Chapter 17
A Look into Students’ Interpretation of Electric Field Lines

Esmeralda Campos
Tecnologico de Monterrey, Mexico

Genaro Zavala
Tecnologico de Monterrey, Mexico & Universidad Andres Bello, Chile

ABSTRACT

On Electricity & Magnetism (EM) courses at undergraduate level, the concept of electric field poses one of the most relevant and basic topics, along with the concept of magnetic field. Professors and students may use different diagrams as a tool to visualize the electric field, such as vectors or electric field lines. The present study aims to identify how students interpret and use electric field lines as a tool or resource to describe the electric field. Two versions of a test with open-ended questions were administered in Spanish in a private Mexican university to a random sample of students taking the EM course, and were analyzed with a qualitative approach. It was found that students do not interpret electric field lines diagrams correctly, which may lead to misconceptions. Many students based their answers on the concepts of superposition, force and repulsion.

INTRODUCTION

This chapter is focused on learning different ways in which undergrad students in introductory Electricity and Magnetism (EM) courses interpret and use electric field lines diagrams to describe the electric field at any point in space. Due to its abstract nature, the electric field is a concept that tends to be misunderstood. Several representations of the electric field may have a different effect on the correct understanding of the electric field; such as the use of vectors and the electric field lines diagram. A correct interpretation of these representations should, theoretically, lead to a better understanding of the concept of electric field, and to a correct use of concepts such as the principle of superposition, electric force and repulsion. The problem that this research tackles is to identify how students interpret electric field lines, and what effect their interpretations may have on the conceptual understanding of the electric field.

DOI: 10.4018/978-1-5225-2026-9.ch017
A Look into Students’ Interpretation of Electric Field Lines

In a Context

The electric field is a concept used in physics to describe electrical interactions at a distance. The idea is that charges have an inherent ability to modify space, creating a field that interacts with other charges; it is more intense around the charge and extends to infinity, where it tends to be negligible. Unfortunately, people cannot see with the naked eye how charges modify space, although it would be very interesting. If it is not possible to see, neither to detect through the senses, then how can it be measured? The good news is that electric force can be measured, which is directly proportional to the electric field.

The electric force, according to Coulomb’s law, is proportional to two interacting charges and inversely proportional to the square distance between them, as posed in Equation 1, where \( q_1 \) and \( q_2 \) are the two charges, \( r \) is the distance between them and \( \varepsilon_0 \) is the permittivity of vacuum. Note that the Force \( \vec{F} \) is a vector which points in the direction of \( \hat{r} \), the unitary vector of the displacement vector from one charge to the other.

Equation 1: The law of Coulomb states that the electric force is proportional to two interacting charges and inversely proportional to the square distance between them.

\[
\vec{F} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \hat{r}
\]

Imagine there is a source charge \((+Q)\) and only the force can be measured. To calculate the electric field, take a positive charge small enough such that its effect on the electric field is negligible and whose magnitude is known \((+q)\) (a test charge) and place it at the position where the field will be measured. The distance between the two charges is \( \vec{r} \). Measure the force that the test charge feels and divide this quantity over the magnitude of the charge, like in Equation 2. Notice that the electric field, \( \vec{E} \), is also a vector and points too in the direction of \( \hat{r} \).

Equation 2: The law of Coulomb states that the electric field is proportional to the source charge and inversely proportional to the square distance between the charge and the point of interest.

\[
\vec{E} = \frac{\vec{F}}{q} = \frac{1}{4\pi\varepsilon_0} \frac{Qq}{r^2} \hat{r} = \frac{1}{4\pi\varepsilon_0} \frac{Q}{r^2} \hat{r}
\]

Both the electric field and the electric force have a linear and vector nature and obey the superposition principle. The principle of superposition of electric fields states that at any given point, the resulting electric field is equal to the vector sum of the electric field contributions that each source exerts on that position as if it stood by itself, as represented by Equation 3.

Equation 3: The Superposition principle of electric fields.

\[
\vec{E} = \vec{E}_1 + \vec{E}_2 + \ldots + \vec{E}_n = \sum_{i=1}^{n} \vec{E}_i = \int d\vec{E}
\]