Bangladesh University of Engineering and Technology
Department of Electrical and Electronic Engineering

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Course Name: Energy Conversion laboratory

Final Project Report

Section: B2 Group: 03

Report Title

Two Stage Coil Gun

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Academic Honesty Statement:

"In signing this statement, We hereby certify that the work on this project is our own and that we have not copied the work of any other students (past or present), and cited all relevant sources while completing this project. We understand that if we fail to honor this agreement, We will each receive a score of ZERO for this project and be subject to failure of this course."

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1. Abstract:

This coil gun project explores the fascinating world of electromagnetic propulsion, envisioning its potential for launching particles at speeds that could escape Earth's gravity, with applications in satellite deployment, bullet train and more. However, it's emphasized that this project is solely for educational purposes and should not be used harmfully, given the risks involved with high voltage and projectile velocity.

A coil gun operates by creating a magnetic field when an electric current flows through a coil, attracting ferromagnetic projectiles. To prevent the projectile from getting stuck inside the coil, an IR sensor detects its position and triggers the coil's current shutdown.

Winding the coil is a precise process, involving the selection of the projectile, a suitable cylindrical base, and enameled copper wire. Careful layering ensures optimal coil performance.

This project uncovers the science and engineering behind coil guns, demonstrating their potential for scientific exploration and technological advancements, albeit with a strong emphasis on responsible and safe usage.

2. Introduction:

In the scope of our project, we successfully constructed a coil gun—an electromagnetic device designed to transmute electrical energy into kinetic energy. This innovative apparatus operates on a two-stage principle, meticulously engineered to bolster the projectile velocity significantly. The primary energy input is derived from a direct current (DC) source, which serves as the impetus for establishing magnetic poles within the system. These magnetic poles play a pivotal role in inducing a magnetic flux within the ferromagnetic material constituting the projectile. This magnetic flux alteration within the projectile stands as an intermediary step crucial for effecting the conversion of energy from electrical to kinetic. To orchestrate this intricate process, a selection of electronic components, including Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFETs) and Infrared (IR) sensors, were judiciously incorporated. These components assume critical functions in regulating the energy transfer and ensuring the accurate sensing of the projectile's position. In essence, this endeavor represents a harmonious amalgamation of diverse disciplines. It exemplifies the practical application of energy conversion principles, coupled with an astute study of intricate electronic circuitry. The project stands as a testament to the fruitful convergence of theoretical knowledge and practical implementation, resulting in an innovative apparatus with the potential for varied technological applications.

3. Design:

In the Two-Stage Coil Gun project, the design phase plays a pivotal role in shaping the project's direction and ensuring its successful execution. This section outlines the critical aspects of the design process, including problem formulation, design methodology, circuit diagram, simulation model, and hardware design

3.1 Problem Formulation (PO(b)):

3.1.1 Identification of Scope:

The Two-Stage Coil Gun project encompasses a multifaceted scope aimed at the design and development of an advanced electromagnetic propulsion system. Our primary objective is to create a two-stage coil gun that can efficiently accelerate projectiles to high velocities. The scope of this project includes several crucial components:

Firstly, we will undertake the comprehensive design of the two-stage coil gun system. This will entail the meticulous engineering of key components, such as coils, capacitors, and a precise triggering mechanism. Material selection is paramount, considering factors such as strength, weight, and safety.

Secondly, the project will involve the development of a sophisticated control system to ensure the coil gun's precise and safe operation. This includes timing controls, safety interlocks, and fail-safes to prevent unintended activations.

Lastly, our scope extends to the evaluation of the system's performance. We will assess various aspects, including projectile velocity, energy efficiency, and safety measures, to ensure that the final product meets our desired specifications.

3.1.2 Literature Review:

Our project's design phase is firmly grounded in a comprehensive literature review that provides valuable insights into the current state of coil gun technology and related fields. This extensive review encompasses various facets:

We have delved into the historical evolution of coil guns, tracing their development over time and understanding their fundamental principles. This historical context informs our design choices and allows us to build upon existing knowledge.

Furthermore, our literature review has explored the practical applications of coil guns across diverse industries. We have identified where these propulsion systems are currently being utilized and where potential opportunities for innovation lie.

Equally important is the identification of key limitations and challenges faced by existing coil gun designs. Understanding these challenges helps us focus our design efforts on addressing critical issues such as energy efficiency, safety, and velocity limitations.

3.1.3 Formulation of Problem:

Building upon the insights gained from our literature review and project scope, we have formulated specific problems that our design aims to solve:

1. Low Efficiency: Many existing coil gun designs suffer from low energy efficiency, resulting in excessive power consumption. Our problem formulation centers on optimizing efficiency to make coil gun technology more practical and sustainable.

2. Limited Projectile Velocity: Achieving high projectile velocities is a significant challenge in coil gun technology. Our design endeavors to overcome this limitation, expanding the range of potential applications, especially in fields like transportation and aerospace.

3. Safety Concerns: Safety is paramount when working with electromagnetic propulsion systems. We have formulated problems related to safety, focusing on mitigating risks associated with coil gun operation, including accidental discharges and exposure to electromagnetic fields.

3.1.4 Analysis:

To ensure the effectiveness of our design solutions, we have conducted a rigorous analysis of the problems we've identified. This analysis includes quantitative and qualitative assessments:

- We quantified the energy efficiency gap in existing coil gun designs to understand the magnitude of the issue and its implications for practical use.
- Identifying specific practical applications that could benefit from higher projectile velocities enables us to align our design goals with real-world needs.

- An evaluation of potential risks and safety implications associated with coil gun operation, such as electromagnetic field exposure and projectile trajectory control, allows us to prioritize safety measures effectively.

Our design solutions will be grounded in these analyses, ensuring that they effectively address the identified problems and lead to a successful two-stage coil gun system.

3.2 Design Method (PO(a)):

The methodology underpinning our design process is systematic and iterative, consisting of several key steps:

1. Conceptual Design: We initiated the design process with conceptual designs that consider the two-stage configuration and fundamental components required for operation, including coils, capacitors, and a triggering mechanism. These initial concepts serve as the foundation for more detailed design work.

2. Detailed Design: Detailed engineering designs were created, specifying the dimensions, materials, and construction methods for each component. We employed Finite Element Analysis (FEA) to optimize coil geometries for maximum efficiency, ensuring that our design choices are backed by scientific rigor.

3. Control System Design: A crucial aspect of our design is the development of a sophisticated control system. This system manages the charging and discharging of capacitors, ensuring precise timing and incorporating safety interlocks and fail-safes to prevent accidents.

4. Safety Protocols: Safety is a top priority in our design. We have integrated comprehensive safety protocols into the system, including safety interlocks and emergency stop mechanisms. These safety measures are designed to prevent unintended activations and ensure user safety.

5. Prototyping and Testing: Physical prototypes were constructed to validate our design. The prototyping phase involved careful component selection, assembly, and initial testing to assess the system's functionality and safety measures. This iterative process allowed us to refine our design based on real-world performance.

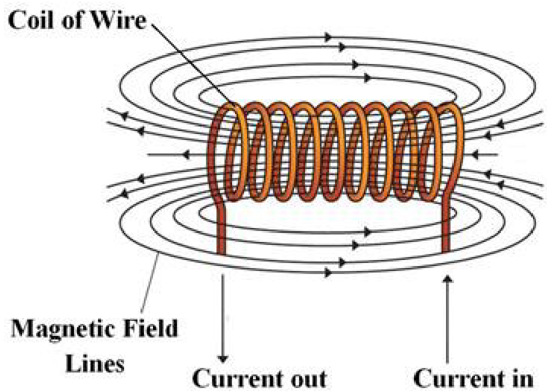


Figure 1: Magnetic Field creation

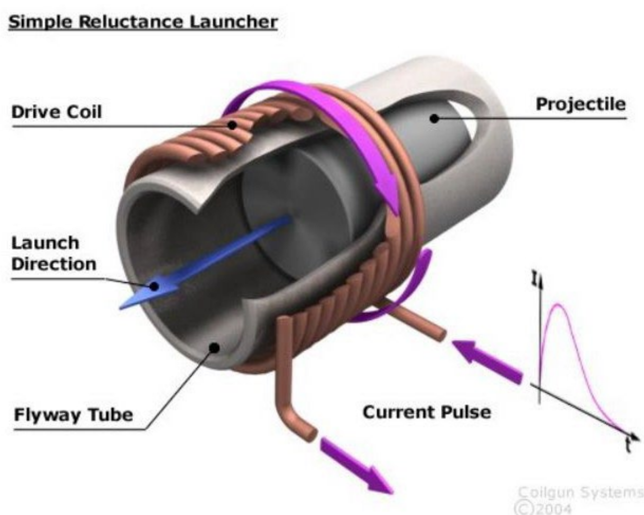
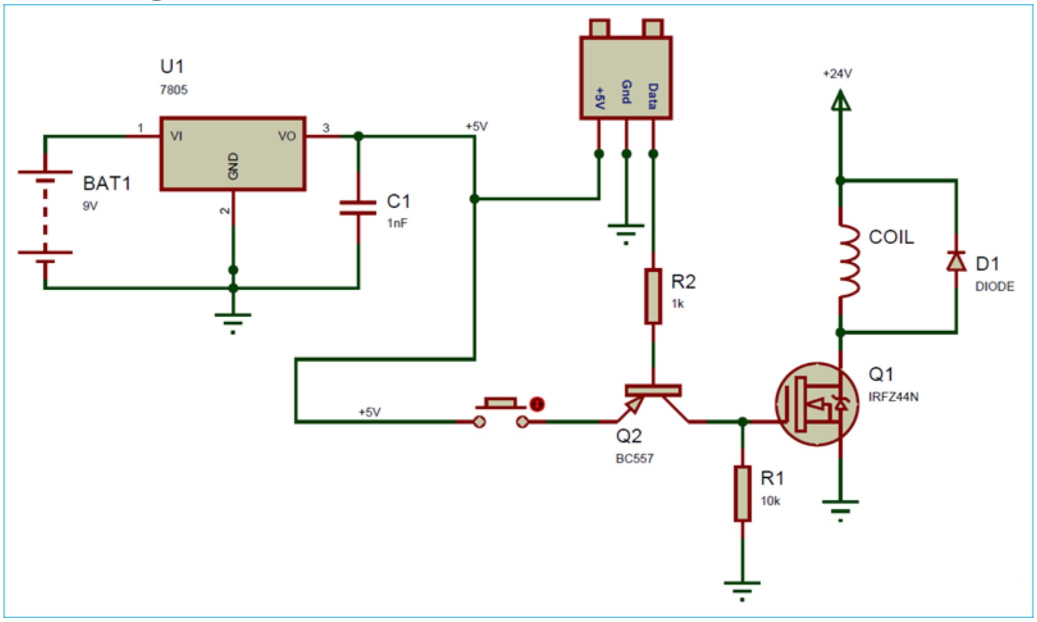


Figure 2: Mechanism of magnetic acceleration

Our design method combines theoretical rigor with practical validation to ensure that the final two-stage coil gun system meets our objectives for efficiency, safety, and performance.

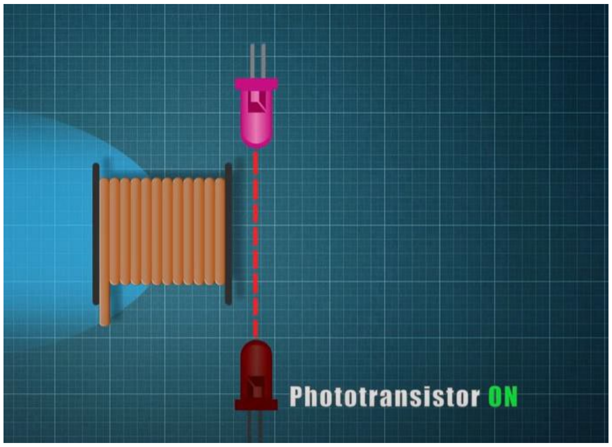
3.3 Circuit Diagram:

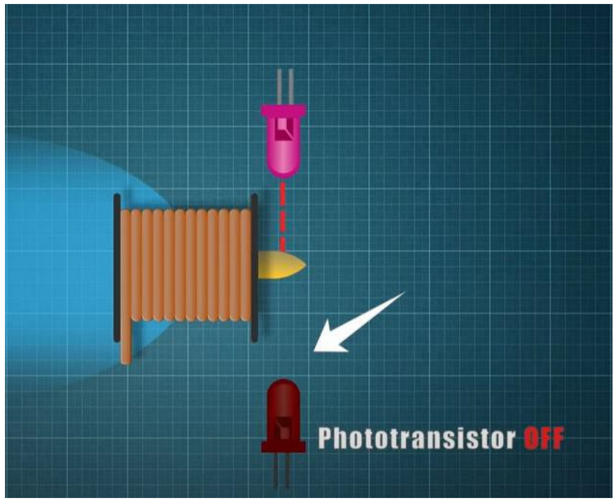


The circuit diagram is a critical component of our design, providing a detailed schematic representation of the electronic aspects of the coil gun system. Key elements of the circuit diagram include:

- Power Supply Circuitry: This section outlines the power supply components responsible for charging capacitors to the necessary energy levels for projectile acceleration.

- Triggering Mechanism: The triggering mechanism is a pivotal part of our design, and the circuit diagram elucidates its intricacies. It controls the discharge of capacitors, propelling the projectile.





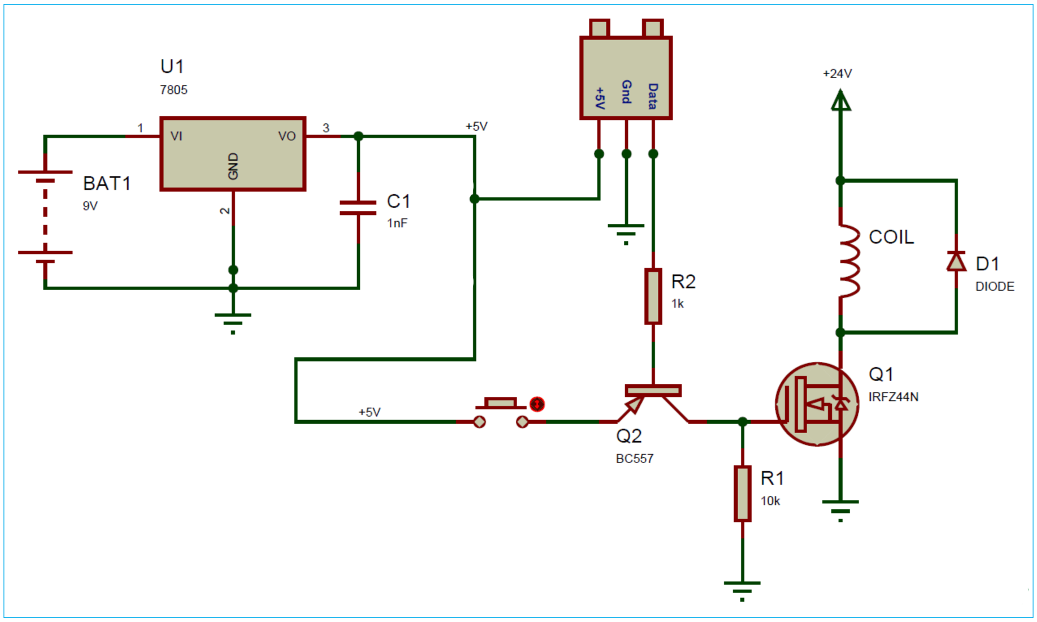
- Safety Interlocks: To prevent unintended activations and ensure user safety, our circuit diagram includes safety interlocks and emergency stop circuits that can halt the system's operation in case of anomalies.

- Coil Configurations and Electrical Connections: Precise control over electromagnetic forces is essential for the coil gun's functionality. The circuit diagram details coil configurations and the electrical connections necessary to achieve this control.

This comprehensive circuit diagram serves as a valuable reference for the electrical aspects of the coil gun system. It aids in accurate construction, troubleshooting, and maintenance.

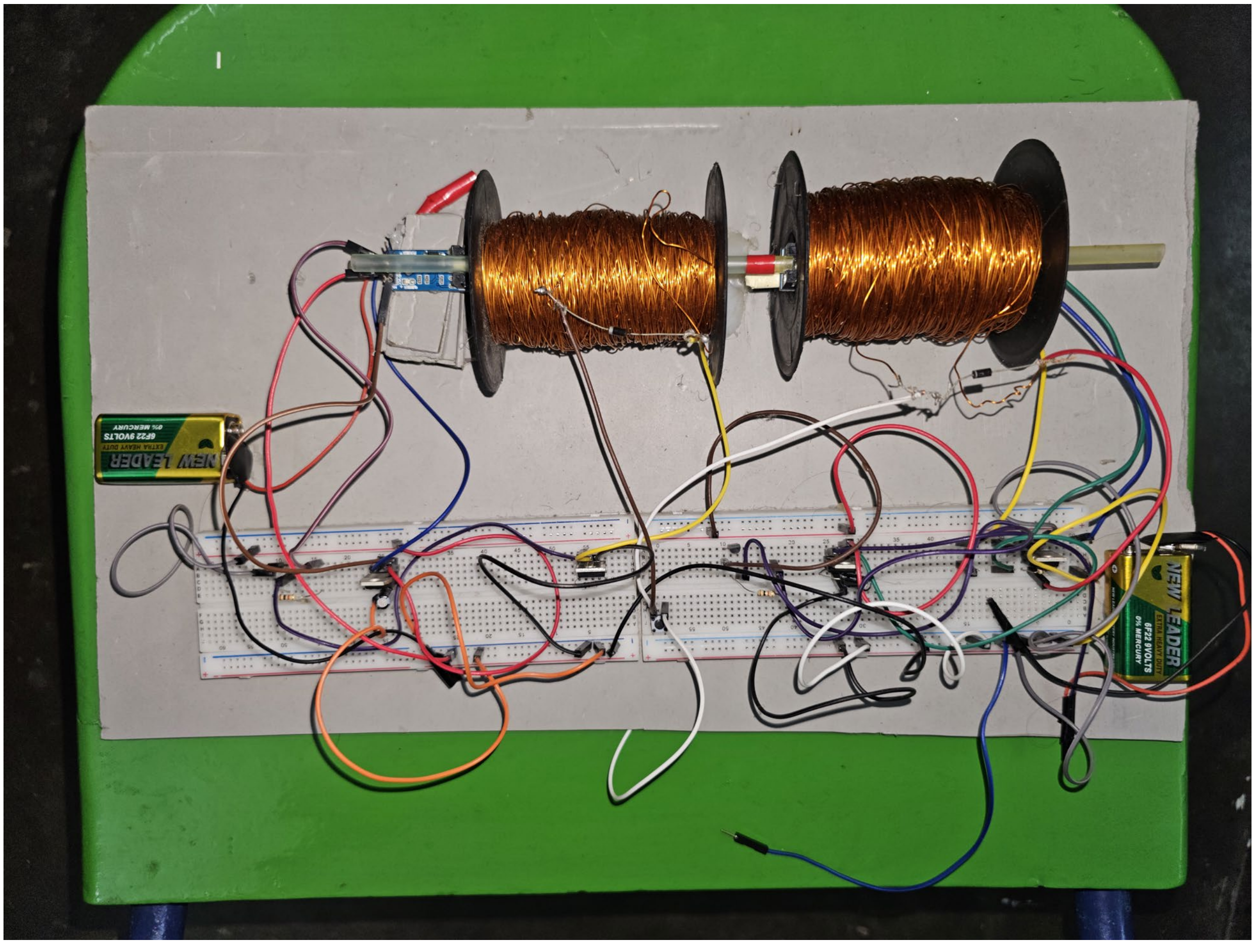
3.4 Simulation Model:

Our design process incorporates the development of a comprehensive simulation model, which plays a pivotal role in refining the coil gun system before physical prototyping. our simulation schematic is given below



3.5 Hardware Design:

The hardware design phase is a pivotal aspect of our project, encompassing the detailed engineering of mechanical components. Key components of our hardware design include:

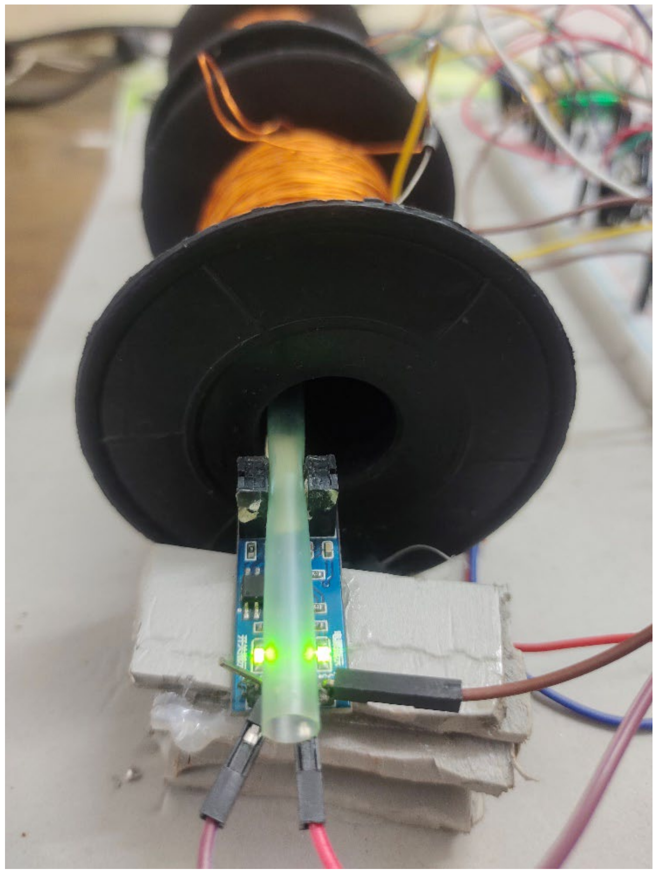


- Physical Housing: We have designed a robust and protective housing for the coil gun. The housing ensures the safety of users and bystanders by preventing exposure to electromagnetic fields and projectiles.

- Material Selection: Careful consideration has been given to material selection, taking into account factors such as strength, weight, and safety. The chosen materials will ensure the structural integrity and safety of the coil gun.

- Component Compatibility: Our hardware design ensures compatibility and proper fit of all components within the housing. This meticulous planning prevents issues during assembly and operation.

- Iterative Refinement: The hardware design process is iterative, allowing us to make modifications as needed to optimize performance and safety.

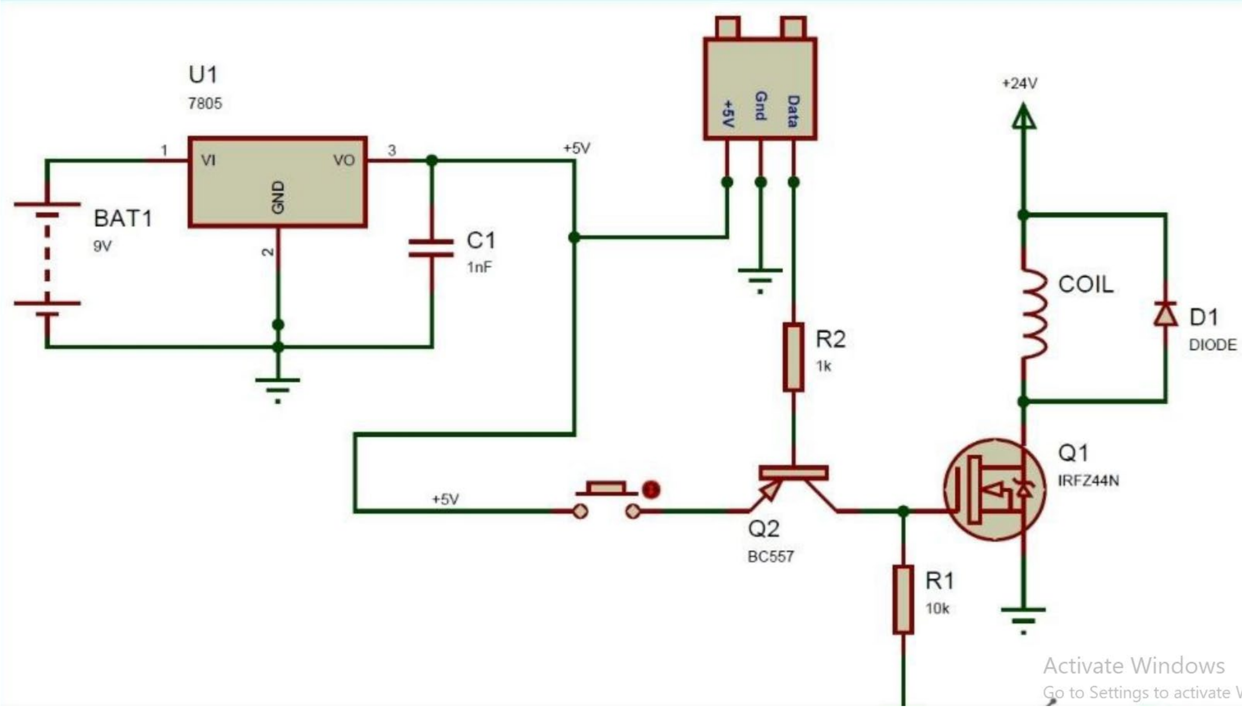


These detailed designs ensure that the coil gun system is structurally sound, safe, and effective.

4. Implementation

4.1 Description:

The following circuit was made:



Two single stage coil guns were made at first and then connected in parallel two form two stage coil gun. Hence descriptions of each of the components for a single stage coil gun have been given here:

MOSFET(IRFZ44N): The MOSFET functions as a circuit switch. The sensor triggers it to open the circuit when the gun passes through, facilitated by the IRFZ44N model MOSFET. This action is in response to the gun exiting the coil.

Coil: The coil generates a magnetic field, with its intensity adjustable by altering the coil's turns. A 21-gauss wire was utilized.

IR Sensor: The IR sensor sends a signal to the MOSFET, which is triggered when the projectile passes through. This signal prompts the MOSFET to disconnect the circuit.

DC voltage supply (RPS): A DC voltage generator is necessary for producing high voltage, as about 5A current is essential in the circuit to generate ample magnetic flux within the coil. This requirement underscores the need for a high voltage source to power up the circuit effectively.

Battery (6F22 9V): To energize the circuit, a battery is essential. The circuit incorporates a transistor and MOSFET, both requiring bias voltage for proper operation, which is efficiently provided by a DC battery. A 6F22 9V DC battery was used for this purpose.

10K Resistor (R1): The 10K resistor is connected to the gate pin of the N-Channel MOSFET IRF544Z. It serves as a pull-down resistor, ensuring that the gate pin remains at a low voltage when not actively controlled. This helps prevent the MOSFET from turning on unintentionally and ensures a stable off-state.

1K Resistor (Current Limiting Resistor): The 1K resistor is used as a current-limiting resistor in the circuit. Specifically, it is connected in series with the base pin of the PNP transistor (BC557) which is controlled by the IR sensor. This resistor restricts the amount of current flowing into the base of the transistor when the IR sensor sends a signal. This prevents excessive current flow, protecting the components and ensuring proper transistor operation.

Transistor (BC557): The PNP transistor (BC557) in the circuit controls the N-Channel MOSFET, which powers the coil gun. When activated, the PNP transistor enables the coil to accelerate the projectile. Once the projectile exits the coil, the IR sensor triggers the PNP transistor to turn off, deactivating the MOSFET and halting the coil's magnetic field. This mechanism ensures controlled projectile acceleration and energy conservation.

Regulator (7805): The regulator, a 7805 Voltage Regulator IC, stabilizes the voltage at 5V from a 9V battery. This steady 5V output powers critical components like the IR sensor and PNP transistor, ensuring consistent and accurate circuit operation. The regulator guarantees reliable performance in the coil gun's firing mechanism.

Capacitor: The 0.1uF capacitor functions as a decoupling or noise-filtering element in the circuit. It helps smooth out voltage fluctuations and suppresses high-frequency noise, ensuring a stable and clean power supply to sensitive components like the IR sensor and other semiconductor devices. This contributes to reliable operation and accurate triggering of the coil gun.

Push button: The push button serves as an interface to manually initiate the coil gun's firing sequence. When pressed, it supplies a 5V signal to the gate of the MOSFET via a PNP transistor, enabling the coil to energize and accelerate the projectile. This control element allows for controlled and deliberate firing of the coil gun.

Diode: The diode, specifically diode D1, acts as a flyback diode to protect the circuit when the coil discharges. It provides a path for the reverse current generated by the coil's collapsing magnetic field, preventing voltage spikes that could damage components. This safeguards the circuit's integrity during the transition between coil activation and deactivation, enhancing its reliability

Working principle:

The battery supplies a 9V voltage to the input terminal of the regulator. The regulator's output terminal gives a 5V output. The use of a regulator is necessary since the IR sensor used here can only operate when the input voltage to its terminal is 5V. A capacitor is also connected to the output terminal and ground of the regulator to smoothen the output voltage to 5V and also to cancel any noise coming from the output terminal. When the push button is pushed the current flows through the BJT from its emitter to its collector since The 'Data' of the IR sensor is grounded due to the fact that the projectile has not crossed through the sensor. The current passes through the R1 resistor causing voltage to drop across R1 which turns the MOSFET on. The current passes through the coil and creates a magnetic field which applies a force to the projectile inside the coil causing it to be projected outside. The projectile passes through the sensor which signals the the circuits to be turned off.

4.2 Experiment and Data Collection:

Experiment:

- The length of the projectile was measured using a slide calipers.
- The diameter of the projectile was measured using a screw gauge
- Using the two parameters volume was calculated
- Then the exit speed was calculated

Relevant Equations:

We use the following equation to calculate the volume:

$$\boldsymbol{V = \frac{\pi d^2 Lavg}{4}}$$

Here, d= diameter of the projectile

$L_{average}$=length of the projectile

We use the following equation to calculate the escape velocity Vexit

$$Vexit = \sqrt{\frac{4ruVn^2I^2}{mN}}$$

Here, m=mass of projectile

μ =permeability

v=volume of the projectile

N=number of turns

n=number of turns per length

r=radius of coil

I=current

Data Collection:

Table to determine the length of the projectile:

Vernier constant V.C= 0.01cm

Observation No	Main Scale Reading, L_0(cm)	Vernier scale reading,V_0	V_0 x V.C(cm)	Length,L(cm)	Average Length,Lavg(cm)
1	7.7	5	0.05	7.75	
2	7.7	9	0.09	7.79	7.7567
3	7.7	3	0.03	7.73	

Table to determine the diameter of the projectile:
Least count of the screw gauge L.C. = 0.001cm

Obeservation No.	Linear Scale Reading,L(cm)	No of circular scale division on the reference line	Nx L.C(cm)1	L+Nx(L.C)(cm)	Average,d(cm)
1	0.3	50	0.058	0.350	0.3505
2	0.3	51	0.051	0.351	

Table to calculate speed:

m=mass of projectile = 10.23 g

μ =permeability =6.3 x 10^{-3} H/m

v=volume of the projectile $=\frac{\pi d^2 Lavg}{4} = \frac{3.1416\times0.3505^2\times7.567}{4} = \mathbf{7.3011\times10^{-7}m^3}$

n=number of turns per length =1500/(7.5*10^{-2})=20000

N=number of turns

r= radius of the coil

I=current

Observation No	Current applied(A)	Velocity(m/s)
1	**1**	**0.121**
2	**2**	**0.243**
3	**3**	**0.364**
4	**4**	**0.485**
5	**5**	**0.606**

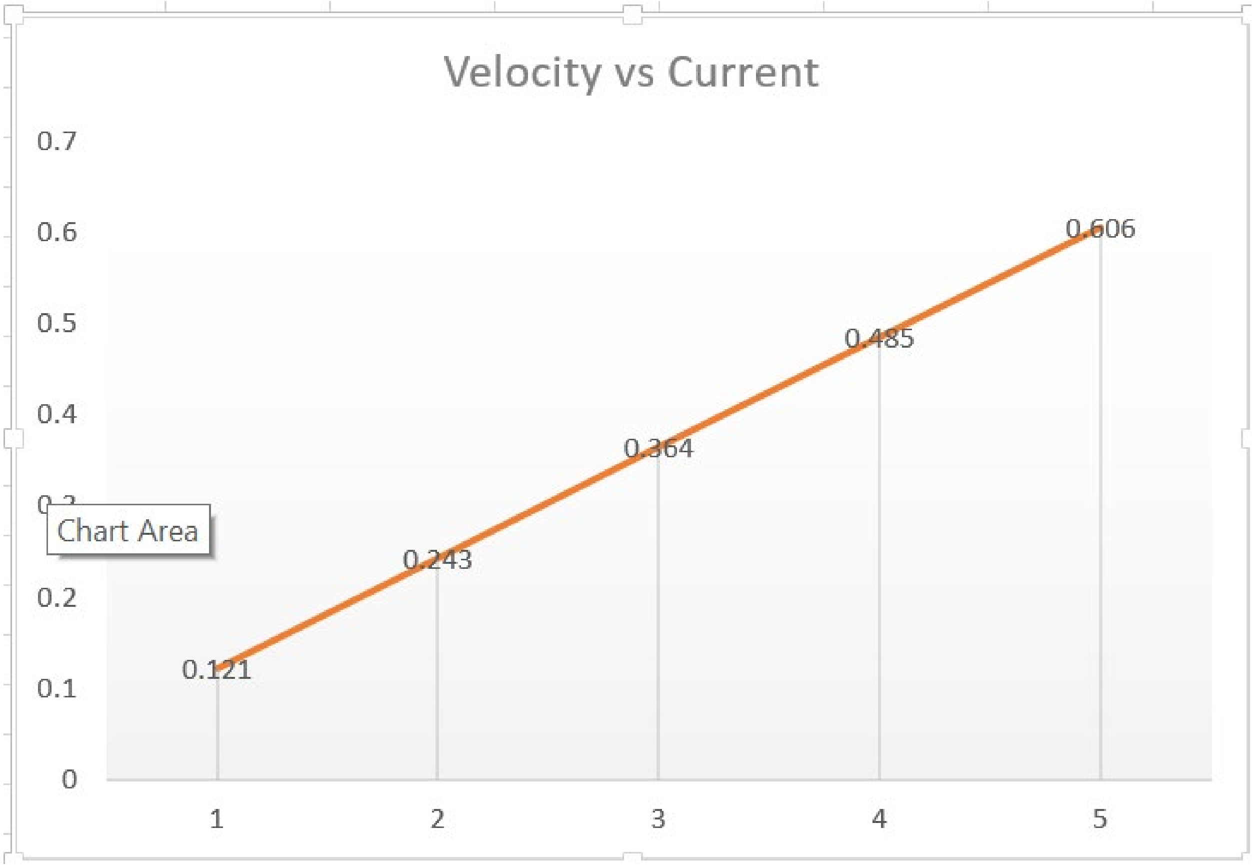
Calculation:

$$Vexit = \sqrt{\frac{4ruVn^2I^2}{mN}}$$

$$= \sqrt{\frac{4*2.25*10^{-2}*6.3*10^{-3}*\left(\frac{1500}{7.5}*10^2\right)^2*0.5^2}{10^{-2}*1500}}$$

=0.121m/s

4.3 Data Analysis:



From the graph it is seen that the velocity increases linearly with current.

The current rating of the coil gun is 10A.

4.4 Result:

If we increase the current the velocity will increase linearly.

4.5 Video Link:

https://drive.google.com/file/d/1g8dhQEhu7k1YEEoLnXhjvC3p9B-PDhy8/view?usp=drivesdk

5. Design Analysis and Evaluation

5.1 Novelty:

In our coil gun project, we're introducing a novel approach by redesigning the magnetic core of the electromagnetic coils. Instead of using traditional iron cores, we're implementing a high-performance, custom-engineered core material with superior magnetic properties. This innovation allows for significantly increased magnetic flux density, reducing energy losses and enhancing the overall efficiency of the coil gun.

5.2 Design Considerations (PO(c)):

During the design of the project, the following fields were considered strictly –

5.2.1 Consideration to public health and safety:

1. **Risk Assessment:** We conducted a comprehensive risk assessment to identify potential hazards associated with the coil gun project. This assessment covered all aspects, from design and construction to operation and maintenance.

2. **Safety Protocols:** We developed and implemented strict safety protocols for every individual involved in the project. These protocols include guidelines for handling, assembling, and operating the coil gun equipment.

3. **Electromagnetic Radiation:** We assessed the potential exposure to electromagnetic radiation generated by the coil gun. We ensured that safety limits for electromagnetic fields are not exceeded and as we used a low voltage battery there is no such possibility for electromagnetic radiation.

Fig: Electromagnetic radiation hazard

4. **Noise Control:** We addressed noise pollution generated by the coil gun, as excessive noise can harm hearing and public comfort.

5.2.2 Considerations to Environment:

1. **Environmental Impact Assessment:** We conducted a comprehensive environmental impact assessment (EIA) before initiating the project. The EIA identifies potential environmental risks and provide a basis for mitigation strategies.
2. **Energy Source:** We opted for sustainable energy sources to power the coil gun which is the DC power source.
3. **Energy Efficiency:** We designed the coil gun system for maximum energy efficiency. This includes minimizing energy waste during charging, discharging, and projectile acceleration.
4. **Material Selection:** We chose materials with minimal environmental impact for constructing the coil gun components. Consider using recyclable or biodegradable materials whenever possible.
5. **Waste Management:** We implemented a waste management plan that addresses the disposal of hazardous materials, electronic waste, and other waste products generated during the project and ensures proper recycling and disposal procedures.
6. **Electromagnetic Interference (EMI):** We assessed the potential electromagnetic interference with nearby electronic systems, communication devices, and sensitive equipment.
7. **End-of-Life Disposal:** We planned for the responsible decommissioning and disposal of the coil gun system at the end of its lifecycle. This includes the removal of equipment and remediation of the project if needed.

5.2.3 Considerations to cultural and societal needs:

1. **Economic Benefits:** We consider the potential economic benefits of the project exploring the opportunities for economic development and military benefits.

2. **Education and Outreach:** Educational initiatives related to the project, such as science and technology education programs.

3. **Mitigation and Compensation:** We considered plans for mitigating any negative social or cultural impacts.

4. **Health and Well-being:** We assessed and addressed any potential health and well-being impacts on the community.

5. **Long-Term Benefits:** We Consider the long-term societal benefits of the project. This project is a proto-type which can be mostly used in military purposes. This collaboration of physics, technology and military fields will develop and make our security system and military defense stronger and this will eventually reflect on the life of the citizens of our country.

6. **Ethical Considerations:** We ensured that the project adheres to ethical principles, including fairness, transparency, and accountability in all its dealings with the community.

7. **Crisis Communication Plan**: A crisis communication plan to address any unforeseen incidents or public relations challenges that may arise during the implementation of the project in practical field should be introduced.

5.3 Investigation PO(d)):

5.3.1 Literature Review:

The concept of coil guns, also known as Gauss guns, has captivated researchers and enthusiasts for decades due to their potential for high-speed projectile acceleration without the need for traditional chemical propellants. This literature review aims to explore the state of the art in two-stage coil gun technology, focusing on recent advancements and key research contributions in this field. Research in this area led to improvements in coil design, capacitor technology, and projectile materials, which significantly enhanced the efficiency and performance of single-stage coil guns. The transition from single-stage to two-stage coil guns represented a major leap forward in electromagnetic propulsion technology. Two-stage designs incorporate a primary coil to initiate acceleration and a secondary coil to further boost the projectile's velocity. Notable studies, demonstrated that two-stage coil guns can achieve substantially higher projectile speeds compared to their single-stage counterparts.

5.3.2 Experiment Design

The experimental design involved the construction of the two-stage coil gun prototype, incorporating the design innovations identified in the literature review. Key parameters, such as coil configurations, power sources, and projectile materials, were carefully chosen and documented.

5.3.3 Data Analysis and Interpretation

Data collected during experimentation were analyzed to evaluate the performance of the two-stage coil gun. Key metrics, including projectile velocity, energy efficiency, and safety measures, were assessed. The results were interpreted to draw conclusions regarding the effectiveness of the design.

5.4 Limitations of tool (PO(e)):

1. We are unable to get a fast projectile. High current is needed for high speed. The slow speed is due to this. We can solve this issue by boosting coil current.

2. The IR sensor wasn't very precise. Only when the bullet passes through the sensor's two ends will it be detected and the circuit current will be shut off. Sometimes the bullet, which oscillates between the coils, can't be detected effectively.

3. In our project, changing the voltage source is the sole option to regulate the bullet's speed. However, it is ineffective. Changing the power source is not a realistic approach to accurately adjust the speed.

4. The coil's asymmetrical turns affected the orientation of the magnetic flux and reduced it inside the coil. Additionally, it slows down the bullet's speed.

5. At the coil's end, the sensor was connected. As a result, when the object reaches the coil's end, current is cut off, and the object escapes. However, the ferromagnetic object experiences its greatest force when it is in the coil's center. The exit velocity would dramatically rise if the sensor were positioned in the middle. We were unable to achieve that since we lacked the necessary tools.

6. The conduit connecting the two stage coils was not quite complete. Some of it was open, which affected how the bullet moved. Sometimes it can't exit the coil because of a disagreement with the pipe.

7. Sometimes the switch press timing wasn't done correctly. Additionally, it slows down a bullet's usual rate of travel.

8. For practically using it in any defense field, the set up needs to be larger and the power source should be more consistent. Rechargeable battery or solar power source should be

introduced and implemented. This couldn't be implemented in our project due to the expense.

9. The project circuit and equipments are not water and dust resistant. In practical field, the instruments needs to be water and dust resistant as it is needed to suit the war field.

5.5 Impact Assessment (PO(f)):

5.5.1 Assessment of social and cultural issues:

- **Public Perception:** We should investigate on how the public perceives coil guns, addressing concerns related to weaponization, public safety, and ethical implications.
- **Cultural Acceptance**: We should examine how coil gun technology aligns with cultural norms and values, both locally and globally.
- **Ethical Considerations:** We have to explore ethical dilemmas associated with coil guns, particularly in military or security applications.
- **Accessibility and Inclusivity:** We have to ensure that coil gun technology does not exacerbate social inequalities by considering affordability, accessibility, and inclusivity factors in its development and deployment.
- **Collaboration and Stakeholder Engagement:** We should engage with diverse stakeholders, including community representatives, policymakers, and advocacy groups, to gather insights and address social and cultural concerns collaboratively.
- **Education and Awareness**: We should develop educational programs and outreach initiatives to raise awareness about coil gun technology, its benefits, and its responsible use.

5.5.2: Assessment of health and safety issues:

- **Projectile Safety:** It's mandatory to evaluate the risks associated with the high-speed projectiles generated by the coil gun and implement safety measures such as protective barriers, safety interlocks, and strict safety protocols.

- **Electromagnetic Radiation**: We should assess the exposure to electromagnetic fields (EMFs) generated during coil gun operation.
- **High Voltage Hazards:** We have to consider the high voltage required for coil gun operation and implement safety measures to prevent electrical shocks, such as insulating materials, proper grounding, and safety training for personnel.
- **Energy Storage Safety:** We should address potential hazards related to energy storage components, such as capacitors.
- **Environmental Impact:** We have to evaluate any environmental hazards associated with the materials or energy sources used in the coil gun project and ensure proper disposal of hazardous materials and consider environmental regulations.
- **Testing and Prototyping Safety:** We should establish safety procedures for testing and prototyping phases, including personal protective equipment (PPE) requirements, emergency response plans, and secure testing environments.
- **Emergency Response:** It's important to develop clear emergency response plans for potential accidents or malfunctions, including procedures for injuries, fires, or other unexpected events.

5.5.3 Assessment of Legal Issues:

- **Regulatory Compliance:** We have to identify and understand the legal requirements and regulations governing coil gun development, possession, and use, including local, state, national, and international laws.
- **Firearms Laws:** We should assess how the coil gun might be classified under firearms laws, particularly if it could be misconstrued as a weapon
- **Intellectual Property:** We should evaluate intellectual property issues, including patents, copyrights, and trademarks, to ensure that the project doesn't infringe on existing rights.
- **Liability and Insurance:** We must consider liability issues related to accidents or damages caused by the coil gun.

- **Privacy and Data Protection:** If the coil gun project involves data collection or processing, we have to assess privacy and data protection laws to ensure compliance with data handling and user privacy requirements.
- **Export Control:** We have to be aware of export control regulations, especially if the coil gun technology has the potential for dual-use applications.
- **Contractual Agreements:** We should review and negotiate contracts and agreements with suppliers, collaborators, or manufacturers to ensure that legal obligations, responsibilities, and liabilities are clearly defined.

5.6 Sustainability and environmental impact evaluation (PO(g)):

1. **Environmental Impact Assessment (EIA):** We conducted an Environmental Impact Assessment (EIA) to identify potential environmental risks and impacts throughout the project's lifecycle.
2. **Energy Sources and Efficiency:** We assessed the energy sources used to power the coil gun and evaluated the energy efficiency of the coil gun system, aiming to minimize energy waste during operation.
3. **Material Selection and Resource Use:** We considered the environmental impact of materials used in the coil gun's construction and favor materials that are sustainable, recyclable, and have a lower ecological footprint minimizing resource consumption and waste generation during manufacturing and operation.
4. **Waste Management:** We developed a comprehensive waste management plan that includes recycling, proper disposal, and hazardous waste handling ensuring that materials and chemicals used in the project do not pose risks to the environment.
5. **Electromagnetic Radiation (EMR):** Evaluated the potential impact of electromagnetic radiation (EMR) on the environment and nearby electronic systems.
6. **End-of-Life Disposal:** Planned for the responsible decommissioning and disposal of the coil gun system, including the removal of equipment and site remediation if necessary.
7. **Regulatory Compliance:** Ensured compliance with all relevant environmental laws, regulations, and permits.
8. **Life Cycle Analysis:** Conducted a comprehensive Life Cycle Analysis (LCA) to quantify the environmental impact of the project from inception to disposal and used this analysis to identify areas for improvement.
9. **Continuous Improvement:** Established mechanisms for continuous improvement, including regular reviews of sustainability and environmental performance.

10. **Alternative Technologies and Practices:** We tried to explore alternative technologies and practices that could reduce environmental impact and improve sustainability.

5.7 Ethical Issue (PO(h)):

Like any cutting-edge technology, the creation and use of a two-stage coil cannon may give rise to a number of ethical questions, such as:

1. **Safety Concerns:** Coil guns have the capacity to produce incredibly high energy and velocities, which can pose serious safety concerns. Making sure everyone participating with the project is safe, as well as the general public, and taking strict safety precautions to avoid mishaps, raises ethical questions.
2. **Weaponization:** The potential for weaponization with coil guns is one of the main ethical issues. Coil gun technology might have disastrous repercussions if it gets into the wrong hands or is used maliciously. It is crucial to ensure proper use and limit access to potentially hazardous applications.
3. **Engagement of Local Communities and Stakeholders:** According to ethical norms, decision-making processes involving coil gun initiatives must involve local communities and stakeholders. It is morally required to provide transparency, address issues, and distribute benefits to impacted communities.
4. **Environmental Impact:** A significant ethical concern with coil gun projects is their potential influence on the environment. For ethical standards to be upheld, minimizing harm to the environment, wildlife, and ecosystems is crucial.
5. **Access and Equity:** Concerns about access to and advantages of coil gun technology could be ethical. For scientific research and innovation in particular, ensuring fair access is crucial to preventing the escalation of social injustices.
6. **Privacy Concerns:** The privacy implications of coil gun technology could be significant, particularly if it is utilized for monitoring or surveillance. To safeguard people's right to privacy, ethical rules should be in place.
7. **Ethical Research Practices:** Coil gun projects require researchers and organizations to follow ethical research procedures, which include the informed permission of human participants and the ethical treatment of animals in testing facilities.
8. **Ethical Research Practices:** Coil gun projects require researchers and organizations to follow ethical research procedures, such as the informed consent of human subjects and the ethical treatment of humans in experimental settings.

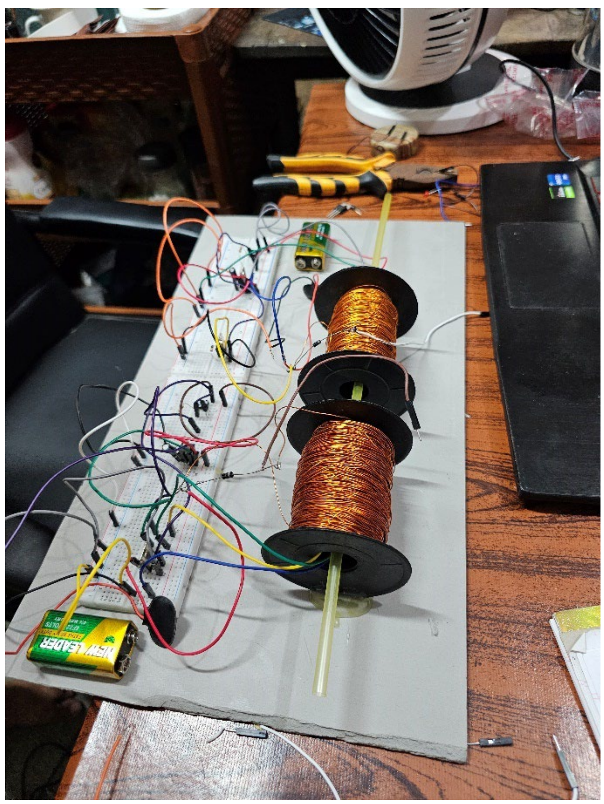
9. **Long-Term Consequences:** The long-term effects of coil gun technology, including its effects on present and future generations and the larger ecosystem, should be taken into account while making ethical decisions.

In order to ensure that the technology is used in ways that benefit society while minimizing harm and risks, addressing these ethical issues necessitates a combination of ethical research and development practices, adherence to ethical rules and regulations, and ongoing engagement with stakeholders and experts.

6. Reflection on Individual and Team work (PO(i)):

6.1 Individual Contribution of Each Member:

Throughout the implementation of the two-stage coil gun project, each team member played a pivotal role in contributing their expertise and skills.



- **Sadaf, Rifat, Shiam, and Wasif** undertook the crucial task of theoretical analysis, providing the foundational knowledge necessary for the project's success. Their comprehensive research laid the groundwork for our practical endeavors.

- **Wasif** further demonstrated his commitment by taking charge of data collection, ensuring that our project was founded on sound empirical evidence.

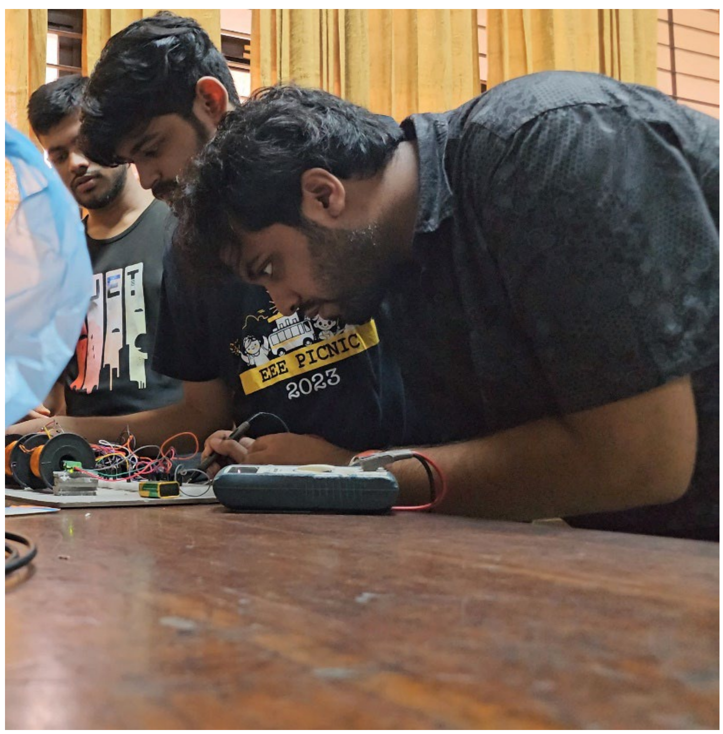
- **Sadaf and Rifat** took on the responsibility of procuring the necessary components, demonstrating their organizational skills and ability to manage resources effectively.

- **Sadaf, Wasif, and Najia** exhibited exceptional teamwork and technical prowess in building the circuit, a complex task that required meticulous attention to detail.

- **Sifat, Shiam, and Rifat** showcased their precision and craftsmanship by skillfully soldering the components, ensuring the durability and reliability of our coil gun.

- During the testing phase, **everyone** in the team played an integral role, contributing their insights and problem-solving abilities to address challenges and refine the design.

- **Shiam and Rifat** took the lead in error detection, demonstrating their keen eye for detail and dedication to quality assurance.



- **Sadaf and Sifat** emerged as key contributors to the project by making the necessary adjustments to enhance the projectile's performance, reflecting his adaptability and problem-solving skills.

- The crucial task of powering the coil gun was expertly handled by **Sifat, Wasif, and Najia**, who ensured that the system operated smoothly and efficiently.

6.2 Mode of Team Work:

1. **Communication and Collaboration**:

Effective communication and collaboration are at the core of the team's mode of work. The team members, including Sadaf, Rifat, Shiam, and Wasif, recognize the importance of open and clear communication. We maintain regular communication channels through meetings, emails, and messaging platforms to discuss project progress, share insights, and address challenges collectively. This transparent and inclusive communication fosters a sense of unity and ensures everyone is on the same page regarding project objectives and tasks.

2. **Leadership and Roles**:

While the team may not have a designated leader, leadership emerges organically based on expertise and responsibilities. Wasif's role as the data collector showcases leadership in a specific area. Clear roles and responsibilities are assigned to team members based on their skills and expertise. For instance, Sadaf and Rifat handle component procurement, while others are responsible for circuit building, soldering, and other critical tasks. This distribution of roles ensures that each team member contributes effectively to the project's success.

3. **Flexibility and Adaptability**:

Our team embraces flexibility and adaptability in their mode of teamwork. We recognize that project requirements may evolve, and we are prepared to adjust our strategies and priorities accordingly. This agile approach allows us to respond to challenges and changes efficiently and ensures that the project stays on track.

4. **Task Ownership**:

Our team values task ownership as a key aspect of their mode of teamwork. Each team member takes responsibility for specific tasks, demonstrating their commitment to the project's success. This approach ensures that every aspect of the project, from data collection to circuit building and error detection, is addressed by individuals with the necessary skills and knowledge..

5. **Transparency and Documentation**:

Transparent communication and documentation are vital aspects of the team's mode of work. We maintained a logbook that documents daily activities, decisions, challenges, and breakthroughs. This logbook serves as a comprehensive record of the project's journey, ensuring that information is accessible to all team members and facilitating continuity in case of team transitions.

6. **Continuous Improvement**:

Our team is committed to continuous improvement, as indicated by our willingness to make necessary adjustments and improvements to the project. We reflect on our progress, identify areas for enhancement, and adapt our strategies accordingly. This commitment to learning and growth is a fundamental aspect of our mode of teamwork.

6.3 Diversity Statement of Team:

Our team embodies a rich tapestry of backgrounds, experiences, and areas of expertise, and this diversity is one of our greatest strengths.

- **Variety of Perspectives and Approaches:** Our team's diversity extends to the diversity of thought. Each member brings a unique perspective and approach to the table. For instance, we have individuals with strong theoretical analysis skills, such as Sadaf, Rifat, Shiam, and Wasif, who have laid the groundwork for our project with their in-depth research. This diversity of thought encourages us to consider different angles, explore various solutions, and ultimately, arrive at more innovative and well-rounded outcomes.
- **Inclusive Decision-Making:** We believe in inclusivity and equal opportunity. Every member's voice is heard and respected in our team discussions and decision-making processes. This inclusivity not only promotes a sense of ownership but also ensures that we leverage the full spectrum of our team's skills and perspectives.
- **Adaptability and Problem-Solving:** Our diverse team excels in adaptability and problem-solving. We understand that diversity leads to diverse challenges, and we view these challenges as opportunities for growth. Whether it's troubleshooting technical issues,

addressing communication barriers, or navigating cultural differences, our team's collective problem-solving skills shine.

- **Inclusivity and Equal Opportunities:** Inclusivity and equal opportunities are not just buzzwords for us; they are fundamental principles. We are committed to creating an environment where everyone feels valued and empowered to contribute their best. We actively seek to remove barriers that may hinder any team member's participation or growth.

Our team's diversity is not merely a reflection of our differences but a celebration of our collective strengths. It enriches our project by fostering creativity, innovation, and inclusivity. We believe that by embracing diversity, we not only create a better project but also contribute to a more inclusive and equitable world.

6.4 Log Book of Project Implementation:

Throughout the project, we meticulously maintained a logbook documenting our daily activities, decisions, challenges, and breakthroughs. This logbook served as a valuable reference, helping us track our progress, identify areas for improvement, and ensure that we stayed on course with our project timeline. It also served as a testament to our dedication and commitment to the project's success.

Date	**Surname and ID of the Group Members Present**	**Task Accomplished**
07/07/2023	Wasif-112, Sadaf-113,Shiam-114, Najia-115, Rifat-116, Sifat-117	Project Approval
13/07/2023	Wasif-112, Sadaf-113,Shiam-114, Najia-115, Rifat-116, Sifat-117	Project Planning- Day 1
14/07/2023	Wasif-112, Sadaf-113,Shiam-114, Najia-115, Rifat-116, Sifat-117	Project Planning- Day 2
20/07/2023	Sadaf-113, Rifat-116	Collecting necessary components
02/08/2023	Wasif-112,Sadaf-113, Najia-115, Rifat-116	Implementation- Coil creating
03/08/2023	Wasif-112,Sadaf-113, Najia-115, Rifat-116	Implementation Day 2- Circuit construction
06/08/2023	Wasif-112,Sadaf-113, Shiam-114, Rifat-116, Najia-115,Sifat-117	Circuit Debugging
07/08/2023	Sadaf-113, Shiam-114, Rifat-116, Najia-115,Sifat-117	Circuit Debugging
13/08/2023	Wasif-112, Sadaf-113,Shiam-114, Najia-115, Rifat-116, Sifat-117	Circuit Debugging
14/08/2023	Wasif-112, Sadaf-113,Shiam-114, Najia-115, Rifat-116, Sifat-117	Circuit Debugging
20/08/2023	Wasif-112, Sadaf-113,Shiam-114, Najia-115, Rifat-116, Sifat-117	Testing
25/08/2023	Wasif-112, Sadaf-113,Shiam-114, Najia-115, Rifat-116, Sifat-117	Testing
27/08/2023	Wasif-112, Sadaf-113,Shiam-114, Najia-115, Rifat-116, Sifat-117	Debugging and testing
28/08/2023	Wasif-112, Sadaf-113,Shiam-114, Rifat-116, Sifat-117	Debugging and testing
03/09/2023	Wasif-112, Sadaf-113,Shiam-114, Najia-115, Rifat-116, Sifat-117	Debugging and testing
05/09/2023	Wasif-112, Sadaf-113,Shiam-114, Najia-115, Rifat-116, Sifat-117	Finalization
06/09/2023	Wasif-112, Sadaf-113,Shiam-114, Najia-115, Rifat-116, Sifat-117	Finalization

In conclusion, the successful implementation of the two-stage coil gun project was a testament to the collective efforts and diverse skills of our team. Each member's individual contributions, collaborative spirit, and commitment to excellence were crucial in achieving our project goals and milestones.

7. Communication (PO(j)):

Effective communication is crucial in complex engineering activities, especially when interacting with various communities, including electrical and electronic engineering and other interdisciplinary groups. Here are some strategies for effective communication in the context of this coil gun project:

1. **Comprehension and Report Writing**: Understand the project thoroughly before attempting to explain it to others. When writing reports or design documentation, be clear and concise. Use diagrams or illustrations where necessary to aid understanding. Always include an abstract or executive summary, a detailed methodology of your work, results, and a conclusion that summarizes your findings.

2. **Presentations**: When presenting your work, structure your presentation logically. Start with an introduction that outlines what you will discuss, followed by the main body of your presentation where you delve into the details of your work, and conclude with a summary of what you've discussed. Use visual aids such as slides or diagrams to help convey your points.

3. **Instructions**: When giving or receiving instructions, be clear and specific. Break down complex tasks into manageable steps. If you're unsure about something, don't hesitate to ask for clarification.

4. **Interdisciplinary Communication**: When communicating with professionals from other disciplines, avoid using jargon that may not be understood by non-specialists. Explain concepts in a way that can be understood by someone without your technical background.

5. **Public Engagement**: When communicating with the public, it's important to convey why your work matters in a way that is engaging and accessible. Use analogies or real-world examples to explain complex concepts.

7.1 Executive Summary

This project involves the design and construction of a coil gun, a device that uses electromagnetic coils to launch a projectile at high speeds. The coil gun is based on the principle that a current-carrying conductor induces a magnetic field around it, which can be used to attract and accelerate a ferromagnetic projectile.

The current design uses a single coil powered by a 24V supply, which is controlled by an N-channel MOSFET. An IR sensor is used to detect when the projectile has reached the end of the coil, at which point the coil is turned off, allowing the projectile to escape.

Future work on this project could involve developing a multi-stage coil gun, optimizing the power source, experimenting with different materials for the projectile and coil, and implementing advanced control systems. Safety measures will also be an important consideration as the project progresses.

This project has potential applications in fields such as space exploration and military technology. It also serves as an educational tool for understanding electromagnetic principles and their practical applications

7.2 User Manual

This manual provides detailed instructions for building a coil gun, a device that uses electromagnetic coils to launch a projectile at high speeds. The coil gun is based on the principle that a current-carrying conductor induces a magnetic field around it, which can be used to attract and accelerate a ferromagnetic projectile.

Operation Instructions

1. Load your ferromagnetic projectile into one end of the coil.
2. Connect 9V batteries and DC power supply to the respective terminals.
3. Press the push button to power on the coil, which will attract and accelerate the projectile.
4. Once the projectile reaches the other end of the coil, it will be detected by the IR sensor, which will turn off power to the coil, allowing the projectile to escape.

8. Project Management and Cost Analysis (PO(k)):

8.1 Bill of Materials:

Serial No	Materials	Price (TK)
1.	Copper wire	**1250**
2.	IR sensor	**450**
3.	IRF244N MOSFET	**50**
4.	10K and 1K resistor	**20**
5.	Capacitor(0.1uF)	**40**
6.	Push button	**80**
7.	Bread board	**400**
8.	Power source (RPS)	**8500**
9.	DC battery (9V)	**200**
10.	Diode	**30**
11.	Transistor	**80**
12.	Jumper wire	**150**
13.	Multimeter	**800**
14.	Others	**450**
	Total cost	**12500**

8.2 Per Unit Cost of Prototype Unit:

We have considered the initial component costs and made adjustments based on component usage. we have made the following adjustments in the first prototype of the two-stage coil gun, taking into account the changes in component usage and the potential cost reduction in copper wire.

Serial No	Materials	Units Used	Price (TK)
1.	Copper wire	14 gauge (1500 turns per coil)	**850**
2.	IR sensor	2	**300**
3.	IRF244N MOSFET	2	**20**
4.	10K and 1K resistor	2 each	**4**
5.	Capacitor(0.1uF)	2	**8**
6.	Push button	2	**32**
7.	Bread board	2	**400**
8.	Power source (RPS)	1	**8500**
9.	DC battery (9V)	2	**200**
10.	Diode	2	**6**
11.	Transistor	2	**16**
12.	Jumper wire	20	**150**
	Total cost		**10485**

8.3 Per Unit Cost of Mass-Produced Unit:

This report provides a detailed cost analysis for the production of the prototype unit of a two-stage coil gun. We have considered the initial component costs and made adjustments based on component changes. Additionally, we will calculate the Total Manufacturing Cost (including labor, materials, and overhead) and the Per Unit Cost of a Mass-Produced Unit (1,000 units).

Total Material Cost for the Mass Production Unit:

Serial No	Materials	Units Used	Price (TK)
1.	Copper wire	14 gauge (1500 turns per coil)	**850**
2.	IR sensor	2	**280**
3.	IRF244N MOSFET	2	**20**
4.	10K and 1K resistor	2 each	**4**
5.	Capacitor(0.1uF)	2	**8**
6.	Push button	2	**28**
7.	Circuits	2	**373.50**
8.	LiPo Batteries	1	**2500**
9.	DC battery (9V)	2	**200**
10.	Diode	2	**6**
11.	Transistor	2	**16**
	Total cost		**4312**

Total Material Cost = Sum of individual component costs

Total Material Cost = ৳850 + ৳280 + ৳20 + ৳4 + ৳8 + ৳28 + ৳400 + ৳2,500 + ৳200 + ৳6 + ৳16

Total Material Cost = ৳4,285.50

Labor and Overhead Cost for the Mass Production Unit:

Labor and Overhead Cost = 0.30 * Total Material Cost Labor and Overhead Cost

= 0.30 * ৳4,285.50

Labor and Overhead Cost = ৳1,285.65

Total Manufacturing Cost for the Mass Production Unit:

Total Manufacturing Cost = Total Material Cost + Labor and Overhead Cost

Total Manufacturing Cost = ৳4,285.50 + ৳1,285.65

Total Manufacturing Cost = ৳5,571.15

Per Unit Cost for Mass-Produced Units (1,000 Units):

To calculate the per unit cost for mass-produced units, we'll use the Total Manufacturing Cost for 1,000 units:

Total Manufacturing Cost for 1,000 Units = Total Manufacturing Cost for the Prototype Unit * 1,000

Total Manufacturing Cost for 1,000 Units = ৳5,571.15 * 1,000

Total Manufacturing Cost for 1,000 Units = ৳5,571,150

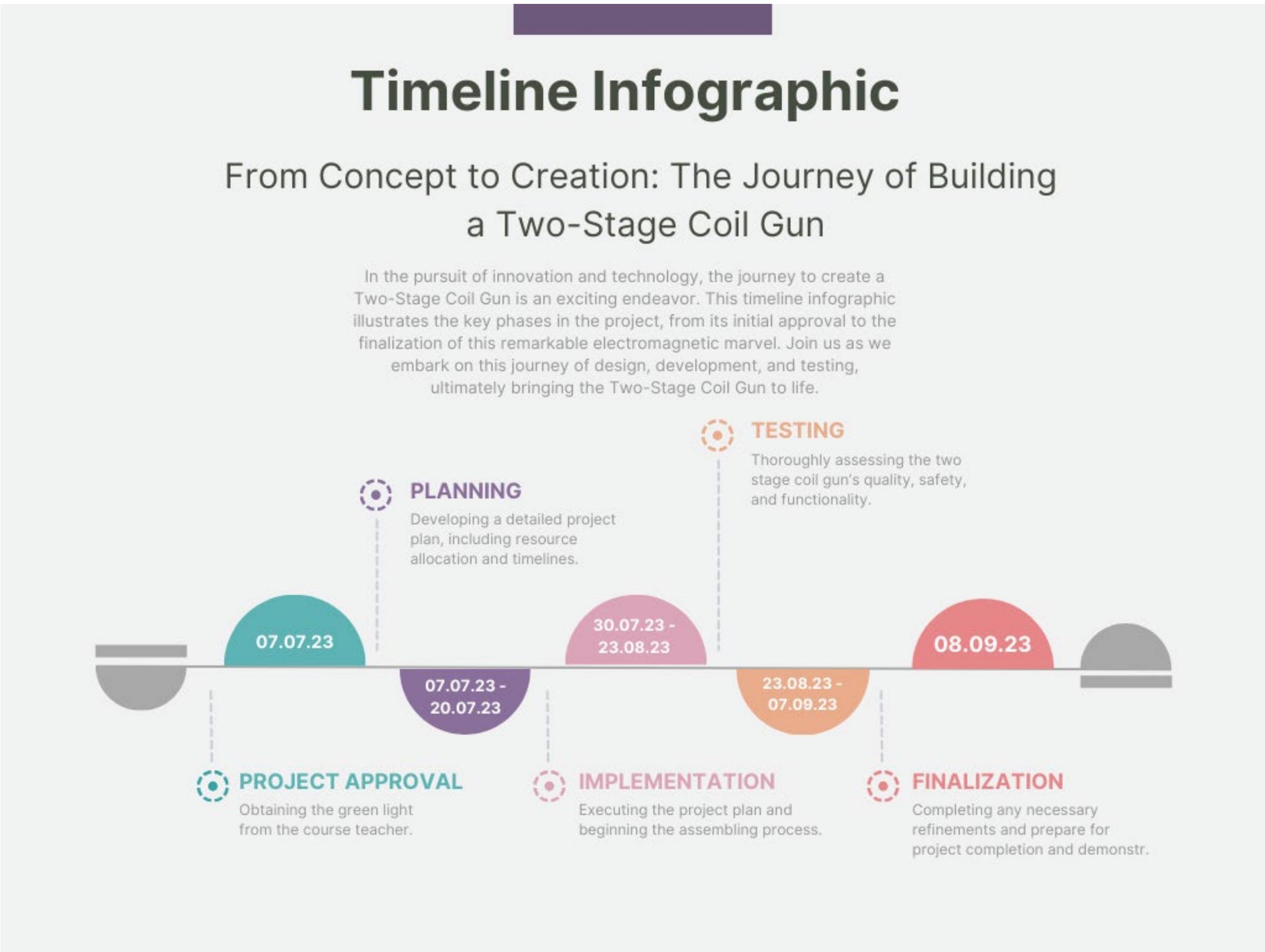
Adjusted Per Unit Cost for Mass-Produced Units:

Per Unit Cost = Total Manufacturing Cost for 1,000 Units / 1,000 units

Per Unit Cost = ৳5,571,150 / 1,000 Per Unit Cost = ৳5,571.15

So, with the change to LiPo batteries and based on the provided cost analysis, the per unit cost for mass-produced units (1,000 units) of the two-stage coil gun is approximately ৳5,571.15, including labor, materials, and overhead.

8.4 Timeline of Project Implementation:



9. Future Work (PO(l)):

The Coil Gun project has immense potential for further exploration and development. Here are some areas you might consider for future work:

1. **Portability**: One potential area for future development is to make the coil gun more portable. This could involve reducing its size and weight, making it more practical for use in the field.
2. **Multi-Stage Design**: Another possibility is to develop a multi-stage coil gun, which could increase the speed of the projectile. By adding more stages, the projectile would experience greater force as it passes through each stage, resulting in higher speeds.
3. **Microcontroller Integration**: To ensure that the multiple stages of the coil gun work together effectively, a microcontroller could be used to synchronize their operation.

4. **Power Source Optimization**: Currently, the coil gun uses two power sources. Future work could explore the possibility of using a single power source to simplify the design.

5. **Battery Power**: In order to make the coil gun portable, the DC power supply used in the current design could be replaced with a series of DC batteries.

6. **High-Quality Sensors**: The sensors used in the coil gun are critical to its performance. Using high-quality sensors could improve the accuracy and reliability of the device.

10. References:

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3. Physical analysis and optimization of electromagnetic coilgun launch. Journal of Applied Physics.

4. Circuit Digest (n.d.). DIY Simple Coil Gun [Online]. Available: https://circuitdigest.com/electronic-circuits/diy-simple-coil-gun