Recommendations
(for material on quantum mechanics and for evaluation criteria)

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The authors are part of the working group (WG5) on Multimedia (MM) established by EUPEN (European Physics Education Network) http://inwfnu07.rug.ac.be/eupen/) and are willing to take the responsibility for some suggestions and recommendations for the physics community concerning two aspects:

- MM material for a lecture on quantum mechanics (QM)
- list of criteria how to evaluate MM

1. From the material which was reported on this workshop by M. Belloni, H. J. Jodl, M. Benedict, E. Debowska (see their articles in these proceedings) we selected the following links representing "good" material:

University level:

- http://www.quantum-physics.polytechnique.fr
  This material (in English or French language) contains 7 chapters. These include an introduction/motivation, then wave mechanics, quantisation in 1D, energy eigenstates and their superpositions in motion in 1D, and in 2D. 3D problems are represented only by visualizing spherical harmonics. Showing the dynamics of spin ½ states as points moving on the Bloch sphere is a speciality of this site. Applications like the scanning tunnelling microscope and magnetic resonance are treated in the appropriate sections. This material uses animations, interactive simulations, short texts and dictionary of names etc. The technique of colour coding is used cleverly to visualize complex functions. At some places the text explaining what we see is perhaps too short for a student. The content and didactical approach is good, but the graphics and overall design is rather basic.
- http://rugth30.phys.rug.nl/quantummechanics/
  The material was written by K. Michielsen and H. De Raedt (University of Groningen). It has seven sub-pages that in addition to certain standard problems contain some good unconventional material. These are: quantum dynamics in two dimensions, charged quantum particle in electric and magnetic fields, Stern-Gerlach experiment, Aharonov-Bohm effect, identical particles. The set of pages has a nice design, they are well organized, and all of them contain short but sufficient background material and require a moderate interactivity.
- http://webphysics.davidson.edu/, http://webphysics.davidson.edu/qmbook/
  The pages contain Physlets by Wolfgang Christian and Mario Belloni from Davidson College, North Carolina, as well as Interactive Quantum Mechanics Exercises for Just-in-Time Teaching. The material is suitable mainly for university students, but the chapter Classical Mechanics vs. Quantum Mechanics should be viewed by school teachers to find something interesting for their pupils. This is the site that requires the largest activity from the student.

- http://www3.adnc.com/~topquark/quantum/quantumapplets.html

This material contains 6 examples, mostly standard topics (H-atom, scattering of square wells etc.). But besides the program, the authors offer excellent necessary material about the physics (about one page) and instructions, how to use the material.

Intermediate level:

- http://www.phys.ksu.edu/perg/vqm/
  The Visual Quantum Mechanics project was prepared and is to be continued by the Physics Education Group at Kansas State University. Each set of the teaching-learning material integrates interactive visualizations with inexpensive materials and written documents in an activity-based environment, and is worth to be used by teachers during their lessons. The project has two parts.

  a./ One is developing instructional materials about atomic physics for *high school* and *non-physics students*. The topics include:
  Spectroscopy Laboratory Suite with Gas Spectra, Emission, Absorption, Solids, LEDs, Incandescence, Lasers, Diode, Luminescence, Infrared Detection, Fluorescence, Phosphorescence.

  b./ The advanced part containing teaching-learning materials for *science and engineering majors* is called the "Next generation", and it is in development now. Some of these tutorials are now available for testing. Part of the material is adapted here from the less extensive but excellent work of the didactic group of the University of München:
  http://www.physik.uni-muenchen.de/didaktik/

Secondary school level:

- http://www.colorado.edu/physics/2000/index.pl
  Physics 2000 is an interactive journey through modern physics, 20th Century science and high-tech devices prepared at University of Colorado. It relies heavily on the use of interactive "applets". The main goal of Physics 2000 is to make physics more accessible to students and people of all ages.
  This site contains a huge amount of MM material for modern physics: Einstein legacy, atomic lab, science trek. The enormous advantage of this material is that the authors tried to present complex phenomena in a simple form (over-simplifications, didactical reduction): the reader may convince himself and look at the part on BEC (Bose-Einstein Condensation). The style of the pages and their text is however not well suited, and seems to be less attractive for university students. They are rather on the level of a course for secondary schools (age 17-18 years or less).
  The pages are in three languages: English, German and Spanish.

2. After a critical analysis of the MM material available to us, we would like to summarize our opinion:
   - About 40% of the material did not work (website not found, server disabled etc.); which means it is not sufficient to produce once good material but this material must be maintained and updated regularly.
   - The MM material on QM offer mostly (80%) standard topics, i.e. orbitals of H-atom, wave package, eigenwert (eigenvalue) problem, harmonic oscillator.
   - Most material has either the form of a traditional textbook now in electronic version with hyperlinks (photos, glossaries etc.) or the form of simulations/animations with small passages of text.

- Most material did not really integrate MM nor exploited the full power of MM.
- Certain topics that have already become standard material in recent textbooks, like Bell inequalities etc. are missing from the MM palette, available on the web. An exception is the page by Franz Embacher (in German) http://www.ap.univie.ac.at/users/fe/Quantencomputer/ that contains some tutorial text, as well as two interactive problems to be solved by the user and by a simulated quantum computer. This field, being on the border of quantum physics and information science, may attract students to physics.

3. The question – what is "good" MM material can be answered either subjectively, according to a long personal experience in lecturing or (pseudo-) objectively, according to a list of criteria:

• multimedia material must be
  - interactive
  - animated
  - motivating
  - user-friendly

• aspect of content
  - correctness
  - levels of deepness
  - relevance
  - innovation

• aspect of teaching
  - suitability for the target group
  - aims and teaching method
  - learning efficiency
  - feedback possibility

• technical aspects
  - use of a standard system
  - software requirements
  - download time
  - performance of videos, sound etc.

The authors believe that this list of criteria must be reasonable and feasible, i.e. not too many criteria, and the meaning of each criterion must be well defined. In addition these suggestions and the evaluation procedure is a first step according to us. Everybody is encouraged – especially on the next workshop in Prague 2003 – to criticize or to discuss our recommendations.