

Report 2112087

by Jacob Brown

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Electromagnetic Radiation - Analysis of Electrostatic and Magnetostatic Problems

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Introduction

General Overview

The general overview of the project consists of 3 parts for simulation in Finite Elements Method Magnetics using the april2019 build version (4.2). Looking into the interactions of various mediums on the dispersal of a mixture signals given set currents and testing their interactions in their respective mediums. Electrostatics and magnetostatics are two fundamental branches of electromagnetism [1], these form the backbone of our understanding of electric and magnetic phenomena. These fields not only provide insights into the behaviour of charges and currents but also lay the foundation for an array of technological marvels that are frequent in our daily lives and are becoming increasingly prevalent in the increasingly modern and signal intensive environments of the current cityscape [2].

Theoretical overview

Electrostatics focuses on stationary electric charges in relation to the electric fields they generate [1]. The concept of electrostatic equilibrium, the various electromagnetic laws, and the distribution of charges on conductors are crucial components that will be investigated herein with relation to their relevant corroboration. In these examples, we can demonstrate the behaviour of charged particles, the characteristics of electric fields, and the principles that underlie the design and functioning of electrical and radio-electrical systems. Magnetostatics, alternatively, investigates steady magnetic fields and the forces they exert on magnetic materials and currents [3]. Key principles include magnetic fields, Ampere's law, magnetic induction, and the behaviour of magnetic materials. Understanding magnetostatics is fundamental to comprehension of critical components and their impacts on emission patterns, such as transformers and electromagnets.

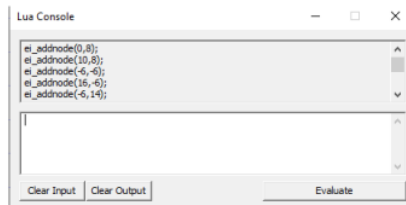
Task 1

Task Detail

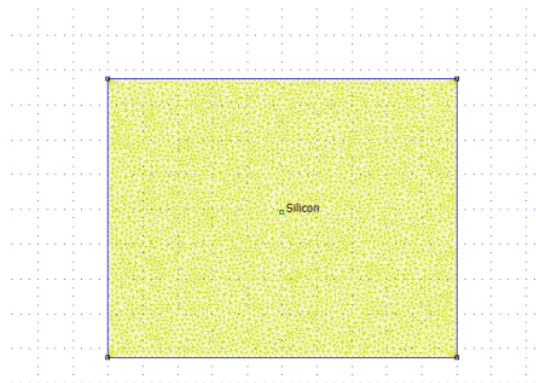
The demonstration required for task 1 is a simple one, mostly a proof of concept and software, requiring a two-step process, that being the outlining of the physical properties that shall remain fixed – those being the boundary variables and the dimensions of the medium. The boundaries feature a 0v on the east and west faces, with a 7v boundary on the northern and southern faces.

Demonstration

The demonstration setup was rather symbol, requiring only a few steps to reach completion. Firstly, node points for the corners were written into the console in order to place all of them at the same time and at exact coordinates [4], as seen in figure 1. While in order to process the electrostatic effect properly, it was equally required to define each boundary and material, as observed in figure 2, a mesh was also added to simulate the various measuring points along. While feeding in a 7V charge into two of the four faces, which should produce a gradually decreasing field.

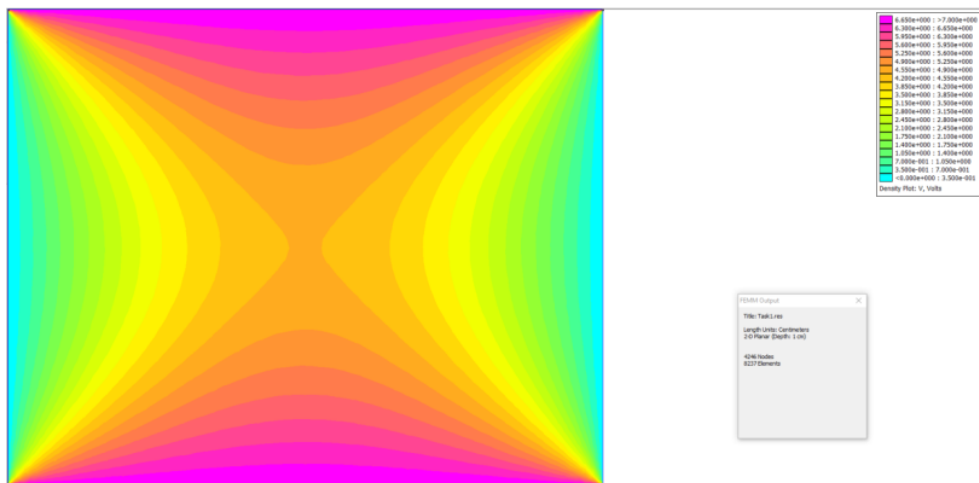


Above, Figure 1

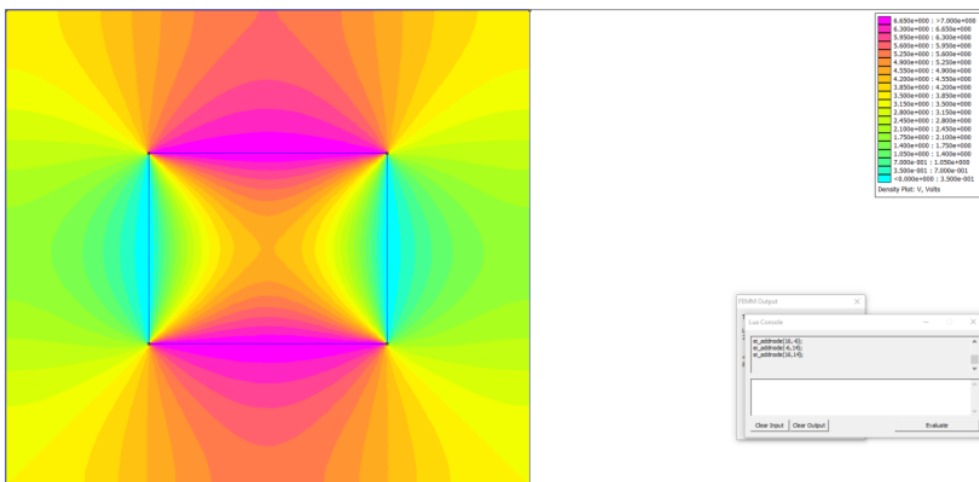


Above, Figure 2

The principle is that of basic electrostatics - When a voltage  applied to a conductor, such as a silicon wire or a conductive silicon substrate or waveguide [5], it can produce a voltage field in its vicinity. As silicon is a semiconductor material, it acts as a very effective conductor, which is represented in figure 3, demonstrated due to the form that the voltage plot displays. As there is no negative current, and instead 0v and 7v exclusively, there is no electrostatic demonstrating a continuous current flow as one would expect in a wire, but instead it demonstrates a closed electrical system entirely within the 80 by 100mm square.



Above, Figure 3

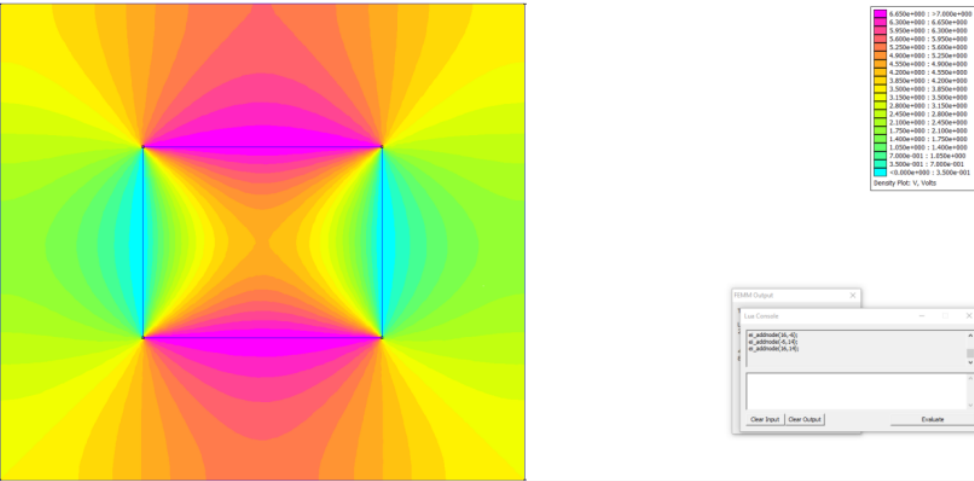


Above, Figure 4

Also of note are the details demonstrated in figures 4 and 5, notably the emission field that traces out of both the air and the silicon as seen in 4 or the air-to-air examples in 5. We can see that the boundaries of the inner medium impact the dispersal compared to the relatively free emissions outside the inner medium. This demonstrates that not only does the conductivity of the material impact its electrostatic footprint, but equally the free space that it must propagate through also retains a high level of influence over the signature produced. As we can see in 4 and 5, the positive currents seem to be far more compact when decreasing towards 0 compared to the external currents, demonstrating the difference that free, unimpeded free space has and, equally, demonstrating that the two positives 7-volt charges do not act in such a way as to promote constructive interference and, instead, promote a repulsive relative interaction. However, we can also note a marginal increase in the voltage field, this is a difficult change to observe due to the similar bounds however, there is a marginal enough change to demonstrate the difference that is apparent from the greater conductivity present in the silicon, though it would certainly have benefitted from being presented in an alternative medium to the voltage field representation utilised.

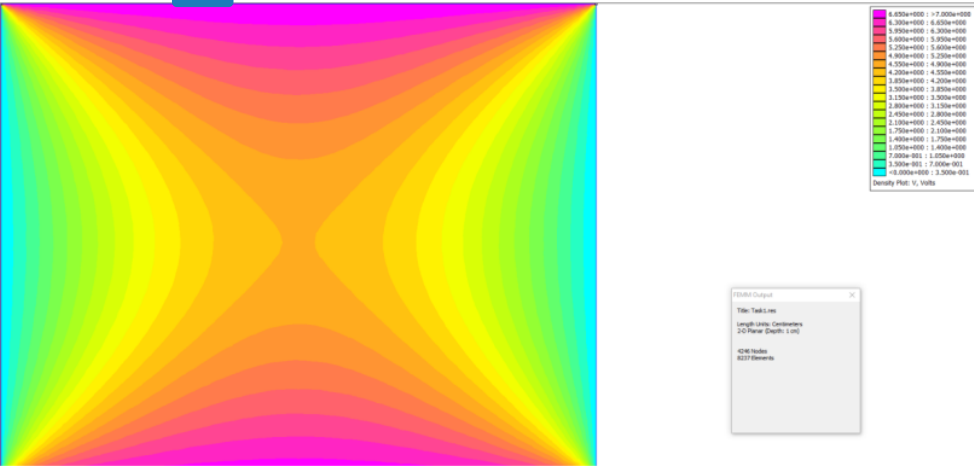
Rather interestingly, in figure 6, it can be observed that the dispersal of charged particles conducive of voltage seems to appear almost identical in pattern despite the ϵ_x equivalent for air being 1 while silicon equates to 12, this pattern seems to be a constant for almost any amount of input as the hourglass shape represents the greater conductivity that has culminated at the centre the medium compared to the neutral boundaries, due to the nature of a waveform not moving exclusively in a y plane and instead propagating, when considered in a distribution curve, in a more spherical shape around the emitting point [6], in this case, the north and south. While some of the numerical values vary marginally, the constant representation of the field is consistent with Gauss's law [7] and is an accurate demonstration of the principles underlined within it, equally demonstrating the conductivity and its effect on any medium regardless of it is relative conductivity. This observation allows for a greater comprehension of particle behaviour as it conducts, not simply the behaviour of particles in a conduct

6



Above, Figure 5

7



Above, Figure 6

Summary

In summary, task 1 is a simple demonstration of a few fundamental principles in electrostatics and electromagnetics as a whole, demonstrating the observation of Gauss's law in two separate materials. Equally, it challenges single schools of thought when approaching fundamental problems, while demonstrating expected patterns of distribution along what should ultimately be expected should the relevant laws be considered.

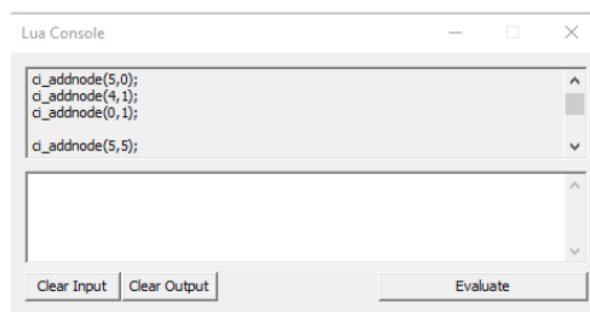
Task 2

Task Detail

The demonstration required for task 2 asks for demonstration within the confines of a current problem, this demonstration focuses primarily on-again demonstrating conductivity of materials with two inputs, those being a 7v on the low western side and a 5v input on the high eastern side. Both aluminium and copper are commonly used materials in conductive applications due to their high relative conductivity to other metals [8], in varying their inputs at different points, we can analyse their response to power and gain insight into their physical properties while demonstrating concepts fundamental to electrical function.

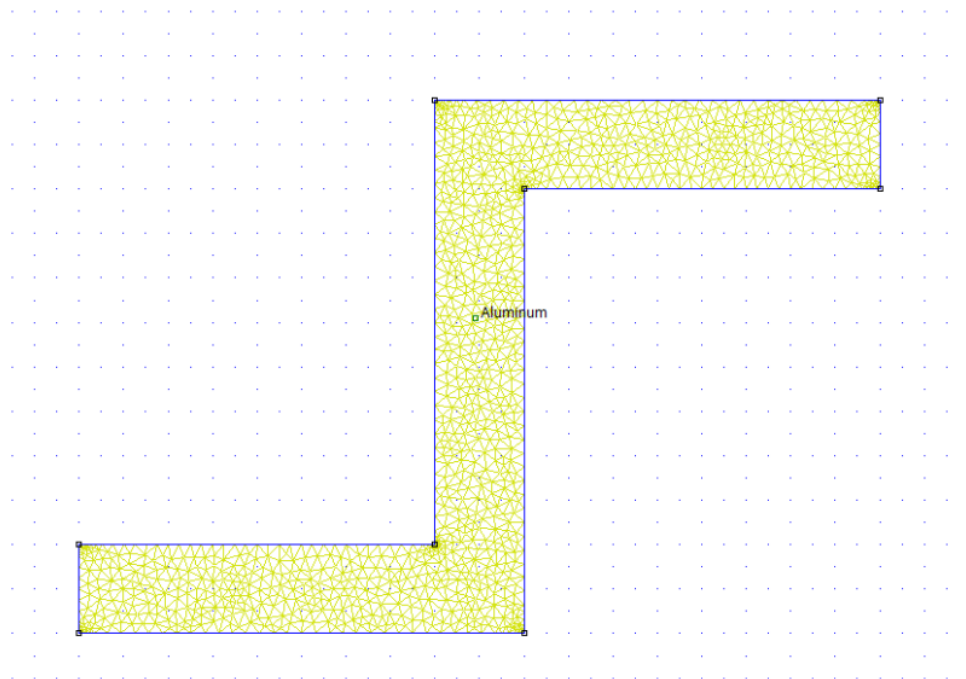
Demonstration

The demonstration for this was fairly simple, mostly comprised of measuring the distances of certain lengths in terms of time investment. Again, to initialise, coordinates for the relevant points were entered into the console using the standard notation as prescribed in the manual [4], as evident in figure 7. The basic diagram of the system is detailed in figure 8, where, as mentioned, the high east and low western edges are fed with a 5- and 7-volt input respectively> As this is a current related simulation, we should expect there to be a continuous path of current emulated throughout the conductor, when the materials are varied, should adjust to the negative between copper to aluminium, notably due to that of a lower relative conductivity, with 37700000 S/m in the aluminium and 58000000 S/m in the copper, as defined internally in FEMM. Though this is likely to be rather difficult to observe as the fundamental difference is likely to be limited in visibility due to the automatic categorisation undertaken by the diagram plotting mechanism, as such, this needs to be noted in theory as the properties, while having a significant difference in relative conductivity, are both good conductors and as such, will perform almost identically to one another without additional knowledge of operation.



Above, Figure 7





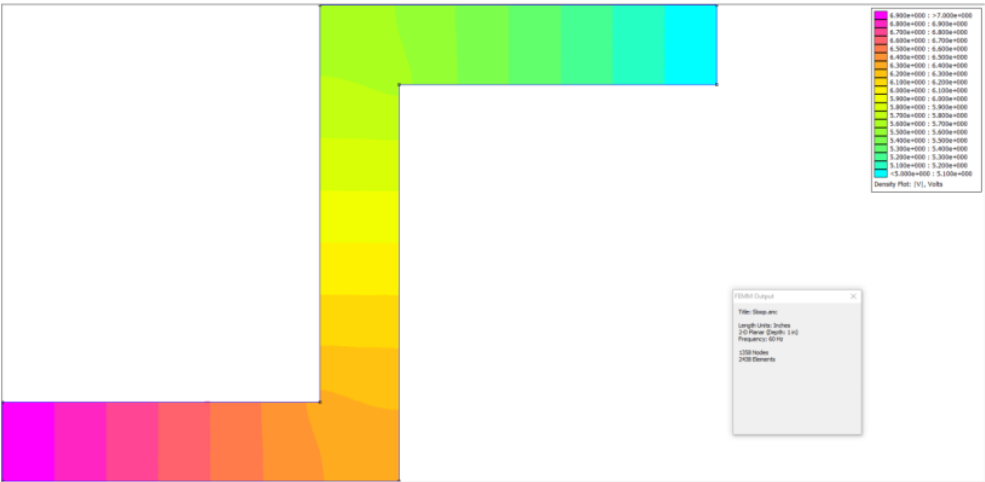
Above, figure 8



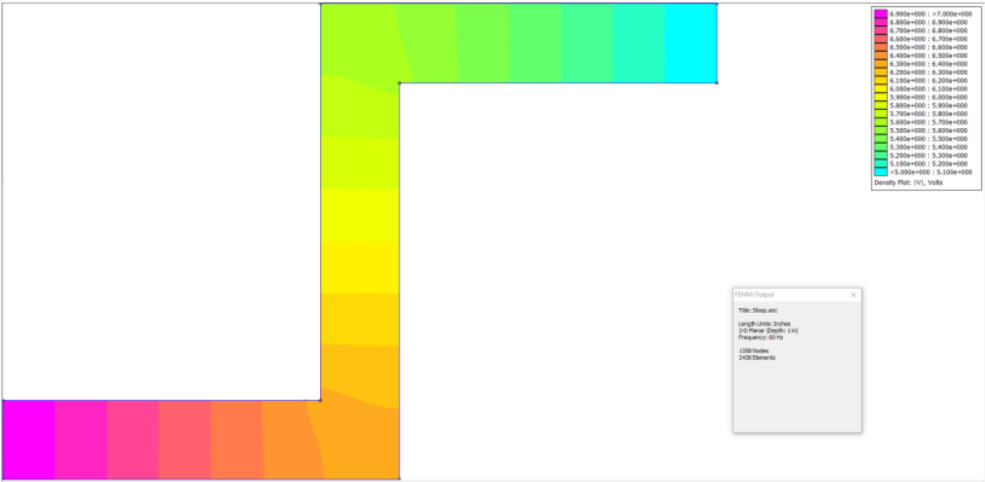
As we can see in figure 9, what was expected to occur, we notice in this case that the 7-volt side of the conductor has a power density when compared to the still charged 5-volt eastern end. In this diagram we witness evidence of several electrical phenomena and interactions. Notably we witness most easily current flow, which is dictated by Ohm's law [9], a representation of one of the most fundamental components of all of electronics, where we can witness the effective movement of electrons that are not lost due to the perfect insulation of the simulation, demonstrates the movement from the higher power to lower by charged electrons, while also demonstrating that when inside a conductive medium, the primary charge carrier exerts a force upon the free electrons, forcing the appearance of movement of the prior mentioned current, again showing that this example demonstrates the movement of the negatively charged electron to the low potential from high, while never dropping below the normalised median value of 5-volts, the lowest value of input.

Additionally, we can witness the impact of a conductive medium of the particular geometric shape as observed in this two-turn-line, as the geometric makeup of a medium also has a visible impact on the transmission of potential. While this exact example has some of the impact dulled due to the perfect insulation present in a perfectly theoretical environment, which would otherwise lead to disproportionate losses when compared to a perfectly normal line [10]. In a real example it would be expected to make losses, though we would still expect a mostly uniform distribution of charge throughout the shape as observed here, as the drop-off from charged electrons generally tends to follow a linear and non-random distribution as is easily visible in this case. As mentioned previously, it is notable that the actual level of difference between the aluminium and copper is almost unobservable, due to the fact that the simulation software works theoretically, both mediums are essentially devoid of resistance and only have a relative conductance, which, when viewed in

isolation, seems to suggest that the two mediums have an identically ideal ability. However, this is not the case and if the resistance were to be simulated along with the conductance, it would be evident that these two mediums do, indeed, have disparities.



Above, Figure 9



Above, Figure 10

10

Summary

11

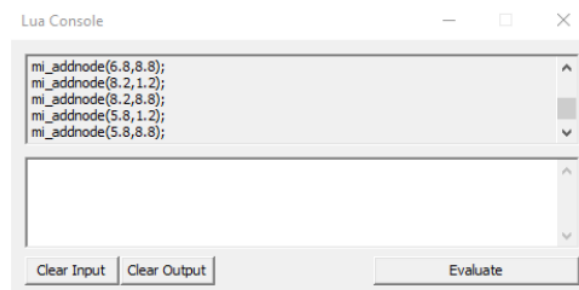
In summary, task 2 acts well as a simulation of current flow and can act as an accurate theoretical representation of current flow only. However, this software has limitation that require further consideration as few of the actual properties of the material are visible and this renders simple simulation that looks to explore anything other than conductance rather limited. It does still, nonetheless, demonstrate fundamental electrical theory effectively and illustrates how a medium functions when provided with a variety of inputs, even if in this case that was a rather underexplored avenue.

Task 3

Task Detail

Task 3 asks to create what is essentially a transformer and analyse it in terms of magnetostatics, this being made of a primary and secondary coil around a pure iron conductor. The diagram is also detailed to require 5 coils on both windings and a 200Amp current into both. Due to there being no specification requirements for the exact kind of wire, it was decided that a British standard 20 SWG [11] would suit a transformer such as this well [12], as it is commonly applied in similar circumstances. As this is a transformer it would function best to design it for an AC circuit, however, the specification for the task specifically details that the system should be designed with DC current – so the requested model would lose a lot of the focus and benefit that would come from analysing the actual magnetic field generated by the transformer operation, as the system would lack an alternating current with which Ampere’s law would define a magnetic field proportional to magnitude and direction, as the direct current would not be capable of inducing a magnetic field of the same magnitude due to the lack of variance drawing an electromagnetic interaction to such a degree. As such, the following will detail the potential uses of using AC in place of DC in this task, in addition to detailing general function demonstrated within. Aside from potentially demonstrating Ampere’s law, this system would be capable of additionally demonstrating inductance, which is witnessed to some degree in the DC variant, however, not to the same effect as an AC would have and mutual inductance simply isn’t present in DC due to the nature of direct current [13]. The details of both models and their benefits are included herein.

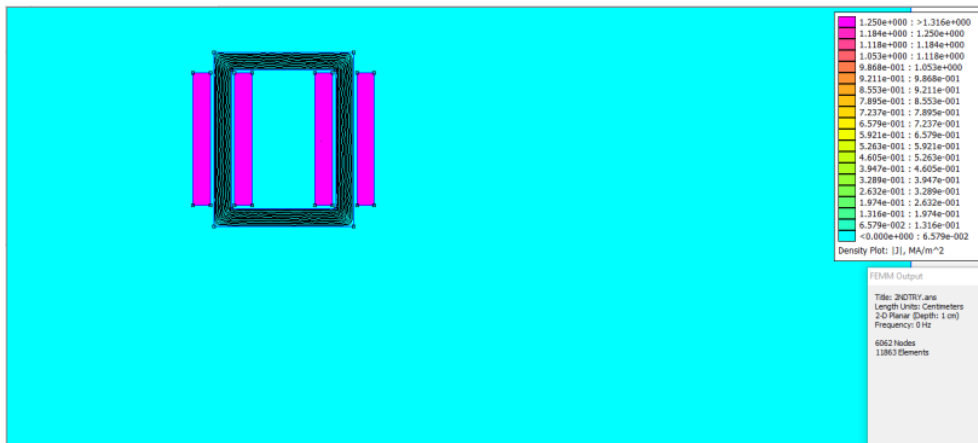
Demonstration



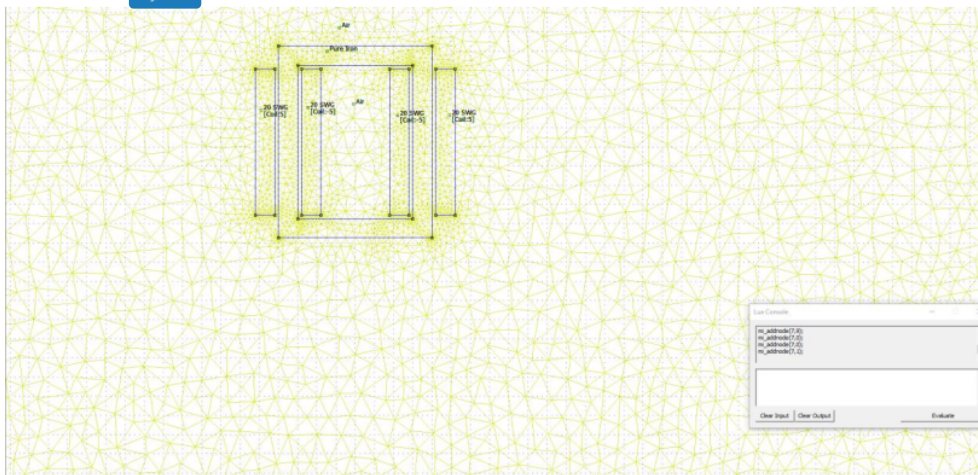
Above, Fig 12

To begin the simulation, it is required to format the diagram correctly, notably, this would have to include some precisely measured points, these being to place the coil exactly 0.2 away from the pure iron conductor, as this would be required to demonstrate the theory of inductance. This was performed akin to others in this paper [4], utilizing the console to place the nodes where required by the specification within the

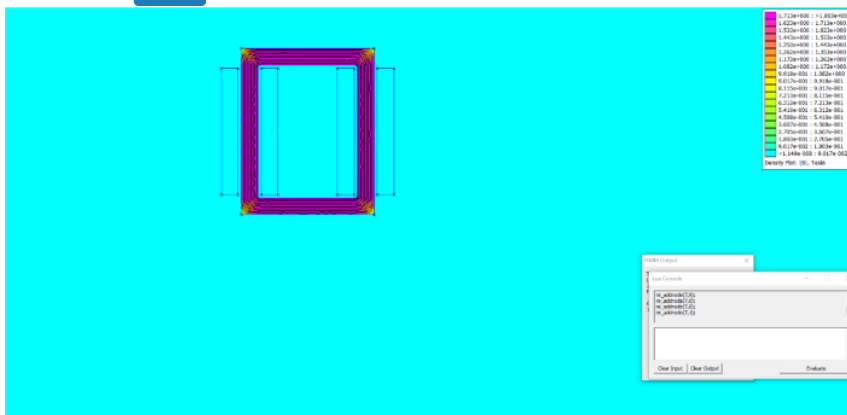
brief, as witnessed in figure 10. Following this, the materials and current were applied which, after generation of the mesh and analysis (as seen in figure 11), generated a magnetic flux diagram, as seen in figure 12, along with a current density diagram as witnessed in figure 13. Figure 12 in itself is capable of proving inductance as a theory, as there was no current passed through the pure iron conductor, as seen in figure 13, and the coil is not directly connected, there must have been induction. This is rather difficult to understand in the DC model, due to the lack of field strength inherent with AC, it is almost all focused within the conductor. This is not the case in AC, as we can witness a magnetic field much more clearly. As the conductor has less inductance on a field induced by alternation of current, it has a much lower magnetic signature comparatively, while the field external to the conductor is much greater, allowing visual confirmation that Faraday’s law has been observed in the inductance of a magnetic field separated from the coils and permeated through the conductor – with the AC variant acting as a more visual confirmation akin to a transformer while the DC variant proves an almost perfectly lossless conductor with a perfect retention of magnetic field, but does so without mutual inductance.



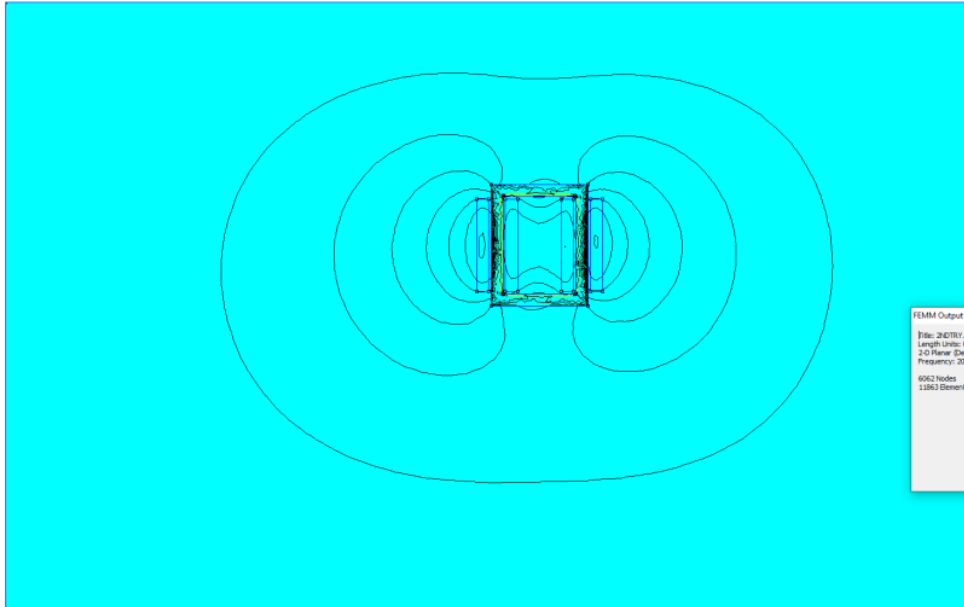
Above, Figure 13  13



Above, Figure 14  14



Above, Figure 15  15



Above, Figure 15



Summary

In conclusion, this demonstration marked by task 3 is a valid example of Faraday's law and demonstrates that a current run through coils, DC or AC, can generate a magnetic field separate to the coil in a valid conductor. Providing an example of a fundamental electronic principle that operates critical components of infrastructure and everyday usage alike.

Conclusions

In conclusion, these demonstrations have provided valuable insights into the laws governing electronics, those being Gauss's law in task 1, Ohms Law in task 2 and Faraday's Law in task 3. As such, they are valid examples of fundamental principles of electrostatic and magnetostatic interaction and provide context for a huge core segment of electromagnetics. Making this compilation of results and theory a useful insight for conducting exercises around furthering ones comprehension of details regarding governing electromagnetic laws and principles.

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FINAL GRADE

63 / 100

GENERAL COMMENTS

Instructor

Brown

Engagement with Literature Skills: *Marks: 6/10*

Inclusion of a wide range of research-informed literature, including sources retrieved independently. Selection of relevant and credible sources. Very good use of referencing conventions, consistently applied. Although some sources were missing some information

Knowledge and Understanding Skills: *Marks: 13/20*

Knowledge is reasonably detailed and accurate. A good critical understanding of the well-established concepts and principles of the electromagnetic magnetic field, which is evident through task 1, 2, and 3.

Cognitive and Intellectual Skills: *Marks: 13/20*

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

Practical Application Skills: *Marks : 20/30*

From task 1 to task 3, it is evident that there is 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 : 11/20*

A good and appropriate application of established methods, materials, tools and/or techniques. Would have

benefited from a more formalised layout, such as breaking down the assignment into more detailed numbered and named sections.

**Overall
total: 63/100**

PAGE 1



Comment 1

It is better to have a tittle page, with the student Name, Student IR , Module name, Module code etc..



Comment 2

Table of content should be in afresh page



Comment 3

It is better to number the headings and sub-headings



Comment 4

start from a fresh page

PAGE 2



Comment 5

Alignment of the text is not proper

PAGE 3

PAGE 4



Comment 6

It is better to have a brief description on the comparison of output in using two different materials is missing in this report



Comment 7

It is better to have a caption for each figure

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Comment 11

The output response graphs are missing.

PAGE 8



Comment 12

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Comment 17

The output graphs are missing



Comment 18

References, not Bibliography

A reference list is the detailed list of references that are cited in your work. A bibliography is a detailed list of references cited in your work, plus the background readings or other material that you may have read, but not actually cited.



Comment 19

It would have been better, if you can refer articles from peer reviewed articles.