UNICUSANO
ROME

**Code: ING-IND/12** **Credits: 9**
**Matter: Industrial measurement and instrumentation**
**Main language of instruction:** Italian
**Other language of instruction:** English

**Teaching Staff**

**Head instructor**
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## Introduction

1. *Objective of the course :*

The first part of the course deals with the topic of measurements in general, the metrological nomenclature and typical conventions used in the field of measurements. The student will learn how to read a manual for a sensor related conditioning instrumentation, and the calibration certificate. This is done by examining in detail the static and dynamic characteristics of the instruments, so that the concept of performance and calibration in the dynamic range is also understood. Moreover, the course focuses on the sensors used for the main physical quantities of interest in industry such as temperature, displacement, velocity, acceleration, strain, force pressure and flow.

## Objectives

2. *Course Structure:*
   - *Measurement Basics*
   - *Static Characteristics*
   - *Dynamic Characteristics*
   - *Temperature Measurement*
   - *Displacement, velocity and acceleration Measurement*
   - *Force Measurement*

## Competencies:

[Knowledge and Ability to Understand]
- Describe the operation of methods of measuring temperature, displacement, velocity, acceleration, strain, and force.

[Application of knowledge]
- interpret and use terminology used in metrology and measurement in general.
- identify the most important causes of error for a given transducer and associated measurement chain.
- identify 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 transducer of temperature, displacement, velocity, acceleration, strain, or force.
[Communication skills]
- explain and describe measurement technique issues to specialists and non-specialists.
[Ability to learn]
- understand, with a good level of autonomy, topics in the field of measurement, including those not directly addressed in teaching.

**Syllabus**

3. *Programme of the course:*

**Subject 1. Measurement Basics**

In this module, the student is provided with the basic concepts for proceeding to the study of methods and measurement instruments. Thus, only the concepts of direct and indirect measurement process are explained. The reference standards for metrological definitions are also introduced used in subsequent modules.
The general concept of transducer and sensor understood as multi-input and multi-output objects is then described, and what are the design criteria for a measurement chain. It concludes with references to the international SI system, and the practical, CGS, MKS and British systems.

**Subject 2. Static Characteristics**

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

**Subject 3. Dynamic Characteristics**
This module discusses the features used to classify and model the performance of instruments in the dynamic domain. After a brief general introduction on dynamic systems linear, the fundamental parameters associated with the frequency response of instruments are described. Then calibration and modeling techniques for first- and second-order systems are explained, using the mechanical and electrical equivalents.

**Subject 4. Temperature Measurement**
In this module, the student gets to know the most widely used temperature measurement methods in industrial settings. After a brief introduction to thermometric scales, fixed points, the bulb, metal resistance and semiconductor transducers, thermocouples, and integrated circuit sensors.
For each instrument, the proper methodology of use, the measurement chain, and possible signal conditioning. Key metrological characteristics are described for each type of transducer, with special attention to the influence quantities and causes of error. Often are reported and illustrated in detail commercial examples of temperature sensors and control instruments, with discussion of technical documentation.

**Subject 5. Displacement, velocity and acceleration Measurement**
In this module, the student gets to know the methods of measuring kinematic quantities most used in industry. The first methodology concerns displacement and velocity measurements, therefore resistive (potentiometers), inductive (LVDT), ultrasonic (piezoelectric), capacitive, strain gauge, laser, eddy current and digital (encoder). The second methodology concerns seismic or inertial sensors. The student then gets to learn the operation of a displacement and acceleration sensor used as vibrometers or accelerometers. The third methodology deals with strain measurements, limiting to the description of strain gauges electrical resistance, piezoresistance, and piezoelectric element strain gauges. Always emphasized are the main metrological characteristics for each methodology, the influence quantities, and the causes of error. Some commercial examples of sensors are also given, with discussion of the technical documentation.

**Subject 5. Force measurements**
This module discusses the most commonly used force measurement methods in industry. After a brief introduction to load cells, in terms of metrological characteristics, implementation and general general design, the various types of spring elements constituting force sensors are discussed. Beginning

with a description of column load cells, we move on to bending and shear load cells, with illustration of the de-couplers for compensating transverse loads. Next, the operation of the piezoelectric load cells and other less common ones such as vibrating element, Hall effect and fiber optics. Particular attention is given to the operation of torque transducers, and to the transmission of the signal of torque on rotating shafts. Finally, hints are given on the static and dynamic calibration of load cells.
In the module, transducers are always described by reporting the influence quantities and 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.

**Subject 6. E-tivity**
In this module the student engages in solving technical cases of nontrivial complexity. The cases are proposed to the student in the form of E-activities (Electronic-Actvities) accompanied by card description and published according to the Study Calendar on the platform. Each E-tivity consists of the production of a report related to the proposed case-study and by appropriate activities to be carried out in the forum of the virtual classroom. 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 computing the final exam grade.
E-activities have a learning purpose as well as an assessment purpose. This means that the Outcomes of Learning stated in the module are not achieved through the enjoyment of lectures, but exclusively through self-study and solving the proposed case-studies.
There are 2 E-activities, the first related to static metrological characteristics and calibration certificate, the second to temperature measurements. E-tivity activities always require the use of the class forum virtual and consist of discussions of theoretical topics and exercises. E-activities are not to be considered Exemptions, but they allow you to add points to the assessment of the Final Examination.

## Evaluation system and criteria

Verification of the achievements is carried out through the evaluation of the E-tivity and the Final Examination. The final grade is the sum of the marks obtained from the two E-activities and of the Examination. Each E-tivity is assessed a maximum of 4 points, for a maximum total of 8 points.
The Final Examination is divided into three parts:

- Part 1 (max 10 marks): question on Static Characteristics or Temperature Measurements
- Part 2 (max 14 points): question on one of the modules not covered in the previous question
- E-tivity Recovery (max 3+3 points): if you did not have 3 in an E-tivity, you can recover points by by answering theory questions and/or quick quizzes on the entire program.

**Bibliography and resources**

4. *Materials to consult:*

*The teaching material consists of a series of video lectures/slides and asynchronous tests related to the video lectures. The slides are structured so that all the topics covered in the video lectures are also reported in detail, by points.*

5. *Recommended bibliography:*


- Doebelin, Ernest O., and Dhanesh N. Manik. "Measurement systems: application and design." (2007).
- Vallascas, Rinaldo. Fondamenti di misure meccaniche e termiche. Grandezze statiche e sistemi. Hoepli, 2008.