COMPUTER SIMULATION AND MODELING IN VIRTUAL PHYSICS EXPERIMENTS

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The work describes a set of virtual advanced physics experiments devoted to electrical resonance, heat transportation in metals, Curie temperature for ferromagnetic materials, statistics, beta absorption in matter and Mössbauer effect. Described virtual experiments are equipped with applications, which simulate physical phenomena and processes, model instruments and experimental measurement systems. In contrast to many other simulations, the following presented experiments are based on real experimental data.

1. Introduction

Usually, the virtual instrument (***VI***) is understood as computer controlled real instrument used for data acquisition, analyses and presentation. In this case the control of the physical instrument, which exists in the background of the computer, may be performed using the computer keyboard, mouse, and display. The VI definition can be expanded for computer-based virtual instrumentation systems (***VIS***). The ***VIs*** and ***VIS*** can be also a wide variety of the computer based applications for the physical phenomenon and measurement process modeling or applications which simulate real-world devices, instruments and measurement systems operating. Such peculiarities of the ***VIs*** and ***VIS*** predestinate them for applications building used for modeling and simulations in the virtual physics experiments. Models of the physical or measurement processes can be built using two methods: one method based on mathematical modeling and the second based on measurements performed with real measurement system regarded as a black box, which input-output relations are only taken into account for particular properties presentation with so-called calibration curve. Below are presented the both methods used for modeling physics phenomena and laws, advanced physic experiments and measurement processes based on the virtual instruments.

2. Analytical models with VIs

The physical phenomena and physical laws can be described analytically using the mathematical equations. As examples of the analytical models using VIs, applications appointed to ***the Planck's Law and Wien's Displacement Law*** and ***the electrical resonance phenomenon*** are presented below.

The Planck's Law and Wien's Displacement Law

When the temperature of the object is known, the distribution of the radiating energy is given by the law of black body radiation, ***the Planck's Law***, as shown in equation:

$$M(\lambda,T)=\frac{b}{\lambda^5}\frac{1}{e^{hc/\lambda kT}-1}$$

where: $b=10^7$ in relative units; λ - wavelength; h - Planck constant; k - Boltzmann constant; c - speed of light in vacuum; T - temperature in Kelvin degrees.
For the given absolute temperature T (K) the peak wavelength λ_p (µm) can be calculated using the relationship $\lambda_p T=2897.9$, known as ***the Wien's Displacement Law***.
The implementations of the above equation and relationship $\lambda pT=2897.9$ allow dynamic demonstrating of *the Planck's Law* and *the Wien's Displacement Law* with application shown in Figure 1.

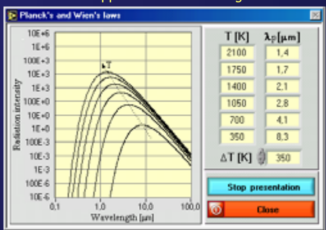

Fig. 1 The *VI* developed for dynamic demonstrating of the *Plank's law* and *Wien's displacement law.*

The Electrical Resonance Phenomenon

The current and voltage as a function of the frequency can be observed in the parallel and series tuned *LC circuits.* Figure 2a shows *LCR$_d$ parallel-tuned resonance circuit.* Its equivalent circuit diagram is shown in Fig. 2b. In this configuration R_d denotes a dynamic resistance, and the resistance R consists of the voltage source resistance R_S added to the leads resistance R_{LEAD}, so $R = R_S + R_{LEAD}$.
Figure 2c shows the VI developed for demonstration how the admittance, reactance and susceptance in the parallel-tuned circuit supplied from the ideal current source depend on the frequency. The VI for the resonance phenomena presentation and simulation how the ratio $y = U / U_m$ depend on the frequency is shown in Fig. 2d. This VI allows also the simulation of the phase displacement φ_P between the current and the voltage U_{LCP} as a function of frequency.

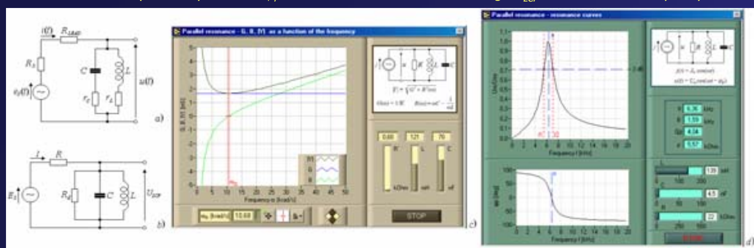

Fig. 2 The parallel resonance: a) *LC* parallel-tuned circuit supplied from the voltage source b) equivalent circuit diagram c) simulation of the admittance, reactance and susceptance as functions of the frequency in the parallel circuit supplied from the equivalent current source d) simulation of the ratio $y = U / U_m$ as a function of frequency in the parallel-tuned circuit.

3. Input/output black box model with VIs

As examples of the method based on input/output black box modeling can be virtual physics experiments completed with VIs. These experiments (which user interfaces are shown in Fig. 3) are appointed to the *electrical resonance phenomena, Curie temperature determination for the ferromagnetic materials* and *heat transportation* studies based on the *Ångström method.* The problem of modeling of the *electrical resonance phenomenon* based on the analytical model, can be alternatively solved using the *input/output black box model with VI implementation.*

Fig. 3 Users interfaces of the experiments appointed to: a) *electrical resonance* b) *Curie temperature determination for ferromagnetic materials* c) *heat conductivity* studies with the *Ångström method.*

4. Simulations in the virtual experiments

Virtual instruments can be successfully used for simulation of the device and measurement systems operating and instrument execution.

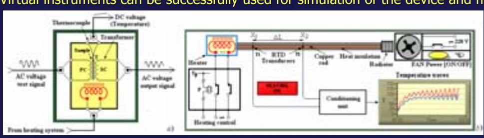

Fig. 4 The models of: a) the transducer used in the virtual experiment appointed to *Curie temperature determination for the ferromagnetic material* b) the experimental arrangement used in the virtual experiment appointed to the *heat conductivity* studies.

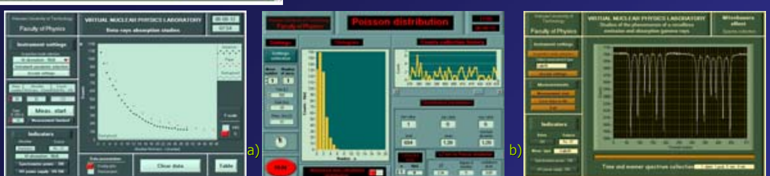

Fig. 5 Users interfaces of the experiments appointed to a) *beta absorption* in matter b) *statistical character* of nuclear decay c) *Mössbauer effect.*

5. Conclusions

Modeling and simulations offer very important tools used in research and techniques for understanding real physical laws and phenomena, measuring methods and processes, also device operating and instrument execution. For this purpose, virtual instruments can be successfully used. With virtual instruments it is relatively easy to build a wide variety of the computer based applications for process modeling, and simulation of the instruments operating and measuring systems execution. Presented virtual experiments can be also attractive models of the measurement processes used in education.
The presented set of virtual advanced physics experiments are included in a specific module for training, dedicated for the in-service teachers training, in the frame of a recent approved **European Socrates - Comenius** three years project: 128989-CP-1-2006-1-RO-COMENIUS-C21 - ***VccSSe – Virtual Community Collaborating Space for Science Education*** -, funded by *European Commission, Education and Training, School Education: Socrates: Comenius.* The project activities will be developed during October 2006 – September 2009 and the training module consists of 6 face-to-face meetings and provides both technical and pedagogical elements with the view of the implementation in the classroom of the proposed virtual applications. The content of the units is oriented on: basics of virtual instrumentation, teaching methodologies and pedagogical strategies involved in the using of the virtual instrumentation, virtual instruments and specific programming languages, basic steps in developing a virtual instrument, virtual instrumentation application designing and implementing.

References

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