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The World's Simplest Electric Field Mapping Apparatus

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Abstract

Electric field mapping is a time-honored experiment in undergraduate physics. The concept of electric fields is an important topic in undergraduate physics for majors and non-majors alike. The design of this apparatus has evolved continually for at least 70 years. The search for the ultimate electric field mapping apparatus has continued unabated since Overbeck published his design in 1948. Currently, the most popular design uses a silver ink pen to paint the electrodes. The silver ink pen is not only exorbitantly priced but also emits toxic vapors. This paper presents the design of an electric field mapping apparatus that is inexpensive, environmentally friendly, student-friendly, and may well be the world's simplest electric field mapping apparatus. Instead of using the very expensive and toxic silver-ink pen to paint the electrodes, we use very inexpensive copper foil tape with a conductive adhesive backing. Electrodes of any desired shape can be cut from the copper-foil tape.

Keywords

Electric field mapping, copper tape, silver ink, toxic

1. Introduction

The concept of electric fields is an important topic in undergraduate physics for majors and non-majors alike. A very important traditional experiment to elucidate the concept of electric fields is electric field mapping in two dimensions. The search for the ultimate electric field mapping apparatus has continued unabated since Overbeck published his design in 1948 [1-10]. A review of Overbeck's apparatus was published in 1958 [2]. Overbeck's apparatus depicted in Figure 1 was first used in our physics laboratory some 40 years ago. A string of equal resistors acts like a voltage divider and provides calibrated voltages in steps of one volt. A conductive paper and templates of conducting plates of different shapes secured by wingnuts are used to create various electric field patterns. A wand probe in the shape of a U-clamp is connected to a null galvanometer. When the null galvanometer reads zero, the probe voltage is equal to the calibrated voltage from the voltage divider. Equipotential lines are thus plotted. Electric field lines are then sketched perpendicularly to the equipotential lines.

2. The Silver Ink Pen

Overbeck's voltage divider resistors, the null galvanometer and the U-clamp wand are circumvented in modern designs which simply use a digital voltmeter and conductive paper. Unfortunately, at the present time, the most popular electric field mapping apparatus uses a silver-ink pen to paint the electrodes on the conductive paper [11].

This silver-ink pen is not only exorbitantly priced, but it also emits obnoxiously toxic vapors [12]. We suspect that the reason for the popularity of this design is that users are unaware of an exceedingly simple alternate design. This paper presents the design of an electric field mapping apparatus which is very inexpensive, environmentally friendly, student-friendly, and may well be the world's simplest electric field mapping apparatus.

Figure 1. Overbeck's Electric Field Mapping Apparatus (1948).

3. Water as the Conducting Medium

One way to map electric fields is to simply use tap water in a plastic tray. The conductive paper is not needed in this design because the tap water serves as the conducting medium. A plastic grid is placed at the bottom of the plastic tray. It works like a charm for the authors. However, the copper electrodes must be purchased separately, and the choice of electrode shapes is limited. Moreover, it requires one to solder the wires to the copper electrodes. All told, this is environmentally friendly but not the most student-friendly design.

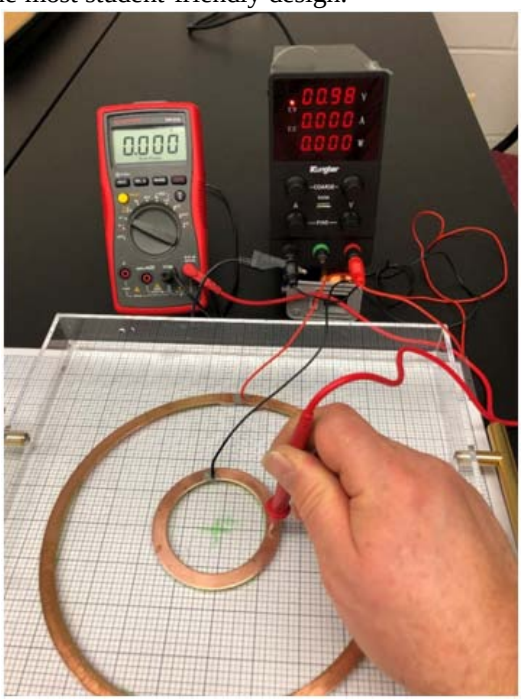

Figure 2. E-Field mapping Apparatus with tap water in a plastic tray (2022).

4. The World's Simplest E-Field Mapping Apparatus

Our ultimate design is the world's simplest E-Field Mapping Apparatus as depicted in Figures 3 and 4. Instead of using the expensive and toxic silver-ink pen to paint the electrodes on the conductive paper, we simply stick a copper foil with an adhesive backing which is conductive to the conductive paper. No muss no fuss! The copper foil tape is easily available and inexpensive [13]. We also use an inexpensive paper hole puncher [14] available at children's craft stores to punch out round electrodes from the copper foil. The conductive paper with grids is secured to a cork board with four aluminum pushpins at the four corners. Electrodes of any desired shape can be cut from the copper-foil tape. We simply stick these copper-foil tape electrodes to the conductive paper with grids. A 12-V voltage source is connected to the copper electrodes with two aluminum pushpins. The digital voltmeter is used to probe all points that measure 2V. These points are marked with a yellow marker and form the 2V equipotential lines. This procedure is repeated for 4V, 6V, 8V, and 10V. Electric field lines are drawn perpendicularly to the equipotential lines with a white marker.

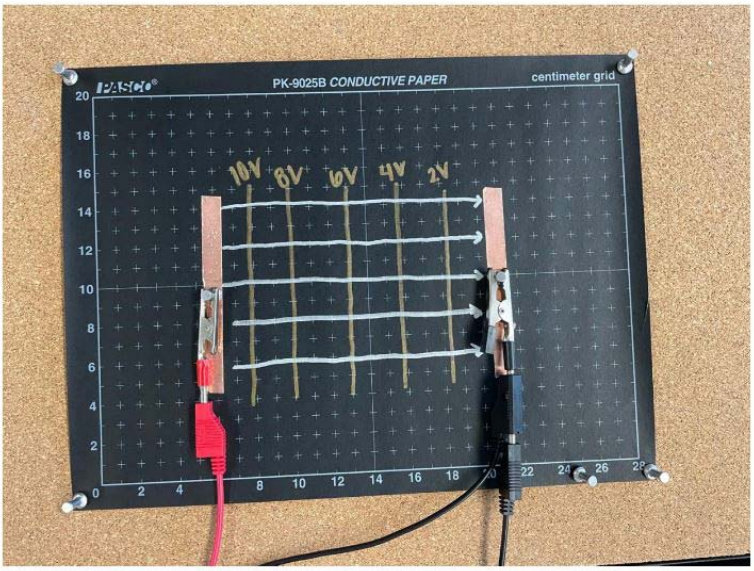

Figure 3. The Ultimate E-Field Mapping Apparatus (2022A).

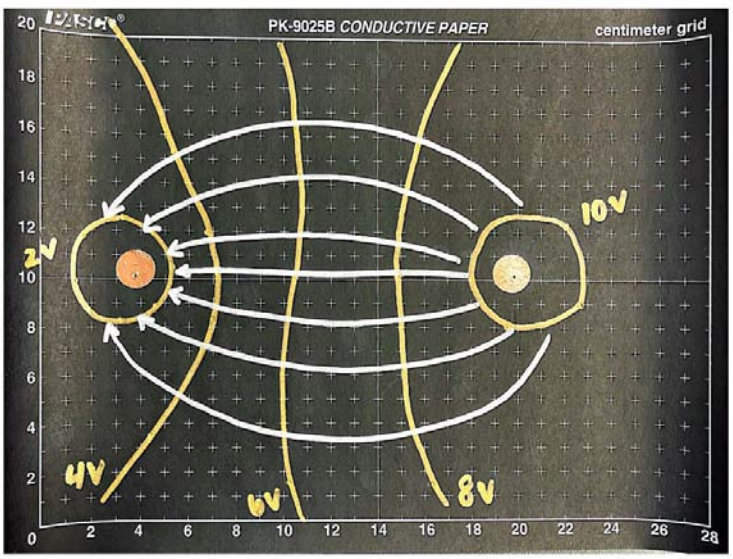

Figure 4. The Ultimate E-Field Mapping Apparatus (2022B).

5. Conclusion

This paper presents the design of an electric field mapping apparatus which is inexpensive, environmentally friendly, student-friendly, and may well be the world's simplest electric field mapping apparatus. Instead of using the very expensive and toxic silver-ink pen to paint the electrodes, we use very inexpensive copper foil tape with a conductive adhesive backing. Electrodes of any desired shape can be cut from the copper-foil tape. We simply stick these copper-foil tape electrodes to the conductive paper with grids. The feedback we received from the users of our electric field mapping apparatus, students, and faculty alike, was overwhelmingly positive.

Acknowledgements

Dr. Steven Binz and Dr. Nicholas Troup graciously tested our Electric Field Mapping Apparatus. They reported that they were impressed with the apparatus and have decided to use it in their undergraduate physics laboratories. They are glad they will never have to use the expensive, toxic, and obnoxious silver-ink pen again.

Data availability statement

No new data were created or analyzed in this study.

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