# MEASUREMENT: CONCEPTS, METHODS AND PRACTICE WITHIN AN ELECTRONIC BOOK

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**ABSTRACT**

*This work reports on a novel use of Information and Communication Technologies for composing an electronic book on the measurement field. The e-book "Laboratórios de Instrumentação para Medição/Laboratories of Instrumentation for Measurement" is written in Portuguese and in English. Dealing with concepts, methods, procedures and hands-on activity it combines sketches, figures, animations, videos and remote and virtual labs on the measurement area, integrating many types of multimedia within the written material. The main goal of this work is to push the users to experimental practice so as to improve the conceptual knowledge, to identify many error sources when measuring and clarify how to minimize them. The online experiments related with different subjects within the e-book are accessible for any interested user. All other set-ups described in the work are described in full detail in order to be easily reproduced by anyone, anywhere, and making it possible to easily replicate the experimental activity.*

***Keywords:*** *electronic book, measurement, metrology, hands-on, remote labs, virtual labs*

## 1. INTRODUCTION

"…when you can measure what you are speaking about and express it in numbers you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind", Sir William Thompson, Lord Kelvin (1824-1907).

Measurement is the bases of science. Instrumentation is vital for the design and implementation of measuring, monitoring and actuation systems and in data acquisition and processing, playing nowadays a fundamental role in many technological areas, as well as in those of certification, control and information.

The increasing demand of experimental accuracy in all scientific areas makes instrumentation for measurement a crucial component, particularly in higher education curricula with a strong technological element, being also essential at research and development level.

The educational objectives of the present work, in terms of Bloom's taxonomy [1] principles, are:

- To stimulate learning through hands-on activity;
- To contribute to the understanding for the need and uniform use of concepts and definitions based on the International Vocabulary of Metrology [2];
- To provide user training on equipment and device manipulation for experimental tasks and on methods and procedures for measuring physical quantities of general relevance;
- To analyse and explore the working principles and characteristics of the sensors and transducers more commonly used in laboratory and industrial applications;
- To clarify and apply important features on signal conditioning and transmission and data acquisition and processing;
- To introduce the concept of virtual instrumentation, together with web monitoring and actuation technologies, by providing access to remote experiments;
- To promote the critical appraisal of measurement results;
- To evaluate the possible reasons for experimental discrepancy evidences;
- To synthesise learned subjects;
- To intensify active/collaborative/cooperative learning activities;
- To provide student self-assessment of his/her mastering of subjects by proposing open-ended questions based on the given materials.

Nowadays printed technical manuals are often complemented with the inclusion of a CD-ROM. In the present case, taking into account that "what I hear, I forget; what I see, I may remember; what I experience, I know for life" [3], the authors decided to adopt a completely electronic format which allows a more efficient and harmonious integration of a wide range of contents: text, images, sketches, videos, animations, simulations and remote experiments. The text can be easily printed if required.

Moreover, given recent contributions of neuro-linguistic programming to education [4], the authors believe that the format adopted is adequate for the diversity of psychological and learning profiles of the large target audience of the developed materials.

It is the authors' intention to further explore other topics within Laboratories of Instrumentation for Measurement. So the electronic edition is the ideal option for easy and economic updating.

This e-book comprises 13 modules. Each one presents a clearly defined learning objective, the essential concepts and a step-by-step guide for performing the experimental activity, various complementary multimedia contents and a final synthesis. A set of open questions that closes each module is intended to provide formative assessment.

These open-ended questions aim to encourage the users to undertake their own analyses and further elaboration of additional questions as an excellent way to achieve deeper learning. Posing questions and problems may be the single most important tool in facilitating learning.

The work also aims to contribute to the dissemination of experimental activity in engineering and science education areas and to facilitate the conception, tuning and exploration of experimental systems for laboratory training. The full technical description of the equipment is provided to make the setups easily reproducible. In addition access to remote experiments has been made available.

## 2. E-BOOK STRUCTURE

Once the chapter index is selected thirteen topics are available. At the very beginning of any chapter level its objectives are listed and a three-level structure is presented: basic concepts, experimental procedures, synthesis and acquired knowledge. The basic concept section provides an introduction to theoretical concepts and metrological methods and procedures, working principles, operation characteristics, signal conditioning and associated techniques. In the experimental procedures section a guided hands-on activity is described for clarifying the basic concepts, getting and processing experimental results and analysing them. Oriented questions are formulated along the activity guide. On the third level a synthesis is made to reinforce the reflection on the subject. Finally, open-ended questions on the correlated concepts are available for student self-assessment. Along each chapter links to videos, animations, simulations and remote labs are presented regularly. Two examples are now described. One relies on a common topic, Fig. 1.


**Fig. 1** Measurement of force and strain

Chapter VII, named "Measurement of force and strain", presents the use of strain gauges for measuring strain and determining some mechanical material characteristics (Young modulus and Poisson ratio). It also explores the use of strain gauges associated with a test specimen of a convenient geometry for measuring forces (load cells).

After the conclusion of this module the user should be able to use resistance strain gauges for determining mechanical characteristics of a material and for force measurement, applying different signal conditioning solutions. He should also be able to create and implement an electronic weighing scale. He also should consider the set of open-ended questions proposed for the subject.

Along this chapter a remote experiment is also available. This experience explores the use of strain gauges for the measurement of strain and the determination of mechanical material characteristics. The system presented in Fig. 2 was specially conceived, designed and built to be remotely accessed, allowing the experimental verification of Hooke's law and illustrating the procedure used for experimental determination of the Young modulus.

**Fig. 2** Experimental set-up

In a blended-learning approach the system can be used before a real lab session for preparing hands-on activity [5], [6], or later for reviewing concepts and getting real values. Fig. 3 shows the user interface for operating in automatic mode.

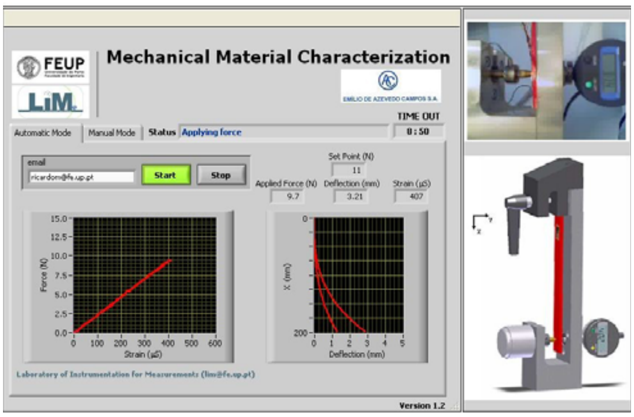


**Fig. 3** User interface in automatic operation mode

The user interface includes on the upper right corner the image of a loaded beam, from an USB webcam. Two additional frames are included; one for the interactive virtual instrument front panel and the other for a drawing of the system on the lower right corner of the interface, providing the entire experimental set-up image in a more clear way.

The other example is related with remote and virtual lab. Chapter XIII is entirely dedicated to "Web Monitoring and Control", Fig. 4. This module uses some of the experimental setups developed at the Laboratory of Instrumentation for Measurement (LIM) of Faculdade de Engenharia da Universidade do Porto (FEUP) to enhance the knowledge about physical quantity measurement and calibration procedures, applying currently existing technologies for web monitoring and control of experimental systems.

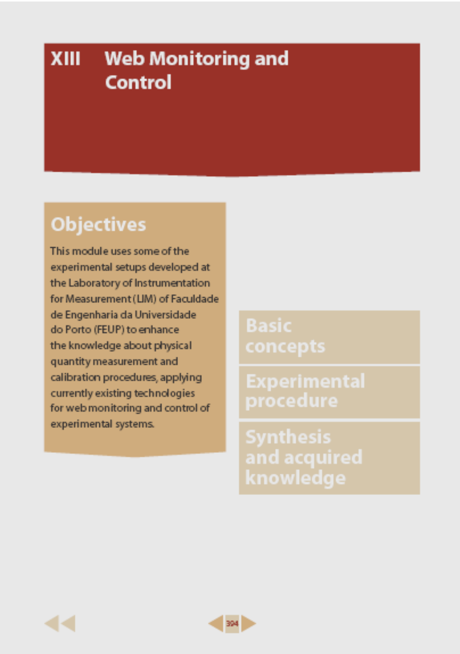


**Fig. 4** Web Monitoring and Control Chapter

After the conclusion of this chapter, the user should be familiar with the use of remote web monitoring and control systems. He should also be familiar with a temperature calibration procedure, a method to evaluate the straightness deviation of a line in a given direction on a surface of a specimen and the technique for experimental determination of mechanical material characteristics, analysing specific parameters based on obtained results. In Fig. 5, a system for straightness evaluation of a line in a given direction on a surface is presented.

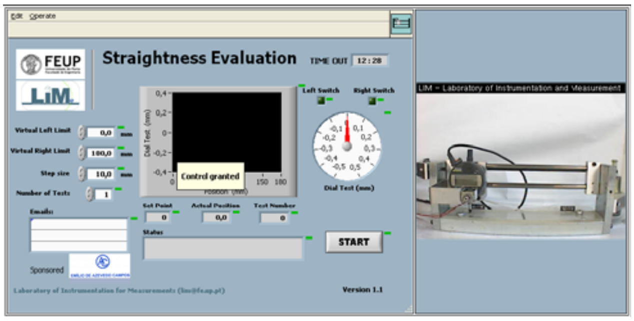


**Fig. 5** Straightness Evaluation interface

This on-line experiment explores the concept of straightness and one of the available methods for evaluating the straightness deviation of a given line on a surface of a specimen.

In Fig. 6 is represented the online experiment available for demonstrating the normalized procedure for calibration of a resistance thermometer.

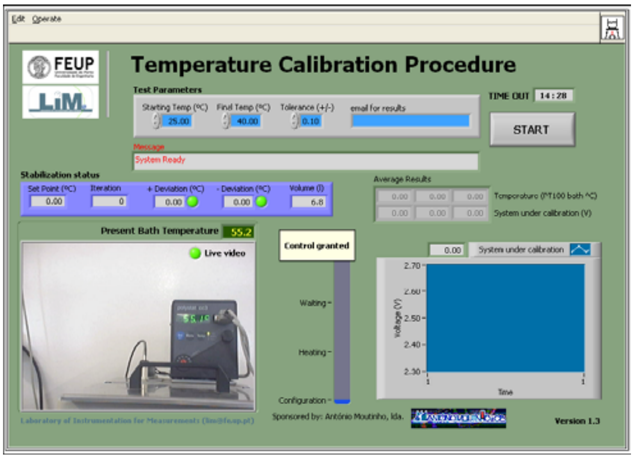


**Fig. 6** Temperature Calibration Procedure

This experiment illustrates a calibration procedure of a temperature measurement system including a $Pt_{100}$ temperature transmitter. A calibration procedure is a set of operations that establish the relation under specific conditions between quantity values displayed by a measurement device or measurement system and the corresponding values obtained from a standard element. Considerations about the uncertainty components associated to each of the measurements should be also of relevance.

At any of the user interfaces an e-mail address may be introduced for subsequent automatic delivery of the recorded data file. Those data should be processed and used to find the answer to the related questions asked on the e-book.

In the next two pictures two simulators are presented.

One, to allow the user to understand and explore the operation of a current/voltage stabilized and regulated power supply, Fig. 7. A stabilized power supply with a continuously stabilised and regulated voltage/current output is crucial equipment in a laboratory.

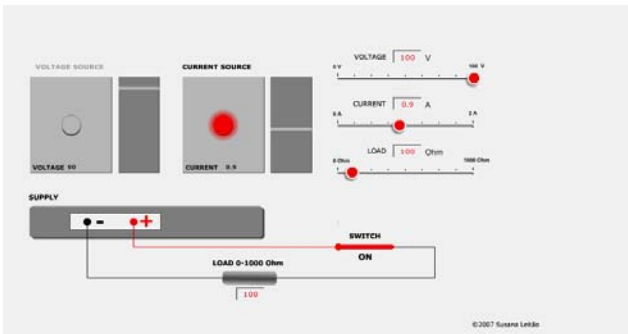


**Fig. 7** A stabilized and regulated current/voltage power supply

A stabilized power supply operates according to the selected values of voltage (V) and current (I) within their range, and also according to the applied load. The user may introduce values for load, current and voltage, within the simulator ranges.

The next example is devoted to the use of bridge circuit, so popular in the conditioning circuit of many sensors, Fig. 8.

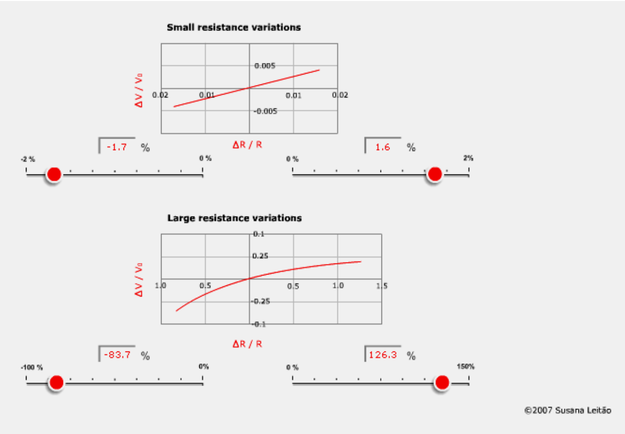


**Fig. 8** The transfer function of a Wheatstone bridge

In fact, some physical phenomena induce changes to resistance, inductance and capacitance of passive sensors. And this is the base of the working principle of a large number of transducers. Because the changes are always very small, very often the respective conditioning circuits involve circuit bridges. For resistive elements the Wheatstone bridge is then used in the static measurement of resistance. Finally, the transfer functions of a Wheatstone bridge circuit are experimentally obtained and analysed for large and small variations of resistance trough an interactive user interface: introducing resistance changes will display the output of the bridge circuit.

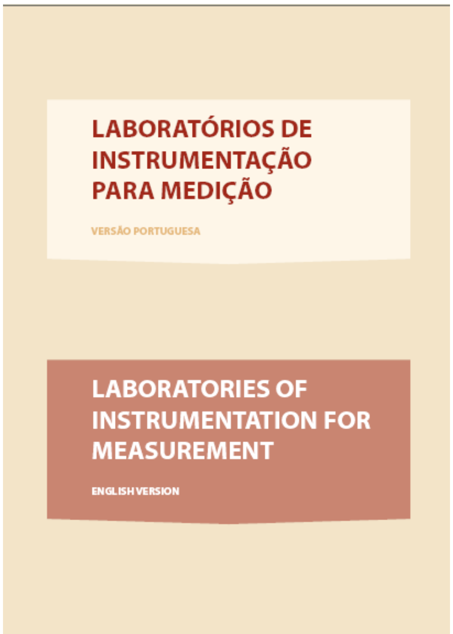


**Fig. 9** The e-book cover

Finally, it is important to add some comments on the electronic navigation through the book. At the first contact the book offers the title in both languages. Selecting one of them the user is conducted to the corresponding version: in Portuguese or in English, Fig. 9.

Once within the chosen version the user has to click on the arrows on the bottom of each page, near the page number. With four clicks the chapter index is reached. Here it is possible to decide where to go: preface, prologue, foreword, acknowledgements, chapter index or bibliography.

From now on in addition to the navigation arrows there is a top menu. Within each chapter different sections are associated to distinct top menu levels, which offer a very easy way of swapping over from section to section, Fig. 10.

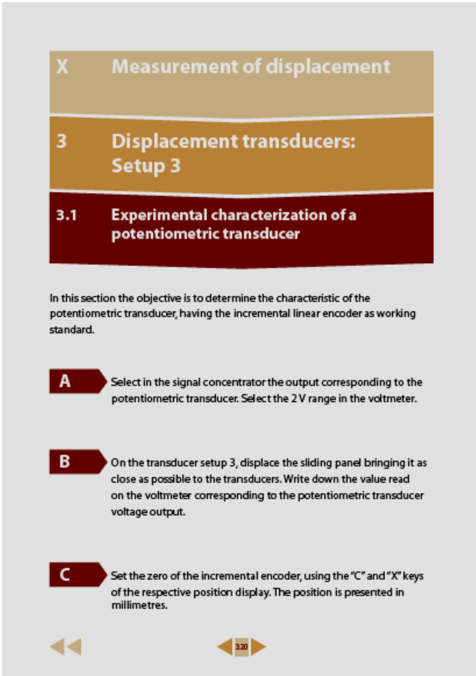


**Fig. 10** Navigation: top menu levels and double arrow

At each new level there is always a double arrow on the lower left corner for switching to the first page of the higher level subject. The structured navigation tries to recreate the speed up way the readers use in order to find a specific subject along a traditional book.

Considering daltonic individuals the navigation using the top menus relies not only on the colour but also on a numbering base.

## 3. FINAL REMARKS

Most of the contents of the present e-book have been tested with undergraduate mechanical engineering students as well as with postgraduate students from other different fields. Students have referred the work as a valuable learning material, as a very good support to training hands-on activities, to think critically, innovatively, and independently, to analyse, to evaluate, to predict and to solve problems. They considered this e-book as a good support to relate information to their own experiences and previous knowledge, to promote understanding and even to help long-term retention. The access to online experiments has also been considered of interest by the possibilities offered, especially due to the flexible 24-hour timetable and by providing contact with the new technology.

The authors would prefer to work only based on open type experimental problems. But, when dealing with large numbers and student diversity there is the need to establish a set of rules and methods and all the activities must be well defined and structured.

Nevertheless, the authors have been currently involved in complementary developments aiming to attract students to project based learning activities. The Laboratory of Instrumentation for Measurement is always open to any student demand as shown by references [7]-[12].

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**António Mendes Lopes** received a PhD degree in Mechanical Engineering from the University of Porto, Portugal, in March 2000. He is currently Assistant Professor at the School of Engineering, University of Porto, where he started teaching in 1991. Besides the research interests in Robotics, namely, force control, parallel manipulators and walking machines, he has also interests in pedagogical matters, distance learning and remote labs.