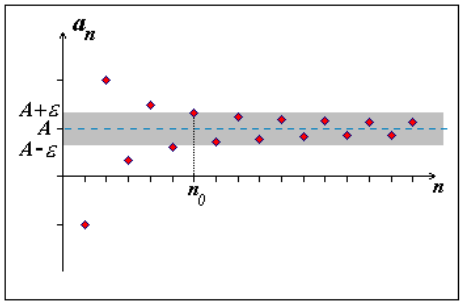
Ing. Blanka Tomková, Ph.D.

Katedra materiálového inženýrství

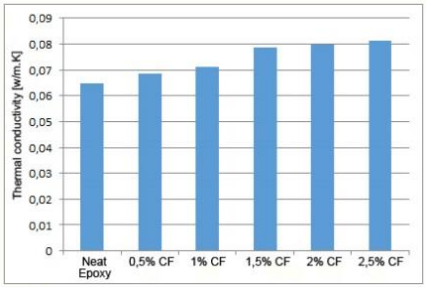
Measurement methodology



- **Theory of measurement**
  - philosophy and methodology
- **Measurement errors**
  - types of errors, prediction
- **Measuring equipment**
  - accuracy and precision
  - comparison of results



- **Design of experiments**
  - time schedule of measurements, classification, selection and preparatiom of samples
- **Data analysis and processing**
  - filtration, compresion, analysis of single and multidimensional data, presentation of results

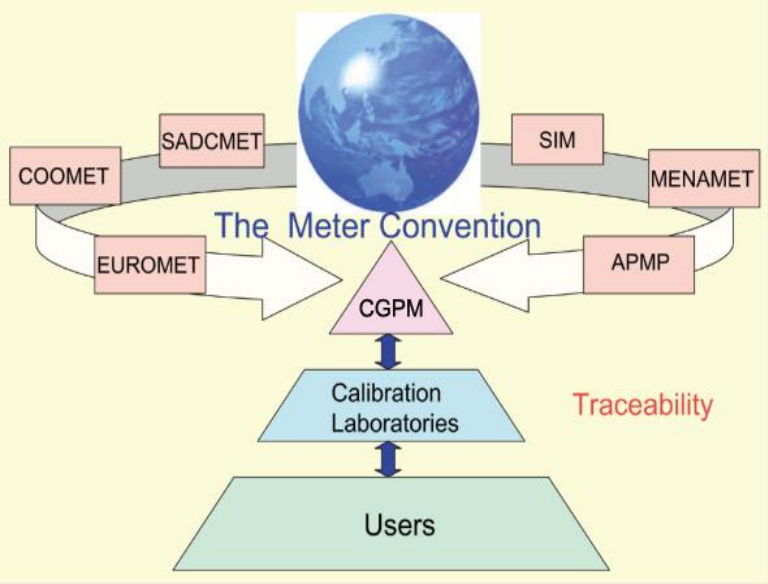


Measurement standards

- Definition/specification of precise measurement standards requires setting of two key elements:
  - definition of used measurement units and methodology
  - validation of used measurement equipments and systems, where these equipmnets are implemented
- Many states decided to use International system of Units (SI)
  - The system of measurement is based on **seven basic units**
    - prototypes of measurement units are deposited in archive of the International Bureau of Weights and Measures (BIPM), Saint-Cloud, Paris, France
    - this units are basis for derivation of other units
- 23.6. 1799 - SI was established by the Metre Convention
  - deposit of platinum prototype metre bar as a standard for measurement of length, that specifies the extent of 1 m in 0°C (Greek metron = measure)
  - prototype was deposited into State Archive of the French Republic
- 25. 5. 1875 - conclusion of metric convention, foundation of BIPM
  - Metric convention was first accepted by 20 states, nowadays it is accepted by almost all countries in the world
  - The system of multiple and partial length units was created on the basis of decimal division, and the whole system was called the metric system

Metrological institutions

- **Metric convention**
  - international treaty of 48 countries, that covers e.g.
  - **CGPM - General convention**
    - Conférence générale des poids et mesures
    - **EUROMET (1983)**
      - European metrology institutes
    - **SADCMET**
      - South-African metrology institutes
    - **COOMET**
      - Eurasian metrology institutes
    - **SIM**
      - American metrology institutes
    - **MENAMET**
      - cooperation of metrology institutes in Middle East and North Africa
    - **APMP**
      - cooperation of metrology institutes in East Asia and Pacific
  - **CIPM - International committee for Weight and Measures**
    - **CC** – advisory committees
  - **OIML - International Organization for legal metrology**
    - production and use of gauges



! Standards unify the measurement methods!

- repeatable, harmonised, agreed and documented way of doing something
  - regulations that contain technical specifications or other precise criteria designed to be used consistently as a rule, quideline, or definition
  - regulation is not obligatory, if it is not determined by law
- **It is obligatory** for areas determined by law!!!
  - fire safety, state security, health protection, environmental protection, and so on

Types of standards

- **Specification standards**
  - explicit set of requirements to be satisfied by a material, product, system or service
- **Test method standards**
  - definitive procedure that produces test result, includes a concise description of an orderly procedure for determining a property or constituent of material
- **Classification standards**
  - systematic arrangement or division of materials, products, systems or services into groups based on similar characteristics such as origin, composition, properties or use.
- **Practice standards**
  - standards for technical activities, set of instructions for performing one or more specific operations that does not include a test result
- **Terminology standards**
  - document comprising definition of terms, explanations of symbols, abbreviations or acronyms

Standards - institutions and authorities

- **ISO** - International Organization for Standardization

  CEN - European Committee for Standardization

  CENELEC - European Committee for Electrotechnical Standardization

  European Committee for Standardization
  Comité Européen de Normalisation
  Europäisches Komitee für Normung

  ETSI - European Telecommunications Standards Institute

- **National standard institutions**
  - **UNMZ** - Czech office for standards, metrology and testing

    CSN - Czech technical standard
  - **DIN** - Deutsche Industrie Normen
  - **GOST -** Gosudarstvennyj standard
  - **BSI** - British Standard Institution
  - **ASTM** - American Standards Test Methods

Czech textile standards – an overview

TECHNICAL STANDARDS CSN ISO

80 - TEXTILE RAW MATERIALS AND PRODUCTS

8000 - Textile industry, general terms

8000 - 8008 *

- 8000 - Textile industry, general tems
- 8001 - Testing of colour fastness of textile raw materials and products
- 8002 - Testing of fibers
- 8003 - Standardization of Testing
- 8005 - Test standards for chemical fibers
- 8006 - Test standards for chemical fibers from natural sources
- 8007 - Testing of threads, yarns, multifilament etc.
- 8008 - Testing of fabrics

8010 - 8019

- 8010 - Natural fibers
- 8011 - Natural textile fibers
- 8013 - Chemical fibers from natural polymers
- 8014 - Chemical fibers from synthetic polymers
- 8018 - Textile wastes
- 8019 - Textile wastes

***Examples**

ČSN 80 0001 (800001) Textiles- Fundamental classification and terminology (EN ISO 3758)
ČSN 80 0005 (800005) Textiles - Care labelling code using symbols (EN 23758 ISO 3758)
ČSN 80 0804 (800804) Textiles - fabrics for apparel (EN 1103)
- Detailed procedure to determine the burning behavior

fFor more see, e.g.: http://www.technicke-normy-csn.cz/technicke-normy/textilni-suroviny-a-vyrobky-80

8020 - 8029

- 8020 - Threads, Yarns, Multifilaments etc.
- 8021 - Threads, Yarns, Multifilaments etc.
- 8023 - Threads, Yarns, Multifilaments etc.
- 8025 - Threads, Yarns, Multifilaments etc.
- 8026 - Threads, Yarns, Multifilaments etc.

8030 - 8039

- 8030 - Textiles and textile products
- 8033 - Textiles and textile products
- 8036 - Ribbons and braids

8040 - 8049

- 8041 - Textiles for healthcare
- 8042 - Textiles - Upholstery fabrics
- 8044 - Textile floor coverings
- 8045 - Technical textiles
- 8046 - Technical textiles

8050 - 8059

- 8050 - Outerwear and knitted garments
- 8058 - Hosiery

8060 - 8069

- 8060 - Special products and accessories, general terms
- 8061 - Nonwovens
- 8063 - Tulles, laces, embroidery and mesh-works
- 8064 - Tulles, laces, embroidery and mesh-works
- 8069 - Headwear and clothing accessories

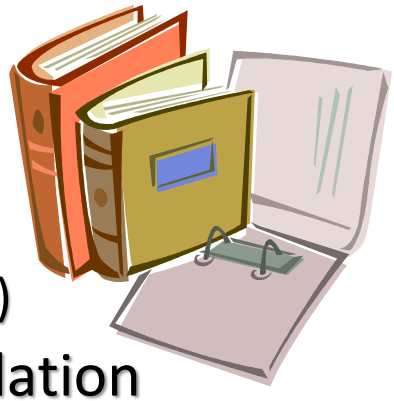
8070 - 8079

- 8070 - Clothing and supplements of dress
- 8076 - Bed linen and piece goods
- 8077 - Overalls and protective clothing
- 8078 - Overalls and protective clothing

8080 - 8089

- 8081 - Piece products for technical purposes
- 8084 - Piece products for technical purposes
- 8085 - Twine, cords and ropes
- 8086 - Twine, cords and ropes
- 8087 - Hoses, belts and similar products
- 8088 - Feathers and down
- 8089 - Touch and close fasteners

Basic terms and definitions



- **Calibration**
  - set of relation between required quantity (hard to measure) and measurable quantity (easy to measure)

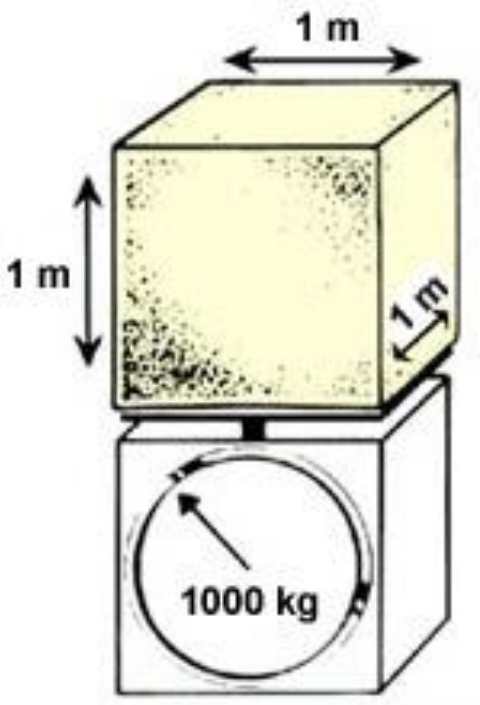
  Two phases: model formulation and model validation
- **Adjustment**
  - setting of instruments for accurate measurements (use of etalons, comparative tests, etc.)
- **Testing**
  - specific activity towards knowledge of materials and product properties
- **Certification**
  - official verification or certification (verification of conformity)
  - document that confirms the product or service suit requirements of certain standards or technical conditions
- **Quality assurance**
  - according to standards ISO, ASME etc.

Physical quantities

- Most of measured characteristics are described using phsyical quantities
  - physically defined properties of phenomenons, bodies or substances, where we can be distinguish quality and estimate its quantity

Physical quantity = numeric value* unit

- **Unit:**
  - Specially derived measure of certain quantity, which numeric value is equal to one, and is basis for measurement of physical values of the kind.
  - Reference units are also basis for description of other physical quantities
    - Example: **Mass** $m = 1000\ kg$
      Volume $V = 1\ m^3$
      Density $\rho = 1000\ kg.m^{-3}$

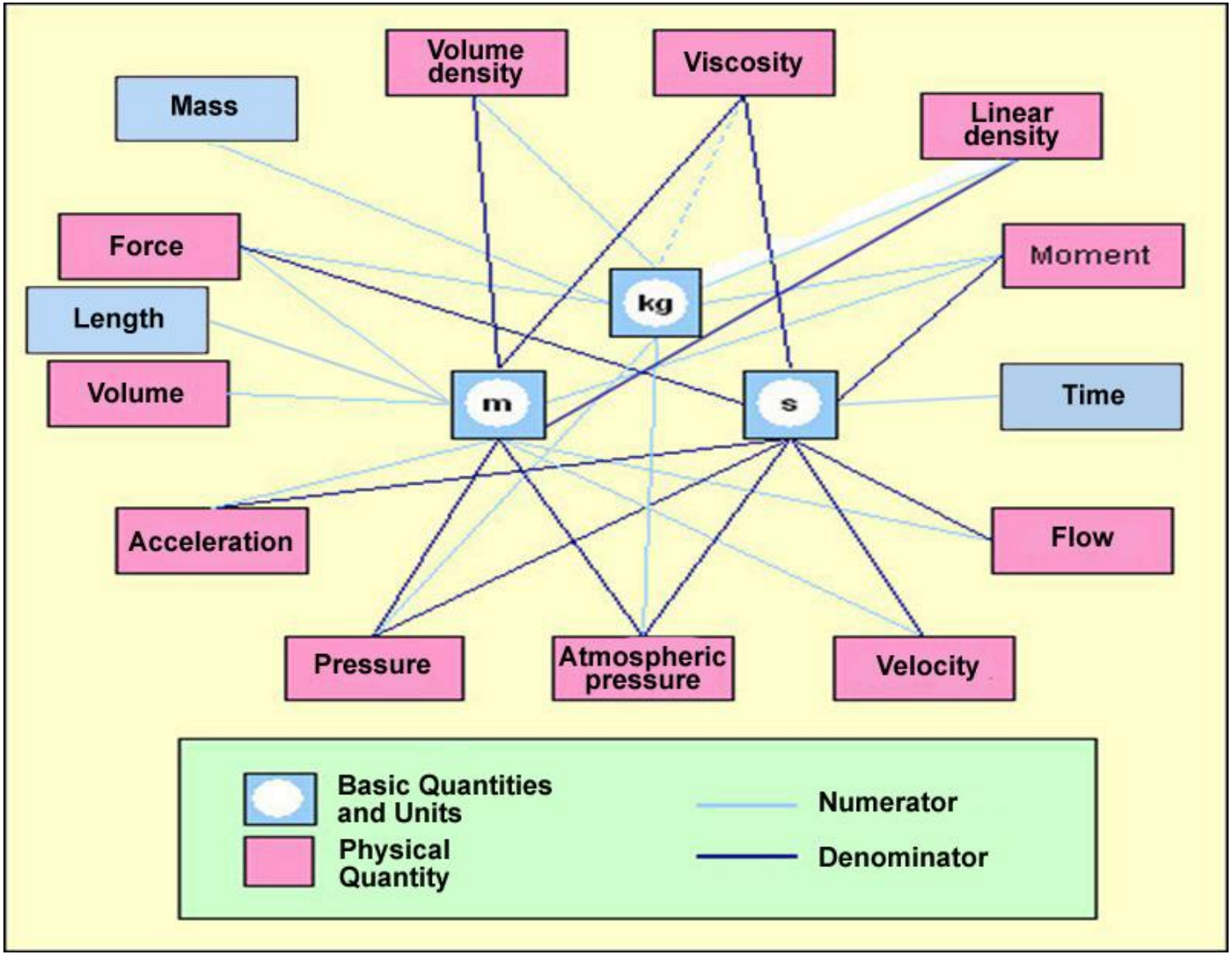


Unit systems

	ounce	grains	grams	kilograms	pounds
ounce		437.5 grains	28.350 grams		
grains	0.03527 ounces		0.0648 grams		
grams	0.03527 grains	15.432 grains		0.001 kgs	
kilograms	35.274 ounces	15432 grains	1000 grams		2.2046 pounds
pounds	16.0 ounces	7000 grains	453.59 grams	0.4536 kgs	

	yard	feet	inches	centimeter	meter
yard		3 feet	36 inches	91.44 cms	0.9144 meter
feet	0.3333 yards		12 inches	30.48 cms	0.3048 meter
inches	0.0278 yards	0.0833 feet		2.54 cms	0.254 meter
centimeter	0.0109 yards	0.0328 feet	0.3937 inches		0.01meter
meter	1.0936 yards	3.281 feet	39.37 inches	100 cms	

Overview of SI Units



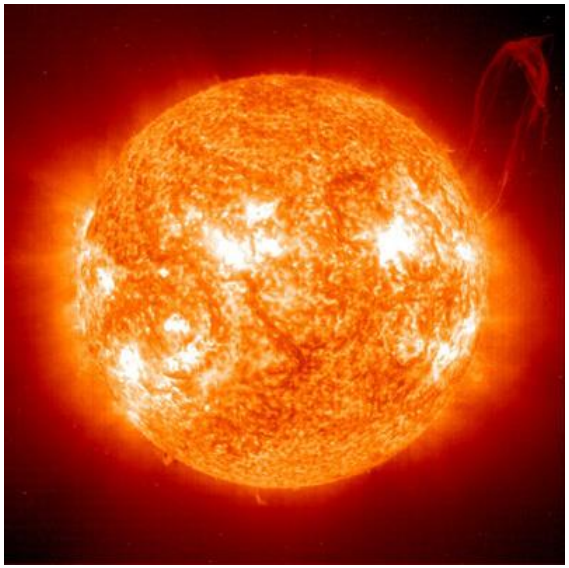
7 basic units

Length	meter	[m]
Mass	kilogram	[kg]
Time	second	[s]
Electric current	amper	[A]
Temperature	kelvin	[K]
Molar substance	mol	[mol]
Luminous intensity	candela	[cd]

Derived units

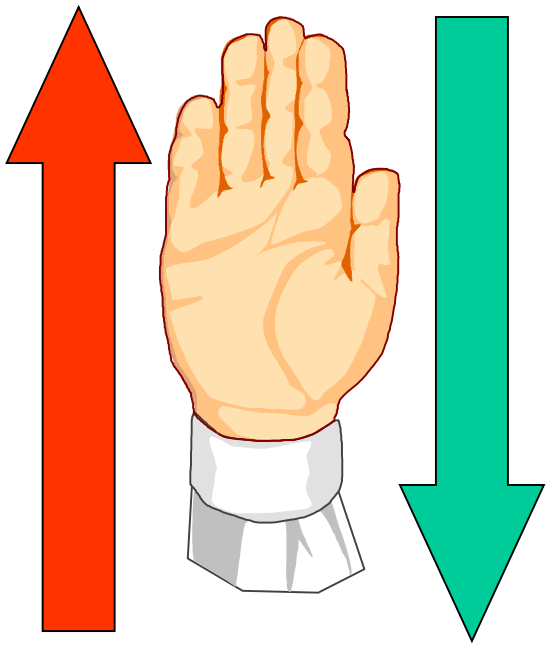
Force	[$N = kg.m.s^{-2}$]
Strength	[$Pa = N.m^{-2} = kg.m^{-1}.s^{-2}$]
Energy	[$J = N.m$]

Suplements: 2 (angles)



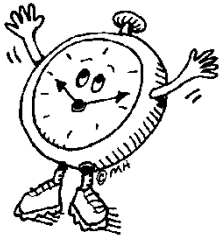
Multiples and parts

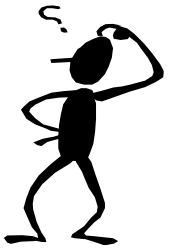
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hekto	h
10^{1}	deka	da



10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	mili	m
10^{-6}	mikro	µ
10^{-9}	nano	n
10^{-12}	piko	p
10^{-15}	femto	f
10^{-18}	atto	a

Only multiples of seconds are not tens!!!





Examples of derived units

1.	**Volume density ρ**	-	**-**	$kg.m^{-3}$
2.	**Force F**	Newton	**N**	$kg.m.s^{-2}$
3.	**Pressure p / Strength σ**	Pascal	**Pa**	$N.m^{-2}$
4.	**Work A / Energy E**	Joule	**J**	N.m
5.	**Power P**	Watt	**W**	$J.s^{-1}$
6.	**Frequency f**	Hertz	**Hz**	s^{-1}

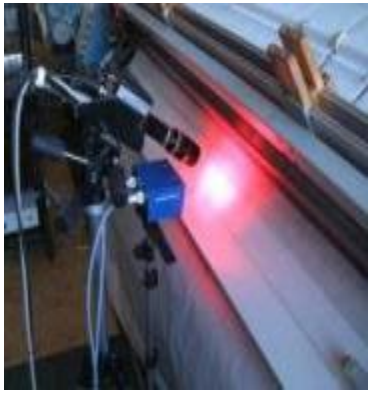
Textile measurements

- **Standard measurements:**
  - Design of experiments
  - Realization of experiments
  - Evaluation of experiments
  - Presentation of results

New aims of measurements:

- Complex quality (products, processes)
- Control of processes
- Design of products
- Simulation and optimizing

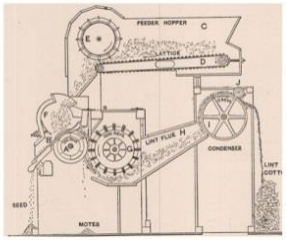
Industry



Laboratories

Market

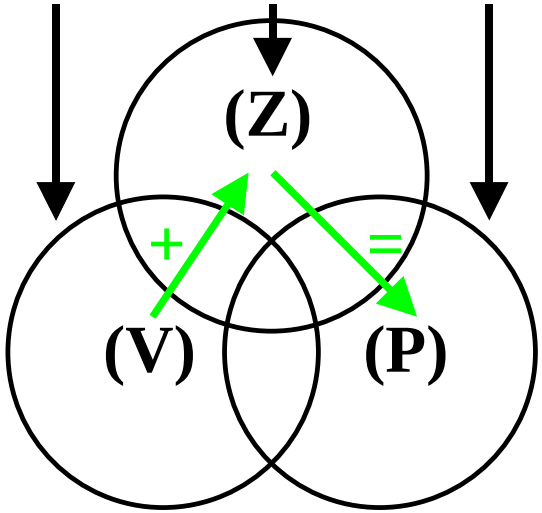
Material properties


- **„Internal“ properties (V)**

  Defined by physical quantities
  Related to substance
  (objective standards for measurement)

Material Process Product



- **Processing properties (Z)**

  Related to manufacturing

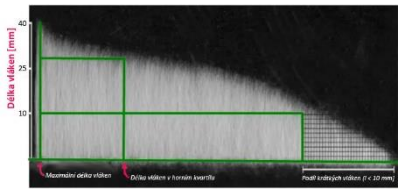
- **Properties of products (P)**

  Complex characteristic – hard to measure
  Related to shape and size (orientation…)

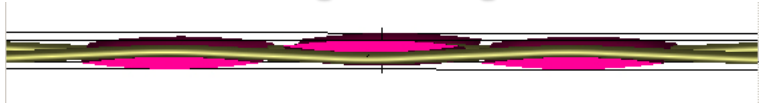
- **Textile products are highly sensitive to manufacturing**

  Fibers: for indentical chemical substances we can obtain various properties using different conditions of manufacturing (spinning, etc.) – physical changes in the structure (orientation, length of polymers, crystallinity …)

- **Changes in time: * degradation * relaxation* wear**



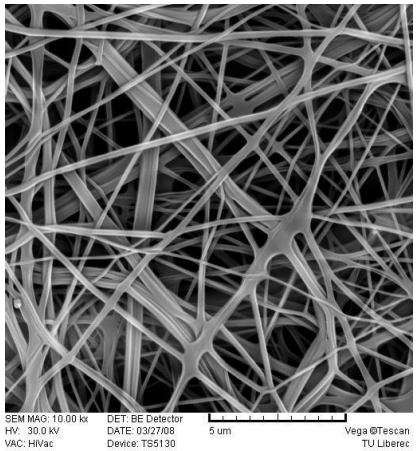
Textile properties

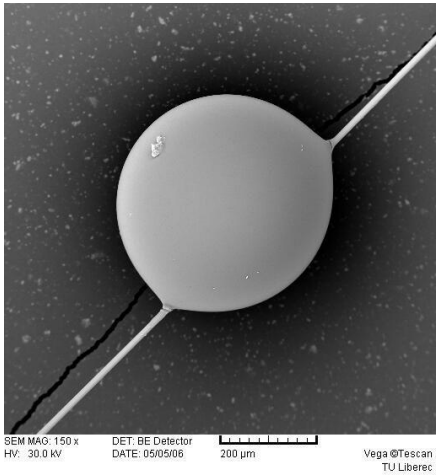


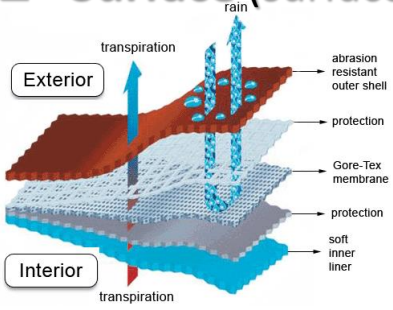
Combination of physical-chemical properties

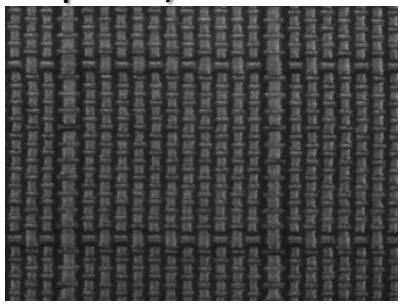
Special type of soft materials

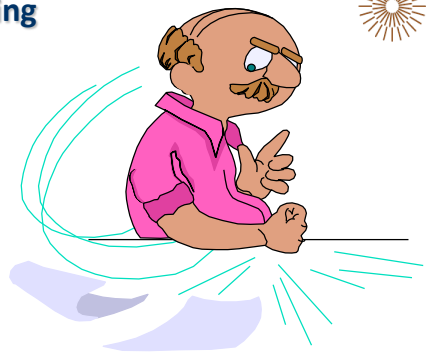
- **Geometric** (shape, volume, porosity, surface roughness)
- **Material** (volume density, linear density)
- **Sorption** (wettability, solubility, swelling)
- **Mechanical** (statistical, dynamical, uni-, multi-directional)
- **Thermal** (heat transition, heat capacity, thermal conductivity)
- **Transport** (transport vlhkosti, tepla, vzduchu)
- **Elektrical** (resistivity, dielectric constant)
- **Surface** (surface tenstion, adhesion, absorption)











Special textile units I.

A. Linear density

$$T_t[tex] = \frac{m[g]}{l[km]} = [g \cdot km^{-1}]$$

$$T_t[tex] = 10^6 \cdot S[m^2] \cdot \rho[kg \cdot m^{-3}]$$

Circular fiber cross-section:

$$T_t[tex] = 10^6 \cdot \frac{\pi \cdot d^2[m^2]}{4} \cdot \rho[kg \cdot m^{-3}]$$

For the same linear density have fibers with higher volume density ρ [kg.m^{-3}] lower diameter d [μm]!!!

- direct systems
  - **higher linear density – higher diameter**

$$Denier\ Td\ [den] = \frac{m[g]}{l[9km]}, Td = 9 \cdot T_t$$

- indirect systems – **higher density*, lower diameter**

Metric number (Nm)

$$Nm = \frac{l[m]}{m[g]}, Nm = \frac{1000}{T_t}$$

English number (Ne)

$$Ne = \frac{840\ yards}{lb}, \mathrm{Ne} \approx 1{,}96Nm$$

Special textile unit II.

B. Specific force

$$F_P[N \cdot tex^{-1}] = \frac{F[N]}{T_t[tex]}$$

Other units

$[cN \cdot dtex^{-1}]$ – fibers
$[cN \cdot tex^{-1}]$ – yarn

C. Strength

$$\sigma[Pa] = \frac{F[N]}{S[m^2]}$$

$$\sigma[Pa] = \frac{F_P[N \cdot tex^{-1}] \cdot T_t[tex]}{S[m^2]} = \frac{F_P \cdot \rho \cdot S \cdot 10^6}{S}$$

$$= F_P \cdot \rho[kg \cdot m^{-3}] \cdot 10^6$$

Higher volume density,
lower specific force F_P [N/tex],
same strength σ[Pa]!!!

$$G[N] = F[N] = m[kg] \cdot g[m \cdot s^{-2}]$$

$$m[kg] = \rho[kg \cdot m^{-3}] \cdot \boldsymbol{L[m]} \cdot S[m^2]$$

D. Breaking length L_G [km]

length, when the fiber breaks by its own weight

$$\boldsymbol{L_T[km]} = \frac{F[N] \cdot 10^{-3}}{S[m^2] \cdot \rho[kg \cdot m^{-3}] \cdot g[m \cdot s^{-2}]}$$

Special textile units III

	tex	Ne	den	Nm	grains/yd
tex			den/9	1000/Nm	gr.yd x 70.86
Ne	590.54/tex		5314.9/den	Nm x .5905	8.33 / gr/yd
den	tex x 9			9000/Nm	gr/yd x 637.7
Nm	1000/tex		9000/den		14.1 / gr/yd
grains/yd	tex / 70.86		den / 637.7	14.1/Nm	

- **grams per meter = 0.5905 / Ne**
- **grams per yard = 0.54 / Ne**
- **tex = den x .11 = 1000/Nm = Mic/25.4**
- **Ne = Nm/1.693**

Vitruvian Man Metrology