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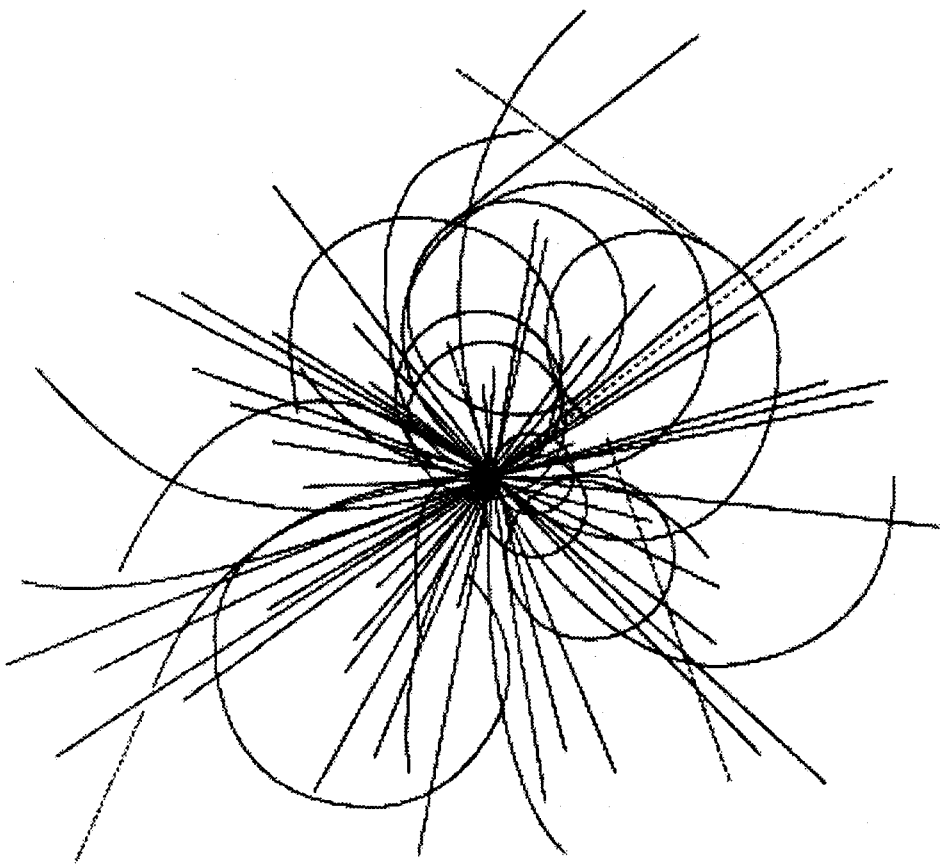

Superconducting Super Collider Laboratory

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An ASD Physics Education Program*

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AN ASD PHYSICS EDUCATION PROGRAM

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INTRODUCTION

I want to thank the Organizing Committee and Program Chairman of the 1993 IISSC for providing this forum to discuss science education issues here in San Francisco. By all accounts, science education in the United States is in trouble. Clearly, teaching science to the young people of our country is an important goal shared by all of us involved in scientific research. The Director, Dr. Roy Schwitters, has made science education a Laboratory goal for the Supercollider. Those of us who share this goal only can have an impact if we become involved actively in teaching science to the future engineers and scientists enrolled at our colleges and universities. The commitment of IISSC to science education is welcomed by everyone of us who wishes to improve the technological base of the nation for the next generation.

PROGRAM DESCRIPTION

At the request of the Cedar Valley College science department, the Accelerator Systems Division offered to develop an introductory physics course for their undergraduate students. The two-semester course was given by a Supercollider staff scientist for the first time at the College during the 1992–93 academic year. The course includes lectures, laboratory experiments, problem sessions, and tests, of course. The material covered consists of Newtonian mechanics and electromagnetic field theory. The students purchase a popular textbook[1] which contains numerous problems from which homework assignments are made; however, hundreds of transparencies specially prepared for use during course lectures are handed out to the students to provide them with study material.

COURSE PREREQUISITES

Over the last several years, Cedar Valley College has made considerable progress implementing advanced level mathematics courses in the College curriculum. These courses include two semesters of calculus, a semester of advanced calculus, and a semester of

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differential equations. This gives the Cedar Valley students an excellent preparation to learn physics. The serious study of physics can begin only after the students have acquired the mathematical background to understand the complexities of the mathematical formalism used to describe the physical phenomena.

Cedar Valley College, Home to the ASD Super Collider Physics Program.

UNIFYING CONCEPTS OF THE COURSE

In this course for science and engineering students, an attempt is made to adopt some recommendations of science educators who are seeking to make introductory physics courses more effective.[2] The course is designed to emphasize a small number of fundamental concepts that are universal to a wide range of physics beyond the material covered in the first two semesters. These concepts are selected first of all because of their basic scientific importance, but also because they can be illustrated by examples that fall naturally within the course material.

SPACETIME

The symmetry of space and time itself is fundamental to all physical theory. Due to many years of indoctrination using plane geometry, the students accept this symmetry uncritically without considering the consequences of assuming this concept axiomatically. The students resist attempts to work in non-Euclidean geometries. All the students know the Pythagorean theorem, but the concepts of 3-dimensional and 4-dimensional vector spaces have to be introduced and practiced.

PRINCIPLE OF RELATIVITY

The principle of relativity was a proposal made by Galileo, who presented the idea using the example of relative motion within the cabin of a ship which was under way.[3] Newton accepted Galileo's proposal and clearly attempted to incorporate it into his mechanics, at least

for the range of velocities within his realm of experience.[4] Newton failed to arrive at what we now would call a relativistic theory of mechanics, perhaps because he had no inkling of the correct transformation between moving coordinate systems. The Newtonian understanding of the principle of relativity is enough to force the description of physics to take the form of second-order differential equations.

LORENTZ TRANSFORMATIONS

One pedagogical benefit of teaching a classical theory of electromagnetic fields is that electromagnetic phenomena naturally are explained on a macroscopic scale by a completely relativistic theory. A discussion of the Lorentz transformation logically comes out of the study of electromagnetism. A covariant formulation of electromagnetic theory is difficult for the students to grasp because the differential operators in 4-dimensional space are unfamiliar to the students, who in fact are still struggling with partial derivatives.

CONSERVATION PRINCIPLES

The solution of specific problems in a mechanics course logically results in constants of the motion in particular cases so that the students can be introduced to the conservation of energy, momentum, and angular momentum in a mathematically rigorous presentation. The conservation of electric charge is introduced as an ad hoc postulate, and the quantization of charge, as well as other quantum effects, are outside the scope of this course.

FROM CONCEPTS TO COURSE LECTURES

During the first semester of the course, two prototypical problems are used to cover the essentials of Newtonian mechanics; however, a considerable amount of lecture time is required before the students are in a position to fully understand these in complete detail. The first problem is depicted in the fresco by Giuseppe Bezzuoli which shows Galileo in Pisa rolling a ball down an inclined plane to experimentally determine the ball's acceleration. A complete understanding of this problem requires a knowledge of the vectorial nature of the gravitational force, a representation of frictional force, and the mathematical description of rotational dynamics. The second problem is the motion of the planets in the solar system. The solution of this problem provides a perfect opportunity to emphasize conservation of both energy and angular momentum in a system constrained by a central force. The integration to obtain the path of motion for a planet is difficult for the students at this level.

Building on the advancing abilities of the students, the second semester challenges them with electromagnetic field theory. The students' background in vector calculus is extended by introducing them to Gauss' (Green's) theorem and Stokes' theorem. A complete presentation of Maxwell's equations in differential form requires numerous hours of lecture. Recasting these equations covariantly depends on the introduction of a 4-potential which has the transformation properties of a vector in spacetime. The 4-potential is an abstract concept which is difficult for the students to comprehend. Several previous lectures on the equation describing wave motion prepare the way for the presentation of transverse waves as the solution of Maxwell's equations in free space.

EDUCATIONAL OUTCOMES

Sixteen students enrolled in the first semester of the course. Their final grades ranged from C to A. Of these students, half continued to the second semester and with much hard work are doing an excellent job of mastering the course material. Certainly, these students

benefit from a sound background in mathematics and the low student-to-instructor ratio at Cedar Valley College.

FUTURE—RIGHT ON THE LIGHT CONE

Cedar Valley College has expressed its interest in continuing to offer this program of physics courses in future semesters. A need appears to exist for new textbook material which could be used to teach introductory, calculus-based physics at the college level. The lecture notes from this project could serve as a starting point for such a textbook; however, an extensive editing effort also would be required.

Science education has received prominent recognition in the Director's statement of the Laboratory's goals. Each week, course preparation for this project averages 20 hours and meetings with the students involve 6 contact hours. This expenditure of time represents a significant commitment to this educational activity by the Accelerator Systems Division.

ACKNOWLEDGEMENTS

The suggestion for this program originally came from Dr. Ted Kozman, Head of the Accelerator Systems Division. The success of this program is due in large part to the support of Dr. David Heitman, the Dean of Science at Cedar Valley College in Lancaster, Texas.

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