Intelligent Method of Teaching Electromagnetics Theory: Measurements under Virtual Environment

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Abstract – This paper details the development of a computer-assisted laboratory under virtual environment which has been put in place to teach the theoretical and practical aspects of Electromagnetics, without physically using any instruments to do the measurements. The virtual laboratory has allowed us to teach Electromagnetics in a new and effective way, helping our students master this difficult subject. In particular, virtual experiments have been designed which the students perform before attempting to do the corresponding real experiments. These virtual experiments help the students to appreciate the essential features of an experiment without being confused or distracted by the complexity of the real experimental procedures. We believe that learning is favorably augmented by using this innovative way of teaching the laboratory material through a computer-based, flexible and interactive environment of virtual experiments.

Keywords – Electromagnetics, Virtual Laboratory, Instrumentation, Laplace's equation, Ferromagnetism, B-H Characteristics Measurement.

I. INTRODUCTION

Electromagnetics is a demanding subject, both to teach and to learn. A student has to comprehend difficult physical concepts and apply advanced mathematical techniques. Even though Electromagnetics is the very basis of our modern life, the material may seem esoteric and divorced from the real world. Student interest must be stimulated so that adequate learning can take place and the use of virtual experiments is one way of doing this. Virtual experiments can introduce students to a wide range of electromagnetic experiences and methods without requiring them to spend inordinate amounts of time, thereby freeing learning time for other rewarding activities. Also, Electromagnetics is such a rapidly evolving subject

sources for conducting the practical experiments, the course is combined together with another course 124.328 Applied Electromagnetism, offered by the Physics department. The laboratory experiments are conducted in the Physics department for the joint courses.

III. STUDENTS' OPINION

SECAT (Student Evaluation on Composition, Administration and Teaching) for this course was done in the year 2002. The students expressed grave concerns about the laboratory experiments. Two of the comments of concern were-

i) Students felt that they learnt the theory *after* the laboratory experiments were completed.

ii) Students often did laboratory experiments on unfamiliar topics, the theory of which was not yet covered in the class.

In essence, it was difficult for the students to grasp the laboratory experiment as they were often not familiar with the theory at the time of doing the experiment. Developing an infrastructure for multiple experimental setups puts a heavy financial burden on the university. Thus the development of virtual experiments was explored with an added intention to make the laboratory experiments much more interesting.

IV. TEACHING WITH LABORATORY EXPERIMENTS

Real practical experiments are conducted to increase the students' practical skills and knowledge, and to give them the opportunity to become acquainted with many instruments as well as the experimental procedures. The students are required to conduct the experiments in pairs and laboratory support is provided. At the completion of an experiment, the students are allowed one week to complete their analysis and submit a report.

In the first year, i.e. in 2002, five experiments were conducted. Since we had only one experimental set-up for each experiment, the students were divided into groups and asked to do one experiment each week. So effectively all the experiments were conducted on the same day, albeit by different student groups.

Fig. 1 shows the photograph of the bound region, a part of the experimental set-up (necessary instruments are not shown) to verify Laplace's equation. The experiment involves determining the electrical potential in a region of interest confined within known boundary conditions. The apparatus is a rectangular-trough whose bottom is lined with conductive paper overlaid by a clear plastic sheet with a rectangular

citing current and the voltage across the sensing coil is measured for the measurement of flux density. The current and sensing voltage signals are fed to a data acquisition card plugged in a PC. The students use an oscilloscope to observe the voltage and current waveforms and also to plot the B-H characteristics. They also get the opportunity to use the data acquisition software to do the necessary calculations from the plot of the B-H characteristics.

Fig. 4 shows a picture of a solenoid which is excited by current carrying coil. The students measure the magnetic field intensity inside and outside of the solenoid. They note the results and plot it using software such as Excel or Matlab. They are able to note the distribution of the magnetic flux density along the axis of the solenoid measured at the mid point. The hall-effect sensor has been fitted on a rod at the mid point of the solenoid which is not easy to change its position during experiment.

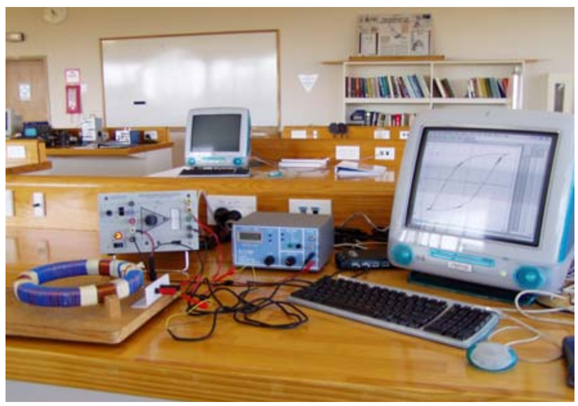

Fig. 3. Set-up for ferromagnetism experimentation

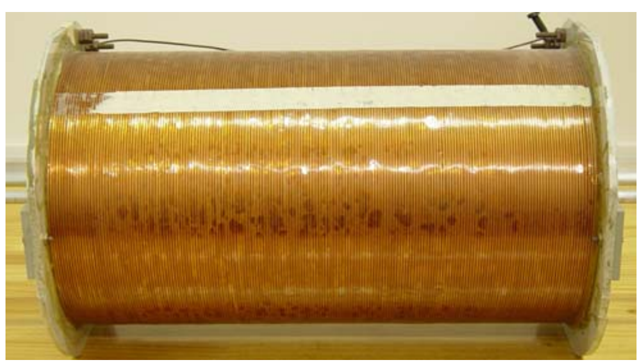

Fig. 4 The solenoid used for practical experiment

The development of virtual experiments has been centered on Visual Basic [15] and FEMLAB software [16, 17]. The students were given a brief introduction to virtual experiments and instructed how to conduct a virtual experiment. An instruction sheet accompanied each virtual experiment and the students had 2 hours to complete it. Some exercises are given and they are asked to submit the report at the end of the experiment.

A brief description of a few virtual experiments is given here.

In the experiment on solution of Laplace's equation, the practical laboratory involves determining electrical potential in the region of interest with given boundary conditions as shown in Fig. 1. They measure the electric potential and the data is used to plot the potential distribution. The same experiment has been developed for the virtual laboratory.

The students follow the method of conducting the virtual experiment which has been explained in the lab-sheet. Once the solution is obtained, they can do post-processing and see the desired waveform. Fig. 5 shows the electric potential distribution for the problem. There are several things that are cumbersome to do during the actual experiment, which are very easily done with the virtual set-up. Fig. 6 shows the distribution of the electrical field intensity (norm) for the problem.

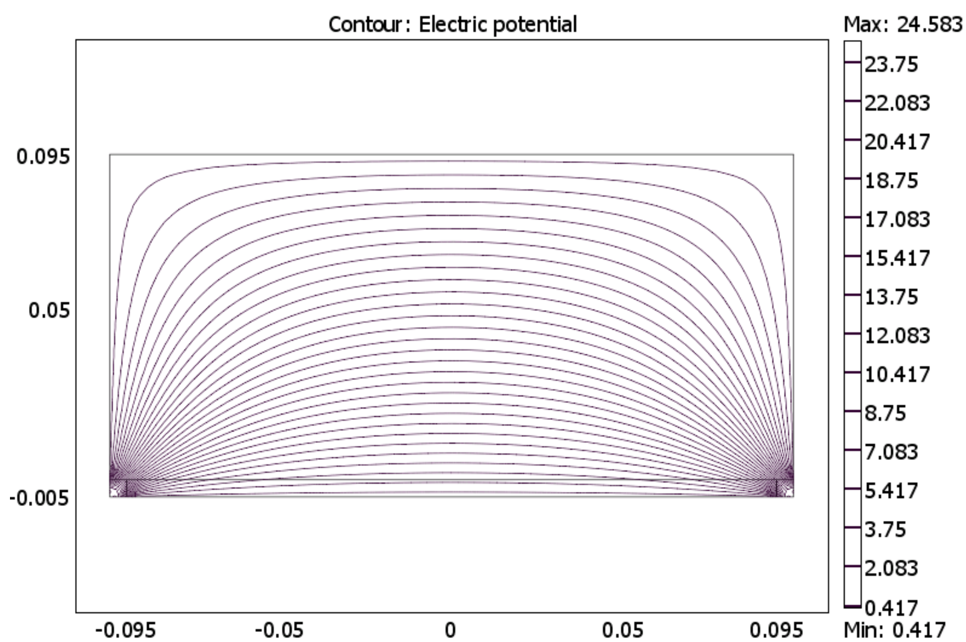

Fig. 5. Potential distribution

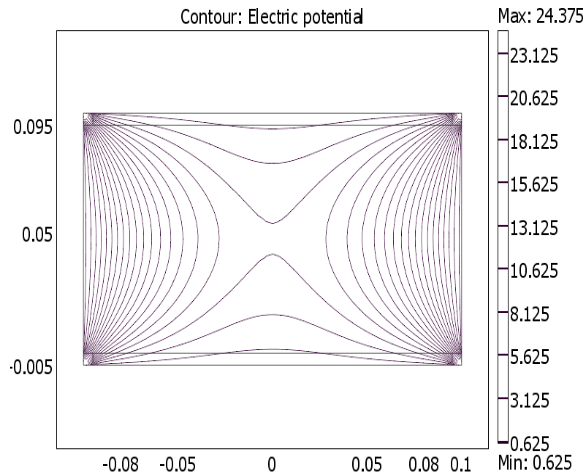

Fig. 8. Potential distribution with different boundary conditions (contour plot)

The virtual experiment on the solution of Laplace's equation has been configured around FEMLAB. On the other hand the experiments on ferromagnetism and the B-H characteristics of ferromagnetic materials have been developed using Visual Basic. The necessary connection and requirement of instruments have been taken care of in the development work. Fig. 9 shows the output B-H characteristics when proper inputs and parameters have been chosen. This is very useful to make the learning interactive as the students get immediate feedback. For off-line analysis, a lot more data is stored in a file.

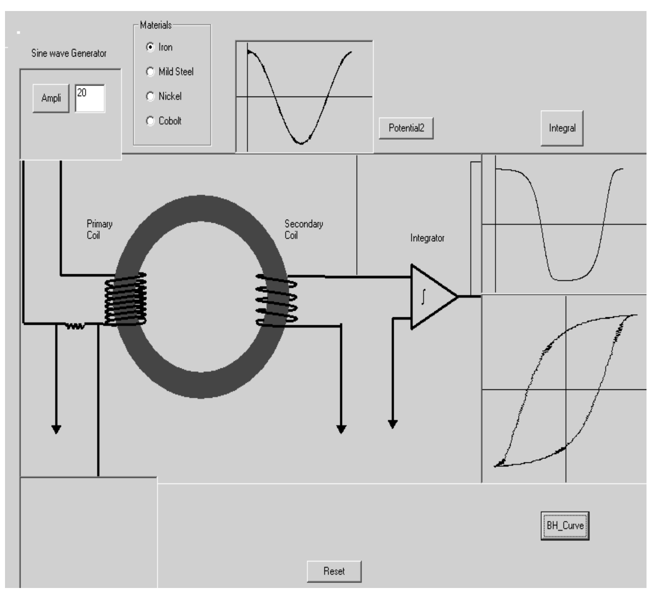

Fig. 9. Virtual experiment on ferromagnetism: B-H curve

In the actual experiment of Helmmoltz coil the students measure the magnetic field distribution inside the coil at different distances. The experimental set up is shown in Fig. 12. They can change only the current through the coil but it is not possible to change the diameter of the coil and the separation distance between them. The Helmmoltz coil has a lot of practical applications, one of them is to study the effect of magnetic field on DNA damage and repair. In the virtual experiment of Helmmoltz coil, the coil configuration is drawn and solved using FEMLAB. Figure 13 shows the model drawn and solved using finite element analysis method. This experiment gives the students an opportunity to deal with a three dimensional problem which is very useful for their learning of different kinds of electromagnetic modeling problem. They can change the coil dimension, excitation current and the separation distance between the coils. Figure 14 shows the variation of the magnetic field as a function of coil separation at different vertical positions. It is seen that the magnetic field is quite uniform inside the coils. The diameter of the coil and the separation between them is taken equal. The magnetic field is also calculated for different separation distance between the coils, keeping the diameter of the coils same. Figure 15 shows one such result. It is seen from Figure 15 that uniformity of the field distribution is achieved while the coil diameter and the separation between them is exactly equal. This helps the students to understand the Helmmoltz coils in a simple way.

Fig. 12. The experimental set-up of Helmmoltz coil

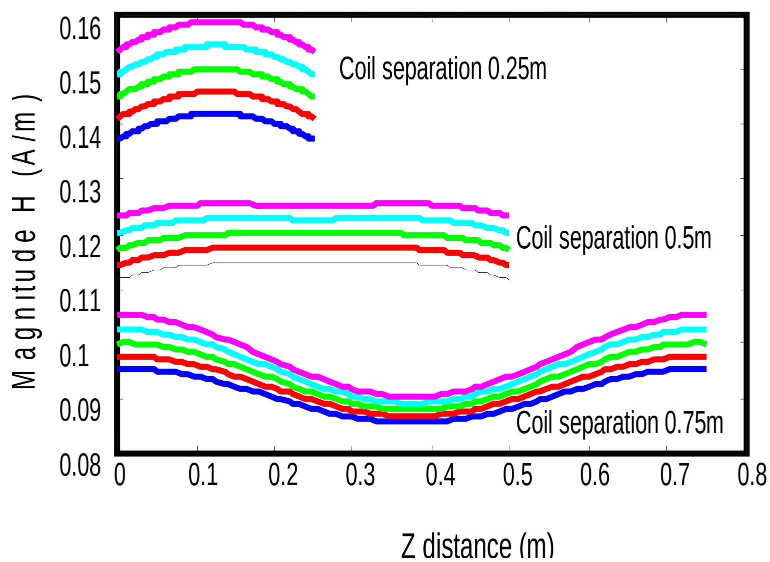

Fig. 15. The magnetic field as a function of coil separation for different separation distances

VI. ASSESSMENT AND STUDENT EVALUATION OF VIRTUAL EXPERIMENTS

The assessment part of virtual experiment can be looked at from two different aspects. First these virtual experiments give the students an opportunity to assess the theory of the subject which they learn through lectures. In a practical experiment it is not possible to observe the effect of changing a parameter on the system performance very quickly which can be done with the virtual experiments with ease. The students are asked to explain the reason for those changes and this ignites their thinking process and reinforces the learning.

Each laboratory is worth 2.5% of the final grade for the course. The students are asked to answer a few questions which are described in the instruction sheet. The exercises form step by step process of the learning cycle and the backbone of the continual assessment. At each stage during the laboratory the students are provided necessary guidance to conduct the experiment. The students are asked to show the results during the laboratory when they are ready and they are assessed for their grading. They submit the final report at the end of the laboratory. The reports are assessed and marked and handed back to the students before the next laboratory so that they get immediate feedback. The student attitudes to virtual experiments and assessment were surveyed so that their usefulness in enhancing student learning and appropriateness of the assessment could be assessed. The survey results are shown in Table 1. The students

(Scale: 1 – Not Agree, 5 – Strongly Agree).

VII. CONCLUSIONS

In this paper we have presented the development work of conducting virtual laboratories for Electromagnetics, a 3rd year core subject for the Bachelor of Information and Telecommunication Engineering degree and Physics specialization offered at Massey University and the assessment part of the laboratory. With the help of FIET (Fund for Innovation and Excellence in Teaching), the development work for an innovative way of conducting laboratory experiments was accomplished. This is part of the development of a comprehensive method for teaching electromagnetism at undergraduate level. The main purpose has been to use a computer assisted teaching environment to make the complex, abstract subject as simple as possible without compromising the subject's integrity, so that the students can learn more effectively with enthusiasm and interest. The questionnaires have shown that the development has greatly enhanced the student learning and has increased their interest of the subject.

As part of the future work, the virtual experiments will be made more interactive so that students can obtain immediate and more constructive feedback. It is also being made available on the web so that it can be accessed anytime from anywhere at the convenience of the student. The development has helped us to teach the subject with more satisfaction and our students have enjoyed this subject in the computer assisted learning environment. The method of assessment for the laboratory is very effective and students appreciate it.

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