# TEACHING ELECTRIC FIELD TOPIC WITH COMPUTER VISUALIZATION

## S. Talele

*The University of Waikato (NEW ZEALAND)*

## Abstract

Electromagnetic field is undoubtedly one of the most difficult course in the undergraduate courses for electronics/physics degrees. The difficulty arises from the fact that electromagnetic fields are not visible unlike some other concepts in mechanical engineering where one deals with concrete objects. Students generally find it hard to grasp the ideas as these ideas are abstract and their learning cannot be supported through simple experiments in which they can handle objects and see what is happening.

Visualisation of electric field lines and equipotential contours in several different scenarios can be demanding to imagine. There are mathematical ways to calculate however these methods can be equally or more challenging.

For the first instance before mathematics of the electric fields is introduced if the electric field lines can be viewed as an output of a simple computer model it can be very beneficial to students for their understanding and retaining/creating their interest and enthusiasm in the subject. Since several parameters in the model can be changed very easily, effects of those parameters on electric field lines can be viewed. The main objective of this article is to demonstrate some such simple modelling possibilities using the available software package.

Keywords: Electric field lines, equipotential lines, conductivity.

## 1 INTRODUCTION

A common instructional approach to the topic of electric field lines and subsequent electric potential is to compare with gravitational potential energy. At lower level teaching we often find that the text books mention topographic maps and relate the lines of constant elevation to their electric equivalents. This obviously helps students in understanding the main ideas in simpler scenarios. However, imagination can get limited very quickly as the system under discussion is having more charges and different values. Also, the importance potential surface and electric field lines in picture form is being recognised more and more as teaching theories start recognising the importance of visual learning. Teaching community have used excel spreadsheets in olden days [2,3] and computer programs more recently for producing these potential contour plots. In early days these computer programs needed to be custom-written or an excel sheet developed from the theoretical formula. Over years the computer world has changed and learners' curiosity for more complex situation could be satisfied by computer software written to do these jobs in specific. An example of such software is COMSOL. Use of this software takes away the burden of heavy mathematics handling at the start. However, in advanced cases a person has the ability to use this software along with a programming language (MATLAB) to describe any specific complicated scenario.

## 2 USING COMSOL

COMSOL helps to solve the problems by using numerical modelling approach rather than an analytical one. While different versions of COMSOL can have the sequence of instructions/icons varying from others, it basically allows one to do the following steps.

1. Create/draw geometry
2. Define/select the mathematical equations you would need to use
3. Set boundary conditions (once again set by the Physics of the scenario)
4. Make the mesh (this is done by the software once you make a choice)
5. Solve (The software will do this at the press of a button provided all the above steps have been done without errors)
6. Plot (This will plot the result. Again this will be done by the software at the press of a button)

As an example Figure 1 illustrates electric field due to a point charge at the centre of a sphere. This is a two dimensional plot and one can get a three dimensional plot as well. This plot clearly can show the spherical symmetry in radial direction. Two fundamental concepts are covered in this illustration namely Gauss' law and spherical symmetry.

Figure 2 illustrates the simulation results of electrical potential in the conducting shell. The simulation is used to help students understand the concept of equipotential surface. Due to the spherical symmetry of the system in this example, the equipotential surfaces are concentric spheres.
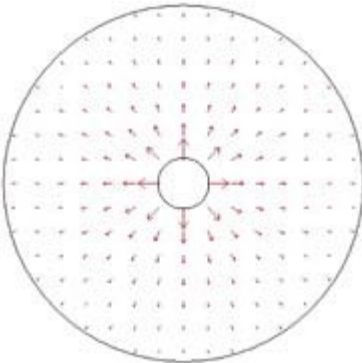


Figure 1

Once this is done it is important for learners to be able to visualise electrical potential plots for the same scenario. As seen below in Figure 2 the equipotential surfaces are concentric spheres, seen as circles in the two dimensional plot.
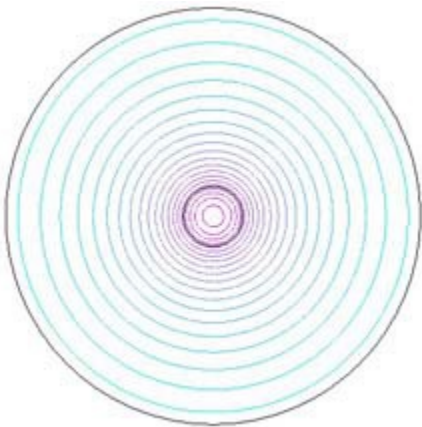


Figure 2

**Boundary value**: Electric potential fields within a source free region bounded by different and known potentials can be mathematically represented by solutions of Laplace's equation. Figure 3 below shows such a scenario in which the potential is positive on the left side of the square boundary and GROUND at the opposite side
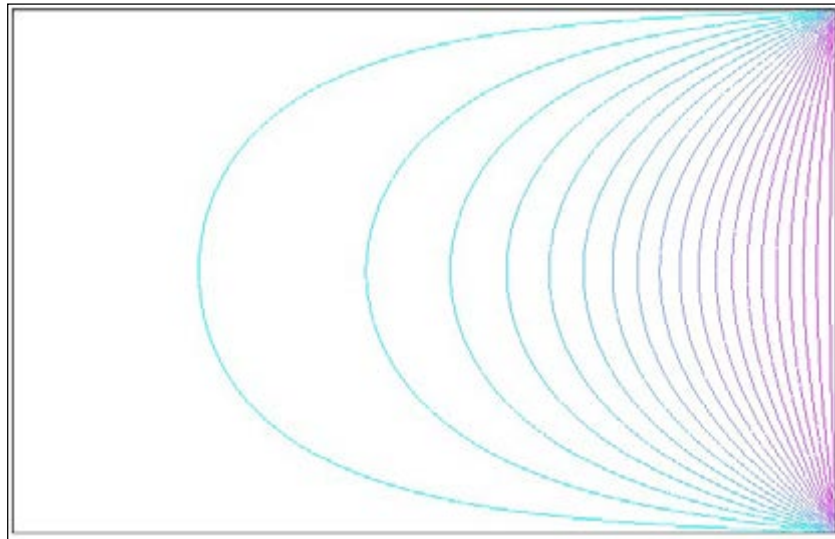
Figure 3

It can be seen that with some introductory information about using COMSOL, one can develop scenarios and be able to see the electric field and equipotential lines. The parameters and geometries can be changed with ease so as to get a good understanding by visualizing rather than mathematical calculations which can be cumbersome and one needs to be confident that the mathematics is without error. With help of COMSOL, such mathematically heavy topic like electromagnetics can be more approachable and easy for self-study.

Another example in the Figure 4 below shows a little complex scenario of electric field lines in a replication bacterium.    This was done to check how the electrical field lines will be distorted when the bacteria is replicating. This is a simple model and was completed using the DC electrostatics module of COMSOL. The physical and electrical parameters were provided to model this scenario.
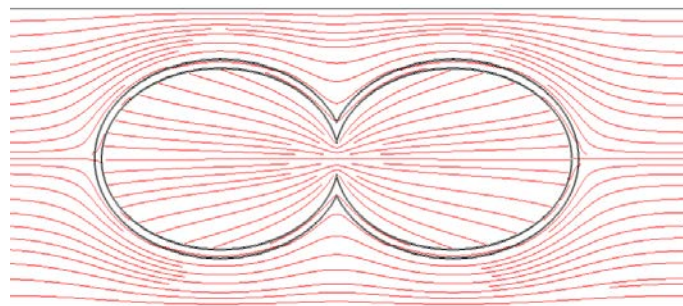


Figure 4

This example of modelling a bacteria also demonstrates the use of COMSOL modelling in visualizing an effect which possibly yet does not have any mathematical proof but an effect that could well be explained with modelling. This also opens up an area for biotechnological topics involving electric or magnetic field applications.

**Conclusion**: A few simple scenarios above emphasize the idea of using computer simulation software such as COMSOL to visualise the electric field and potential pattern. This would make the students get attracted and retained in this area of study rather than run away due to the bug for Mathematics which is an increasing trend in modern times.

## REFERENCES

[1]     Robert A. Dory, "Contour plots for spreadsheets," Comp. in Phys. 4, 529-532 (1991).

[2]     T. T. Crow, "Solutions to Laplace's equation using spreadsheets on a personal computer," Am. J. Phys. 55, 817-823 (1987).

[3]     http://www.comsol.com/shared/downloads/IntroductioToCOMSOLMultiphysics.pdf