Interactive Quantum Mechanics

Teaching quantum mechanics at a beginner's level can sometimes be an unpleasant experience—for teachers and students alike. Due to the higher-level mathematics usually involved in this subject, quantum mechanics seems to loom as a bizarre ghostly feature in an obscure, impenetrable fog and mist for many students. The two websites presented here try to dispel the mist with the aid of visualization and interactivity.

Quantum Physics Online developed at Ecole Polytechnique in Paris provides interactive programs with brief explanations in both French and English, which cover many of the topics usually taught in quantum mechanics classes.

The first chapter of the site is concerned with wave – particle duality and wavepackets. Here, the users can perform a virtual Young slit experiment, create onedimensional wavepackets and observe their spreading, or they can animate Gaussian wavepackets at potential steps or barriers. In the third chapter, the visitor can for instance observe the time evolution of general states in a two- and later also in a multilevel system (Figure 1). These studies are extended to two and three dimensions in the forth and fifth chapter, where for example the energy eigenvalues of the C_{60} molecule are computed with a Hueckel MO approach. The last chapter, which appears to be under development, deals with the basics of NMR.

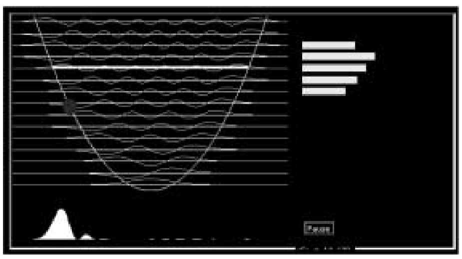

Figure 1. Illustration of the superposition principle at "Quantum Physics Online".

Back and forward buttons unfortunately require Javascript. Animations may be interactive and are realized with small Java applets, so that the pages can be downloaded in a reasonable time. The graphics generated with these applets are mostly simple, twodimensional line drawings, which are fully sufficient to attain the goal of this website. Unfortunately, color is not used in a consistent way. More options to enter or at least display explicit numbers would however be desirable to visualize the results of numerical examples.

In summary, Quantum Physics Online provides a number of simple animations and simulations, which can conveniently be used in quantum mechanics courses. At present however, the site is not well suited as self-study material because background information and plot labeling is not sufficient for this purpose—and because some promising hyperlinks lead into the void.

The Visual Quantum Mechanics project at Kansas State University goes one step further and provides instructional units that combine simple experiments, interactive computer programs, and text. The target group of this website are college and high-school students who lack a deeper knowledge of modern physics and higher-level mathematics. One of the site's objectives is to visualize quantum mechanical effects rather than to derive the mathematical equations which describe them.

The topics covered by the tutorials range from wave – particle duality to LEDs, fluorescent lamps, phosphorescent materials as well as infrared detectors, and finally to numerical solutions of the Schrödinger equation. For example, the unit on hydrogen spectroscopy opens with a brief comment on the motivation for studying spectra of atoms and with an outline of the content and methodology of this course. As a first step, the visual part of the hydrogen emission spectrum is shown and the students are asked to report their observations with the help of forms. In the second step, an interactive

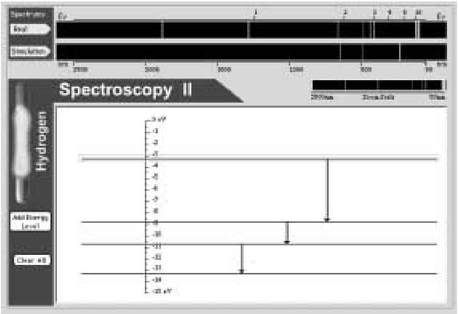

Figure 2. Virtual spectroscopy laboratory of "Visual Quantum Mechanics".

program is launched, which displays the experimental setup, the observed visible spectrum, and an empty energy diagram (Figure 2). Users can then add energy levels and transitions between them to match the resulting theoretical spectrum with the experimental one. Guidance is provided to help students to decide which of the various possible schemes is a reasonable model for the hydrogen emission spectrum. Once an acceptable model has been found, the level diagram is used to obtain a relation between the energy of the levels and their quantum number.

Other interactive programs can be used to study luminescence, LEDs, and various laser systems. There is also an energy band creator, a diffraction simulation, and a quantum tunnelling animation to name just a few. Apart from Java applets, a number of interactive programs on this site require the Shockwave plugin, which is only available for MS Windows and MacOS, not for Unix or Linux. With one of the former systems, you can enjoy nice animations and well designed graphical applications with an intuitive user interface. Apart from minor flaws, such as incorrect titles, wrong tables of contents, and the excessive use of color in the "laser adventure", the website provides excellent tutorials, which render an interactive approach to quantum mechanics very appealing.

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For further information visit:

http://www.quantum-physics.polytechnique.fr

http://phys.educ.ksu.edu/

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