





metrology				
theoretical	legal	applied		
quantities and units systems of quantities measurement scales uncertainty analysis	homogenity and legality of measuring devices law acts norms technical conditions	construction and usage of measuring devices measuring quantities necessary for human activity		
measurement \rightarrow cor	nparison \rightarrow reference	<i>electronic metrology</i> - measurement of		
BIPM Bureau international des poids et mesures NMI National Metrology Institution GUM Główny Urzad Miar	ISO International Organization for Standarization IEC International Electrotechnical Commission PKN	electrical quantities - measurement of non electrical quantities using electronic methods - electronic measuring instruments		



1) introduction: measurement, units, standards, etc.

2) signals and their parameters; principles of basic measurements

3) digital measurements

4) measurement of non-electrical quantities: force, mass, pressure

5) oscilloscope and oscilloscope measurements (two lectures)

6) impedance measurements: indirect and bridge methods

7) measurement uncertainty (two lectures)

Laboratory exercises are closely connected with the lectures so it is generally recommended to attend the lectures...



Q = Q [Q] Q - quantity value Q - numerical value [Q] - unit				
International Sy	stem of Units	s - SI (1960)		
oase units				
quantity	symbol	quantity unit	quantity symbol	
length	l, h, r, x	metre	m	
		1.11	1	
mass	m	Kilogram	ĸg	
mass time	m	kilogram second	s	
mass time electric current	m t I,i	kilogram second amper	kg s A	
mass time electric current temperature	m t I, i T	kilogram second amper kelvin	kg s A K	
mass time electric current temperature amount of substan	m t I,i T ice n	Kilogram second amper kelvin mole	kg s A K mol	







Units – definition, realisation, uncertainty

time:

1 second [s] is the duration of 9 192 631 770 periods of radiation corresponding to the transition between two hyperfine levels of the ground state of Cs^{133} atom



commercial cesium reference standard 5071A (Symmetricom, formerly HP) uncertainty 5×10⁻¹³ - 1×10⁻¹²



caesium clocks at PTB Physikalish-Technische Bundesanstalt Braunschweig , Germany uncertainty 1.2×10⁻¹⁴ 1×10⁻⁹ s/day 1 s/2.7×10⁶ years

cesium fountain 1x10⁻¹⁵

























 measurement → comparison with the stand comparison → direct or indirect one assumes that such comparison is repeated one uses adequate measurement eauipment one knows how to use them properly the measurement is performed under properties we are aware about possible errors and uncerto a standard or a s	ard and determining relationship table and reproducible and procedures er conditions ertainty of measurement measurement
Gross Errors deffective instruments (measurement p the range or type of a measurement is s hand-held multimeters	robes, cables etc) et improperly, eg Α, Ω, etc

Recommended literature and other sources

• S. Tumański: Principles of Electrical Measurements, Taylor & Francis, 2005

 R.A. Witte (Agilent Technologies): Electronic Test Instruments: Analog and Digital Measurements, Prentice Hall, 2002

- SI Units Brochure:
- http://www.bipm.org/utils/common/pdf/si_brochure_8_en.pdf
- The NIST Reference on Constants, Units and Uncertainty
- http://physics.nist.gov/cuu/Units/index.html
 International Vocabulary of Metrology (VIM):
- http://www.bipm.org/utils/common/documents/jcgm/JCGM_200_2012.pdf
- R.A. Witte (Agilent Technologies): Spectrum & Network Measurements, Prentice Hall, 1993
- A.K. Ghosh: Introduction to Measurements and Instrumentation, PHI Learning, 2012
- R.B.Northrop: Introduction to Instrumentation and Measurements, Taylor & Francis, 2005

(some books in Polish)

- S. Tumański: Technika Pomiarowa, WNT, 2013
- A. Zięba: Analiza danych w naukach ścisłych i technice, PWN, 2013
- J. Dusza, G. Gortat, A. Leśniewski: Podstawy miernictwa, Oficyna Wydawnicza Politechniki Warszawskiej, 2007
- A. Kamieniecki: Współczesny oscyloskop, btc, 2009
- A. Zatorski, R. Sroka: Podstawy Metrologii Elektrycznej, Wydawnictwa AGH, 2011
- J. Arendarski: Niepweność pomiarów, Oficyna Wydawnicza Politechniki Warszawskiej, 2003
- Niepwenóść pomiarów w teorii i praktyce praca zbiorowa, GUM http://www.gum.gov.pl/pl/komunikacja/publikacje/niepewnosc-pomiarow-w-teorii-i-praktyce/spis-tresci/