The Faraday Flashlight:
A Unique Freshman Hands-on Experiment for both Engineering and Technology

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Abstract

The continuum of knowledge: how do Engineering, Technology and Science fit together? Are they really separate and (un)equal realms? Do we "live" in one? Or do we operate in them all, but "sleep" with one? We live and work in a complex world. A relatively recent invention, the Faraday Flashlight, is an excellent example of the intricate web that is woven between science, engineering, and technology. This paper will illustrate the differences and similarities among science, engineering and technology using the Faraday Flashlight as a teaching tool. An experiment using an array of inexpensive equipment, well within the budget of any program, is presented. This exercise requires no prerequisite math or science. The history of the science necessary for the Faraday Flashlight and the engineering and technical developments required to make this invention a reality are discussed. Microsoft Excel is used to analyze and plot data. The students are introduced to the fundamental KSAs (Knowledge, Skills, and Aptitudes) essential to laboratory experimentation.

Introduction

What are the essential differences between the realms of Science, Engineering and Technology? There have been many different attempts at distinguishing among these "vineyards". For the purposes of this paper the following distinctions are used:

1. Science is the discovery of phenomena.
2. Engineering is the ingenuity of invention or creation of things useful for society.
3. Technology is the art and craftsmanship of bringing all of this to fruition.

Very little, if anything, we use in our everyday life would exist without the discoveries of the scientist, the ingenuity of the engineer, and the craftsmanship of the technician.
Using a recent innovation, the Faraday Flashlight, the interrelationship among these three domains of human activity will be illustrated in an experiment for freshmen students of any inclination with no requirement for prerequisite science or mathematics.

The Faraday Flashlight

The Faraday flashlight is a unique invention based on the principle of magnetic induction. It consists of a copper coil, a soft iron core, a capacitor, a printed circuit, and a light emitting diode (LED). The unique features of this flashlight are that there is **no battery** and **no light bulb**. The electric current is produced by the motion of the iron core through the coil. This is obtained by shaking the flashlight. The electricity generated is stored in a capacitor and the illumination for the flashlight is produced by an LED. The weaving of the intricate net that exists between Science, Engineering, and Technology is the beauty of this flashlight.

History

Why has it taken so long for this simple device to come into being? The science took place almost 200 years ago when Michael Faraday discovered the principles of electromagnetic induction in the 19th century. The engineering occurred more than 250 years ago when the Leyden jar (precursor to the capacitor) was invented in the mid-1700s. Where in the world has the Faraday Flashlight been? Well, there were still a number of discoveries and inventions to be made before a commercially viable product could be produced. The amount of current that is possible to generate by manually moving (through shaking) the iron core through the coil is extremely small, totally insufficient to light an ordinary incandescent lamp. Therefore the realization of the Faraday Flashlight required the invention (engineering) of the LED, which required the discovery (science) of the phenomenon of electro-luminance in the early 1900s, and, it was not until the mid-twentieth century that LEDs of any significant illumination were invented (engineering). Finally, it was not until late in the 20th century that technology and engineering had produced LEDs with sufficient illumination to function as light bulbs. For all of these events to come together in a functioning flashlight, the discovery (science) of solid-state-physics was required, followed by the invention (engineering) of printed circuitry and the technology of inexpensive mass production of solid state electronic devices, that we could market a battery-less, light bulb-less illumination “gadget”, ERGO! THE FARADAY FLASHLIGHT!

The “Experience”

We like to call the experiment an “experience” because for the student this is not only an exercise in experimentation but also a valuable learning experience. As this is intended for freshman students the preparation of the students is quite varied. So the Faraday Flashlight experience (experiment) is intended to introduce the student to the fundamental aspects of experimentation with the added emphasis of grasping the reasons for experimentation and the significance of science and mathematics as tools in engineering and technology.

This experiment, and the course it is designed for, are intended to interest a broad spectrum of students from different backgrounds. A precursor to the experiment to be described may include more or less material on the historical facts surrounding the scientists, engineers, and the technicians that played an essential role in the discovery and development of the components that make up the Faraday Flashlight.

The core of this experiment is to quantify the characteristics of the Faraday Flashlight and to present this data in graphical form. The characteristics to be quantified are the illumination obtained by shaking the flashlight and the relationship of this illumination as it deteriorates with time.

Depending on the time one has to devote to this experience, the relationship of the illumination created by flashlight and distance from the source of illumination may also be studied. The science and mathematics related to these characteristics are explained and the collection and plotting of the experimental data are processed using MS Excel. The results of this experience are presented by the students in a formal report including narrative, graphics and digital photos.

Consuetude

1- The first activity in the consuetude (accepted mode of doing something) is to have the students observe how much effort is required to illuminate an ordinary incandescent lamp using a hand generator. In a short period of time they see that it requires a significant amount of effort (see photos 1 & 2). As an ancillary activity they may also measure the voltage produced by the hand generator.

2- The students then shake the Faraday flashlight to produce a current that is stored in the capacitor of the flashlight to produce illumination. They see how much easier it is to generate a reasonable amount of illumination. At this stage, this is a qualitative assessment. Intuitively they see that the Faraday flashlight requires much less effort to illuminate an LED than a hand cranked generator to illuminate an incandescent lamp.

3- With students' interest piqued, we then collaboratively discuss and formulate an experiment to measure quantitively the illumination produced by the Faraday Flashlight. Resulting in the following:

    a- Using a simple mailing tube with a light meter (sensing element) taped on one end, the flashlight is shaken to obtain a reasonable level of illumination and then placed in the tube directly in front of the sensing element.

    b- The students start a stopwatch and the level of illumination is read from the light meter and recorded every 30 seconds for a period of 5 minutes.

    c- The students tabulate the data on an Excel spreadsheet. One of the initial activities in this course was to bring all students up to a minimal level of proficiency in using a spreadsheet. (The facility with Excel that students bring to the course varies).

4- Having tabulated the data, the students are then introduced to the "Chart Wizard" in Excel. Using the Chart Wizard (scatter diagram option), the students prepare a graph of the relationship between illumination and time (see chart 1).

5- Depending on the time to be devoted to this project, this stage may be considered as an ideal time to terminate the experiment. Then the students are required to prepare a written report using a word processor (as with Excel, at the beginning of the course the students are given a brief overview on the features of Word)) and present their results using Power Point (the rudiments of PowerPoint are covered with the first exercise of the course). If time permits the students can run an experiment to observe the effect of distance on the illumination intensity. The results of this exercise are shown in chart 2. An interesting discussion arose as to the reason for the small increase in intensity beyond the first foot from the light source.

At the end of the paper are additional photos with a brief explanation of each.

In that this exercise, is part of a Freshman Course, intended to interest and excite students about engineering and related fields of study, many of the students come to the course with very diverse preparation, therefore, an important objective of the course is to familiarize those students who have not already done so with the basic essentials of Microsoft Office (Word, Excel, and Power Point).

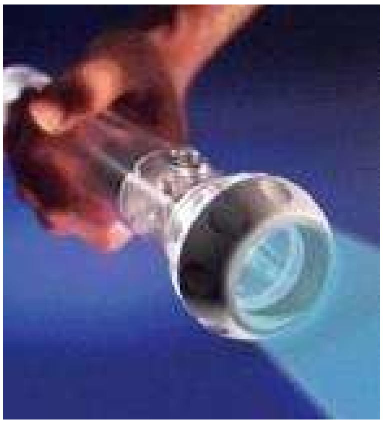
Conclusion

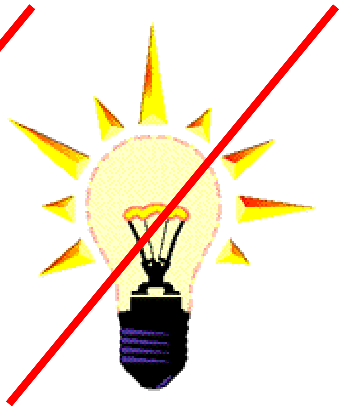
This paper has been a brief overview of one experience (experiment) from a series of experiences (eventually, expected to be between 12 and 14 experiments) that are being developed as part of a Department of Education Grant to create a two-course sequence that may be used to interest and motivate students to pursue careers in science, engineering and technology.

The original design is for the course to be a college freshman level course. However, the experiments are being designed so that they may be stand-alone experiences that may be incorporated into high school curricula as well. As such the mathematical rigor may be varied based on the ability of the student population to be served. It is important to recognize and acknowledge that the rigor of math and science incorporated with any experiment is not intended to diminish the importance of these tools to the study and practice of science, engineering, and technical disciplines.

The primary objective is to awaken the curiosity and interest of young minds to these exciting disciplines and hopefully to inspire and provide them with the incentive to pursue studies in these areas.

Graphics





Faraday Flashlight **NO Battery** **NO Light Bulb**

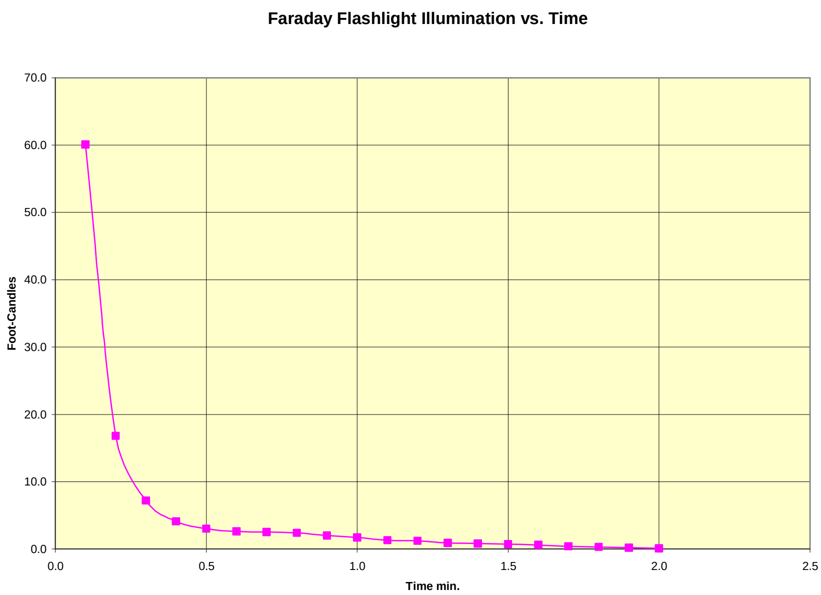


Chart 1 The Relationship of Illumination vs. Time for a Faraday Flashlight

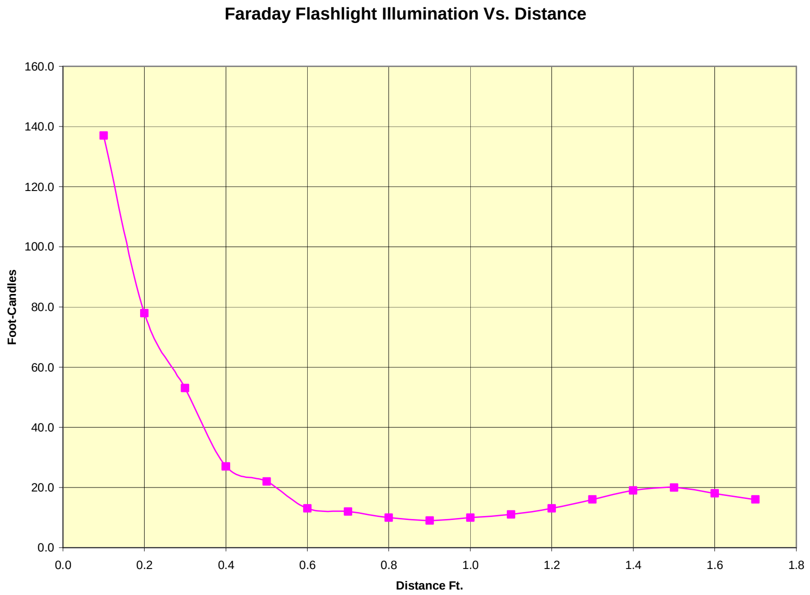


Chart 2 The Relationship of Intensity of Illumination vs. Distance from the Source

Photo 1

Photo 2

Photo 1 A demonstration board with a hand cranked generator with a number of electrical devices (a bell, motor (with propeller, and light bulb), extremely difficult to illuminate the light bulb.

Photo 2 A much easier hand cranked generator with leads to measure the voltage produced by cranking

Photo 3

Photo 4

Photo 3 Multimeters with hand cranked generator. Both analog and digital meters are used to observe the voltage generated with the hand-cranked generator. Ancillary topics may be discussed, such as the "readings" characteristics of the each meter. For example the reason for the mirrored surface on the analog meter to assist in reading the scale correctly (elimination of the parallax that exist because the needle and the scale are in different planes).

Photo 4 Light Meter used to observe the illumination of the Faraday Flashlight

Photo 5

Photo 6

Photo 5 Faraday Flashlight, with "Tail" so that it can be inserted into the tube for measurements.

Photo 6 Experimental equipment, note mailing tubes (gray and multi-colored tubes) for the quantification of the level of illumination of the Faraday Flashlight.

Photo 7 **Photo 8**

Photo 7 More practical form of the Faraday Flashlight. One in which the current is generated by rotation in the same manner as electric power is produced commercially.

Photo 8 Faraday Flashlight with Radio as well as light. These additional products are used to illustrate the growth and development of discovery into ingenuity and technology, thus bringing the web of science, engineering and technology full circle as we continue the ever essential contribution to advancement and well being of society.

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Return to Main page