

Modelling and Design of Experiments (PHYS 442)

Project description

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August 22, 2024

Objective

The objective of this semester project is to apply the principles and methods learned in the course to design and analyze an experiment. The project will allow students to gain hands-on experience in the various stages of experimental design, including problem formulation, design selection, data collection, and analysis. The project also aims to foster teamwork, critical thinking, and scientific communication skills.

Core of the Project

The central objective of this project is to model the resistance of a box of inductances, organized in decades—a common apparatus in an electronic lab. This box is used to practice various concepts in electronics, and when the resistance of the box is measured, it is observed that the resistors linked to each inductor do not sum up in a straightforward manner. This anomaly forms the basis for the project's investigation.

The project will be divided into the following key steps:

1. Modeling of Two Consecutive Elements

In this first phase, the goal is to model the resistance behavior when two consecutive inductive elements are connected within the box. Specifically, teams will focus on pairs of inductances such as 4H-3H, 3H-2H, 2H-1H, 4mH-3mH, 3mH-2mH, and 2mH-1mH. The procedure will involve:

- **Experimental Design:** Execution of a 2^2 factorial design to explore the interaction between the two inductors.
- **Data Collection & Analysis:** Measurement and analysis to fit a model that explains the resistance behavior.
- **Model Interpretation & Theoretical Discussion:** Understanding the results in relation to Kirchhoff's laws.

2. Modeling of a Full Column of Inductances

The second phase extends the analysis to an entire column of inductances within the box. Teams will model the resistance from the highest to the lowest inductance in a column, including columns such as 4H to 1H, 4mH to 1mH, and $4\mu H$ to $1\mu H$. The steps involve:

- **Experimental Design & Data Collection:** Systematic measurement across all possible combinations of inductances in the column.
- **Data Analysis & Model Validation:** Analysis to develop a comprehensive model, followed by validation.
- **Theoretical Discussion:** Interpretation in light of Kirchhoff's rules and electrical theory.

4. Comprehensive Modeling of the Entire Box of Inductances

In this final phase, teams will expand their modeling efforts to encompass the entire box of inductances, integrating the findings from all previous steps. The steps involve:

- **Global Experimental Design:** Designing an experimental approach that considers the interaction between multiple columns.
- **Extensive Data Collection:** Comprehensive resistance measurements across different configurations.
- **Holistic Data Analysis:** Developing a global model that explains the cumulative effects of all inductances.
- **Final Model Validation:** Validating the global model and discussing its robustness.
- **Synthesis and Final Discussion:** Synthesizing the final model and exploring its implications in electronic systems.

Schedule

The project will be conducted over the course of the semester according to the following timeline:

- **Week 1-2:** Formation of teams and selection of project topic.
- **Week 3-5:** Development of experimental plan and submission of the intermediary report.
- **Week 6:** Peer review of another team's intermediary report.
- **Week 7-10:** Execution of the experiment and data collection.
- **Week 11-13:** Data analysis and interpretation of results.
- **Week 14:** Oral examination and presentation of project findings.

Team Organization

Students will work in teams of three. Each team member is expected to contribute equally to the project. Team members should collaborate on all aspects of the project, even if specific roles are assigned.

Evaluation Criteria

The project will be evaluated based on the following four components:

1. **Intermediary Report (20%):** This report should include the problem statement, experimental objectives, chosen design, and initial plans for data collection.
2. **Peer Review (10%):** Each team will review another group's intermediary report, providing constructive feedback and suggestions.
3. **Final Report (30%):** The final report should comprehensively document the entire project, including the methodology, data analysis, results, and conclusions.
4. **Oral Examination (40%):** The oral examination will consist of a presentation of the project findings followed by a Q&A session with the course instructor.

Important Information

- **Deadlines:** Adherence to deadlines is crucial. Late submissions will be penalized unless there are extenuating circumstances.
- **Plagiarism:** All work must be original and properly cited. Plagiarism will result in severe academic penalties.
- **Communication:** Teams are encouraged to communicate regularly with the course instructor for guidance and clarification of any issues.

Conclusion

This semester project is a critical component of the course and provides an opportunity to apply theoretical knowledge in a practical context. Successful completion of the project will not only enhance your understanding of experimental design but also prepare you for future research and professional work.