Introductory Electricity

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Course Syllabus

1 Course Description

This course is designed for the enthusiastic high school students who wish to explore exciting topics in electricity and have not had formal instruction in the subject. We will start from the very basic ideas of electric charges and conclude with fundamental applications to electric circuits and beyond. In between, we will study electrostatic interactions, conductors, insulators, and capacitors. Along the way, we will emphasize applications so that students can see the profound practicality of what they learn. Some of the potential applications that we will cover include superconductivity and semiconductors. To further enforce the course content, we will spend a major portion of the class getting students' hands dirty by constructing a Van de Graaff generator and an electrostatic motor. This way, each student walks away with a little demonstration of electricity and magnetism to show his or her friends.

Prerequisites: We will use basic algebra and trigonometry extensively. Whatever mathematics used beyond algebra and trigonometry will be introduced in the course. Thus, students without prior exposure to the more advanced mathematics will not be at a disadvantage. Students should also be familiar with basic concepts of forces (Newton's laws) and energy.

2 Course Instructors

Christian I Cardozo-Aviles – I am a second-year electrical engineering, computer science, and physics student at MIT. My primary areas of interest in physics are electricity and magnetism, which weave themselves into my studies in electrical engineering, and cosmology, on which I produced "Cosmology for the Science Enthusiast," a ten minute video introduction to the universe that went on to be well-received by members of the MIT community at a campus-wide screening (the video is available at `http://www.youtube.com/watch?v=7Ao6PKQeRjg`). Having taught for past MIT ESP programs like HSSP, I can undoubtedly say I am very excited to working with you all this summer, enlightening you about electricity and its inextricable ties to the world of today.

David Mayo – *To be filled in ...*

Phong T. Vo – I am a second-year undergraduate Physics major at MIT. My current research interest is in solid-state physics experiments and theory. I am also fascinated by certain aspects of particle & nuclear physics and cosmology. In addition to my research and schoolwork, I also dedicate much of time sharing what I know with others through teaching. As such, I look forward to discovering electricity with you over the next two months.

3 Course Mechanics

As the course description states, this course is designed to give you a flavor of the exciting world of electricity. Electromagnetism is an extremely fundamental subject in physics that has far-reaching consequences for our every-day lives. In fact, both of the two major scientific revolutions in physics of the last century, quantum mechanics and relativity, can be traced back to careful examination of classical electromagnetism. As such, many of our technologies today owe their existence to electricity and magnetism, from solid-state devices to information technologies to medical devices to space exploration. Thus, it is our hope that this course will provide you with enough basic theory about electricity that you can start exploring the structure of the universe around you.

This course meets seven times over a period of two months on the dates outlined below. Each class session is two hours long. The first six classes are lectures, each concluding with an introduction to some exciting modern applications that are relevant to the topics covered thus far. The last class is designed to allow you in-class time to construct your Van de Graaff generator. At the end, you can walk away from this class with a neat project (in addition to your new-found expertise in electricity) to show your friends.

This course moves very quickly. Thus, it is important that you stay top of the course material to get the most out of this class. To this end, we will assign a problem set (about 5-7 problems) each week to help you master the course content. Each problem set will have simple problems for you to sharpen some necessary basic skills as well as challenging exercises for you to hone your critical thinking. Although this class is not graded, we will collect problem sets to give you feedback on your understanding only if you desire. Even though we cannot stress enough how much we encourage you to complete the problem sets, we also want to emphasize that handing them in for "grading" is totally optional. We understand that you are taking this class in addition to your normal summer workload, and we do not want to add unnecessary stress onto your schedule.

In addition to the problem sets, there will also be a short one-page report on the project demonstrating your understanding of how a Van de Graaff generator works. This will be due before you start constructing your project. More details on this are in the "Course Project" section. Moreover, at the start of every class, you will give you a chance to test your understanding through a short 10−minute, one-question quiz. Lastly, at the end of the sixth class, we will hand out an *optional* (but highly encouraged) take-home, open-note exam for you to test your ability to integrate your understanding of different parts of the course in one coherent assessment.

Finally, the material in this course is of great practical importance. Therefore, we hope that you will enjoy learning as much as we looking forward to sharing with you. Have fun!

4 Course Schedule

We expect to cover the following topics in the following order. However, as the course progresses, we are happy to adjust the schedule to accommodate student interests and needs.

1. July 6th – ***Problem Set 1*** distributed;
   (a) Introduction to vectors
   (b) Electric charge and Coulomb's Law
   (c) Superposition principle
   (d) **Application:** Historical discovery of the electric charge and its role in the development of quantum mechanics and early atomic models
2. July 13th – ***Problem Set 2*** distributed; ***Problem Set 1*** due
   (a) Gauss's Law
   (b) Electric Potential
   (c) Classical Theory of Conductors
   (d) Current
   (e) *Application:* The semiconductor (introduction to band gap) and its role in the technological revolution of the past half century
3. July 20th – ***Problem Set 3*** distributed; ***Problem Set 2*** due
   (a) Resistance and Ohm's Law
   (b) Temperature Dependence of Resistance
   (c) Simple Electric Circuits
   (d) **Application:** The beauty of superconductivity
4. July 27th – ***Problem Set 4*** distributed; ***Problem Set 3*** due
   (a) Energy in electric field
   (b) Capacitance
   (c) Parallel circuits
   (d) Series circuits
   (e) **Application:** Alternative energy (battery, solar cell, etc...)
5. August 3rd –***Project Proposal*** due; ***Problem Set 5*** distributed; ***Problem Set 4*** due
   (a) Electric Fields in Matter
   (b) Linear Dielectrics
   (c) Susceptibility
   (d) Polarizability
   (e) **Application:** The unification of electric and magnetic fields
6. August 10th – ***Exam*** distributed; Construction of Van de Graaff
   (a) Introduction to Magnetism

(b) Lorentz Force Law

(c) Three Basic Types of Magnetic Materials

7. August 17th – Grand Finale; ***Exam*** due[1]

(a) Building the Van de Graaff

(b) Testing the Van de Graaff

(c) **Final remarks** (about what? who knows???)

5 Course Project

To reinforce the course content, you will be building an electrostatic motor and a Van de Graaff generator. These two devices utilize many of the concepts we cover in this class for operation. To make sure that each of you is familiar with the function of these two devices. We ask that you submit a one-page report summarizing how an electrostatic motor and a Van de Graaff generator work on or before **A date which will be filled in here**.

Instead of providing you with a step-by-step instruction, we will leave it up to you to search the Internet and gather ideas for construction for the electrostatic motor. The Van de Graaff generator comes out of a kit. There are no restrictions on the electrostatic motor, except that it should be able to be powered by your own miniature generator.

We hope that you will have fun building these devices.

[1] If you would like your physical exam back, please hand it to us (or email us) before the last class so we can grade it before then. Otherwise, we will email you with comments on your result.