Hands-on quantum physics — Introducing quantum principles to non-physics major's students

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Abstract. *An effort to enrich a university course of non-physics majors, with principles of quantum mechanics is mainly not widely supported because it demands strong competences in physics and mathematics. This obstacle can be surpassed by the use of ICT applications and hands-on activities. An intervention was conducted to students of the Pedagogical Department of the University of Athens.*

In order to support the intervention, educational material was developed including the subjects: mechanical waves, duality of light – with reference to duality of electrons–, line spectra, atomic models for the atom of Hydrogen

Keywords. curriculum, hands on activities, quantum mechanics, software

1. Introduction

The last two years in the Pedagogical Department of the University of Athens the curriculum of science education course is enriched with principles of quantum mechanics. The students of our Department have a low background in physics and mathematics. The effort to enrich a university course of non-physics majors, with principles of quantum mechanics is mainly not widely supported because it demands strong competences in physics and mathematics. This obstacle can be surpassed by the use of ICT applications and hands-on activities.

2. Reviewed literature

The so far reviewed literature brought out researches which introduce quantum mechanics to non-physics major's or to students of high school education. These researches aim to estimate the mental models of students of upper high school [4], [2], [3], or of students of non-major physics Departments [5], [1], concerning quantum phenomena (duality of light / electrons, non locality…) and the atom of hydrogen, while in some cases the research is followed by an intervention based on educational material which includes simulations / visualizations, animations, applets.

3. The Software

3.1 The characteristics

In order to support the intervention, educational material has been developed the previous academic year. The developed educational material has the following characteristics: a) methodology based on the educational method. The consisting steps of the method, in both options, may be described as (table 1):

Table 1

Scientific method	*Educational method*
trigger in research	trigger student's interest
making hypothesis	questioning the problem
experimentation	work in the lab or/and in situ
Developing theory	conclusions
testing of theory	problem transfer, generalization

Educational method used for the intervention

b) scientific and historical models transformed to curricular / educational models, c) simulations / visualizations of probabilistic microkosmos and quantum mechanic model of Hydrogen, based on methods of the stochastic analysis and Monte Carlo techniques, d) hands on experiments in order to study phenomena concerning the wave nature of light (diffraction, interference) or different spectra, e) web-based environment.

3.2 Description of the units

The developed software includes six units:

1. mechanic waves, 2. duality of light, 3. spectrum, 4. early models of atom, 5. the quantum –probability– model for the atom of hydrogen 6. electric current.

In the first unit we examine the characteristics of a wave, longitudinal and transverse wave, wave interference and stationary waves.

In the second one, we have included experiments with laser and hands on materials in order to show interference (figure 1), diffraction (figure 2) and a simulation program (figure 3) for the photoelectric effect.

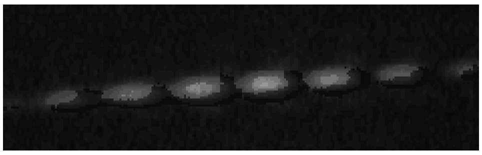

Figure 1. Interference pattern

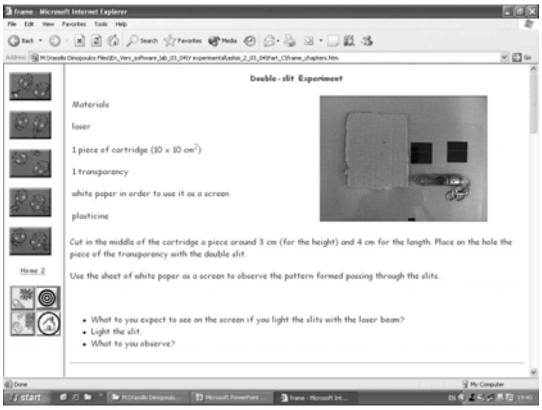

Figure 2. The page of the software for the double-slit experiment

In the simulation program both the macro and the micro-scopic view of a circuit appear, in order to present the photoelectric effect. The program aims to bring out, that when the intensity of light is changed, although the number of electrons emitted is proportional to the light intensity, the maximum kinetic energy of the electrons is independent of light intensity, a fact that cannot be explained by the concepts of classical physics and the wave nature of the light. The kinetic energy of the electrons increases when we increase light frequency.

Furthermore, in this unit, reference is made to historical experiments, concerning the nature of light / electrons such as the two slits experiment of Claus Jönsson conducted in 1961.

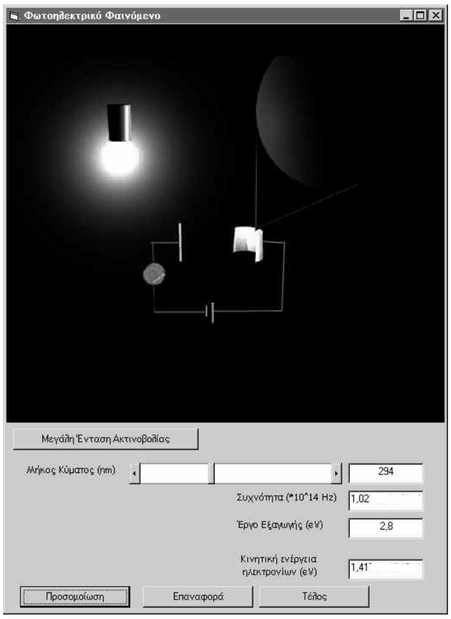

Figure 3. Visualization program for the photoelectric effect

In the third unit we have included experiments with spectroscope in order to study continuous and linear spectra (figure 4). The unit, also, includes a page with instructions for the building of a spectroscope.

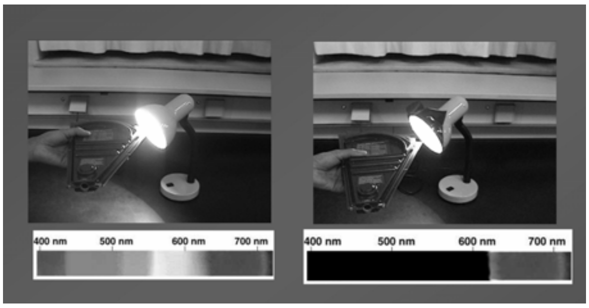

Figure 4. Observing spectra

In the next two units we study the early models of atom (including the Thomson's, the Rutherford's model and the Bohr's atom of hydrogen) and the probability quantum mechanics model. In order to present the probability model, a simulation programm has been developed which includes 2D and 3D models representing the radial probability distributions of an electron for the 1S, 2S and 2P states in hydrogen (figure 5-6). The models have been developed in 3d studio max. In this program the possible positions of an electron, around the nuclei, are represented by dots and the shape of the probablity model is created. The shape, the size and the orientation of the probability model is determined by three quantum numbers.

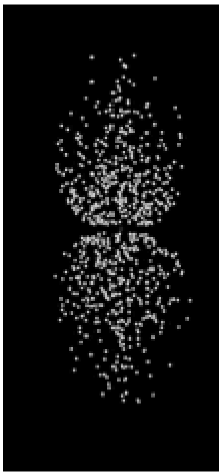

Figure 5. Probability model for the n=2, l=1, m=0 state of the atom of hydrogen

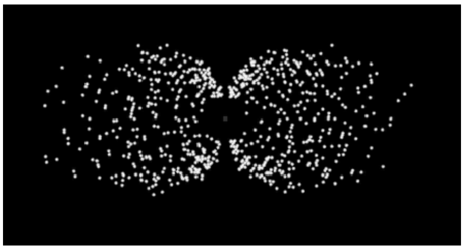

Figure 6. Probability model for the n=2, l=1, m=1state of the atom of hydrogen

In the last unit we study electric current, in order to show an application of quantum mechanics to phenomena that can be explained by both a classical and quantum mechanic model.

The software was implemented in four classes of 120 students of the Pedagogical Department of the University of Athens. The students had limited mathematics and science background and were on the third year of their studies, taking the obligatory physics lab course.

5. Conclusions

The developed material aims to present one of the most attractive thematic of Physics to a broader audience –to students with limited math / physics background. The so far research showed that this can be achieved up to a level by the educational approach we propose.

6. References

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