

Modelling of Gauss's Law Application for Electromagnetic Fields and Waves Courses

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DOI: <https://doi.org/10.30880/eeee.2021.02.01.029>

Received 31 January 2021; Accepted 25 March 2021; Available online 30 April 2021

Abstract: Nowadays, there are several alternatives that are used by students and lecturers for teaching and learning purposes. With the rapid technology enhancement, it is easier to improve the study method for a better understanding and problem-solving. Electromagnetic Field and Waves Theory (EMT) is an important course in engineering fields this can be used as an example to improve the teaching and learning method. This course is to introduce the fundamental of electromagnetic including electrostatic, magnetostatic, and electromagnetic waves. The main laws governing the electrostatic and magnetostatic are discussed thoroughly in this course as well. Among the important law is Gauss's Law, which states that the net electric flux through any closed surface is equal to the net electric charge within that closed surface. To solve any problem using Gauss's Law, students need to have a better understanding of how to imagine the situation and have a strong background in multivariate calculus, especially on integration and differentiation. Students have trouble with the theory of superposition and in understanding whether there is sufficient symmetry for a given distribution of charges to determine an electrical field under Gauss law. Therefore, an application utilizing Gauss's Law is developed to help students in imagining the movement of the electric charge, as well as providing the solution using Gauss's Law without performing manual mathematical solution as a reference before or during problem-solving in the EMT courses. The development of this project is an alternative to help students and lecturers to learn and teach this course in a better way. The application focuses on Gauss's Law only and it is developed using MATLAB R2017a software. Users able to customize the value needed and the application will do the calculation according to the requirement from users and the outcome will be given in terms of C/m^2 (electric charge density, D). The outputs obtained from the application shows good agreement with manual calculation. The application can be further upgraded to include other laws related to Electromagnetic fields and Waves in the future.

Keywords: Electromagnetic Field, Waves Theory (EMT), Gauss's Law, MATLAB R2017a, Appdesigner

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1. Introduction

Electromagnetic Fields and Waves Theory (EMT) is one of the core subjects for electrical and electronic engineering students. This subject is taken during second year in semester two. Nowadays, with the advancement development of university teaching and learning method, the old way or traditional ways of teaching cannot satisfy the demand of the present teaching. Presently, teaching EMT course has become quite challenging to the lecturers due to high number of failure contributed by this course. To help student to increase the proficiency of calculation and imagine skills, the quality of the teaching materials must be engaging, interesting, up-to-date, while currently being a tool that helps the students to learn. It is important for the teacher to provide an interactive teaching media to attract interest of students. Good teaching media can stimulate the student's interest and encourage student's participation in learning practice [1, 2]. EMT covers the basic principle of electromagnetism such as electrostatics, magneto static, time varying fields and electromagnetic field and waves propagation. This subject required a strong mathematical background and visual skills to imagine the movement of the electric charge or current as well as to solve the mathematical problems related to electromagnetism. At the end of the semester, it is expected that the student is able to understand and solve problems related to Maxwell equation. There are five laws governing to the electromagnetic fields and waves which are Columb Law, Gauss Law, Biot Savart Law, Ampere Circuital Law, Gauss's Law [3] for Magnetism and Faraday Law. However, only Gauss's Law is selected and applied in this application as a first moves in providing an effective teaching and learning tools. Electromagnetic theory is a major element of technical education, but at the same time one of the most challenging topics for students to learn and lecturers to teach. [4]. In order to decrease the amount of failure in this course, a development of an application is proposed to help gaining and understanding about the Gauss's Law, as well as helping lecturer in teaching and learning process. Some fundamental electrostatic and magnetostatic field equations are studied on different examples that use Mathematical Software to encourage a virtual environment by enabling electrical engineering students to teach these subjects on a computer. [4] This application is fully developed by using MATLAB software which widely used by engineers and engineering students.

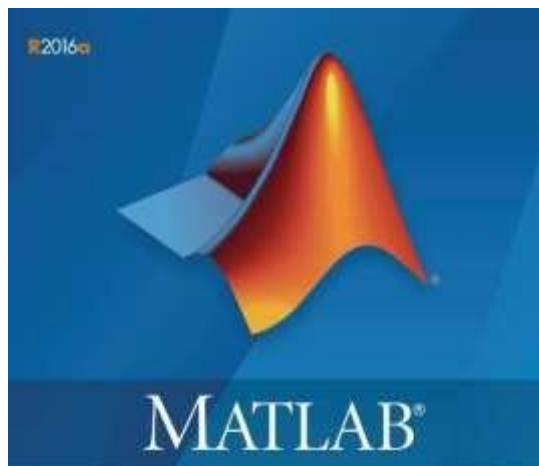
1.1 Educational Graphical Interface for EMT

There are so many advances way to teaching and learning for lecturer and student. Graphical User Interface is one of the methods for the improvement as stated by Majherová et al. The general approaches to overcome difficulties in EM education are by present strategies for interactive discussion by using realistic examples other than that integrated path to education in electrical engineering integrating MATLAB-based computer-assisted teaching and learning in electromagnetics courses [5]. Many research studies show that difficulties in engineering student achievements can often be attributed to discrepancies between different learning styles and teaching styles of teachers [6]. The ICT help to achieve higher quality, expertness, and effectiveness compared to teaching resource and tools, which have been used until now [7]. A pedagogical experiment has shown that this kind of teaching is appropriate to students and supports and develops their creativity [8]. In classrooms, graphical user interfaces have been rapidly used to provide computer simulation users with a user-friendly and visual solution to define all input parameters with improved configuration capabilities, Naim, N. F et al. [9]. In this thesis there are four types of GUI is used as reference and among these four Interactive Educational Software for Engineering Subjects is the most effective and user friendly. There are three subjects in this app which is Electromagnetic, Communication Engineering, and Power Engineering as shown in Figure 1. For electromagnetic this app solve a problem for Dot Product, Electric Field Intensity due to a point charge, Cylindrical coordinate conversion, and Electromagnetic Wave Propagation. This educational software is very helpful software for student as it very easy to use and gives clear visualisation to student.



Figure 1: Main menu of educational software.

2. Materials and Methods



This modeling is fully developed by using *appdesigner* in MATLAB software version R2017a. Software development is conducted at the early stage of the process. There are several important characteristic needs to be considered to make sure the project can be successfully developed. MATLAB software as shown in Figure 2 is a high-performance technical programming language. It combines computation, visualization, and programming in an easy-to-use setting where familiar mathematical notation communicates problems and solutions. MATLAB is one of the engineering tools which can be used to solve and develop software. [10]. for software development, the packaged software is associated with some subject related to the applied electromagnetism and communication theory [11]. Figure 3 shows the software flowchart to open the application interface which is by simply double click the Gauss's Law application at the application section in Matlab and the UI Figure as shown in Figure 4. After that, user can choose the type and condition depends on the situation. User can add any desired value in the value box and double check the values before proceed to click calculate and get the answer in units.

Figure 2: Matlab Software

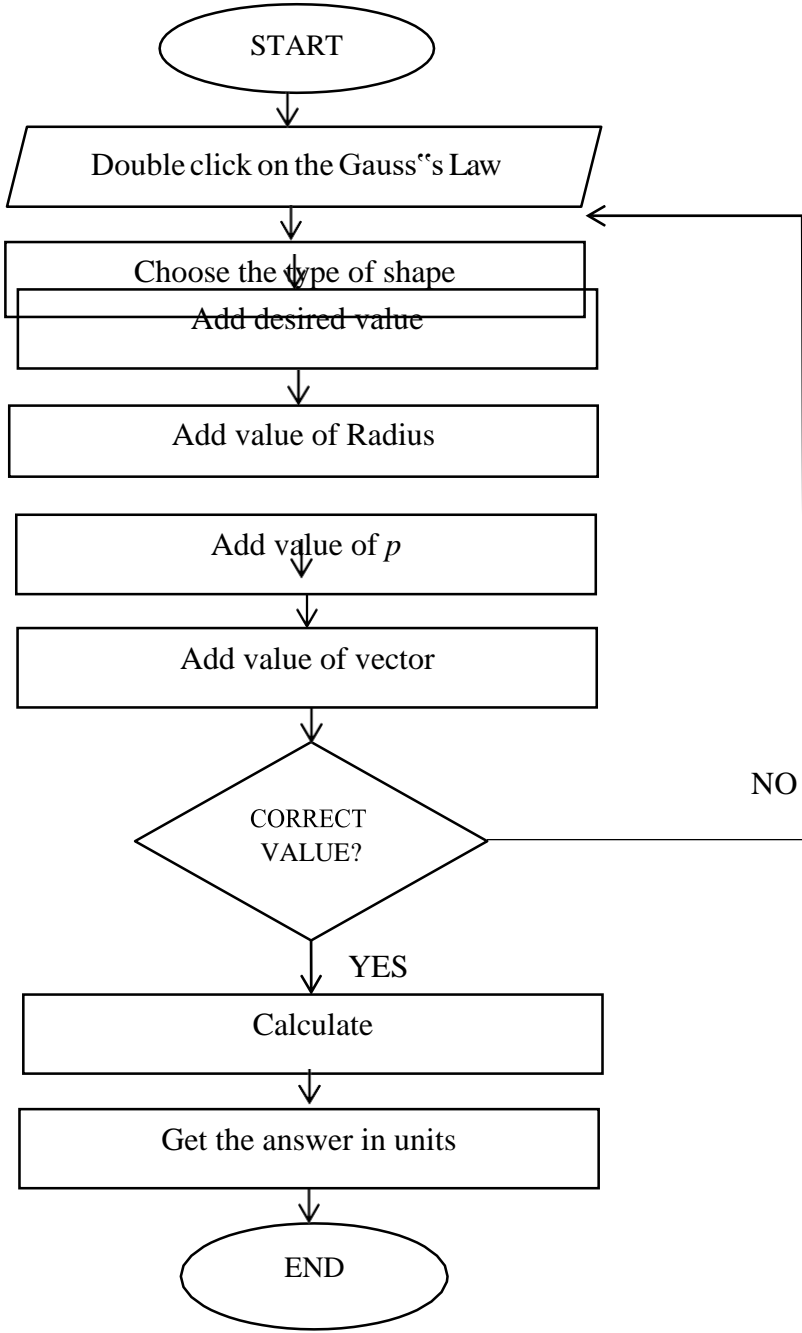


Figure 3: Software sequence flowchart

In this project, the modelling of Gauss's Law application for electromagnetic field and waves courses was designed. The modelling that is designed was represented in the form of simulation software. With this modelling, the user can learn to plot the output signal of the Gauss's Law application equation question by only entering the specification value that is needed. Through this modelling, the studies of EMT have become much easier and interesting.

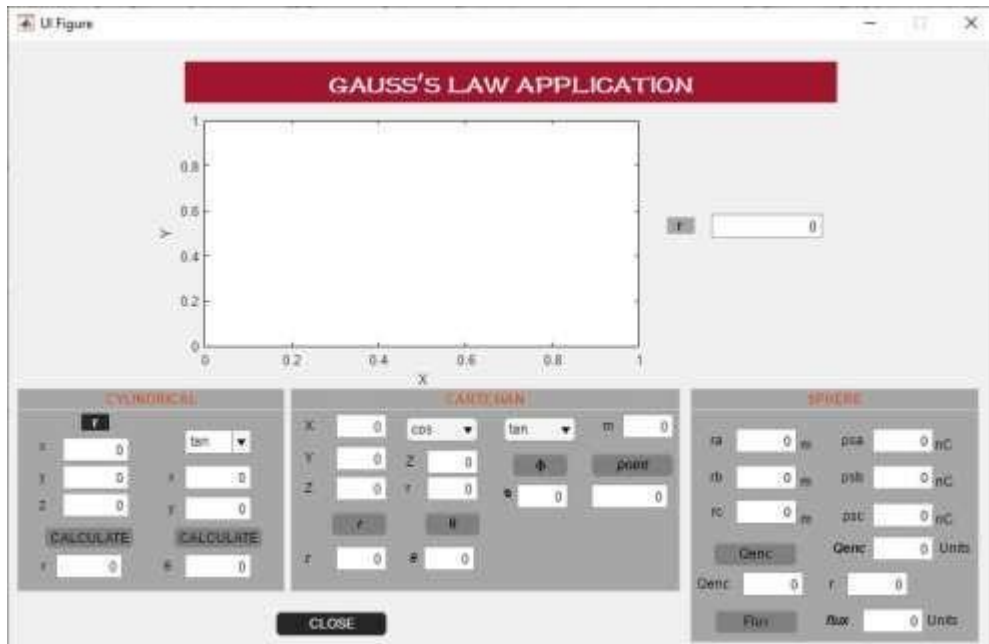


Figure 4: UI figure of modelling using *appdesigner*

Figure 4 shows the interface for this modeling. The question is calculated manually and the answer will be compared with the modelling answer. Here the initialization coding for Spherical, Cylindrical, and Cartesian equation is shown. Those three conditions have a different equation and question the equation is translated into coding form and get tested if the coding is successful or not.

3. Results and Discussion

The equation that has been translated into coding is analysed and the UI figure for each question are shown. In this project, the three questions that have been chosen are tested by choosing the type of shape and entered the value in the value box on the UI figure. The analysis is conducted by comparing the manual calculation and the modelling calculation answer. If both get the same answers it is showing that the modelling is achieved the project objectives.

3.1 Spherical

Figure 5 shows the sphere section, user can plug in any desired values on the r box and ρ box and click the calculate button the modelling starts doing the calculation, and the sine waveform of r for the sphere. The comparison between the answer from the modelling and the manual calculation show that the answer for both is the same.

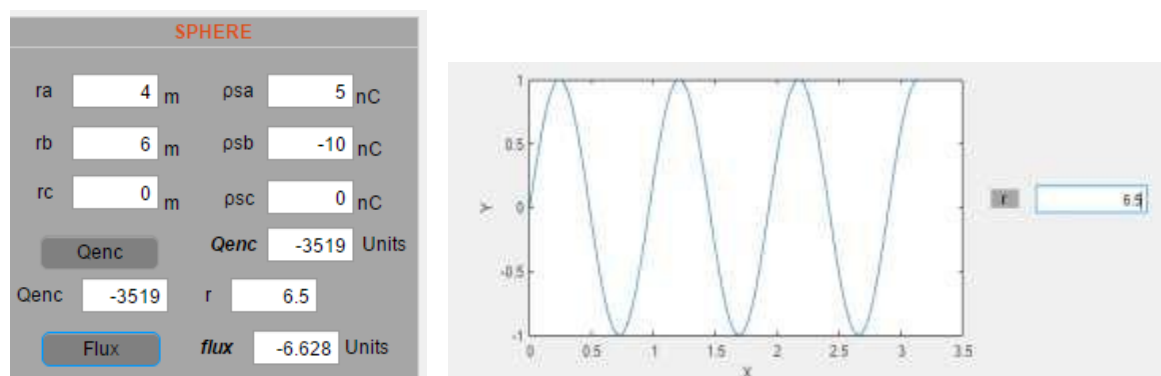


Figure 5: Spherical and UIAxes

3.2 Cylindrical

Figure 6 shows the cylindrical section, user can plug in any desired value on *the* x , y , z values box and click the calculate button the modelling starts doing the calculation, and the sine waveform of r for cylindrical. The comparison between the answer from the modelling and the manual calculation show that the answer for both is the same.

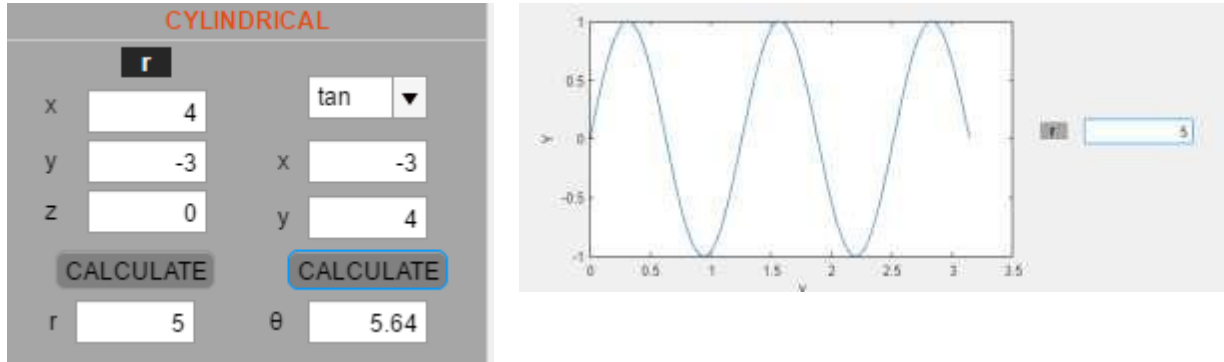


Figure 6: Cylindrical and UIAxes

3.3 Cartesian

Figure 7 shows the Cartesian section, user can plug in any desired value on x , y , z values box, and click the r , θ , and ϕ button the modelling start doing the calculation and the UIAxes for sine waveform of r for cartesian. The comparison between the answer from the modelling and manual calculation showing that the answer for both is the same, this proves that the modelling is achieved the objectives and the modelling can produce a sine waveform for Cartesian.

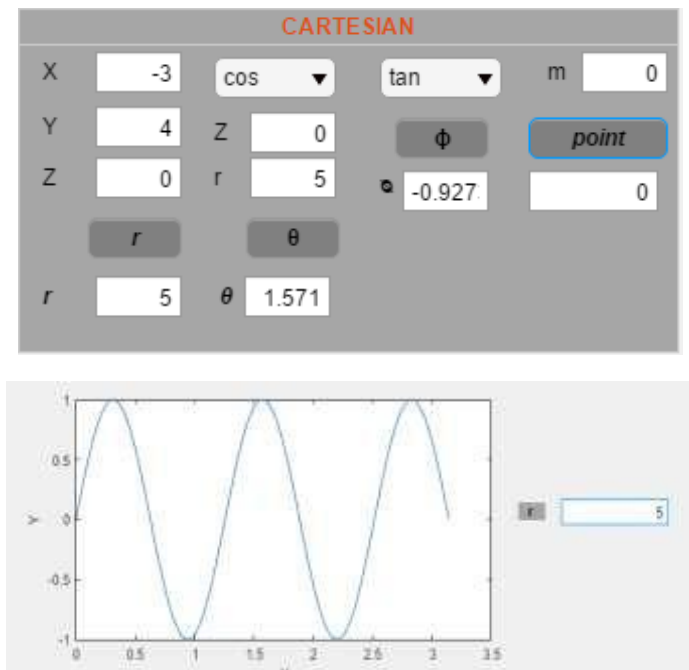


Figure 7: Cartesian and UIAxes

4. Conclusion

A comparison has been done between manual calculation and modeling calculation to check the accuracy of the answers given by the developed application. The result shows good agreement between manual calculation and the developed application for all types of the coordinate system. The advantages of this application are its do not require internet access during the usage and can be used by numbers

of student without any restriction. By developing this modelling of Gauss's Law Application for Electromagnetic Fields and Waves Theory (EMT) Courses It is expected that the outcome can be one of the alternative methods in helping students to understand the nature of the EMT subject because, For practical applications such as electrical engineering and chemistry, an understanding of electromagnetism is important, Daniel R. Stump [12].

Acknowledgement

The author would like to thanks the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia for the facilities especially Mechatronic Laboratory that has been provided to complete this project and for its support.

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