

A MULTIMEDIA TUTORIAL FOR CHARGED-PARTICLE DYNAMICS

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Abstract

We are developing a computer-based tutorial for charged-particle beam optics. The tutorial, "*Accelerators and Beams*," will be delivered on Macintosh and Windows platforms. It uses multimedia techniques to enhance the student's rate of learning and length of retention of the material. As such, it integrates our interactive On-Screen Laboratories™ with hypertext, line drawings, photographs, animation, video, and sound. We are targeting a broad audience from technicians to graduate students in science and engineering. There will be both an academic version and specialized versions for companies that have particular training needs. The tutorial content is about equivalent to a one-semester course at the upper undergraduate level. At this time we have about a third of the material available in prototype form.

1 INTRODUCTION

In late 1993 the DOE solicited Small Business Innovative Research (SBIR) proposals for a "novel apparatus for teaching beam optics." WhistleSoft, Inc., then a newly-formed company in Los Alamos, NM, responded with a proposal to develop a self-paced, interactive multimedia tutorial on the subject.

We were awarded a grant for such a project, now entitled "*Accelerators and Beams*," and have since moved into Phase II of the project. Since beginning Phase II we have been authoring the tutorial directly for both Windows and Macintosh computers. The first piece of the tutorial, *Vectors*, will be published this summer. The remaining pieces of the course will be completed and published over the next year.

This paper reports our progress on this ambitious project and gives of flavor of what the final tutorial will look like.

2 TUTORIAL CONTENT

The content of the course is roughly equivalent to a three-hour semester course at a university, although our intended target audience is broader than just upper-undergraduate university audiences. An important feature is the ability of the student to choose to work at a comfortable level of detail. We indicate these levels – "Introductory," "Intermediate," and "Advanced" – by a

color-coded background, but an alternative labeling could just as well be "Technician," "Junior Engineer," and "Physicist." The presentation ranges accordingly from one which is mostly text and graphics to one which is mathematical and abstract. We have developed materials at each of these levels. Most of our effort so far has been at the Introductory Level, since it is more difficult to shape the material at this level into a form appropriate for student consumption.

The tutorial has twelve content modules:

1. Overview (an "Overture")
2. Forces, Electricity & Magnetism
3. Motion in a Magnetic Field
4. Focussing Elements, I
5. Beams, Beam Sizes, Phase Space
6. Matrix Beam Optics
7. DC Acceleration
8. Focussing Elements, II
9. Periodic Transport
10. Space Charge
11. Radiofrequency Cavities and Linacs
12. Using Professional Design Software

The difficulty of the material obviously increases as one gets into the later modules, but the goal is to always have something accessible at the Introductory Level throughout the tutorial.

In addition to these twelve content modules, we also have three "refresher modules" on topics that the student might want to brush up on:

- A. Vectors
- B. Matrices
- C. Special Relativity

In a sense these modules are like appendices in a textbook.

At this point in time we have nearly complete prototypes of three of the modules (Topics 2, 3, and 5). The first refresher module, *Vectors*, has been scheduled for publication by Physics Academic Software in July 1997. We will describe the content of these modules below.

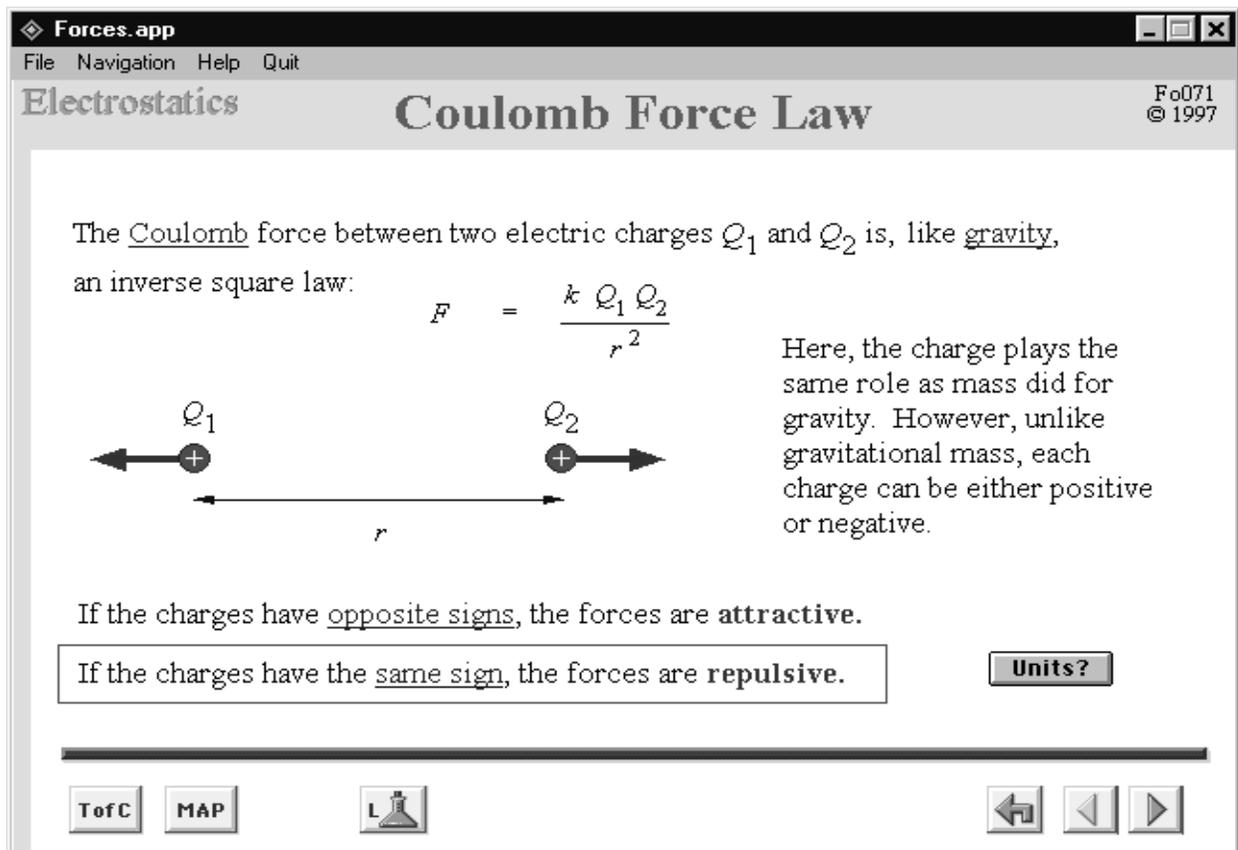


Figure 1. A typical page from *Forces* module.

3 THE PRODUCTION TEAM

A multimedia project necessarily involves a wide variety of talents. WhistleSoft is fortunate to be leading a very capable team. The people who have so far been deeply involved in this project, along with their specialties, are:

Andrew A. Browman, physicist (domain expert)
 Charles S. Brownrigg, design and authoring
 Richard K. Cooper, original principal investigator
 Catherine Malloy, instructional and graphic design
 J. Patrick McGee, senior programmer
 William C. Meade, physicist and senior programmer
 Robert A. Williams, senior programmer

Cooper and McGee are no longer involved with the project. All these people are local to Los Alamos.

3 TOPIC 2: FORCES

We decided to begin, in Phase II, with something a little less difficult than an Overture. Topic 2 reviews forces and motion, with an emphasis on electromagnetism, the fundamental force of importance for accelerator physics. A somewhat more broadly oriented version of Topic 2 will be submitted to the *Computers in Physics* software contest at the end of May, 1997.

Topic 2 opens with a title page (splash screen) while loading initialization files, and then proceeds to a Table of Contents page. The subtopics covered in this module are:

1. Fundamental Quantities
2. History; Quick Tour of Fundamental Forces.
3. Forces and Motion
4. Electrostatic Forces
5. Electromagnetic Forces

One can return to this page by means of an always-present “T of C” button (see Fig. 1). When one of these sections (which are blue-underlined hyperlinks, as in a World-Wide Web browser) has been visited, the link after return is purple instead of blue. When the student has viewed *all* pages of a section, a red check mark appears beside that entry.

An alternative way of navigating through the material of the tutorial is available by clicking on the “Map” button, also in the lower left corner of Fig. 1. The Concept Map page displays ellipse- and box-objects which are hyperlinked to tutorial content pages. The Map Button is always available to the user. On returning to the Map after having looked at some of the content

frames, you have an indication of where you have been in this module, as the ellipses and boxes for the concepts you have visited are outlined in purple instead of blue. A red star indicates the page that you just came from.

A variety of other navigational transitions can be accessed through the navigational control buttons at the bottom of the window (see Fig. 1) and through a pull-down menu in the window's title-bar. One of these is a Go Back button, which retraces the path taken by the student. The Table of Contents and Map pages also have buttons which take the student to an Index, which is also hyperlinked to its subjects.

A typical content page illustrating Coulomb's Law for electrostatic forces is shown in Fig. 1. The student has gotten to this point through a series of progressive disclosures. At this point he or she has the choice of several interactions, including going to the next page (or the previous one) in this section. The (upper) blue underlined words are hypertext links going to related pages, including a short historical vignette on Charles Augustin de Coulomb. (The lower blue words alternate the force arrows between attractive and repulsive.) Clicking the Units button at the lower right takes the student to a sidebar-page that discusses the physical units of the quantities in the force law equation. Finally, the button at the bottom left with the Erlenmeyer flask takes the student to a "laboratory" which imparts the feel of just how fast the "long-ranged" electric force falls off with distance.

On other pages, there are buttons which take the student to self-test questions, usually multiple choice in nature but with useful explanations and guidance for the wrong choices of answers. The student can gauge his or her progress by calling up a Report Card (in the Help pull-down menu) detailing how many pages have been visited, how many questions have been attempted, and how many of those were answered correctly.

Another important aspect of the tutorial is our use of two- and three-dimensional animations to impart the sense of a page's concept. For example, the concept of conservation of momentum is helped by a simple 2D animation involving a cannon recoiling from shooting its ball. For discussion of the electromagnetic forces (which involve a lot of use of the Right Hand Rule) we use more complicated 3D animations involving "moving camera" points of view.

For now, we have used the sound sense only sparingly in this module. Buttons click when "pressed" and there are short sound effects associated with actions on the screen, but we have eschewed providing narrative sound files to go with each content page. This has been partly inspired by a hope to keep this module small enough to be deliverable on diskettes rather than CD-ROMS.

In its present state, the Forces Topic has 71 content pages, 10 question and answer pages, and 6 On-Screen Laboratories.TM

4 TOPIC 3: MOTION IN EM FIELDS

This module deals with cyclotron motion of a charged particle moving in a (uniform) magnetic field, with magnetic rigidity, and touches on cyclotrons and spectrometers. In the near future, we will add an Intermediate Level section on the Wien Filter (motion in crossed electric and magnetic fields) and an Advanced Level section on magnetrons.

The module has only very recently been converted from an earlier version to a form more consistent with the tutorial style guide. As a result, it is in a rougher state than the *Forces* module. It is also smaller in size. At the time of the PAC97 conference it has 9 content pages, many "stubs" referring back to pages in Topic 2, and one interactive laboratory. In addition to the two missing sections mentioned above, it will need filling out with questions and more laboratories.

5 TOPIC 5: BEAM SIZE, PHASE SPACE, BEAM ENVELOPES, AND SPACE CHARGE EFFECTS

This module has the most advanced materials of the prototypes that we have built so far. It too has only recently been converted to the new tutorial style. It incorporates many of the same features as described for Topic 2, but with a more extensive use of sound in the form of narrations accompanying the content pages. Also, here, we have experimented with jump-outs and returns from an ancillary piece which constitutes a Glossary of Beam Dynamics Terms.

As can be judged from the section title above, Topic 5 is a more lengthy module than Topic 3. At the time of this writing it has 31 content pages. It too will need filling out with more self-test questions and laboratories.

6 ACKNOWLEDGEMENTS

The WhistleSoft development team has had the benefit of many useful suggestions from a large number (~100) of user testers of our prototype modules.

The tutorial prototypes discussed in this paper have been authored mainly using Macromedia's Authorware software package, but with content prepared using other software such as Macromedia's Extreme 3D, Macromedia's FreeHand, Adobe Photoshop and Adobe Premiere.

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