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 superconductors and semiconductors. To further enforce the course content, we will spend a portion of the class getting students' hands dirty by constructing an automatic LED nightlight. This way, each student walks away with a little demonstration of electricity 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 (`cica@mit.edu`) – 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 I. Mayo (`dmayo2@mit.edu`) – Of the three teachers I am clearly the most awesome. I also look a lot like Phong.

Phong T. Vo (vophong@mit.edu) – 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 7 times over a period of two months on the dates outlined below. Each class session is two hours long. Of the 7 classes, 5.5 classes are lectures, each concluding with an introduction to some exciting modern applications that are relevant to the topics covered thus far. The 6th class is designed to allow you in-class time to construct your automatic nightlight. 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 (7 problems) each relevant 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. Solutions to a problem set will be posted on the course website, whose link appears below, on the Thursday following the Sunday on which that problem set was distributed. We strongly encourage you to look at the solutions after you have attempted the problems yourself. However, even if you do not intend on doing the problem sets, it is advisable that you peruse the problem set solutions before the next class. Doing so will help you better internalize the material you learned in the previous lecture.

Moreover, at the end of 4 of the 7 classes, you will have an opportunity to test your understanding through a short 15−minute quiz (1 or 2 questions each). As an incentive, each student who earns a total combined score of 50% or more on the quizzes will receive a special electricity-related prize on the last day of the course (if that student attends such session). Lastly, at the end of the 5th 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.

All course documents, including problem sets, quizzes, lecture notes, and solutions, will be posted on the course website located at `introductoryelectricity.com`.

Finally, the material in this course is of great practical importance. Therefore, we hope that you will enjoy learning as much as we are 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 the early atomic models and quantum mechanics
2. July 13th – ***Problem Set 2*** distributed; ***Problem Set 1*** due; ***Quiz 1*** administered
   (a) Electric field and 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; ; ***Quiz 2*** administered;
   (a) Resistance and Ohm's Law
   (b) Temperature dependence of resistance
   (c) Simple electric circuits
   (d) Parallel and series circuits
   (e) Combination circuits
   (f) **Application:** The beauty of superconductivity
4. July 27th – ***Problem Set 4*** distributed; ***Problem Set 3*** due; ***Quiz 3*** administered
   (a) Energy in electric field
   (b) Capacitance
   (c) Properties of capacitors
   (d) R-C circuits
   (e) **Application:** Brief introduction to complex R-C impedance and circuits with multiple voltage sources

5. August 3rd – ***Exam*** distributed; ***Problem Set 4*** due; ; ***Quiz 4*** administered
   (a) Introduction of the project
   (b) Project orientation
      i. Review of basic circuitry
      ii. Light-emitting diode (LED)
      iii. Photoresistor
   (c) Drawing circuits
6. August 10th – Construction of an automatic nightlight; ***Exam*** due[1]
   (a) Construction
   (b) Testing
   (c) Final remarks on the project
7. August 17th – Grand Finale; ***Problem Set 5*** distributed
   (a) Electric fields in matter
   (b) Polarizability
   (c) Linear dielectrics
   (d) **Application:** Alternative energy sources (solar cell, wind power, etc...)
   (e) Forward-looking final remarks

5 Course Project

To emphasize and apply your understanding of basic series and parallel circuits, you will be creating an automatic nightlight using a small solderless breadboard, LEDs, and a photoresistor. Pre-cut wires and resistors will also be provided. To ensure that everyone understands how their project will work, we will ask that you submit a schematic of your proposed nightlight circuit by a date which we will specify one week in advance. There is no right or wrong implementation of the nightlight so long as it is automatic, meaning it turns itself on only in darkness, so creativity will be highly encouraged (surprise us, or ask us for ideas!). We will provide a steady 3-volt power source for the nightlight in class using two AAA batteries; this should be kept in mind as you design the circuit.

[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.