A COURSE OF ACOUSTICS FOR ENGINEERS

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Abstract *¾ Traditionally, Acoustics has formed one of the fundamental branches of Physics and Engineering education. Throughout the last decades, the field of acoustics has become increasingly interdisciplinary. Specialists in modern Acoustics work in areas spanning from musical instruments to architecture and to problems related with speech perception. In this work, we try to accomplish a set of coordinated materials for teaching of Acoustics: books, CD-ROM's and on-line materials. It pursues a double objective. On one hand, the design of varied, complementary, easy access, flexible and gradual teaching materials valid for future engineers formation and also for engineers' continuing learning. On the other hand, in the process of making the education effective and international, we try to contribute to the improvement of the technological and scientific literature, actualized with the resources furnished by information technologies.*

Index Terms ¾ Education, Acoustics, Multimedia, Teaching Materials.

INTRODUCTION

The Physics of sound and vibrations has always played a main role in the basical formation of both physicists and engineers. In fact the oscillatory behavior is the most basic movement of a body that is subjected to an elastic force and it is the fundamental of wave movement. In the 20th century, the importance of the acoustical subject has been deeply enriched with the point of view of other scientific and engineering matters, which have contributed to the multiform character of Acoustics.

These other disciplines, like Materials Science, Architecture, Telecommunications, Multimedia, Psychology, Biophysics, Ecology and so on, have been linked to Acoustics in a growing interdisciplinary knowledge.

Nowadays, modern Acoustics professionals could work in a lot of different topics, e. g. the construction and improvement of traditional, electrical and electronic musical instruments, the architectural design of the best halls for artistic performances, the speech perception and transmission, etc. Whether it is speech or music, listen spaces, hearing, signals in sonar or in ultrasonography, they seek to maximize their ability to convey information and minimize the effects of noise.

OBJECTIVES

This project is focused to the development of a course of Acoustics, which adopts the form of an interrelated set of didactic materials. These different materials are thought to satisfy two diverse needs: on-line materials and books and CD-ROM materials.

The on-line materials try to benefit university students and also engineers interested in a field of Science encountered in everyday life. In their design we take into account several features such as gradual progress, completion, flexibility and easy accessibility.

The books and CD-ROM are specifically designed as a helping and complementary tool for teachers.

As a matter of fact, with an educational objective in mind, we look for the improvement of technological and scientific literature, using the modern resources provided by the information technologies. We use Java technology to develop and build an on-line interactive acoustics learning environment comprised on simulations (applets). These all are associated to several texts, figures, sounds, images and hands-on activities that appear in the books and CD-ROM.

GENERAL CONTENTS

The complete course will cover some aspects of Acoustics, focused around Basic Principles, Musical Acoustics and Noise [1]-[16]. These topics have been developed by the authors in several elective courses in the School of Engineering of Bilbao (University of the Basque Country), during the last four years, with a very good students' acceptance. In the students' opinion, these courses have supposed an opportunity of diversification and deepening in the topics of another subject matters of their studies. The list of these general topics is detailed afterwards:

- Basic Principles of Acoustics: Vibrations and Waves
- Musical Acoustics: Musical Instruments
- Architectural Acoustics
- Electroacoustics
- Noise
- Physiological Acoustics

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All the above topics are interrelated with the daily life observations that could be explained from different and complementary points of view. In Table 1 we show an example of how a common daily experience could be studied in this multifocused approach.

TABLE I
AN EXAMPLE OF THE RELATIONS BETWEEN DAILY LIFE AND THE GENERAL TOPICS OF THE ACOUSTICS COURSE

Daily life observation	General topic	Sub-topic
Musical performance	Musical Instruments	String Instruments Wind Instruments ...
	Architectural Acoustics	Indoor Acoustics Reverberation Time ...
	Physiological Acoustics	Human Hearing System Intensity Sensation ...
	...	...

By the moment, other important aspects of Acoustics will not be treated. Among them we can cite the followings:

- Acoustical Oceanography
- Acoustical Signal Processing
- Animal Bioacoustics
- Biomedical Ultrasound
- Computational Acoustics
- Non-Linear Acoustics
- Psychological Acoustics
- Speech
- Underwater Acoustics
- Vibration and Structural Acoustics

DETAILED CONTENTS

Each general topic is being developed in a series of sub-topics. Each of them is developed and related with other ones. In this section we detail them.

Basic Principles of Acoustics: Vibrations and Waves

It tries to discuss the Physics of mechanical and acoustical oscillators, the way in which they coupled together, the way in which they radiate sound and the behavior of sound when it propagates in different media. These subjects are developed in the following items:

- Introduction
- Simple Harmonic Motion
- Damped and Forced Harmonic Motion
- Resonance
- Coupled Oscillators
- Longitudinal Waves
- Transversal Waves
- Superposition of Waves: Beats, Standing Waves
- Acoustical Phenomena: Reflection, Refraction, Diffraction, Absorption, Echo and Reverberation

Musical Acoustics: Musical Instruments

The core of this topic is the detailed description of all kinds of resonating and radiating systems used in musical instruments, according to the following schema:

- Generalities
- String Instruments
- Wind Instruments
- Percussion Instruments
- Electric and Electronic Instruments

Architectural Acoustics

It covers all the phenomena that occur from the sound production by a source to the perception of the sound event by the listeners. Under this heading we deal the following subtopics:

- Introduction
- Geometrical Acoustics: Ray Tracing
- Statistical Acoustics: Reverberation
- Wave Acoustics: Resonance Modes
- Outdoor Acoustics
- Indoor Acoustics
- Reverberation Time

Electroacoustics

This topic discusses the processes related to the picking up sound at one point and reproducing it either at the same point or at some other point, at the same or at some subsequent time. Under this broad heading we can find these elements:

- Introduction
- Transducers
- Microphones
- Amplifiers
- Sound Recording Systems
- Speakers
- Equalization
- Sound Reproducing Systems

Noise

This offers a comprehensive coverage of the aspects related to the problems produced by noise, how to measure them, and how to improve them, developed according to the following aspects:

- Generalities
- Measurement Techniques
- Measurement Instruments
- Acoustical Isolation

- Acoustical Conditioning
- Noise Control in Buildings
- Noisy Equipment and Installations

Physiological Acoustics

This topic introduces basic description of human beings' hearing system and the audition process itself. These points can be summarized using the following schema:

- Introduction
- Human Hearing System
- Intensity Sensation: The Decibel Scale
- Masking
- Directional Characteristics: Direction perception
- Tone Perception: Mechanisms, Critical Bands
- Tone Combination

METHODOLOGY

This course looks at the fulfillment of a coordinated set of materials to teach and deep in the subject of Acoustics: on-line materials, books and CD-ROM's. Materials are presented in different formats for different users, with diverse levels of previous formation and knowledge needs: engineering students or engineers and teachers.

STUDENTS' MATERIALS

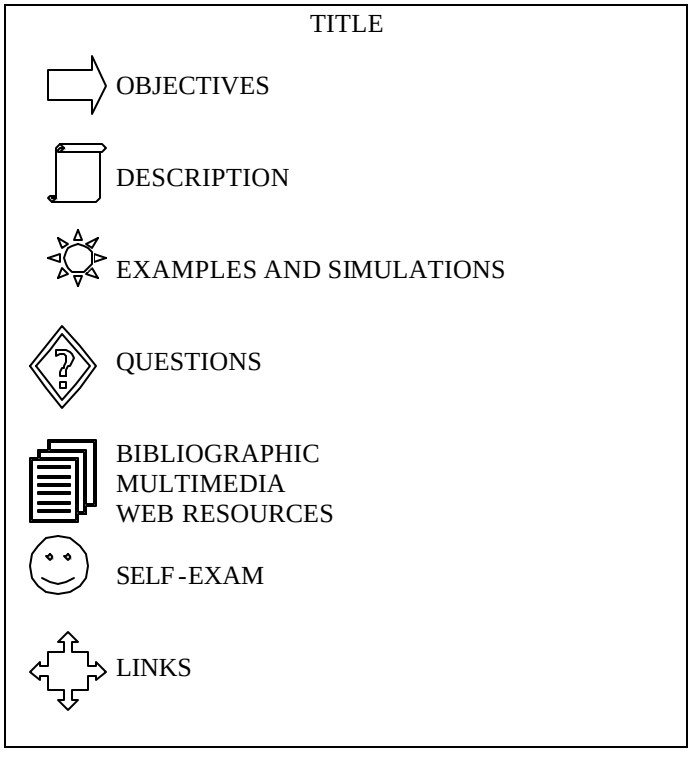


FIGURE. 1
SCHEMA OF AN ON-LINE TOPIC DEVELOPMENT.

On-line materials are thought to be a course of Acoustics for engineering students or engineers' continuing formation developed in various chapters. A single student or a team could use these materials, with or without the help of a teacher and everywhere a computer is accessible. Among these on-line materials, we wish to underline the important role of the simulations that will be shown more in detail in the following step.

All the chapters are referred to a single topic, although several of them might be related between them. With the correspondent link that is included in the web page we can make that relation more obvious. Each of the chapters presents a topic according to a general format that is presented in Figure 1.

Simulations

The experience in the design and elaboration of computer programs and the observation of the students' behavior when they work with them, permit to create effective and well defined models.

The creation of interactive teaching programs is a very complex process that needs a complete knowledge of the subject, the numerical processes that will be used and the programming language. Moreover, it is necessary to make a lot of temptations, and to have a wide observational experience of the student- computer interaction [17].

Usually, the creation of a program has the following steps:

- Election of the topic we want to teach in an interactive way
- Determination of the simulations
- Making of a conceptual design that describes all the aspects of the simulation. The core of the program consists on the statement of the situation: to calculate an equation roots, or to resolve a differential equation, or to apply Montecarlo method, or to obtain a function values, etc. After that, we have to design the interface, communication between the user and the program, in order to introduce initial values, to control the system evolution and to present the results.

Now we will comment some about technical aspects of the simulations. Applets are being created in the actual version 2.0 of Java language. Although Microsoft Internet Explorer 5.0 and Nestcape Communicator 4.5 can not run applets created with this Java version it is expected that in few time they could do. In some cases it is necessary to create some applets that represent a three-dimensional function, e. g. in order to observe the vibration modes of a circular plate. In these cases we have two possibilities: to use a library that makes three-dimensional representation of the original two-dimensional functions (Java 2D), or to use the 3D extension of Java language. This second possibility is not very useful, because this extension does not work in the navigator.

In Figure 2, we show the aspect of one of these interactive simulations. In this case the simulation is related to the Kundt's tube for measuring of the sound velocity in different media.

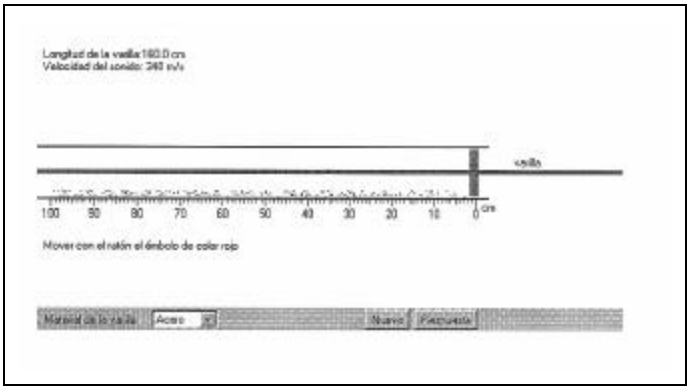


FIGURE. 2
EXAMPLE OF AN INTERACTIVE SIMULATION: KUNDT'S TUBE.

TEACHERS' MATERIALS

With books and CD-ROM's we try to elaborate didactic guides and complementary materials specifically indicated for the teachers. Al the topics that appear in the Internet course appear again in an extended version with a special emphasis in the scientific contents and the didactic procedures. In addition, there are suggestions about experiments that might be performed at very low cost. In these guides they could find a general format that is presented in Figure 3.

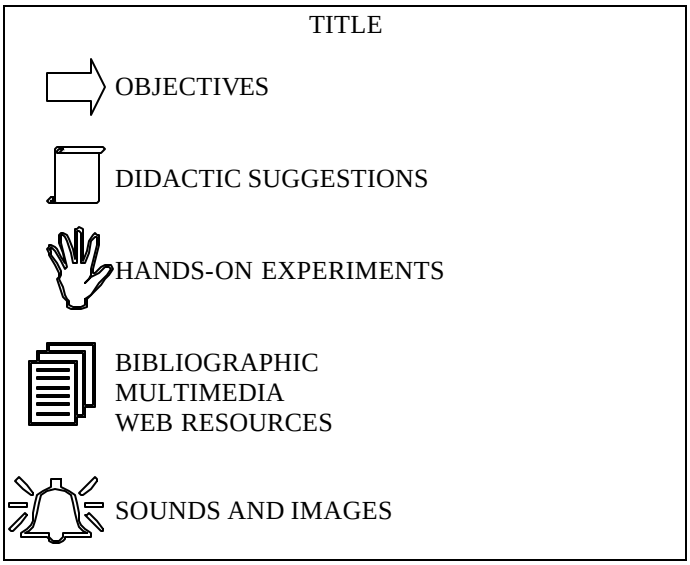


FIGURE. 3
SCHEMA OF A BOOK OR CD-ROM TOPIC DEVELOPMENT.

Didactic suggestions

After the definition of the didactic objectives, the contents are developed in form of text and some figures that clarify the text. In this material format, the text is more extensive than in on-line materials. Some didactic suggestions are introduced in teacher's materials, emphasizing the developing a set of human abilities that are of increasing importance for the future engineer (among these we can cite management, leadership and co-responsibility, public relations and expression abilities, etc.). To promote these abilities we suggest an active learning method that impels the collaboration between students and their abilities for scientific reasoning and communication of their work. In this sense, we suggest the collaborative working between the students to develop different elective topics. The suggestion is that these works have to be done by teams of students with the tutorial of the teacher and the corresponding bibliographic and Internet search of information. After that, the students should explain their works in both a written and an oral form. In this way, it could be possible the debate with the other students of the classroom and the growing of the scientific and social knowledge.

Hands-on Experiments

In some times, hands-on experiments can be a good substitute of other more complicated and expensive experiences. Habitually, they are cheap, easy and rapid to make. Frequently they are possible with materials and apparatus of daily life that can become the elements of a scientific laboratory. Besides of this, hands-on experiments contribute to the educational process greatly stimulating creativity and improvisation. We can mention some kinds of these experiments: physics toys that can be used by children and adult people, easy demonstrations using some laboratory materials more indicated for advanced students, and those that use sensors connected to a computer with an interface.

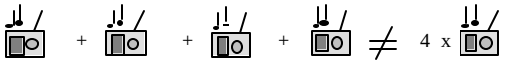
These experiments can be made varying some parameters, and then each of them has to be very well explained in the teacher's guide. For each hands-on experiment, we use to include:

- Title
- List of items related with the experiment
- Objective
- Explanatory figure that permits to understand the experiment
- List of necessary materials
- Description of the experimental device and procedure
- Elaborated scientific explanation
- If necessary, historical and/or methodological annotations, comments, advertisements and a list of recommended references.
- For the CD-ROM format, some of the hands-on experiments could include several video or audio sequences.

In Figure 4 we show an example of hands-on experiment, corresponding to the teaching of the Decibel Scale.

THE DECIBEL SCALE:

Related items: Loudness, Sound level, Decibel scale, Human ear response
Objective: To understand the decibel scale
Materials: Four identical sound sources (radio)
Experimental procedure:
With this demonstration we could understand the meaning of the decibel scale. It consists in hear a sound source and immediately a set of four sources equal to the first one. The listener has to indicate if, in the second case, the loudness sensation multiplies by four.



Explanation:
The sound level that the listener perceives from the four sources is not four times the sound level that he or she perceives from only one source. This is because the human ear does not work in a linear way but in a logarithmic one.

FIGURE. 4
AN EXAMPLE OF HANDS-ON EXPERIMENT.

Bibliographic, multimedia and web resources

- TEXTBOOKS
- JOURNALS
- VIDEOTAPES
- FILMS
- RECORDS
- LABORATORY GUIDES
- INSTRUCTION MANUALS AND TECHNICAL INFORMATION OF DEVICES
- ON-LINE RESOURCES

FIGURE. 5
SCHEMA OF THE CLASIFICATION OF BIBLIOGRAPHIC, MULTIMEDIA AND WEB RESOURCES.

In order to permit the teachers to deep in these subjects a list of bibliographic, multimedia and/or web resources are included in both books and CD-ROM's. These resources are classified according to the list format that appears in the Figure 5.

Sound and Images

The materials have relation with Acoustics, so we try to combine in them both the visual and sonorous perceptions. We pretend that all simulations, images and sound introduced in the course correspond with real cases when this is possible. To attain this, we want to introduce experimental results obtained by acoustical analysis of signals from various systems (plates, strings, horns, etc.).

To introduce sound and video sequences, we use Java Media Framework.

COURSE BENEFITS

In modern society, Internet phenomenon has had a very rapid and important development. The presence of the web reaches a lot of human activities, education being one of them. But from the educational point of view, the web can be a valid tool, only if it is a high quality information source that could be easily encountered and adapted to education necessities. Comparing with other traditional media, the web presents some advantages:

- The number of users is higher
- The possibility to publish the materials while they are being prepared
- The possibility to modify these materials after their publication so many times as necessary
- The opinions and comments received via e-mail, permit to ameliorate and to adapt the product, which can be considered in a continuing progress process

But these materials present some disadvantages:

- In some world zones, actually there is not possibility of access to this type of technology
- In world zones where these technologies are accessible, the problems are basically related to the telephone line transmission velocity and to the number of people that use the web. As an example, we can cite that it is problematic to incorporate multimedia elements like sound and video tracks in this type of material
- Other aspect is that in many countries there are structural changes of educational system; so there is a great mobilization for discussing the best computational technologies that contribute to the formation of socially responsible people
- Besides of this, for many teachers the computer is only a tool that has to been present as a consequence of social impellent, but they have not significantly changed their didactic method. So teachers' formation is necessary

TABLE II
ADVANTAGES AND DISADVANTAGES OF WEB SUPPORT

ADVANTAGES	DISADVANTAGES
Number of users	Material scarcity
Rapid publication	Velocity of telephone line
Easy modification	Transition stage
Continuing progress process	Teachers' formation

In spite of these difficulties, there are efforts in the research and development of hardware, software and teaching materials in Mathematics, Science and Technology subjects al all levels of education [18]-[20].

CONCLUSIONS

Science didactic is having a deep transformation. One of the uses of new technologies and informatics applications are multimedia tools. These tools permit the increase of the meaningful learning, with the development of important physical concepts and scientific reasoning skills. Also, multimedia didactic products improve the access to the knowledge to those students that prefer to read, to listen or to "virtually" touch.

We have a wide education field that offers a lot of possibilities for the development of quality multimedia hardware in all the branches of science and technology, particularly in all Physics branches.

In the preceding sense, the development of Acoustics contents appears like a great source of experiences and materials design that could be used in diverse education contexts, to introduce basic principles or modern technologies [21]-[26]. So we are making an Acoustics course under an interrelated set of didactic materials format: on-line materials and books and CD-ROM materials. These different materials are thought to satisfy two diverse needs: students' and/or engineers' formation, and teachers' materials aid.

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