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NANOTECHNOLOGY AS A PART OF PHYSICS TEACHING AT SCHOOL

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Abstract

The progress in teaching should be in accord with the progress of science, that's why the subject of teaching must be supplemented by the elements of modern knowledge which permit pupils to understand better what happens around us. The end of XX century is characterised by the rapid development of nanotechnology, which we deal with in this paper.

The fast progress of nanotechnology, which belongs to the most dynamically developing branches of science and technology and brings together various sciences such as solid state physics, chemistry, material science and molecular biology has been already observed for the past several years.

Today quantum technologists can catch and trap single atoms and make experiments with them. They can reflect atoms in the electromagnetic field, draw the atomic graffiti, move the atoms on solid surface, copy the structure of crystal and reveal separate atoms. These experiments deeply penetrate into the quantum world, associating strongly quantum mechanics with the practice [1].

Today there are many things around us, which owe to nanotechnology their own existence e.g.: the compact discs player, non - drop paint, car stop lights, optical waveguide telecommunication, the brain tomography which uses nuclear magnetic resonance and scanning tunneling microscopy [1].

The natural questions arise:

Can the nanotechnology achievements open up the perspectives of introducing the basic concepts of this sphere into physics curriculum at high school?

If we notice that:

- The world of quanta is necessary,
- There is no other basic science concerning Nature like Physics which bear the responsibility to search for the answers to ultimate questions,
- And if we also consider the *"Contents of Teaching".*

An answer to the above questions seems to be affirmative.

It is necessary to familiarise the pupils with the fundamental concepts of quantum mechanics for the better understanding the principles, which rule the microworld.

If one wants to introduce new concepts into Physics curriculum, it is necessary to make an analysis of the topics, which are to be introduced. This analysis should be made from the both points of view - the "teaching contents" as well as didactics. It should lead up to the structural configuration of contents which means it should be able to make the model of the physical reality.

One can distinguish in the analysis of "teaching contents" the following steps:

1. To make the precise records of the goals, which are to be achieved by the pupils after they have gone through definite parts of the course. These goals have to be expressed in terms of concrete knowledge, skills and habits.

2. To prepare the list of basic theorems (the record of the basic knowledge), which the learner is to assimilate. This list can be eventually of help later on at preparing the knowledge test.

3. To prepare the "didactic matrix", by means of which one can carry out an analysis of the essential and logical relations between chosen rule and the rest of them.

The first two steps, which are related to nanotechnology and could be, in our opinion, introduced into Physics curriculum at the high school level, are presented below.

Ad. 1)

a) the record of knowledge, which learner have to assimilate and remember:

    - the fact that the Universe is irreducibly random;
    - hypothesis about hidden variables, which would qualify the comportment of quants;
    - probability of the event we can count using the amplitude of the probability;
    - Heisenberg's uncertainty principle;

- what is hidden under the notion of low - dimensional structures (2DEG - *2 dimensional electron gas*, 1DEG - *1 dimensional electron gas*, 0DEG - *0 dimensional structures*);
- tunneling effect;
- to give the examples of quantum circuits (e.g. *split-gate).*

b) record of skills:

- to show that hidden variables do not exist;
- to interpret the electron's energy formula in the potential well;
- to explain the "energy level" notion;
- to talk over the principle of operation of STM (*Scanning Tunneling Microscope*) and AFM (*Atomic Force Microscope*);
- to talk over the utilisation of "laser cooling of atoms" (the idea of optical crystal and the atomic laser);

c) record of habits:

- to characterize the density of states and to draw the $\rho(E)$ characteristics for quantum structures with different dimensions;
- to talk over the directions of heterostructures;
- to interpret the $\rho(E)$ characteristics for each heterostructures;
- to describe the quantum work of QPC (*quantum point contact*) and SET (*Single Electron Transistor*);
- to compare the changes of conductance in classical and quantum circuits;
- to explain the logical gates and quantum computer idea.

Ad.2) Basic theorems, which the learner should assimilate during nanotechnology learning:

- Quantum processes are subject to the quantum rule (hidden variables do not exist, they might qualify the particle's behaviour in microworld).

- Light can be regarded as a flow of energy packets. These particles are called photons.

- Dualism of light is expressed by Einstein's hypothesis that associates the photon energy with the frequency of the light wave: $W = hf$.

- Physical quantity that does not occur as a continuous variable is the value of action H, which is defined as a product of energy and time:
  $H = Wt = n_H h$, thus action H is made up of quanta h.

- The elementary charge is proportional to the square root of the action quanta h. The Coulomb - blockade effect is based on the quantization of charge.

- The action of process, where an electron would travel along with velocity v and momentum $p = mv$, is given by $H = mv\ x$, which should increase continuously with x.

- Heisenberg's uncertainty principle denotes that the location or the mometum of a particle, and its energy or its time of observation can only be determined imprecisely.

- The probability P of finding the particle in a specific spatial region is defined by $|\Psi|^2$, where Ψ is wavefunction.

- Particles in the locked area can only assume discrete energy values. For example: electron's energy in one - dimensional potential well of length L that is enclosed infinite potential walls is given by

$$E_n = \frac{n^2 h^2}{8mL^2}; \qquad n = 1, 2, 3, \ldots, +\infty$$

  where h - Plank's Constant.

- The lowest energy state of the particle (the basic state) doesn't represent the motionless particle.

- With the tunneling effect one can meet in quantum phenomena, consisting in penetration of the particle through the potential barrier.
- Tunneling effect is used in modern scanning microscopes (STM, AFM).
- Magneto - optical traps are used to stop and to research atoms. Thanks to this the atomic laser came into being - the coherent source of the matter.
- One can use so-called heterostructures (e.g.: 3DEG - *3 dimensional electron gas*, where the carriers move is not limited to any direction) to building nanocircuits.
- *2 - dimensional electron gas* (2D) - the carriers move is limited in one dimension,
- *1 - dimensional electron gas* (1D) - the carriers move is limited in two dimensions,
- *0 - dimensional electron gas* (0D) - the carriers move is limited in three dimensions.
- Quantity of possibly electrons states on the volume unit and the singular partition of the energy is the density of states - $\rho(E)$.
- Elements of quantum circuits are: QPC - *quantum point contact*, that is the narrowing between two areas 2D, SET - *Single Electron Transistor* - mechanism which controls the flux of the current - by single electron.
- Example - circuit is: the gate with the gap - 2D closed between two different semiconductor materials, on which metallic electrodes are ; the Taylor's circuit - 6 surface gates which we can be individually controlled by reducing the depletion areas in 2DEG.
- Gate (e.g. the gate NOT or AND) is the system which realizes the certain logical operation, and we can use the simple diagram to describe it.

- Fundamental elements - gates - are used to the construction of the quantum computer. These elements are joined together into greater functional units, which are elements of further units etc. until the construction of the all computer is done.

It is worth mentioning that the above analysis of material will be the basis for the realisation of aims which learners have to attain and fundamental notions which the teacher must exhibit during realization of the lesson and the proper preparation of the knowledge in meritory and logical succession.

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