

Assignment Analysis of Electrostatics and Magnetostatic problems

by Matthew Prentice

Submission date: 10-May-2023 12:12PM (UTC+0100)

Submission ID: 205556838

File name:

32460_Matthew_Prentice_Assignment_Analysis_of_Electrostatics_and_Magnetostatic_problems_497416_1655357015.pdf
(1.07M)

Word count: 1175

Character count: 7212



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David



ACDA5009 - Electromagnetic
Radiation

Assignment: Analysis of
Electrostatics and Magnetostatic
problems

Matthew Prentice (2116359)

Introduction

Electromagnetics are at the heart of modern computing, it's used everything from power supplies to hard drive storage to the transistors that make up a CPU.

In this report we will investigate the materials used as dielectrics in capacitors and how the material used effects the characteristics of the capacitor. We will investigate the current carrying abilities of different metals and finally we will investigate the electromagnetic force with the use of an electromagnet.

Content

Introduction	1
Background	2
Task 1	3
Task 2	5
Task 3	6
Conclusion	8
References	9

Background

To help us model electromagnetic problems in the 2D plane, a software package called FEMM 4.2 is used.

Task 1

The first task set was to model a rectangle with dimensions of 10cm by 8cm as an electrostatic problem. Two faces of the rectangle had a voltage of 9v applied to them and the other two were held at 0v. The task then stipulated that the internal material of this rectangle was to be set as Air and then Silicon, and to conduct an analysis of the two different models. The resulting model, in both cases, was effectively a capacitor with different dielectric materials.

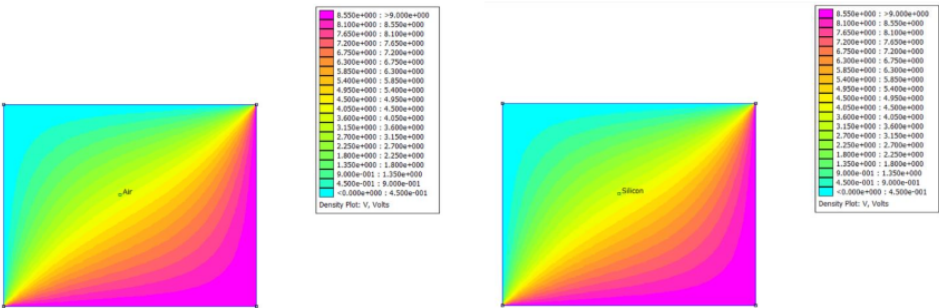


Figure 1 - Simulation of both rectangular models showing Electric Field density

The first obvious difference between ⁴ two models can be seen when inspecting the FEMM 4.2 Material library. In the library it can be seen that Air has a relative permittivity of 1 and Silicon has a relative permittivity of 12. These values are approximate and are more widely held to hold a value of 1.000528 and 11.68 respectively.

Material	Relative Permittivity (FEMM)
Air	1
Silicon	12

Table 1 - Relative Permittivity value of materials as used in FEMM 4.2

Permittivity is the measurement of how resistive a medium is to forming an electric field with Relative Permittivity being relative to Absolute Permittivity, or the resistance to forming an electric field in a vacuum. Absolute Permittivity is typically held at being approximately 8.85×10^{-12} Farads per metre. ⁵

Another obvious characteristic difference of the two models is the electrical conductivity of the two materials. Silicon is well known as being used in modern electronics such as integrated circuits due to silicon being classed as a semiconductor. Semiconductors differ from conductors like metals due to having a lower number of conduction electrons and requiring less energy to promote valence electrons to the conduction band. ² Air on the other hand is well known as an insulator with an electrical conductivity that can be improved with the introduction of aerosolised water droplets. ³

With held from the FEMM 4.2 analysis it can be seen that across the model, the use of silicon as a dielectric allows for an order of magnitude higher level of electric flux density as shown in Figure 2. This is due to the significantly higher Relative Permittivity value. ⁶

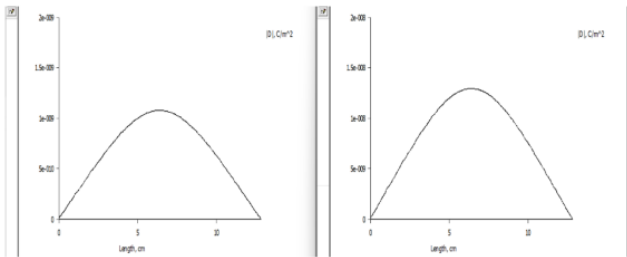


Figure 2 - FEMM Analysis of the magnitude of Electric Flux density for Air (left) and Silicon (right)

The higher relative permittivity can also be seen when integrating a cut of the model in FEMM 4.2 as shown below in Figure 3. Due to the higher relative permittivity the model using silicon is able to store significantly greater charge within the same volume.

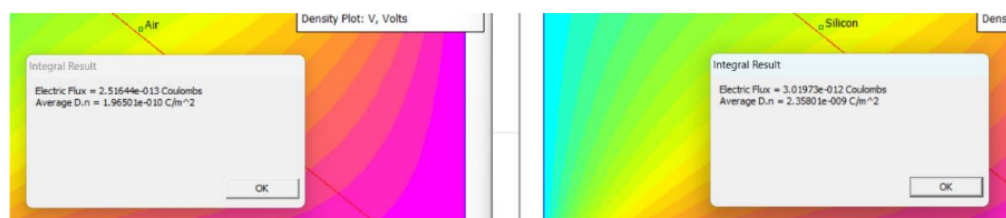


Figure 3 - Integral of the density plot of each model; Air (left) and Silicon (right)

Task 2

Task 2 required the modelling of a zig-zag shape made with aluminium and then made with copper. The model was to have 9v applied at the lefthand end and 5v applied on the righthand side. The expectation from these models was that a higher current flow and lower resistivity would be seen in the copper model compared to the aluminium. This is due to aluminium, even when mixed as an alloy, is only 61% as conductive as copper. [4]

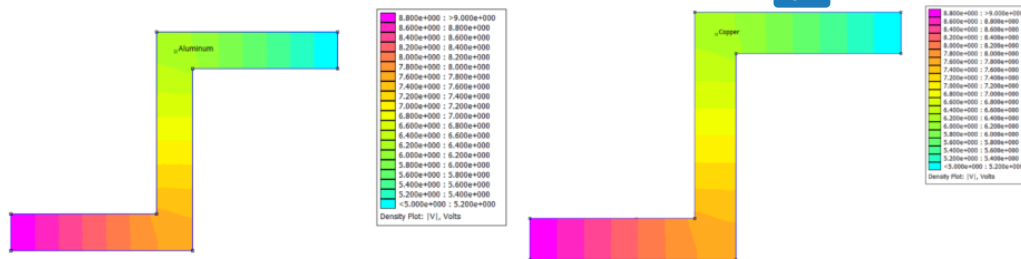


Figure 4 - Zig-Zag model simulated to show potential difference across the design

Due to the lower conductivity of Aluminium, we see that when analysed in FEMM 4.2 a significantly smaller current flow is calculated compared to copper. The results shown in Figure 6 are negative due to the direction of drawing the contour.

Material	Current (A)	Average Current (A per m ²)
Aluminium	116564+I*1.49934e+006	9.42363e+007+I*1.21215e+009
Copper	179329+I*2.30668e+006	1.44979e+008+I*1.86484e+009

Figure 5 - Table of values calculated by FEMM 4.2

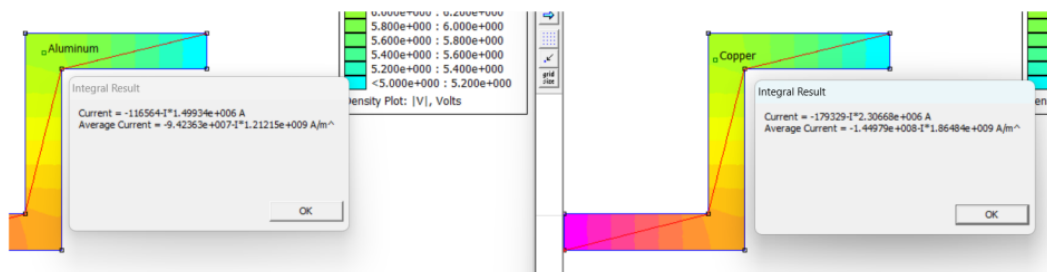


Figure 6 - Integral of the cross-section in FEMM 4.2 showing the current flow and average current flow across the model. Aluminium (left) and Copper (right)

While the use of Aluminium may well perform poorly when compared to copper in terms of conductivity, it's increasingly being used in industrial applications due to its cost and weight benefits. [4] Aluminium weighs 2.7g per cm³ equating to 35.1 grams in this model assuming a thickness of 1cm. Meanwhile copper has a density of 8.95g per cm³ equating to 116.35g for the same volume, or over three times heavier than aluminium.

Task 3

Task 3 required the modelling of an iron core electromagnet with 5 turns on each set of coils and 200A flowing through both coils.

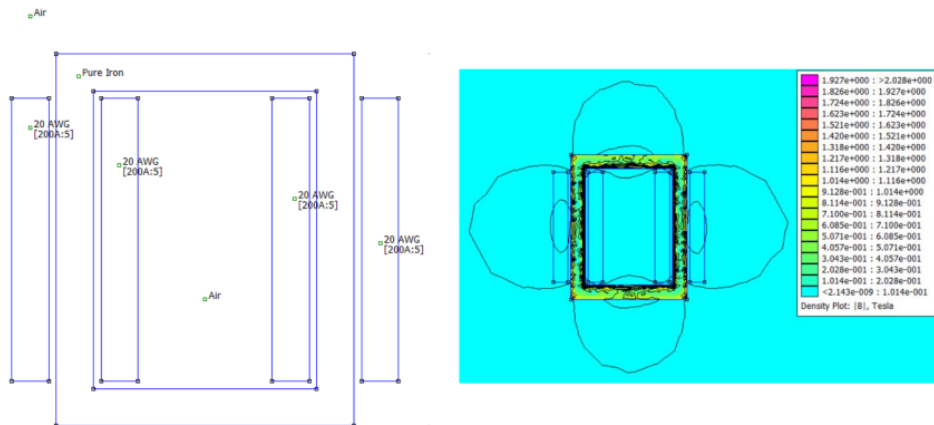


Figure 7 - Electromagnet designed and simulated in FEMM 4.2

This electromagnet makes use of the principle of electromagnetism whereby when current flows through a conductor a magnetic field is created, and when a conductor is in the presence of a varying magnetic field a electromotive force is induced.

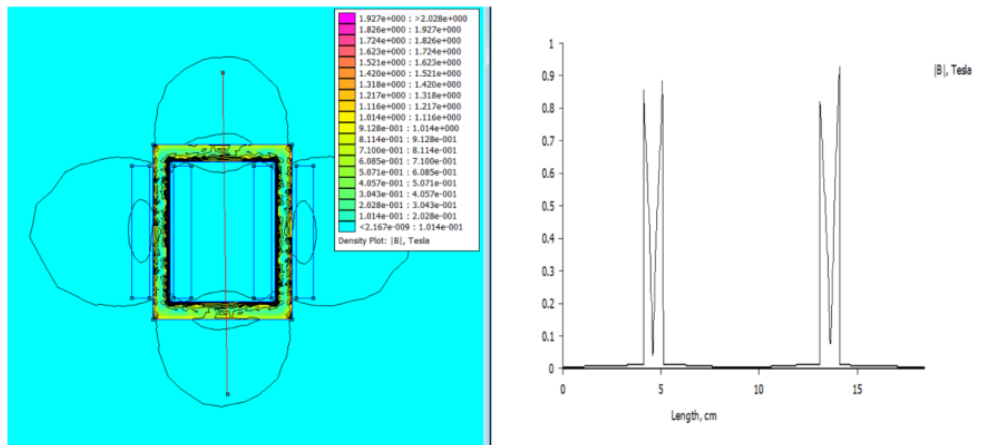


Figure 8 - Magnitude of Magnetic Flux density across the vertical axis

When analysing the magnetic flux density of the electromagnet we see that the majority of the magnetic force is induced and contained within the iron core of the electromagnet with very little projecting out into the surroundings.

However when placed against a steel plate, as in Figure 9, we see that a magnetic force is not only induced in the steel plate, but also projected much further into the surrounding environment.

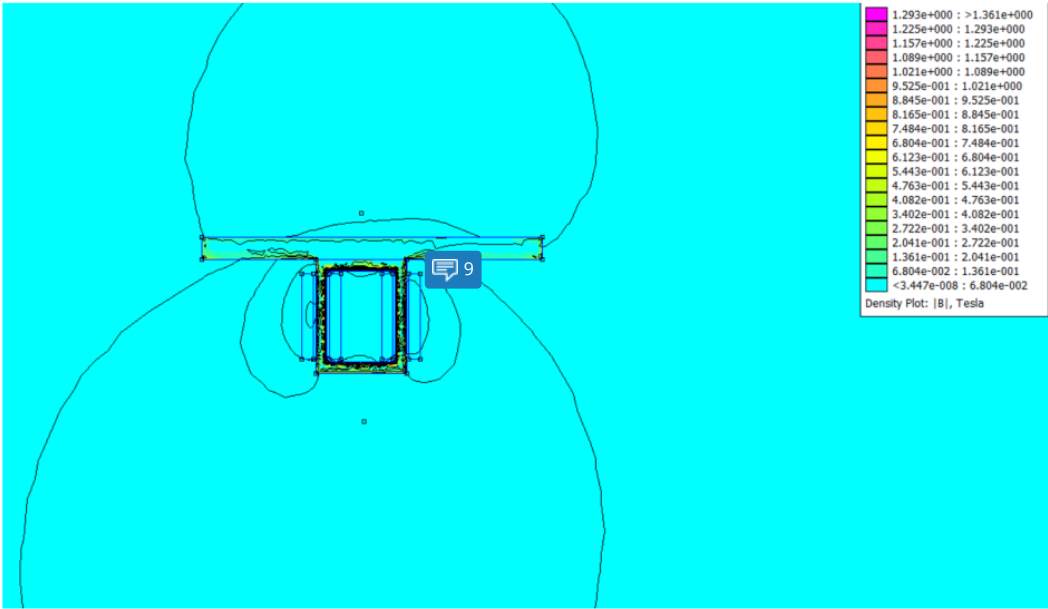


Figure 9 - Steel plate placed against the electromagnet

Conclusion

In conclusion, FEMM 4.2 is a very useful tool for modelling electromagnetic systems in 2D with a variety of analytical tools. It's been shown in the three tasks that careful selection of dielectric material is important when constructing a capacitor and that some metals have much higher current carrying capacity than others although there are other drawbacks.

Finally it's been shown that a magnetic force can be induced in a conductor through the use of an electric current.

References



- [1] Electronics Notes, "Electronics Notes," [Online]. Available: https://www.electronics-notes.com/articles/basic_concepts/capacitance/dielectric-constant-relative-permittivity.php. [Accessed 10 05 2023].
- [2] Institute of Physics, Institute of Physics, [Online]. Available: <https://spark.iop.org/conductivity-electrical>. [Accessed 10 05 2023].
- [3] H. R. Carlon, "Electrical Conductivity of moist air," *US Army Armament Research and Development Command*, May 1978.
- [4] Wilson Power Solutions, "Wilson Power Solutions," 2021. [Online]. Available: https://www.wilsonpowersolutions.co.uk/app/uploads/WPS_Aluminium-v-Copper_white-paper_-2021.pdf. [Accessed 10 05 2023].
- [5] J. Markell, "Calculating the Relative Permittivity Constants of Various Dielectric Materials Using a Parallel Plate Capacitor," *Physics*, no. Physics, 2016.

Assignment Analysis of Electrostatics and Magnetostatic problems

GRADEMARK REPORT

FINAL GRADE

62/100

GENERAL COMMENTS

Instructor

Engagement with Literature Skills: Marks: 5/10

Engagement with a limited range of mostly relevant and credible sources. Some omissions and errors in citation. It would have been better if referred from sources, such as textbooks from reputable academic publishers and articles from peer reviewed journals.

Knowledge and Understanding Skills: Marks: 14/20

Knowledge is reasonably good. Exhibits competent critical understanding of the well-established concepts and principles of the subject.

Cognitive and Intellectual Skills: Marks: 11/20

Some critical evaluation and analysis of concepts and principles, though descriptive in parts. Evidence to support findings/ views, but evidence not consistently interpreted. Some relevant conclusions.

Practical Application Skills: Marks : 22/30

A very good application of a range of established methods, tools and techniques, with perceptive use of examples, where relevant.

Transferable Skills for Life and Professional Practice: Marks : 10/20

Can communicate effectively in a suitable format. Mostly coherent work and is in a suitable structure, but may have minor errors

Overall total: 62/100



Comment 1

The table of content should be after the title page



Comment 2

It would have been better to include the title number / subtitle number in the table of content



Comment 3

Page number is missing



Comment 4

It would have been better if some theoretical backgrounds of electrical and magnetic fields were described and discussed



Comment 5

Citation should be included before the full stop



Comment 6

Citation should be included before the full stop



Comment 7

Citation should be included before the full stop



Comment 8

Figure 7 and figure 8 are not included in the description. If figures are included they should be referred in the description



Comment 9

The metal plates should be placed in air,.

PAGE 9

PAGE 10



Comment 10

You should try to use more high quality reference sources, such as textbooks from reputable academic publishers and articles from peer reviewed journals.