

## ELECTROMAGNETISM: INTERACTION OF SIMULATION AND REAL LAB EXPERIMENT

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**Abstract:** *eLearning at universities is taking an increasingly larger part of academic teaching methodologies. In part this is caused by different pedagogical concepts behind interactive learning system, in part it is because of larger numbers of students that can be reached within one given course and, most important, actively integrated into the teaching process. We present here the development of a novel concept of teaching, allowing students to explore theoretical and experimental aspects of act of magnetic field on moving charge through real experiments and simulation. This problem is not only part of the basic education of physics students, but also element of the academic education of almost all engineers.*

**Keywords:** *Electromagnetism, Physics labwork, Engineering education, Simulation and real experiment, eLearning*

**ACM Classification Keywords:** *I.6.5 Model Development.*

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### Introduction

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It is extraordinarily difficult to assess the impact of Information and Communication Technologies on education. The critical role of new learning technologies is undisputed. The rapid pace of change, the shift from a training philosophy of "just-in-case" to "just-in-time", and the changing nature of the workforce itself, underpin this development. E-learning raises expectations about the contribution of sophisticated multimedia technologies to meeting training needs. This, in turn, is posing new challenges in developing pedagogy and is leading to new roles for teachers and trainers. The European Commission [1], in their Barcelona declaration of March 2002, declared: "In order to raise the niveau of learning in Europe, the integration of ICT in the educational process is seen as an opportunity to advance the change process and to increase both quality of and accessibility to learning processes."

Early development of the use of ICT for learning focused on technology and on the use of technology to essentially replicate traditional learning environments [2]. More recently there has been a refocus in the discussions on e-learning. Rather than the emphasis on technology, the focus of new thinking on e-learning is increasingly on the learner and on competence [3]. This is seen as more important for the quality of e-learning provision and the success of ICT-supported learning processes.

It is indeed one of the challenges in eLearning and e-Teaching to reproduce adequately the intellectual combination of experiment and theory as found in natural and engineering science labs. Thereby, the purpose of experiments differs between theoretical and practical studies: in theoretical disciplines, experiments in virtual spaces offer a new approach for demonstrating abstract concepts in realistic models. While it is seemingly sufficient – or even necessary – to rely on simulations or purely abstract constructions in the theoretical fields, this does not hold true for the "practical" or applied sciences. Here it is important to include both the presentation of the characteristic features of the basic phenomenon and the experience of the "real" experiment (e.g. how to setup a realistic experiment correctly and how to choose and handle the equipment to measure the desired effects).

The e-learning methods of physics study in Bulgaria are still not popular. Our efforts in the last years have been connected with creation of different Web-based materials for physics education [4-10]. For the purposes of this paper we choose the physics of act of magnetic field on moving charge as an example where abstract and experimental aspects are treated successfully through a combination of demonstration of simulation and real experiments.

## Concept of e-learning

In engineering education the concepts taught are mostly complex concepts, where some links go from of the object/event world to the theory/model world. Tiberghien [11, 12] makes a categorization of knowledge between the object/event world and the theory/model world, which is shown to be very effective when analyzing and developing lab-instructions. She points out that the links between the theory/model world and the object/event world is important to make explicit in education. During labwork students are expected to link observed data, to either theoretical models, or to the real world they are exploring. In order to find these links and to make it possible to highlight them in the labinstructions, there is a need for an extended model that shows all links, and whether these links belong to one of the worlds or link between them. Fig.1 presents our concept about categorization of knowledge based on a modeling activity.

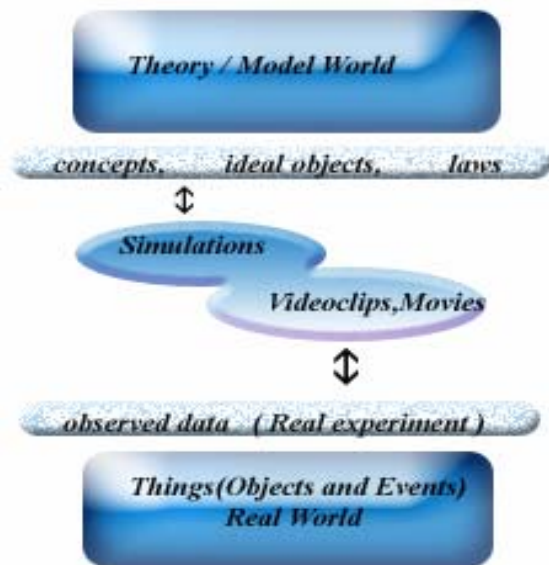


Fig.1. Categorization of knowledge based on a modeling activity

## A Brief Introduction into the Physics of Charge Particle in Magnetic Field

Observations show that a constant magnetic field acts on moving charges (*ideal object*). From experiments have been found that a force (the so-called Lorentz force) acts on a charge  $q$ , which moves (in vacuum) with velocity  $\vec{v}$ , in a constant magnetic field of induction  $\vec{B}$ , equal to  $\vec{F}_m = q(\vec{v} \times \vec{B})$ . The direction of the force  $\vec{F}_m$  depends on the sign of the charge and is perpendicular to the plane containing the vectors  $\vec{v}$  and  $\vec{B}$ , so that the force does no work as the electron moves and so its velocity is constant in magnitude. The force  $\vec{F}_m$  only changes the direction of velocity moving a charge in a curvilinear trajectory. The magnetic field also acts on the electrons inside a conductor, whose motion creates an electric current. Assume that a conductor with current is situated in a magnetic field of induction  $\vec{B}$ . The Lorentz force acts on all the electrons moving with uniform velocity  $\vec{v}$  and it is perpendicular to  $\vec{v}$  and  $\vec{B}$ . Because of this the electrons will describe curved paths. A surplus negative charge appears on upper surface of the conductor, so that a potential difference appears across the upper and lower surfaces (**Hall effect**). In semiconductors with hole conductivity the upper surface becomes positively charged and the lower surface negatively charged (the anomalous Hall effect).

## Charge Particle in Magnetic Field in Simulation Laboratory Experiment

Experiments based on computer simulations have already found widespread use as a supplementary material in the teaching process. The major advantage of computer simulations is an excellent visualization effect that is of special interest in the description of electromagnetic phenomena since the effects of magnetic field on moving charge and Hall effect through action of abstract field that is hard to imagine. A variety of technologies may be used to create computer simulations. We used Web based technology. Web pages were created by Microsoft FrontPage, ArcSoft Photostudio 5.5 and Microsoft Photo Editor. The core of simulation laboratory exercises "Charge particle in magnetic field" [13] and "Hall' effect" [14] are Java applets. These simulation experiments have analog in real laboratory experiments in University of Rousse. Because most standard applets are written with English controls and instructions, students with limited knowledge of the English language might have problems understanding the basic concepts governing the applet behaviour. For our purpose some of the text in the applets has been translated in Bulgarian.

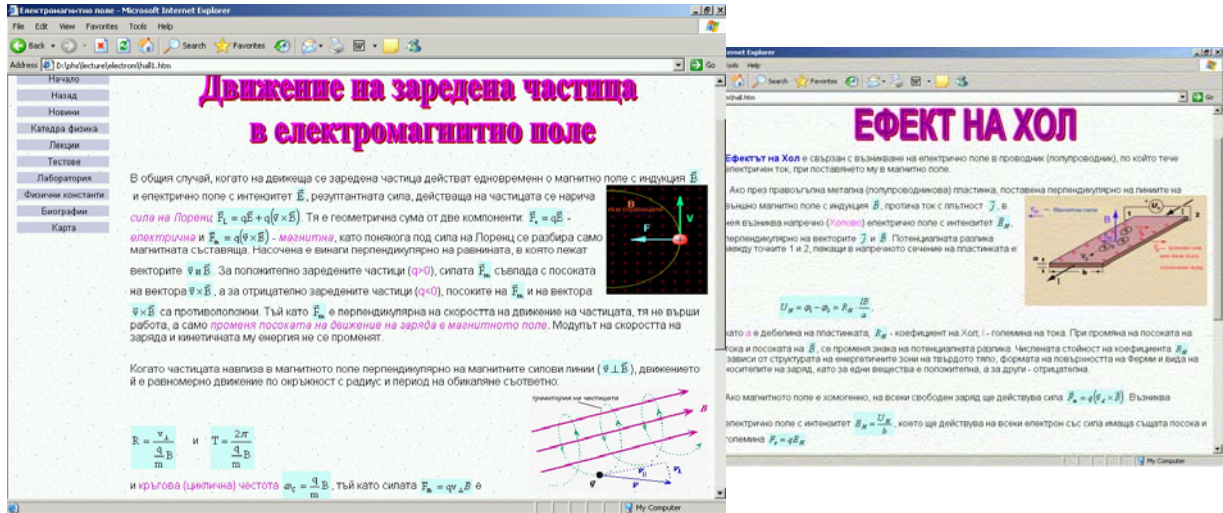


Fig.2. Theoretical part of simulation labs

The simulation lab exercises have:

- Theoretical introduction and analysis of physical phenomenon, which is demonstrated in simulation lab exercise (Fig.2).
- A part where the students may be prompted for the answers to three questions (entry test). The student can only proceed with the exercise after giving the correct answers (Fig.3).
- A part giving the practical instructions describing how to carry out the actual activities and measurements of the lab exercise.
- Detailed measuring process description and the applet used in simulation and measuring process.
- A part giving an overview of the results of the exercise allowing the student to print these results. It is based on these data that the student will prepare a lab report.

Figs. 2, 3 and 4 are examples for theoretical part, entry test, tasks, which students must execute, detailed measuring process description, the applet used in simulation [13,14] and measuring process in the case of simulation exercises "Charge particle in magnetic field" and "Hall` effect", respectively.

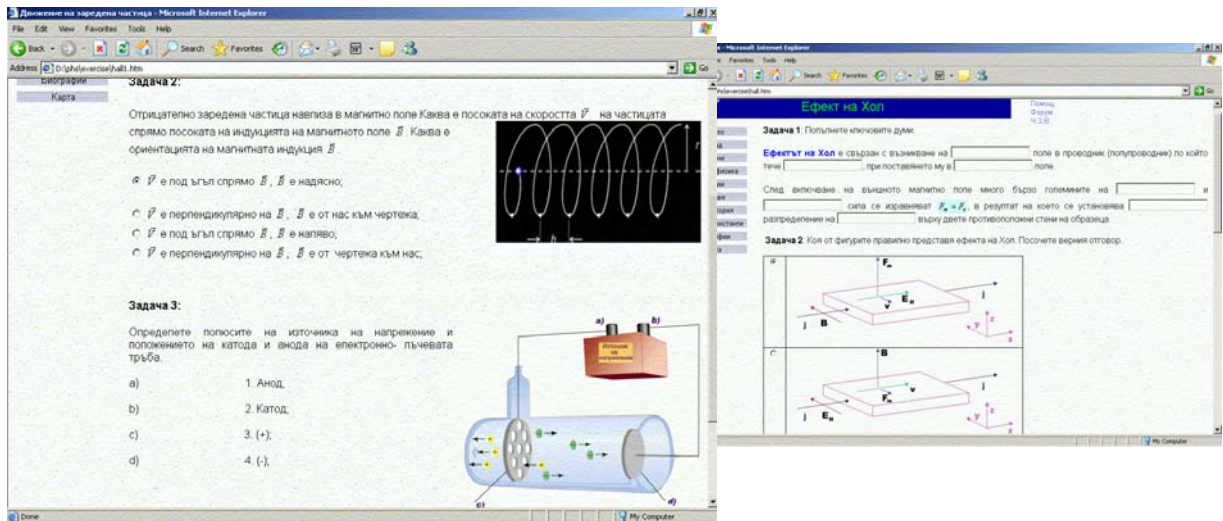


Fig.3. Entry test

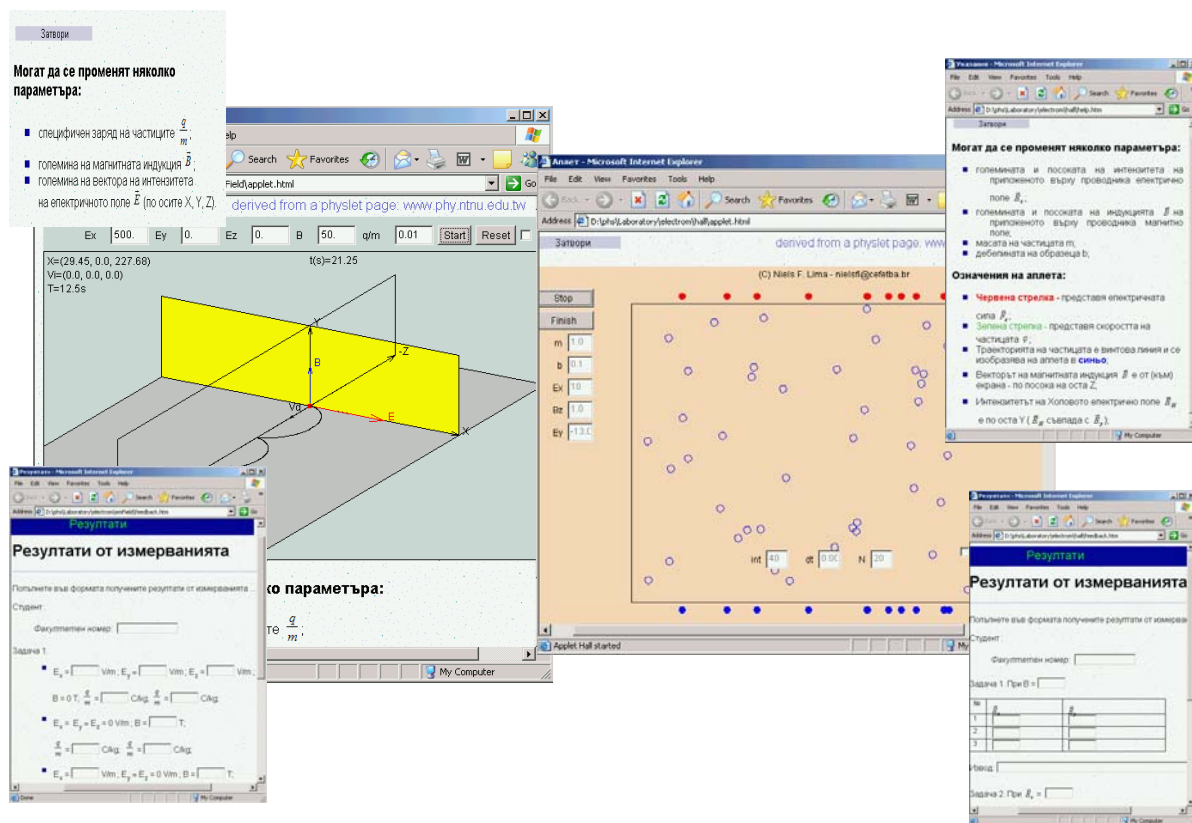


Fig.4. Applets, detailed measuring process description and results

In simulation laboratory experiment "Charge particle in magnetic field" students have possibility to investigate the motion of charge particles with different sign and different specific charge in magnetic field. In the case of "Hall effect" there are possibility for investigation of dependence between intensity of Hall electric field and applied magnetic field.

The presented simulation laboratory experiments are examples from the simulation laboratory [10], created for students from University of Rousse.

### Video Clips and Movies as a Tool for Visualization the Act of Magnetic Field on Moving Charge

Interactive video clips and movies are logical step in the progression of creating useful visualizations for students. According to Kozma [15, 16] "the advantage of any video is in its use of dynamic, visual symbolic systems that allow scientists to view any scientific experiment or discovery from multiple or different perspectives". In [17, 18] has been shown that:

- The digital video activities and tools can be used by students to make connections between concrete, real-life phenomena and the abstract ideas and models of physics.
- Students can create visual representations of their model and display it directly on the video scene. In this way students can make direct visual comparisons between complex events and simplified scientific models.
- Students can also combine images from different video frames and modify the presentation of motion on the screen.

In the case of lab exercises "Charge particle in magnetic field" and "Hall effect", we used movies [19, 20] and video clip [21], respectively to demonstrate the motion of positive (in red) and negative (in blue) particles in magnetic field. Fig.5. shows different frames from the experiment.

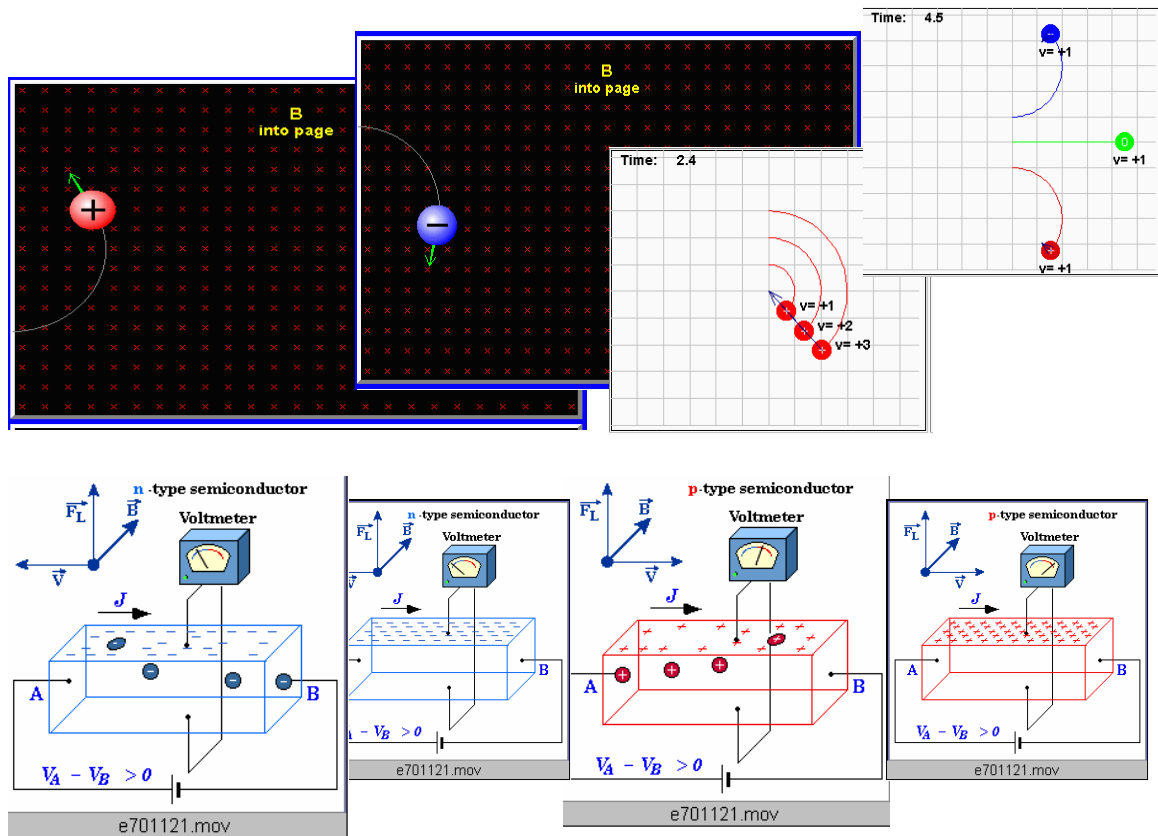


Fig.5. Video clips presented the simulation lab exercises

Video clips and movies can be included in electronic tests for knowledge estimation with the help of appropriate Test Generator [6]. Question examples with integrated multimedia element are presented in Fig.6. This allows creation of more attractive and varied test questions.

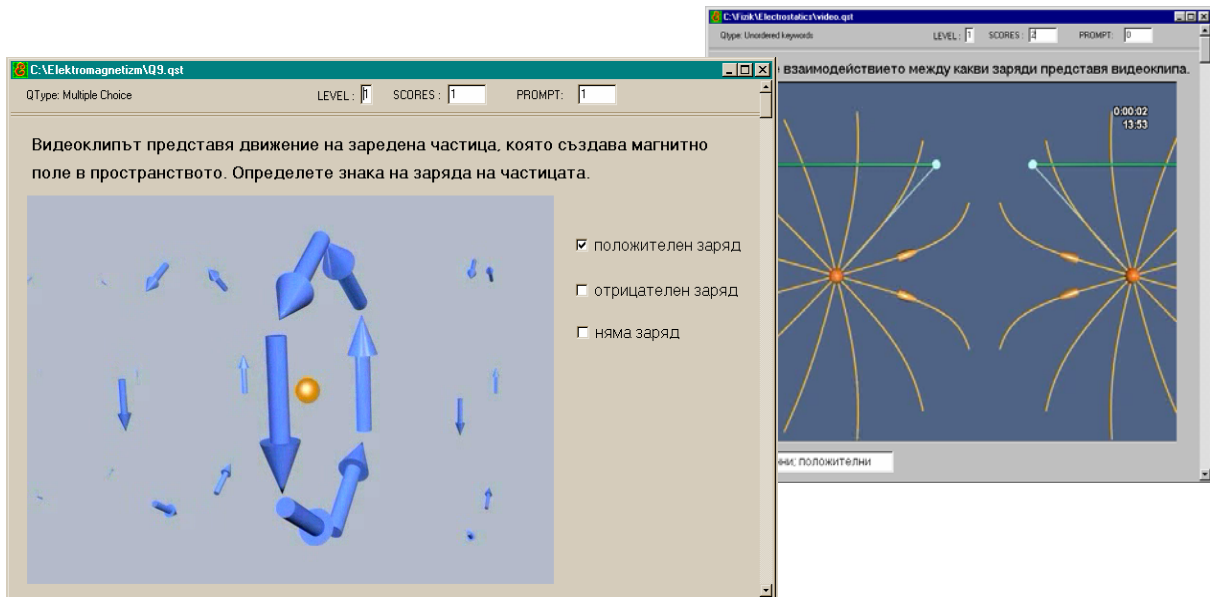


Fig.6. Question examples with integrated movies

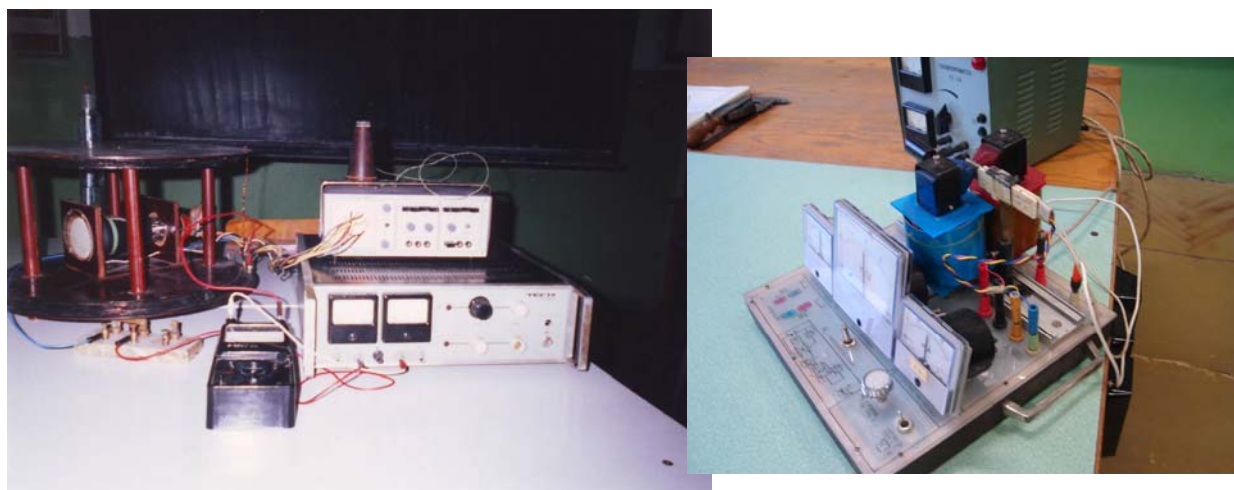
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### Charge Particle in Magnetic Field in Real Laboratory Experiment

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In real experiment "Charge particle in magnetic field" (Fig.7a) the cathode-ray tube, used as source of electrons, is arranged in homogenous magnetic field created by Helmholtz' coils. From the deviation of electrons, give on the screen of the cathode-ray tube, it is possible to estimate the specific charge of electrons [22].

In real experiment "Hall' effect" (Fig.7b) there are possibility to determine the character of the conduction (by electrons or by holes) and also the concentration and mobility of the carriers [22].



a

b

Fig.7. Real experiment equipments

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### Practical Applications of the Investigated Physics Phenomena

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For students of engineering courses it is important to investigate the deviation of charged particles in a magnetic field, because it is widely used in electronic devices (charged particle accelerators, electron microscopes, measuring instruments for the study of vibrations or very fast reactions, television sets, magnetic traps for charge particles, etc.). The Hall' effect is widely used in measurement work (miniature Hall effect counters, the modulation of electric vibrations, the taping of sound waves, the amplification of direct and alternate currents, etc.)

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### Conclusion

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Many fields of modern engineering are closely interwoven with physics. The physics teaching needs the study of many physics notions, methods and phenomena in a limited time. The major advantage of computer simulations, video clips and movies is an excellent visualization effect that is of special interest in the description of electromagnetic phenomena since the effects of magnetic field on moving charge and Hall' effect through action of abstract field that is hard to imagine. In this paper we present the development of a novel concept of teaching, allowing students to explore theoretical and experimental aspects of act of magnetic field on moving charge through simulation and real experiments.

The laboratory exercises presented in this paper can be used in addition of real laboratory experiments. It can also be profitably used by the distant learners, who have often scarce or null opportunity to access the laboratory in the university. Of course, when using simulation exercises, it is important to bear in mind that the actual reality is inevitably more complicated than the virtual one, so everybody should be invited to try, whenever possible, home made experiments or to directly look at physical phenomena in nature. Although the simulation exercises are very good as an educational addition, they could not recompense the classical education.

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