Modulbezeichnung: **Fundamentals of Metrology (FoM)** **5 ECTS**
(Fundamentals of Metrology)

Modulverantwortliche/r: Tino Hausotte
Lehrende: Tino Hausotte

Startsemester: SS 2015	Dauer: 1 Semester	Turnus: jährlich (SS)
Präsenzzeit: 60 Std.	Eigenstudium: 90 Std.	Sprache: Deutsch und Englisch

Lehrveranstaltungen:

Fundamentals of Metrology - Grundlagen der Messtechnik (SS 2015, Vorlesung, 2 SWS, Tino Hausotte)
Fundamentals of Metrology - Grundlagen der Messtechnik - Übung (SS 2015, Übung, 2 SWS, Tino Hausotte)

Inhalt:

Basic principles

- **Essence of measuring:** SI unit system - Definitions of SI units (cd, K, kg, m, s, A, mol) - What is measuring? - Extensive and intensive quantities - Measuring, testing and gauging - Objective and subjective testing - Basic requirements for measuring - Transmission and use of the units - Correct use and notation of units - Measured value, true value, output value - Measurement deviations
- **Principles and methods of measurement:** Principles, methods and procedures of measurement - Deflection, differential, substitution and compensation measurement methods - Direct and indirect measurement methods - Analog and digital measurement methods - Absolute and incremental measurement methods - Resolution and sensitivity - Curve and kinds of curves
- **Statistics - Evaluation of measurements series:** Calculation of a measurement result based on measurement series - Basic terms of descriptive statistics - Presentation and interpretation of measured value distributions (histograms) - Frequency (absolute, relative, cumulative, relative cumulative) - Calculation and interpretation of basic parameters: location (mean, median, mode), dispersion (range, variance, standard deviation), shape (skewness and excess kurtosis) - Stochastics and distributions (rectangle, U and normal distribution) - statistical tests and statistical estimation methods - Correlation and regression
- **Measurement errors and measurement uncertainty:** Measured value, true value, conventional quantity value, detected value, output value - Influences on the measurement (Ishikawa diagram) - Measurement error (systematic, random) - Correction of known systematic measurement errors - Calibration, verification, legal verification - Measurement precision and accuracy - Repeatability conditions and precision , Comparison conditions and precision, extended comparison conditions and precision - Measurement uncertainty - Correct specification of a measurement result - Overview of standard method of the GUM (measurement uncertainty)

Mesurands of the SI system of units

- **Measurement of electrical quantities:** Measurement of current and voltage (current and voltage correct measurement), range adjustment - Wheatstone bridge circuit (quarter, half and full bridge, differential method and null balancing procedures) - Characteristic values of sinusoidal alternating quantities (alternating voltage bridge) - Operational Amplifier (Inverting amplifier, non-inverting amplifier, impedance converter) - Digitising chain (filters, sample-and-hold device, analog-digital conversion) - Variations in the analog-to-digital conversion
- **Measurement of optical quantities:** Light and properties of light - Photo detectors (photo resistors, photo diodes) - Sensitivity range of the eye - Radiometry and photometry - Luminous intensity (cd, candela) - Radiation laws
- **Measurement of temperatures:** Temperature, SI unit, definition - Heat transfer (conduction, convection, radiation) - Fixpoints (triple points, freezing points), fixpoint cells, International Temperature Scale (ITS-90) - Contact thermometers - Metal resistance thermometer, measurement circuits for resistance thermometers - Thermocouples, measurement circuits for thermocouples - Measurement errors of contact thermometers - Radiation laws, pyrometers (see optical quantities) - Measurement errors of pyrometers

- **Time and Frequency:** Time measurement - Atomic clock - Global Positioning System - Representation of time - Propagation of UTC - Frequency and phase angle measurement
- **Length:** Meter definition - Abbe comparator principle, errors 1st and 2nd order - Length measurement with linear encoders, motion direction, output signals, differential signals - Absolute coding (V-Scan and Gray code) - Interferometer, Michelson interferometer, basics of interference, homodyne principle, heterodyne principle, interference on homodyne interferometer, destructive and constructive interference, influence of air refractive index
- **Angle and slope:** plane angle, angle unit - material measures - angle measuring devices - slope measurement - optical angle measuring devices - measurement deviations - spatial angle, solid angle
- **Mass and force:** Definition of SI unit kilogram, mass standards, principle of mass dissemination - Definition of mass, force and torque - Measurement principles of weighing - Beam balance, spring balance, hanging and top pan balances, corner load sensitivity, DMS balance, EMC balance, mass comparators - Influences for mass determination - Force measurement, force measurement with DMS, Magneto-elastic and piezoelectric force measurement

Branches of industrial metrology

- **Process Measurement Technology:** Definition of pressure - Pressure types (absolute pressure, overpressure, differential pressure) - Pressure balance (piston manometer), U-tube manometer, bourdon pressure gauge, diaphragm pressure gauge - Pressure sensors (with DMS, piezoresistive, capacitive, piezoelectric) - Flow measurement (volume flow and mass flow, flow of fluids) - volumetric method, differential pressure method, sinker flow meter, magnetoinductive flowmeter, ultrasonic flow measurement - Mass flow rate measurement (Coriolis, thermal)
- **Manufacturing Metrology:** Subtasks of manufacturing metrology, objectives of manufacturing metrology - Form parameters of workpieces (micro-and macro-shape), structural error types, measuring, checking, monitoring - Comparison of classical measuring and coordinate measuring, standard geometrical features - Designs and basic structure of coordinate measuring machines - Procedure for measuring with a coordinate measuring machine
- **Micro and Nanometrology:** Demands of the microsystem technology on metrology - Sensors and probing systems of microsystem technology (tactile sensors, opto-tactile fiber probe, focus sensor, chromatic white light sensor) - Atomic force microscope (structure, working methods), scanning tunneling microscope - Nano coordinate measuring: 3-D realization of the Abbe comparator principle - Measures to reduce influences

Lernziele und Kompetenzen:

Learning targets and competences:

Remembering

- The students have basic knowledge of fundamentals of metrology and metrology activities. - The students have fundamental knowledge for methodological and operational approach to measuring tasks of static measurement types, to solve basic measurement tasks and to establishing measurement results from measurement values.

Understanding

- The students are able to describe the characteristics of measuring instruments and measurement processes. - The students are able to describe the international system of units (SI) and the traceability of measurement results

Applying

- The students are able to run basic measurements of static measurands.

Evaluating

- The students are able to evaluate measuring systems, measurement processes and measurement results.

Literatur:

- DIN e.V. (Hrsg.): Internationales Wörterbuch der Metrologie - Grundlegende und allgemeine Begriffe und zugeordnete Benennungen (VIM) ISO/IEC-Leitfaden 99:2007. Beuth Verlag GmbH, 3. Auflage 2010
- Hoffmann, Jörg: Handbuch der Messtechnik. 4. Auflage, Carl Hanser Verlag München, 2012 - ISBN 978-3-446-42736-5

- Lerch, Reinhard: Elektrische Messtechnik. 6. Auflage, Springer-Verlag Berlin Heidelberg, 2012 - ISBN 978-3-642-22608-3
- Richter, Werner: Elektrische Meßtechnik. 3. Auflage, Verlag Technik Berlin, 1994 - ISBN 3-341-01106-4
- Kohlrausch, Friedrich: Praktische Physik : zum Gebrauch für Unterricht, Forschung und Technik. Band 1-3, 24. Auflage, Teubner Verlag, 1996 - ISBN 3-519-23001-1, 3-519-23002-X, 3-519-23000-3
- Ernst, Alfons: Digitale Längen- und Winkelmesstechnik. 4. Auflage, Verlag Moderne Industrie, 2001 - ISBN 3-478-93264-5
- Pfeifer, Tilo: Fertigungsmeßtechnik. R. Oldenbourg Verlag München Wien, 1998 - ISBN 3-486-24219-9
- Keferstein, Claus P.: Fertigungsmesstechnik. 7. Auflage, Vieweg+Teubner Verlag, 2011 - ISBN 978-3-8348-0692-5
- Warnecke, H.-J.; Dutschke, W.: Fertigungsmeßtechnik. Springer-Verlag Berlin Heidelberg New York Tokyo, 1984 - ISBN 3-540-11784-9

Studien-/Prüfungsleistungen:

Fundamentals of Metrology (Prüfungsnummer: 47701)
(englische Bezeichnung: Fundamentals of Metrology)

Prüfungsleistung, Klausur, Dauer (in Minuten): 60
Anteil an der Berechnung der Modulnote: 100%
weitere Erläuterungen:

- **Prüfungstermine**, eine **allgemeine Regel der Prüfungstagvergabe** und **Termine der Klausureinsicht** finden Sie auf StudOn: Prüfungstermine und Termine der Klausureinsicht
- Die Lehrveranstaltungen *Grundlagen der Messtechnik* [*GMT*] im Wintersemester und *Fundamentals of Metrology* [*FoM*] im Sommersemester sind **inhaltlich identisch**. Beide Lehrveranstaltungen werden **bilingual** (Vorlesungsunterlagen: englisch-deutsch, Vortragssprache: deutsch) gehalten.
- Die **Prüfungen** über *Grundlagen der Messtechnik* [*GMT*] (Prüfungnr. 45101) und *Fundamentals of Metrology* [*FoM*] (Prüfungnr. 47701) sind **inhaltlich identisch**. Die Aufgabenstellung der Prüfung über *GMT* ist nur **in Deutsch**, während die Aufgabenstellung der Prüfung über *FoM* **bilingual** (englisch-deutsch) ist.

Erstablegung: SS 2015, 1. Wdh.: WS 2015/2016
1. Prüfer: Tino Hausotte

Organisatorisches:

- Unterlagen zur Lehrveranstaltung werden auf der Lernplattform StudOn (www.studon.uni-erlangen.de) bereitgestellt. Das Passwort wird in der ersten Vorlesung bekannt gegeben.