## Project Title:

A Study Into The Fundamentals and Enhancements Of Solenoid Based Accelerators

## 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 the construction of 4 test systems, 2 of these test are supplies based capacitor and battery bank, the other 2 are solenoid shapes. As these supplies are very expensive, as they are large in terms of energy density and power output. The components are estimated to be the following:

[Battery Bank](https://shop.advanceautoparts.com/p/diehard-marine-starting-battery-24m-group-size-500-cca-625-ca-95-minute-reserve-capacity-m24-1/2080001-p?product_channel=local&store=5904&adtype=pla&product_channel=local&store_code=5904&&&gclid=Cj0KCQjwpc-oBhCGARIsAH6ote8AkTu7i8Tuw4bXQCP0HfSs5ijMwDyGb7BZ105aqWUab9OIV7qp-NgaAiQjEALw_wcB&gclsrc=aw.ds) | 4x$121.99 | This is to get the voltage to 4x12Vdc=48Vdc and with enough current to prevent over current faults. The quantity is necessary, as to get the voltage high enough to allow current to go through the power MOSFETs and high enough to generate a significant magnetic field.

Capacitor Bank | unk | This bank will be designed to get a single run of a coil gun to operate for one run though this maybe at a high voltage drop through the circuit.

Circuit Charger | $100 | this is to get one charger to get even voltage charging on both circuits

[Control Power MOSFETs](https://www.digikey.com/en/products/detail/vishay-general-semiconductor-diodes-division/VS-FC420SA10/7427232) | 4x$23.29 | These are very high power mosfets designed to handle incredible power of the circuit

[MOSFET Coolers](https://www.digikey.com/en/products/detail/ohmite/VXA-55-101E/13242738) | 4x$4.47 | These are to ensure safety of the power mosfets.

Battery Depassivator | $150 | This circuit is a tester into a partial study into batteries as an alternative source. Using a [large resistor](https://www.digikey.com/en/products/detail/riedon/UAL25-200RF8/3886594) to allow the batteries to discharge to clean their plates. This is to minimize the voltage delay. \*This includes a custom board controlled by the Arduino.

[Resistor shunt](https://www.digikey.com/en/products/detail/vishay-dale/WSBS85181L000JK35/6709522) | $20.20 | This a measuring device to get the current measurements out of the capacitor bank

## 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