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INTERACTIVE COURSE IN ELECTROMAGNETIC FIELD THEORY ON THE INTERNET

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Abstract: This paper summarizes particular results achieved while working on Interactive Course in Electromagnetic Field Theory on the Internet project, which received funding for 2003 from the "Fond rozvoje vysokých škol" under grant no. FRV2449/2003. The aim of the project is to create and to present on the faculty server an interactive course in electromagnetic field theory. Students can gain practical experience and improve their knowledge of the subject. The final aim is to improve students' ability to solve general problems in electromagnetic field theory, which forms the basis of all branches of electrical engineering.

Keywords: electromagnetic field theory, computer aided education, e-learning.

1 Introduction

The new educational program being introduced at the Faculty of Electrical Engineering, Czech Technical University, substantially reduces the number of hours spent by students on Electromagnetic Field Theory (EFT). On the other hand, the University has to give students a broad technical background, as they must be able to respond to a rapidly changing field of electrical engineering. EFT is a field of study which provides students with basic background knowledge. Most of branches of electrical engineering are based on EFT.

The proposed project helps to solve this problem. It includes production of a textbook, which will be available on the internet. It will help students to gain a better understanding of particular branches of EFT, to gain practical experience and consolidate their skills by solving a number of problems.

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2 Electromagnetic Field Theory

This course provides an introduction to electromagnetic field computation, which forms the starting point for many other courses, and is a basic part of the knowledge of any electrical or electronic engineer. Based on fundamentals, students learn the characteristics and solution methods of static, stationary and time varying fields. Methods for capacitor, inductor, transmission line, magnetic circuits and transformer design are presented, together with wave propagation in a free space and along various transmission lines. The course consists of two hours of lectures and two hours of seminars per week. Previously there were three hours of lectures. The course program is however nearly the same, with no substantial reduction of the syllabus. So the lecturer has to reduce his or her lecture input and the student's task is to learn all necessary items on his or her own. The course content is:

Lectures:

1. What is Field Theory good for. Basic laws of electromagnetism.
2. Maxwell's equations in a vacuum. Direct use for field computation.
3. Static field of electric charges. Laplace's and Poisson's equations.
4. Analytic and numerical methods, and their use in electrostatics.
5. Macroscopic model of materials. Polarization, magnetization and its exploration.
6. Magnetic field caused by steady currents.
7. Magnetic potentials. Self and mutual inductance and its applications.
8. Magnetic circuits, ferromagnetics and their practical applications.
9. Nonstationary field. Complete form of the Maxwell equations. Material properties.
10. Induction law. Energy and force.
11. Poynting's theorem. Power absorbed in a material.
12. Electromagnetic waves, with emphasis on plane waves.
13. Fields and waves inside conductors. Skin effect.
14. Guided waves - examples. Paired lines, coaxial lines.

Seminars/Labs:

1. Mathematic foundations - vector and differential operators.
2. Static electric field - intensity, potential.
3. Basic methods of calculation. Application to capacity, energy and force determination.
4. Project 1: Electrostatic field
5. Laplace's equation. Method of separation. Steady current field.
6. Computer lab. Numerical field solution by finite elements method, electrostatic field.
7. Project 2: Stationary field
8. Stationary magnetic field. Ampere's law and Biot-Savart's law.
9. Scalar and vector magnetic potentials. Determination of inductor value.
10. Laboratory, electrostatic field, magnetic field, inductances, skin effect
11. Computer lab. Magnetic field, magnetic circuit design.
12. Project 3: Nonstationary field
13. Faraday's induction law. Nonstationary magnetic field.
14. Planar electromagnetic wave and skin effect.

3 The textbook

The textbook presented on the internet is divided into chapters devoted to specific problems according to the syllabus listed above. Each chapter contains the basic text, which explains the particular field and presents the basic facts. Part of the text is presented in Fig. 1. This basic text is appended by three databases. Items from these databases are referred from

the basic text by clicking on the particular word pointed up by a different color, Fig. 1. This clicking opens an additional window showing the content of the particular item. The most important element is the database containing the entries explaining or presenting basic items, such as Maxwell's equations, Coulomb's law and other equations. An example of a window with an entry is shown in Fig. 2. These entries also present some facts from mathematics, e.g., vector product, differential operator rotation, divergence and gradient. Some entries also introduce well known scientists who have contributed to the progress of EFT. The words referring to these entries are pointed up by red color. There are several levels of entries. One entry can refer from its window to another entry, Fig. 2.

The fluency of the text for the reader may be impaired by the derivation of particular equations and laws. However, these derivations are important, as they help the student to understand the principles of EFT. They are therefore not presented to in the basic text, but are referred by a symbol "Důkaz n >>> " marked by blue color. Clicking on it, the reader invokes an additional window, which shows the corresponding procedure. Fig. 3 shows an open window with an example of a derivation.

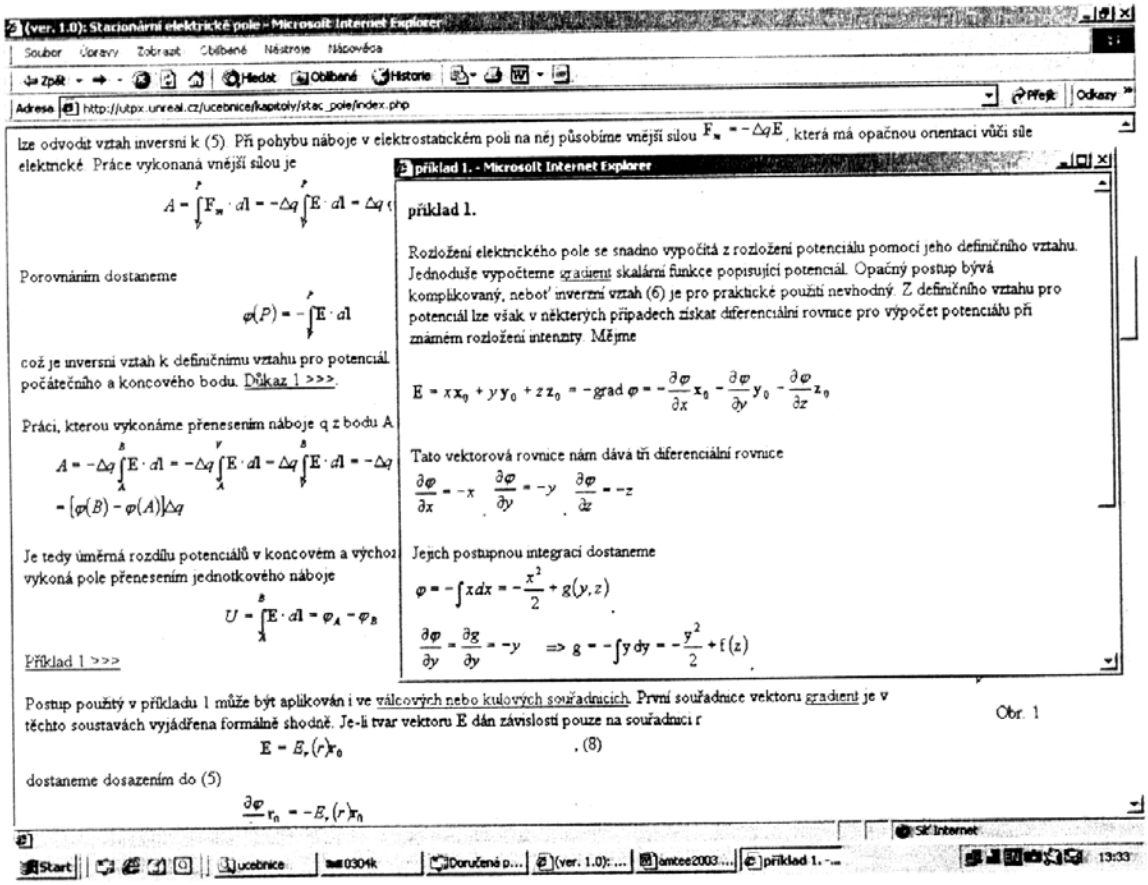

Fig. 1 Part of the text of the book in the main window with an opened additional window, which presents the solution of a problem.

At particular points the material is explained and clarified by solutions of problems. These offer the students an opportunity to check their mastery of the subject matter. The problems are referred by symbols: "Příklad n " marked by green color. Clicking on this symbol the reader opens the window and the problem is presented. An example of an opened window with a solution to a problem is shown in Fig. 1.

The chapters are appended by some problems for the student to solve. These problems present the aim and numerical values of all quantities. The student computes all necessary

quantities sequentially, and writes the results into the corresponding windows. The code compares the number inserted by the student with the proper value taking into account the allowed tolerance limit, and tells the student if the answer is correct. If the answer is wrong, the code offers prompt, useful hints, and suggests actions to be taken.

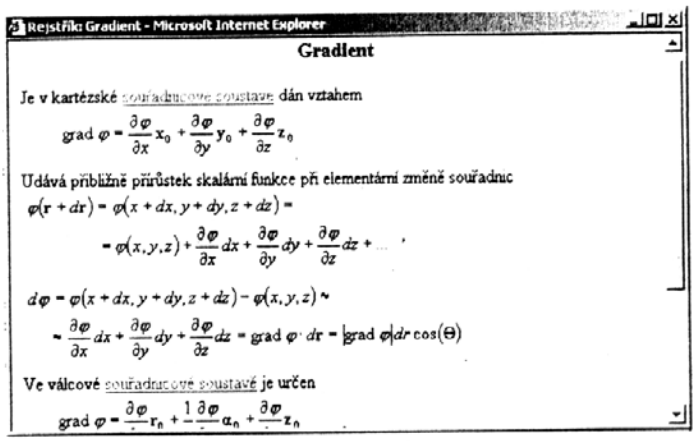

Fig. 2 An entry in its opened window

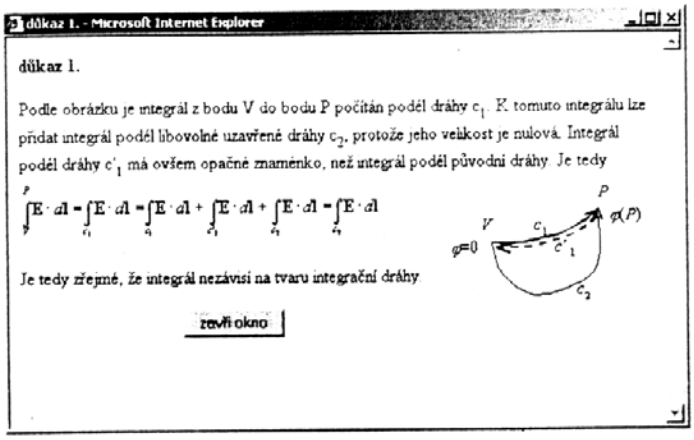

Fig. 3 Window presenting a derivation.

4 Conclusions

The Interactive Course in Electromagnetic Field Theory on the Internet project gives students access to a textbook on the theoretically very exacting field of Electromagnetic Field Theory. Students have an opportunity to widen and deepen their knowledge of the subject. The textbook is freely accessible at any time. It saves students money, as textbooks are nowadays very expensive.

The project is still being worked on, and the textbook has not yet been completed. Only the first parts are already available on the internet.

Acknowledgments

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