

MOSEM² project: Integration of data acquisition, modelling, simulation and animation for learning electromagnetism and superconductivity

E. KEDZIERSKA⁽¹⁾, F. ESQUEMBRE⁽²⁾, L. KONICEK⁽³⁾, W. PEETERS⁽⁴⁾,
A. STEFANEL⁽⁵⁾ and V. S. FARSTAD⁽⁶⁾

⁽¹⁾ *AMSTEL Institute, University of Amsterdam - Amsterdam, The Netherlands*

⁽²⁾ *University of Murcia - Murcia, Spain*

⁽³⁾ *Physics Department, University of Ostrava - Ostrava, Czech Republic*

⁽⁴⁾ *PONTOn - Belgium*

⁽⁵⁾ *Dipartimento di Fisica, Università di Udine - Udine, Italy*

⁽⁶⁾ *Simplicatus AS - Lillestrøm, Norway*

(ricevuto il 30 Novembre 2009; pubblicato online il 20 Luglio 2010)

Summary. — The MOSEM² project, funded by European Commission, seeks to extend the minds-on experiments and materials from the twin project MOSEM by adding a set of computer aided activities covering a series of topics in Electromagnetism and Superconductivity. The new activities will integrate different ICT technologies: data logging, data video, modelling, simulation and animation. The MOSEM² primarily targets physics teachers in upper secondary schools and trainee physics teachers. Teacher training departments at universities will implement the teacher seminars and new materials developed in the project. During the WS4 workshop held at MPTL 14 examples of teaching and learning activities from MOSEM² were demonstrated.

PACS 01.50.-i – Educational aids.

PACS 01.50.F- – Audio and visual aids.

1. – Introduction

The MOSEM² project builds on the foundations of several collaborations in national and/or European projects, most recently the MOSEM⁽¹⁾ and SUPERCOMET 2⁽²⁾ projects, which are the direct sources of the ideas and the MOSEM² consortium. The 30 partners include teacher training institutions, professional organisations for teachers and engineers, private companies and municipalities in a total of 11 countries across Europe.

⁽¹⁾ <http://supercomet.no/gb/MOSEM>

⁽²⁾ <http://supercomet.no/gb/SUPERCOMET-2>

Targeting pre-service and in-service teachers, the MOSEM² project aims to improve physics teaching through use of data-logging, models and simulations combined with on-line learning modules containing animations, textual descriptions and media files (videos, photos, etc.).

MOSEM²⁽³⁾ will contribute to innovation in scientific curricula of the European schools, in particular by offering educational paths that show how it is possible to reconstruct classical physics in a modern perspective, developing new teaching/learning strategies and methodologies and using materials, tools based on multimedia and ICT.

During and after the project, around 20 testing schools and 10 development partners in 11 countries will try out and use the developed materials. Many of the development partners are teacher training institutions that will implement the teacher seminars and new materials developed in the project. The network of pilot users extends beyond the MOSEM² partnership due to the family of related projects. We expect the results to spread across borders, based on the international collaboration of the project and the project's discussion forum which is intended to grow into an online community connecting teachers in different countries in order to share experience, teaching materials and methods as well as improving language skills and cultural understanding.

This paper describes some of the teaching and learning activities developed in the MOSEM² project and presented during MPTL14 workshop 4. We use multimedia and ICT to integrate the use of modelling, simulation, experiment and video-analysis to create new settings for learning of Electromagnetism and Superconductivity.

2. – ICT tools used in the project

According to S. Papert (Papert, 1999) the broad range of educational software falls into two main categories: “informational” and “constructional”. In “informational” category ICT facilitates novel methods of examining ready accumulated information. Within this category the strands relevant to science include:

- Internet - access to informational sources
- Multimedia - video presentations
- Visualisations - presentation technologies
- Tutorial and instructional programs.

In “constructional” category ICT serves a tool for constructing new information and understanding. Within this category, the strands relevant to science are:

- Data logging
- Data video
- Modelling
- Simulations
- Data processing etc.

⁽³⁾ <http://supercomet.no/gb/MOSEM2>

The MOSEM² project focuses primarily on activities in the second category. The project extends the minds-on experiments and experimental materials, animations⁽⁴⁾ and videos⁽⁵⁾ from the twin project MOSEM by developing sets of data-logging, data-video, modelling and simulation experiments covering a series of topics in electromagnetism and superconductivity activities and creating a collection of pictures and videos.

Data-logging experiments. – Data-logging experiments allow collecting data from sensors *e.g.* for voltage, current, magnetic field via an interface connected to the computer and displaying in real-time measured sensor values and calculated quantities. Presenting data while being collected helps students to make immediate observation of the data. This encourages critical thinking skills.

Data-video experiments. – Data-video experiments allow making measurements of position and time of moving objects on digital video clips or images. During the measurements the data are collected in the form of points (manually, or automatically by point tracking). The possibility of synchronizing graphs with the video frames help students to bridge the concrete visual display of a motion event and its abstract graphical representation.

Modelling experiments. – In Modelling experiments students can create, explore or use computer models of dynamical changing systems. A key feature of modelling activity is the process of editing and altering a model to study the change of behaviour. Students can use the model to test their theories and knowledge about a phenomenon. They can compare the result of theoretical models with experimental results (data logging or video measurements).

The MOSEM² experiments are developed in the Coach 6 program which has been created by the AMSTEL Institute (Amsterdam Mathematics Science and Technology Education Laboratory) at the University of Amsterdam, The Netherlands. The program is widely used throughout Europe as a comprehensive system which integrates tools for computer measurement and control, video-measurement and modelling. The program provides an environment allowing simultaneous use of a variety of tools: explanatory text, images, videos, graphs, tables, displays, models and programs. It is an authoring system that enables creating multimedia activities (Heck, Kędzierska, Ellermeijer 2009).

3. – Learning with Simulations

The Easy Java Simulations⁽⁶⁾, also known as EJS, is a free, Java modelling and authoring tool designed for creation of interactive computer simulations of scientific phenomena. These simulations can be used in computer laboratories with students to explain better difficult concepts, to let students work with the simulations or (for more advanced students) even create their own simulations. EJS has been created by Francisco Esquembre and is part of the Open Source Physics project (Esquembre 2004).

EJS structures the authoring process in three parts: creating a description, specifying the model, and building the view for the simulation. Each task has a dedicated work-panel that provides the needed functionality. The first panel, *Description*, allows

⁽⁴⁾ <http://online.supercomet.no>

⁽⁵⁾ <http://youtube.mosem.no>

⁽⁶⁾ <http://www.um.es/fem/Ejs>

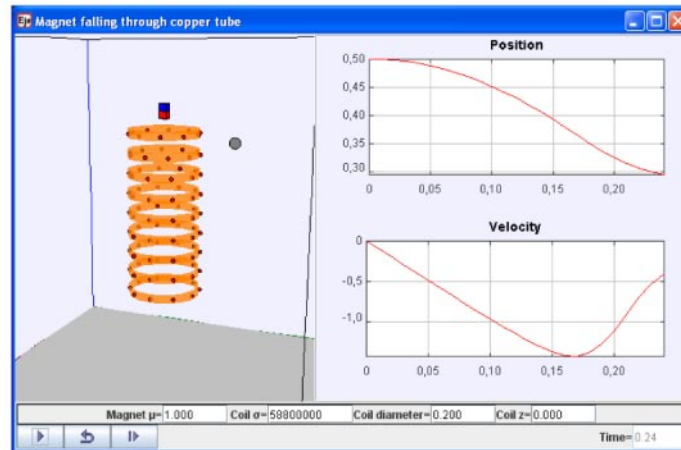


Fig. 1. – EJS experiment: magnet falling through copper tube.

creating and editing a multimedia HTML-based narrative that describes the model. The second work-panel, *Model*, is dedicated to the computational modelling. This panel allows creating variables that describe the model, to initialize these variables, and to write algorithms that describe how this model changes in time. The third work-panel, *View*, is dedicated to the task of building the graphical user interface that includes visualization, user interaction, and program control with a minimum of programming. EJS has been designed to help a person who wants to create a simulation to concentrate most of his/her time in writing and refining the algorithms of the underlying scientific model, and to dedicate the minimum possible amount of time to the programming techniques (Christian, Esquembre, 2007).

In the project a collection of ready-to-use interactive EJS experiments will be developed. Teachers and teacher trainers will be able to use them directly or, by using EJS program, to modify them according to their own needs.

4. – Teacher seminars

Specially developed teacher seminars will allow teachers and teacher trainers, involved in the project, to experience both the developed resources as pedagogical methods for facilitating active learning. The teacher seminar will not only focus on transfer of knowledge to teachers, but will also aim at different levels of professionalization of teachers. It will make use of an approach based on the EFQM (European Forum Quality Management)[©] model.

The EFQM Model distinguishes five levels of development of organisations, which, in terms of teacher professionalization can be described as follows:

1. *The **activity** level (teacher as occasional learner)*

The teacher at this level is very content oriented, needs large amount of support materials and remains rather passive for new teaching ideas.

2. *The **process** level (teacher as member of a group learners)*

The teacher at this level is in control of primary processes: teaching and collaboration. He is responsible for the implementation of new ideas, discusses with his colleagues learning paths, educational materials, experiments and reflects on how to do things in the classroom. He is willing to become a learner, but needs help from equally regarded colleagues.

3. *The **system** level (teacher as developer)*

The teacher at this level has competencies on all levels: know-how, skills and attitudes to tackle new challenges. The group discussions and the materials presented are regarded to him as an opportunity to improve his competencies. He uses the new materials as part of a bigger plan for improvement of his lessons.

4. *The **chain** level (teacher as a manager)*

The teacher at this level is able to assemble new lessons (materials, strategies and methods included). He can present the self-made materials and discuss it with colleagues. He is capable of integrating (collect, evaluate, adapt and implement) all new materials himself. He gets easily inspired by other excellent teachers.

5. *The **excellence** level (teacher as a leader)*

The teacher at this level tries to be at the top in education; definition of “top” can vary: results oriented, social oriented. He is aware of educational research in his field and pilots methods for testing and getting experience. He is a trainer and developer himself.

Using EFQM principles means an approach in levels of competences: a teacher needs to develop himself from lower levels to higher levels. Every raise of level is regarded of equal value. The teacher seminars of MOSEM² will be worked out in a way that teachers determine what kind of seminar they want to get. For this a self reflection tool is developed. Based on his conclusion he decides with which kind of seminar he needs to raise his level of competences. For example from the level of “activity” to the level of “process”. Apart from this, in order to meet all requirements of European projects, the teacher seminar format will give several possible approaches to training teachers, as they occur in different countries.



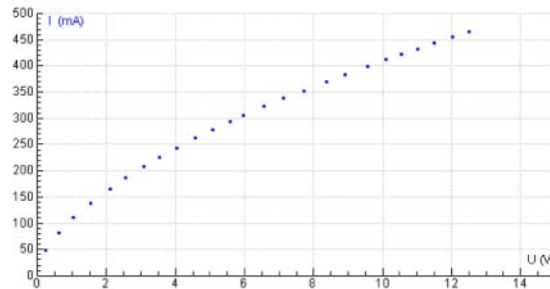


Fig. 2. – The $I(U)$ characteristic of a bicycle bulb.

5. – Exemplary project materials

The activities developed in the project are designed according to the principle of full integration of experiments - data logging, modelling and simulation. Below three examples of such activities are presented.

5.1. Temperature depending of resistivity in bulb. – High temperature resistivity measurements for metals are difficult to organize in the school lab. Measurement of the current-voltage characteristics of an incandescent bicycle bulb offers a possibility of determining the relation between resistivity and temperature of a bulb filament in a more simple way (Bosio *et al.* 1996).

By using the voltage and current sensors students record the $I(U)$ characteristic of a light bulb. During the measurement the voltage is gradually varied from 0 to 12 Volt. To avoid transient phenomena due to the heating of the lamp, each measurement should be taken after the measured values have been stabilized. Then the resistance R and the resistivity ρ are determined. Based on an assumption that the system is in dynamical equilibrium conditions in which all electrical energy supplied to the system is emitted as electromagnetic radiation $P_{el} = P_{rad}$, students find the relation between resistivity ρ and temperature T .

Using the provided model, in which again the dynamical equilibrium conditions are assumed, further exploration of the relation between resistance (resistivity) and temperature of a tungsten wire filament is done. Students have to construct the expression for

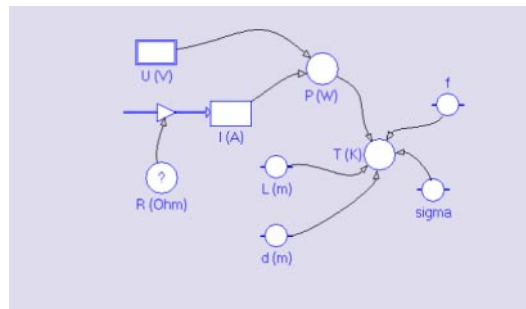


Fig. 3. – The Coach 6 graphical model.

the resistance as part of the model and explain the definition of the temperature. The data generated via model can be then compared to data collected in the experiment.

5.2. Electromagnetic induction. – Electromagnetic induction is an interesting and important topic in upper secondary school because of its role in recognizing the link between electricity and magnetism (Galili, Kaplan 1997). In the project a set of data-logging and modelling experiments were designed that aims to create a context in which students explore electromagnetic induction and recognize the role of magnetic flux of B field as the quantity always involved in this phenomena and therefore fundamental to interpret it (Michelini, Viola 2009). The modeling and data fit activity aims to overcome a qualitative approach to the phenomena.

In the developed experiments the following situations are considered: a magnet moving with a constant speed, a free falling magnet, a uniform accelerated magnet, a magnet oscillating on the spring. In the experiments students recognize the role of the change of magnetic flux, model a movement of a magnet into a coil, and explore the field around a magnet using a flux-meter.

One of experimental setups is shown in Figure below; a magnet attached to a spring oscillates through a coil. The graphs of the current induced in the coil show an asymmetric periodic motion due to the finite dimension of the magnet and the asymmetry of its magnetic field B .

Two paths can be followed with students: a) analyzing experimentally the causes of the asymmetries, and b) modelling the electromagnetic processes involved. In the first path the irregular behaviour of the magnetic field B flux can be explored by using a home-made flux-meter or a Hall-effect B -probe.

In the second path, to construct a model of the induction phenomena, we can consider a simpler situation as that founded in the experiment of the Fletcher or Atwood modified machine.

In this experiment a magnet fall down into a coil and the position of a falling magnet, its velocity and the corresponding induced current are acquired by sensors interfaced with computer. The B field flux, estimated by integrating the experimental induced e.m.f. and expressed as a function of the magnet position, is compared with the behavior foresees using the model based on the analogy of the B fields produced by a magnet and by a coil (fig. 5).

5.3. Ski jumping in a magnetic field. – When a rolling iron ball passes along a permanent magnet, the ball changes its trajectory. How do a permanent magnet and ball interact?

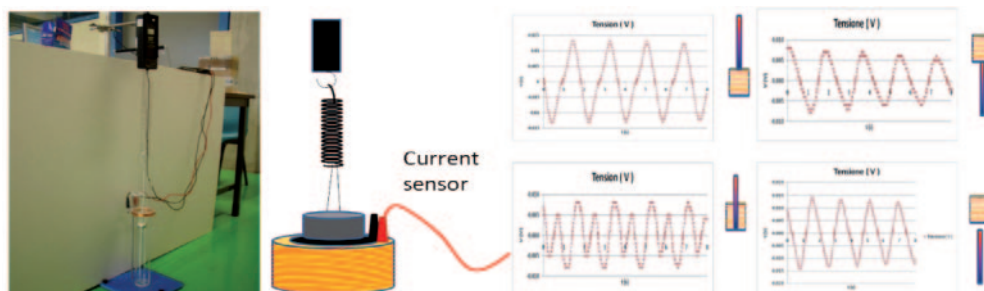


Fig. 4. – The experimental setup and exemplary data.

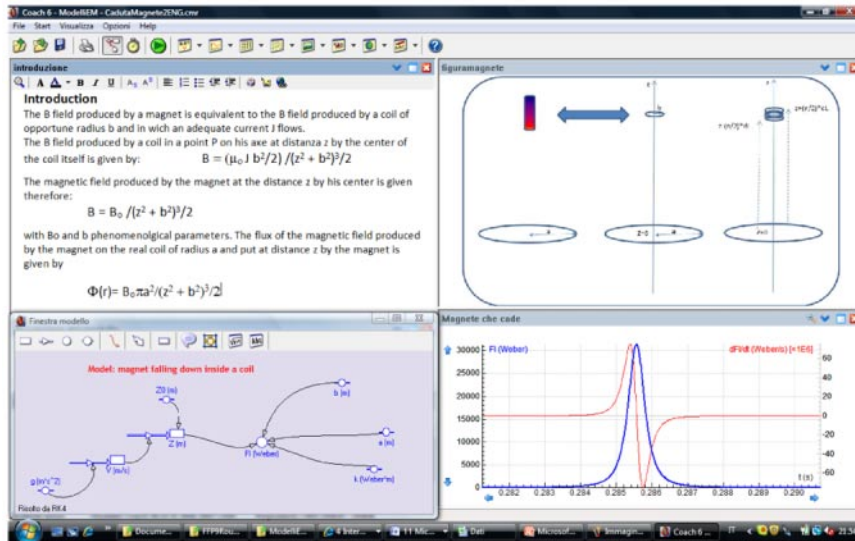


Fig. 5. – The model of the induced phenomena when a magnet is inserted into a coil: implementation in Coach 6 environment.

The interaction between a magnet and a rolling iron ball is an interesting and challenging physics problem. By using video-measurement and modelling tools students can determine empirically the magnetic force between the ball and the magnet.

First students explore how the distance between the magnet and the ball influence the motion of the ball. For more precise measurements they can video-record their experiments or used provided video clips. In each video the distance between the magnet and the moving ball (the impact parameter b) and the deflection angle θ are measured. The approximate relation between the impact parameter b and the deflection angle θ is assumed as $\theta = \frac{K}{b^m}$, for which m can be determined via the graph of $\log(\theta) = \log(K) - m \log(b)$. This equation demonstrates a linear relationship between $\log(\theta)$ and $\log(b)$ in which the constant m is regarded as the gradient of a line.

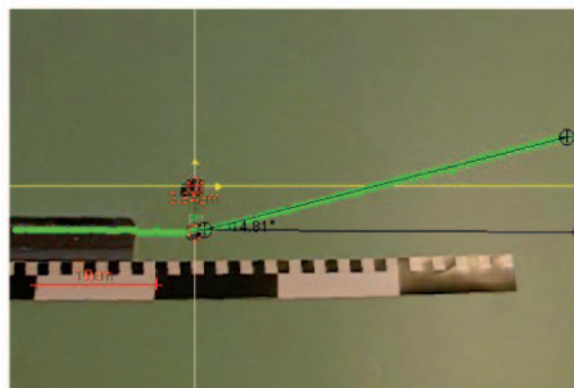


Fig. 6. – Data-video measurement.

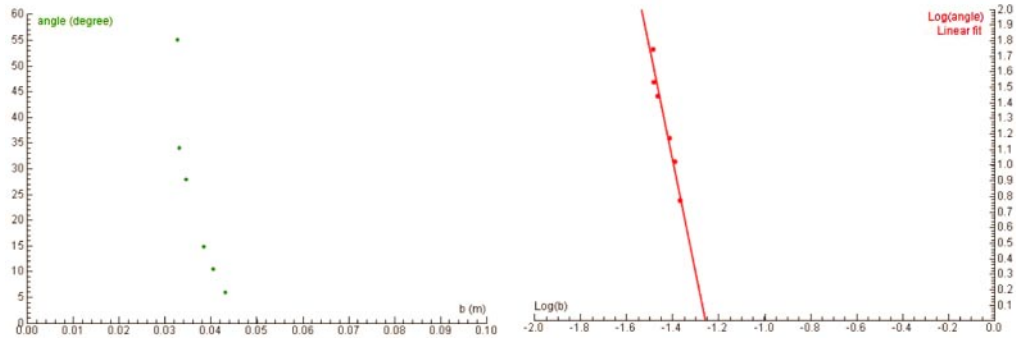
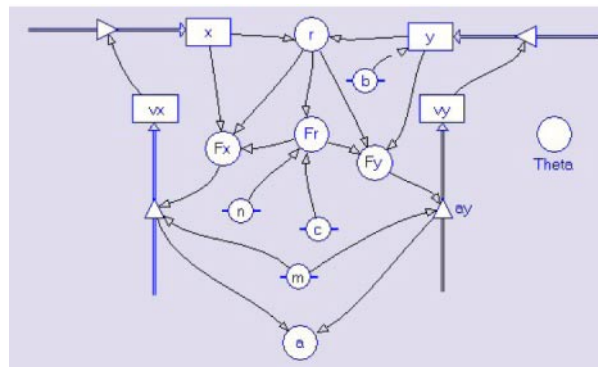
Fig. 7. – Exemplary data, here $m \approx 7$.

Fig. 8. – Coach 6 model.

In the next step, a computer model for the motion of the ball in the central potential field is used.

In this model force is described by $F(r) = \frac{c}{r^n}$ where c and n have unknown values.

The constant c is determined from the model for each possible value of n . Models for different n -value (with its corresponding c value) are used to find the theoretical relation between θ and b .

For each n -value the impact parameter b is varied and the value of θ is calculated by the model. The theoretical m -values are determined from the resulting theoretical $\theta(b)$ graphs in the same way as the experimental m value was found (via $\log(\theta)$ versus $\log(b)$ graph). By comparison of theoretically found m -values with the experimentally determined m -value the best value of n can be concluded.

* * *

The MOSEM² Project is a 2-year project supported by the European Commission under the Leonardo da Vinci, Transfer of Innovation programme, project number: NO/08/LLP-LdV/TOI/131.013

REFERENCES

- Bosio S., Michelini M., Santi L., (1996) From an incandescent lamp to the electrical properties of tungsten, in Teaching the Science of Condensed Matter and New Materials, GIREP-ICPE Book, Forum 1996, p.216
- Bonanno A, Bozzo G., Camarca M., Sapia P., (2009) An on-line experiment on electromagnetic induction, MPTL 14 proceedings
- Christian W., Esquembre F., (2007) Modeling Physics with Easy Java Simulations, The Physics Teacher, vol. 45, n. 8, pp 475-480.
- Esquembre F., (2004), Easy Java Simulations: A software tool to create scientific simulations in Java, Comp. Phys. Comm., vol. 156, pp. 199- 204
- European Quality Procedure Manual for Improving Competence Based Vocational Education and Training (EU project number B/05/B/F/PP-144.341), <http://project.kahosl.be/qpm/index.html>
- Galili I., Kaplan D., (1997) Changing approach to teaching electromagnetism in a conceptually oriented introductory physics course, Am. J. Phys. 65 (7), 657-667
- Heck A., Kędzierska E., Ellermeijer T. (2009). Design and implementation of an integrated working environment for doing mathematics and science. Journal of Computers in Mathematics and Science Teaching, 28(2), 147-161
- Michelini M., Viola R. (2009) Electromagnetic induction: a proposal for a teaching/learning path, in Garip M. *et al.* Eds, Frontiers in Science Education Research 2009 - FISER09, Famagusta: Univ. Famagusta
- Papert, S. (1999). Introduction in: Logo Philosophy and Implementation, Logo Computer Systems Inc. (www.lcsi.ca)