## Project Title:

A Meta-analysis And Study Into Fundamentals and Enhancements Of Solenoid Based Accelerations

## Abstract:

From initial research under my electrical engineering capstone the project of a coilgun or solenoid accelerator has appalling inefficiency. There are many factors that come into the design and operation of solenoids which make them complicated to utilize effectively. The goal for this analysis is to do a large dive into the topics of solenoids, magnetic domains, feedback, external influences, and more. These topics have been lightly covered in ECE and would require further review from meeting with professors, scholarly article review, and textbook review. To get this data and review its interpretation I have my committee for my Honor’s Thesis. Furthermore, to enhance the data retrieved from this project I will test initial found results onto the manufactured coilgun, as stuff found later on may not be able to be attached to the prototype. From, documented experiments and actual experiments a comparison can be drawn and potentially modified to verify conclusions from new avenues of testing.

There is a dual approach to this problem of one using initial researched data and then using that data to create an experimentally modified coilgun from my capstone project.

## Project Description:

To enhance the operation of magnetic acceleration as well as mitigating loss due to the system there are many aspects of their operation to be studied. These aspects are quite large and can be explored into extreme depths. In this I plan to cover 3 main fields of topics which should cover the entire design of any magnetic accelerator. First is the major field of solenoid design and electromagnetics to explain the operational principles of the acceleration and some phenomena that may cause losses. Second is the technology used in coilguns/solenoids as these components need to be combined with the fundamentals for the third topic. The third topic is the technologies’ losses and their effect with delays and operational faults creating more losses. These topics are discussed below by category to explain them in detail.

## Electromagnetic Principle

To start with the electromagnetic principles of a solenoid and coil gun I have begun review with the ECE 351 textbook *Fundamentals of Applied Electromagnetics* and plan on meeting with professors in the College of Engineering and Physics department to get their experience and data on all topics. Also, there will be research into studies/experiments I can find either from professors or any research/studies found in the library or online. This section aims to cover the main principles such as electromagnetic fields (E/D and B/H), magnetostatics, electrostatics, and time-varying fields to determine effects on components tied to solenoids and the nearby system.

## Technology

Going off what is found from the experiments and research from the previous experiments to determine technologies used. These technologies will be documented for comparison and potential use in the coilgun prototype to be constructed for capstone. Furthermore, the system and layout will be also documented for the next section. This section will get review from the Thesis committee and potentially and few other peers to get the most insight into the devices and their operation. This review will include details like datasheet specifications, device principles, and combined effects of device layouts.

## System and its Losses

This section aims to combine the research from the previous sections and from the capstone project to realize faults in the system. These features will document details such as supply power, connections to and from devices, programming routines, and details that may have been left out from the technology section. The previously two sections combined will be used here to reach into how a system works in operation to make conclusions about system shortcomings and how they can be mitigated or changed to eliminate them.

# Importance:

This research aims to cover a multi-variable optimization including terms of wire cost, wire size, cooling system, cooling size, current, force, capacitor vs constant power source, solenoid layout, and likely more variables. This research in tandem with documenting others’ research will lead to many optimization programs based on what purpose of design one is doing. These topics could be solenoid valves which require long on periods and cannot suffer of overheating. Magnetic acceleration from solenoids may require high speed responses which may become a property of many aspects of the solenoid such as wire size (resistance reduction), solenoid shape (vertical vs horizontal), and overall projectile shape. Another case, is when the target is fixed and solenoid principles need optimization separately.

Another aspect of this is that most if not all aspects of a solenoid will be documented. These will include standard and experimental concepts to try to further document solutions such as fluorinert liquid pumped through the solenoid to help deal with hear conductance/convection. Different conductor shapes as to optimize conductance and field shape.

## Timeline:

For this project is tied between the Thesis and Capstone processes so both of these processes are documented below:

## A screenshot of a computer Description automatically generated

## Budget Justification:

This project aims to fund both sides of the research {Thesis and Capstone}. The main focus of investment is experimentation and documentation of the device. As well as funding partial construction of the coilgun project. As the capstone provides $150 for the construction of the project and that will cover a small portion of the project. The goal for this is to alleviate the burden of funding the parts and time to test and alter this device past capstone requirements.

For the supply side of the capstone implementation an estimate was made last semester to discuss how expensive it was. The total cost of this project came out to $868 before more research into the design. However, the main components have been determined off of this list, these being transformers, enclosures, wire, and structural aluminum.

Transformer: This has been changed to be oversized to ensure that it will not be damaged from overcurrent/overheating/switching loads. This model is a 240/480Vac to 120/240Vac 5kva transformer which will be used as a 120Vac to 60Vac transformer at 2.5Kva {linear decrease by current requirement}. Part number is [t2530144s](https://www.automationdirect.com/adc/shopping/catalog/power_products_(electrical)/transformers/encapsulated_core_general_purpose_transformers_(nema_rated)/t2530144s) 1x$575

Enclosure: This is a small enclosure to mount exposed power electronics such as 60vac to 83..2vdc, 120vac to 5vdc circuit, and circuit to control the solenoids. This is beginning to be modeled and should not be larger than a 10x10x4 enclosure. Part numbers are [sce-12n1004lp](https://www.automationdirect.com/adc/shopping/catalog/enclosures_-z-_subpanels_-z-_thermal_management_-z-_lighting/enclosures/wall-mount_enclosures/sce-12n1004lp) and [sce-12n10mp](https://www.automationdirect.com/adc/shopping/catalog/enclosures_-z-_subpanels_-z-_thermal_management_-z-_lighting/enclosure_parts_-a-_accessories/subpanels/sce-12n10mp) total of $82

Wire: From research into wire sizes the best seems to be 16awg wire which has the maximum benefits of being the cheapest and coldest wire would be 16awg wire at ~82ft at 200 turns or ~41ft at 100 turns. There will be 6 stages, which means ~492ft or ~246ft spools. The price for the spool above 492ft (625ft) is 1x$103.71. Part number is [16HNS5](https://www.digikey.com/en/products/detail/remington-industries/16HNS5/11612796?s=N4IgjCBcoOwBxVAYygMwIYBsDOBTANCAPZQDa4ADAMxxwwgC6hADgC5QgDKrATgJYA7AOYgAvoQBMVMFUQgUkDDgLEyIACwBWAJxaETEGw7d%2BwsaNFA).

Aluminum: As an estimate before getting into field decay from solenoid gap the overall mounting structure is estimated to be roughly 400cm. Automation Direct offers a decent price at $0.3/cm which comes to a total of 1x$68.70. Part website is [automationdirect](https://www.automationdirect.com/adc/shopping/catalog/structural_frames_-z-_rails/t-slotted_rails/40-4040c).

Test time: As to allow time off to drive to a test location and inspect the device operation is the purpose of the remaining funds. Or, if there is an interest in extreme modification of design such as series resistances or different control structure this fund could go into that as well. 1x$1252.59.

## Does this topic relate to Artificial Intelligence (AI)?:

No

## Does your research project have applications in Aerospace, Space Sciences, or Engineering?:

Yes, as this project is tied directly to electrical engineering. This research ties into the field of electromagnetics. Specifically, magnetic and electric fields in magnetostatics, electrostatics, magnetodynamics, electrodynamics, and kinematics.

## Does your project have applications in Health and Life Sciences to develop transformative medical-based solutions?:

No

## Does your research project relate to the COVID-19 pandemic?:

If your research is related to the COVID-19 pandemic, answer yes to this question. If you answer yes, please be sure to include details in your project description.

## Does your project require the use of Advanced Research Computing (ARC)?:

## No

## Have you taken any Research Trainings?:

I have not taken any form of research training.

## Use of CORE Equipment and Services

**Do you plan to use any CORE Equipment and Services?:**

No

## Please specify which CORE service(s) you propose to use in your project?:

## Briefly describe how your research will benefit from the service:

## What is your estimated cost of lab use fee?:

The experiments for this project will not be done on campus and will be documented by me and have the processes reviewed by committee to verify integrity and focus of each experiment to prevent error. The major test will be the projectile test otherwise additional tests will require equipment to be borrowed to be performed off campus. These could be series current shunts and a datalogger to determine current through solenoids and solenoid voltages.

Visit <https://umaine.edu/core/> to determine how much it will cost for you to use the facility/equipment. All CORE facilities have pricing listed on their websites, or someone you can contact for a cost estimate.

## Student Information Student Name:

William Poole

# Student MaineStreet ID number:

1083686

# Student Telephone Number:

603-548-6102

## Student GPA:

3.711

## University:

University of Maine

## University of Maine

If, in the previous question, you indicated that you are attending the University of Maine, you will be sent to this section.

## Student Major:

Electrical Engineering Major

## Student Program:

Bachelor of Science

## Student’s College:

College of Engineering (COE)

## Are you part of the Honors College Program?:

Yes

## Student Expected Graduation Date:

May 2024

## Are you a U.S. Citizen?:

Yes

## Faculty Mentor Information

Research Interests:

Microelectronics Analog and Mixed-Signal

Integrated Circuit Design

Electronic Materials

Computer Modeling and Simulation Education

Ph.D. Engineering Applied Science, University of California, Davis, 1988

M.S. Engineering Applied Science, University of California, Davis, 1984

B.E.E. Electrical Engineering, University of Dayton, 1981

## Faculty Mentor Name:

David E. Kotecki

## Faculty Mentor College:

COE

## Faculty Mentor Department:

College of Engineering

## Faculty Mentor Telephone Number:

 (207) 581-2248

## Faculty Mentor’s Email:

kotecki@maine.edu

## Has this proposal been submitted to any other funding program?:

## No

## Additional Documentation:

If you have additional documentation you would like to add, you may upload it into the Google Drive. Please label it as follows: lastname.firstnameAwardtypeandyear (Example:Smith.JohnAY2324 or Smith.JohnSummer24) and paste the link in the text box provided. Please be sure to make the file(s) shareable with all of the UMaine system so we can access it.

## How did you hear about CUGR and our fellowship opportunities?:

Honors college meeting in intro to thesis class.

## Would you like to opt into the UMaine System’s Micro-Credentials Undergraduate Research Scholar Program?:

## No

## Faculty Commitment Letter:

Faculty commitment letter is a letter from the faculty member who will be mentoring you through the fellowship program. This letter should be submitted by the Faculty Commitment Letter Form. The link for this form is on our website or you can send the form to them directly to be sure we receive it before the deadline. The letter text should be pasted into the text box provided or uploaded to the form as a PDF. They are part of the rubric as well.

* The rubric for the Faculty Mentor Commitment Letter is as follows:
  + 1- Lack of faculty commitment letter
  + 2- The letter is missing both student potential and faculty commitment
  + 3- The letter states faculty commitment but is lacking student potential
  + 4- The letter states student potential but is lacking faculty commitment
  + 5- The letter clearly states both student potential and faculty commitment