UNICUSANO
Università degli Studi Niccolò Cusano - Telematica Roma

Teaching	Sensors & Transducers
Level and course of study	Master's Degree in Mechanical Engineering LM-33 Master's Degree in Electronic Engineering LM-29
Academic discipline (SSD)	ING-IND/12
Course year	1
Total number of credits	9
Prerequisites	None.
Teacher	Fabrizio Patanè Faculty: Engineering Nickname: patane.fabrizio Email: fabrizio.patane@unicusano.it Office hours: Consult the calendar on the following page of our website by checking the Videoconference times http://www.unicusano.it/calendario-lezioni-in-presenza/calendario-area-ingegneristica
Presentation	In the first part, the course deals with the topic of measurements in general, metrological nomenclature and the typical conventions used in the field of measurements. The student will learn to read a manual of a sensor, the related conditioning instrumentation, and the calibration certificate. To this end, the static and dynamic characteristics of the instruments are examined in detail, in order to also understand the concept of performance and calibration in the dynamic field. After some rudiments of electrical measurements, the sensors used for the main physical quantities of interest in the industrial field such as temperature, displacement, velocity, acceleration, strain, force, pressure and flow are discussed. The E-activities to be carried out for the course are proposed in the form of Case-Studies and/or Simulations, and are necessary for a deeper understanding of some topics of the course, as well as useful for the determination of the final grade. The approach is however such that the student can acquire a method of analysis, and is therefore able to extend what has been learned for specific conditions to different situations.
Learning objectives	The course begins with references to the static and dynamic characteristics of instruments, with the definitions in the technical and metrological fields of the characterization of all the main static and dynamic characteristics. Methodologies for electrical measurements are then described, then temperature, displacement, velocity, acceleration, strain, force, pressure and flow sensors are used. The student then has the opportunity to examine the operating principle of numerous sensors and transducers in use in the industrial field corresponding to the aforementioned physical quantities. Suitable measurement chains and typical causes of error and influencing quantities are discussed for each method. Application examples are always reported with discussion of excerpts from technical manuals
Prerequisites	Knowledge of electrical engineering and construction science. Possessing knowledge of the fundamentals of Mechanical and Thermal Measurements at the level of the degree course greatly helps the understanding of some topics of the Course.
Expected learning outcomes	**At the end of the course, the student will have demonstrated the ability to:** *[Knowledge and understanding]* • describe the operation of methods for measuring temperature, displacement, velocity, acceleration, strain and force. *[Application of knowledge]* • interpret and use the terminology used in metrology and measurement in general. • Identify the most important causes of error for a given transducer and associated measurement chain. • identify the useful characteristics for the use of an instrument from a technical manual and a calibration certificate. *[Ability to draw conclusions]* • Determine the most suitable measurement chain for a given temperature, displacement, velocity, acceleration, strain or force transducer. *[Communication skills]* • illustrate and describe issues related to measurement techniques to specialists and non-specialists.

	[Learning Skills] • understand, with a good level of autonomy, issues in the field of measurement, even if not directly addressed in the course.
Course structure	**Teaching Activities and Learning Activity** The course consists of didactic activities and learning activities. The teaching activities correspond to pre-recorded lessons and/or synchronous lessons in web conference. The learning activities correspond to the autonomous study of the slides and handouts provided by the teacher, and to the autonomous study necessary for the performance of the self-assessment tests and the E-tivity. The self-assessment tests within the video lessons are necessary to quickly verify the understanding of the topic under study. **Study calendar** The Study Calendar is available on the platform with a bimonthly periodicity. The Study Calendar must be understood as a suggested calendar for carrying out teaching and learning activities. If you fail to follow the suggested timeline, it is likely that two months will not be enough to allow for adequate preparation. The course is organized according to two different modalities: *Autonomous Mode* and *Guided Mode*. Students must inform the teacher in which way they intend to start studying the teaching material. Only after the student has made this choice, the teacher makes the material available on the platform. *[Standalone Mode]* As soon as the student feels ready, the latest E-activity 01 available on the platform is downloaded and the process begins. The E-tivity sheet indicates the maximum deadline by which to return the E-tivity (usually two weeks); the E.tivity will then be corrected by the teacher, who will provide feedback on it and a grade. If you do not deliver the E-tivity within the indicated deadline, it will be cancelled and you will need to download a new E-tivity. The same procedure for the E-tivity 02. It is advisable to schedule the Profit Exam no less than two months before the start of the study. *[Guided Mode]* This modality was created to meet the needs of working students who always have difficulty organizing time and have a greater need to be "guided". The dates on which it is possible to "enrol" in the Guided Mode are indicated in the Study Calendar. The Profit Exam is scheduled two months before the start of the study. Unlike the Autonomous Mode, it is possible to send the teacher a draft, before the final delivery of each E-activity. **Virtual Classroom** The course is equipped with a virtual classroom, which, for students who follow in Guided Mode, progresses comteporously in the study. All communication with the teacher regarding the topics of the course must take place in the virtual classroom forum. E-tivities always require teacher-student and student-student discussion activities in a dedicated forum. **Study load** The total Study Load of the course is approximately 234 now divided into approximately: • 57 hours needed to view the study of the videotaped material • 162 hours dedicated to self-study.
Course unit content	**Module M10 - Measurement Basics** *[Study load: 18 h - 0.7 CFU - 3.5 days]* *Teaching activities* The module provides for the delivery of 2.5 hours of pre-recorded lessons. Given the time required to listen to the video-recorded lessons and any lessons delivered synchronously, a total of 5.0 hours of student commitment are required for the use of these lessons. *Learning Outcomes* At the end of the module the student will be able to: • explain the characteristics of the measurement process • Explain the general operation of a transducer • distinguish the characteristics of integrated and intelligent transducers • correctly use the units of measurement of the international system and the practical system *Learning Objectives* In this module, the student is provided with the basic concepts to proceed with the study of measurement methods and instruments. The concepts of direct and indirect measurement are therefore only explained, the process of measurement, and measurement. Reference standards for metrological definitions used in subsequent modules are also introduced. The general concept of transducer and sensor as a multi-input and multi-output object is then described and what are the design criteria of a measurement chain. It concludes with references to the international SI system, and to the practical ones, CGS, MKS and British. **Module M01 - Static Characteristics** *[Study load: 23 h - 0.9 CFU - 5.0 days]* *Teaching activities* The module provides for the delivery of 3.4 hours of pre-recorded lessons. Given the time required to listen to the video-recorded lessons and any lessons delivered synchronously, a total of 6.7 hours of student commitment are required for the use of these lessons.

Learning Outcomes

At the end of the module the student will be able to:

- distinguish the fundamental metrological characteristics of the instruments
- identify the elements characterizing the tools in the technical manuals
- Read and illustrate a calibration document
- interpret the definitions of standards and guidelines relating to metrological issues
- explain the meaning of metrological terms

Learning Objectives

In this module the student is introduced to the fundamental metrological terms used to characterize the performance of instruments in the static field. The definitions of the UNI standard and the V.I.M. vocabulary are examined one by one and compared.
Characteristics such as, for example, sensitivity, linearity, hysteresis, the various declinations of the measuring range are reported and explained in detail. The difference between repeatability and reproducibility, and between drift and stability, is explained. Particular attention is paid to the description of the quantities of influence. Finally, it is explained how to read a calibration certificate.

Module M06 - Dynamic Characteristics

[Study load: 31 h - 1.3 CFU - 6.5 days]

Teaching activities

The module provides for the delivery of 4.7 hours of pre-recorded lessons. Given the time required to listen to the videotaped lessons and any lessons delivered synchronously, a total of 9.3 hours of student commitment are required for the use of these lessons.

Learning Outcomes

At the end of the module the student will be able to:

- analyze a Bode Frequency Response Diagram
- define the parameters characterizing a linear dynamic system
- distinguish and differentiate dynamic calibration techniques
- illustrate and model simple physical phenomena, by means of linear dynamical systems of first and second order
- Calculate the dynamic parameters of first- and second-order systems

Learning Objectives

This module describes the characteristics used to classify and model the performance of tools in the dynamic field. After a brief introduction of a general nature on linear dynamical systems, the fundamental parameters associated with the frequency response of instruments are described. The calibration and modeling techniques of first and second order systems are then explained, using mechanical and electrical equivalents.

Module M12 - Temperature Measurement

[Study load: 62 h - 2.5 CFU - 12.5 days]

Teaching activities

The module provides for the delivery of 9.0 hours of pre-recorded lessons. Given the time required to listen to the video-recorded lessons and any lessons delivered synchronously, a total of 18.0 hours of student commitment are required for the use of these lessons.

Learning Outcomes

At the end of the module the student will be able to:

- describe the operating principle of bulb, metal resistance and semiconductor transducers, thermocouples, integrated circuit sensors
- Critically read a technical manual for a temperature sensor
- Choosing the most suitable measuring chain for a given temperature sensor
- Use the standard conversion tables, for metal thermometers and thermocouples

Learning Objectives

In this module the student has the opportunity to know the most widely used temperature measurement methods in the industrial field. After a brief introduction to thermometric scales, fixed points, bulb, metal resistance and semiconductor transducers, thermocouples, integrated circuit sensors are illustrated. For each instrument, the correct methodology of use, the measurement chain and any signal conditioning are examined. The main metrological characteristics for each type of transducer are described, with particular attention to the quantities of influence and the causes of error. Commercial examples of temperature sensors and control instruments are often reported and illustrated in detail, with discussion of the technical documentation.

Module M13 - Displacement, velocity and acceleration Measurement

[Study load: 28 h - 1.1 CFU - 6.0 days]

Teaching activities

The module provides for the delivery of 4.0 hours of pre-recorded lessons. Given the time required to listen to the video-recorded lessons and any lessons delivered synchronously, a total of 8.0 hours of student commitment are required for the use of these lessons.

Learning Outcomes

At the end of the module the student will be able to:

- describe the operation of displacement, velocity, or strain sensors

- Critically read a technical manual for a displacement, velocity, or strain sensor
- Choosing the right measuring chain for displacement, velocity or strain sensors
- explain and describe the frequency response of seismic transducers

Learning Objectives

In this module the student has the opportunity to know the most widely used kinematic measurement methods in the industrial field. The first methodology concerns displacement and velocity measurements, so resistive (potentiometers), inductive (LVDT), ultrasonic (piezoelectric), capacitive, strain gauge, laser, eddy current and digital (encoder) displacement sensors are illustrated. The second methodology concerns seismic or inertial sensors. The student then has the opportunity to learn the operation of a displacement and acceleration sensor used, respectively, as vibrometers or accelerometers.
The third methodology concerns strain measurements, limiting itself to the description of electrical resistance, piezoresistance, and piezoelectric element strain gauges. The most important metrological characteristics for each methodology, the influencing quantities and the causes of error are always emphasized. Some commercial examples of sensors are also reported, with discussion of the technical documentation.

Module M14 - Force Measurement

[Study load: 33 h - 1.3 CFU - 6.5 days]

Teaching activities

The module provides for the delivery of 4.8 hours of pre-recorded lessons. Given the time required to listen to the video-recorded lessons and any lessons delivered in synchronous mode, a total of 9.7 hours of student commitment are required for the use of these lessons.

Learning Outcomes

At the end of the module the student will be able to:

- Describe the operation of a force and torsion sensor
- Choosing the Right Measuring Chain for Force and Torsion Sensors
- Critically read a technical manual of a force and torsion sensor

Learning Objectives

In this module, you will learn about the most commonly used force measurement methods in industry. After a brief introduction to load cells, in terms of metrological characteristics, implementation and general design criteria, the various types of elastic elements consisting of force sensors are discussed. Starting with the description of column load cells, we move on to bending and shear load cells, with an illustration of the decouplers for compensating transverse loads. The operation of piezoelectric load cells and other less common ones such as vibrating element, Hall effect and optical fiber cells is then reported. Particular attention is paid to the operation of torque transducers, and to the transmission of the torque signal on rotating shafts. Finally, notes are provided on the static and dynamic calibration of load cells.
In the module, the transducers are always described, reporting the influence, and the causes of error. In addition, commercial examples of load cells and torque transducers are always reported and illustrated in detail, with discussion of the technical documentation.

Module E02 - E-tivity

[Study load: 40 h - 1,6 CFU]

Teaching activities

The module does not provide for the provision of lectures, Learning is pursued only through the autonomous study necessary for the performance of the activities proposed by the teacher

Learning Outcomes

At the end of the module the student will be able to:

- interpret guidelines and technical documentation
- use appropriate terminology in metrology
- Locate and use data from a calibration manual
- identify the most suitable components for the realization of a temperature measurement chain

Learning Objectives

In this module the student engages in the resolution of technical cases of non-trivial complexity. The cases are proposed to the student in the form of E-tivity (Electronic-Actvities) accompanied by a descriptive sheet and published according to the Study Calendar on the platform. Each E-activity consists of the production of a report relating to the proposed case-study and appropriate activities to be carried out in the virtual classroom forum. The descriptive sheet reports both the activities to be carried out by the student and the methods of evaluation by the teacher for the purpose of calculating the final exam grade.
E-activities have a learning purpose as well as an evaluation purpose. This means that the Learning Outcomes declared in the module are not achieved through the use of lectures, but exclusively through independent study and the resolution of the proposed case-studies.
There are 2 E-tivities, the first relating to static metrological characteristics and the calibration certificate, the second to temperature measurements. The activities of the E-tivities always require the use of the virtual classroom forum and consist of discussions of theoretical topics and exercises.
The E-tivities are not to be considered Exemptions, but they allow you to add points to the evaluation of the Exam.

Study materials	**Teaching materials by the teacher** The teaching material on the platform is divided into: 7 modules, one of which is dedicated to the performance of E-activities, and the remaining ones organized in a series of video lessons/slides and asynchronous tests related to the video lessons. The slides are structured in such a way as to report in detail, by points, all the topics covered in the video lessons. Some lessons are provided with text in English, when the topic is extracted from a European technical standard or from original technical notes. It is important to study a large part of the teaching on untranslated material, since the technical documentation in practice is generally provided in English. It is of fundamental importance to follow the video lessons by taking notes on the slides provided, in order to fully understand the topics illustrated. It is strongly recommended to proceed with the use of the study materials by following the Study Calendar available on the platform. **Recommended learning materials** For the profession of Islam, it is recommended, for consultation purposes, to include in one's library of fundamental texts: • *Measuring instruments and methods*. 2008 by Ernest O. Doebelin (Author), edited by A. Cigada and M. Gasparetto. McGraw-Hill To deepen or clarify the contents of the course, it is recommended: • *Fundamentals of mechanical and thermal measurements*. 2008 by Rinaldo Vallascas. Hoepli
Assessment methods	**Final Grade** The verification of the achievement of the Learning Outcomes is carried out through the evaluation of the E-tivity and the Profit Exam. The final grade is given by the evaluation of the Profit Exam and the two E-tivities, evaluated as a whole. *E-tivity Rating* Both E-activities are not compulsory, but are strongly recommended for the successful and optimal achievement of the Learning Outcomes of the Teaching. Both E-tivities must receive at least a sufficient grade, otherwise the Exam will include an additional question. E-activities are evaluated differently depending on the way in which the course is followed: • Standalone Mode: Each E-tivity is rated at a maximum of 3 points, for a maximum total of 6 points • Guided Mode: each E-tivity is valued at a maximum of 4 points, for a maximum total of 8 points The E-tivity evaluates all the Apprenticeship Outcomes listed for the Course, and in particular those related to *Learning Ability*. *Evaluation of the Exam* The E-tivity assesses all the Learning Outcomes listed for the Course, and in particular those related to *Learning Ability*. *Evaluation of the Exam* The **On-Site Exam** contains three parts: • Part 0 (max 8 points): Theoretical question on form M12 • Part 1 (max 11 points): Theoretical question on form M01 M10 M06, 3 points of recovery E-tivity • Part 2 (max 11 points): Theoretical question on all modules, 3 points of recovery E-tivity In the case of the first partial exam: Part 0 + Part 1 (but part 0 is worth max 4 points) In the case of the second partial exam: Part 0 + Part 2 (but part 0 is worth max 4 points) The **non-on-site Exam** is divided into two parts: The **non-on-site Exam** is divided into two parts: • Part 1 (max 24 points in Guided, 20 points in Self-Driven): Quiz on all modules • E-tivity recovery (max 10 points): if you did not have the maximum score in the E-tivity, it is possible to recover by answering an open-ended question on all modules.
Criteria for the assignment of the final paper	The assignment of the final paper takes place following the interview with the teacher, in which the student will expose his/her specific interests in relation to some topic he/she intends to deepen; there are no preclusions to the request for assignment of the thesis.