

**EGR 346 Mechatronic Systems Dynamics and Control**

**Laboratory Guide**

**Last Revised Aug. 22, 2022**

Acknowledgements

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Important Background Requirements

**This lab requires knowledge, and successful completion, of the two courses: EGR 107 and EGR 226, or equivalent courses focusing on C-Language programming and digital systems.**

**It is the students’ full responsibility to review relevant material from previous courses focusing on C-Language programming and digital systems to be able to complete this lab. During this lab, instructors are not expected to and should not debug or teach programming.**

## INTRODUCTION

The theoretical content of this course, Mechatronic Systems Dynamics and Control (EGR 346), as delivered in the lecture sessions is supported by weekly lab sessions. This manual is provided to guide the student through the lab, which is a critical part of the course.

During lab, students are expected to perform the required experiments to gain meaningful hands-on experience. Sufficient background and context for each experiment will be provided. However, by design, **the instructions for the experiments are not recipe-style as is the case with many prior lab courses**. Students should expect directions to become less prescriptive as the semester progresses. This will result in numerous open-ended questions for the students to answer, with the objective of focusing on the process of learning through designing meaningful experiments and efficient information acquisition. The ultimate goal is to bring students to a professionally competent level of knowledge and experience in the design, execution, analysis, and reporting of well thought out experiments, even when facing situations which are completely new and different. Moreover, students will learn how to efficiently learn! Students are expected to take full advantage of the lab sessions by following a structured plan of preparing and executing the lab experiments. To facilitate maximum learning benefits to the students, a list of items, to be completed early in the semester, is provided. In addition, a detailed description of the lab execution plan is provided.

### TO BE COMPLETED EARLY IN THE SEMESTER

1. If not qualified to work in the machine shops, arrangements should be made to go through the training ASAP. Sign up is usually done with Mr. Roy Visser for training. Qualification is required for the use of the welding equipment. You are encouraged to complete the lathe and mills trainings as well. All these trainings should be completed by **October 28, 2022**.

### GENERAL POLICIES

1. The labs are to be conducted in a professional manner. The steps which are expected to be followed are listed in the following section. In essence, the calculations and design of experiments are to be completed before the lab session. When arriving at the lab, students are expected to build experimental setups, conduct tests, and collect data and observations to verify the system performance. After the lab work, students will compare the theoretical and experimental data, and report their results and conclusions.
2. In many cases most of the work will be before the lab. **Expect some long pre labs**. In general the division of work will be about 40-50% of the work before the lab, 30-40% during the lab, and 10-20% after the lab.
3. If any of the required components in a lab experiment is missing, 50% of the final grade will be automatically deducted. If two or more required sections are missing, the lab will not be graded and will be returned with a grade of zero.
4. The lab space is to be used in a professional manner. Equipment and other materials used during the lab time are expected to be organized and returned to their appropriate places before the students leave the lab. In general, the lab should be left clean, organized, and in a better order than it was found when the lab session started.
5. Safety rules pertaining to the lab will be strictly enforced and are expected to be followed as such.
6. Absences: Missing a lab session without a valid excuse will result in an automatic “zero” grade in the work or report of that lab. Missing three lab sessions without a valid reason grants you an automatic “F” in the course.
7. Attitude, active participation, and effort can and will be used to change borderline grades up or down.
8. Untimely submissions of work will not be accepted without previous arrangements with the instructor.
9. Review of graded work, for grade changing purposes, is allowed within two weeks from the day it is handed back to the students. For purposes other than changes in the grade, reviews of graded work and questions are welcome anytime.

### LAB EXECUTION PLAN

1. **Before the lab (Pre-lab) / design of the experiment (DOE):**
   1. A written pre-lab is expected to be presented at the beginning of each lab session to the instructor, for evaluation.
   2. All required pre-lab calculations should be done in the Pre-lab sheet. Usually, calculations will be done by hand, unless otherwise noted in the lab descriptions. However, it is useful to verify hand-calculations with software.
   3. The experimental procedure and the equipment setup (plan of action) should be designed and prepared in the Pre-lab sheet. Reasonable assumptions of unknowns are expected. Any relevant block/circuit/setup diagrams should be provided in the Pre-lab sheet.
   4. All relevant variables and data tables to be collected, as well as relevant calculations, should be set to receive data for final execution.
   5. Software programs to run the experiment or verify hand calculations should be prepared or at least outlined in a flow chart.
   6. Relevant theoretical background should be noted and some expectation/anticipation of results and problems should be provided, as appropriate. This will require reading and understanding the “Experiment” section of each lab.
   7. ***If the pre-lab work is not done and verified by the instructor, the student will not be allowed to proceed to the next step. In addition, points will be deducted accordingly.***
2. **During the lab / execution of the experiment:**
   1. Arrive on time. Arriving late is unfair to everybody; it diminishes the student’s educational experience and it places extra demands on teammates and the lab instructor.
   2. Pre-lab work should be checked by the instructor before any work can be conducted. Once approved, the experiment can be set up and run.
   3. Equipment list, including unique ID numbers, should be collected on the data sheet.
   4. Data and observations should be collected at this time with great accuracy. Notes on observations as they are being collected, of conformance or non-conformance to theory or expectations should be provided.
   5. Once finished, a decision should be made on whether the experiment should be repeated or not, before the equipment is disassembled, based on the results, i.e., conformance to predictions. The instructor should be consulted at this point.
   6. If the results are acceptable, then the equipment and lab area should be cleaned and organized.
   7. The instructor is not expected to debug programs. However, concept questions and consultation are always welcome.
   8. Equal participation is expected of all team members.
3. **After the lab / analysis and reporting of experimental results:**
   1. Data and information collected by different methods (Theoretical, Experimental, Simulation, etc.) should be compared in value. Brief tables and graphs are the best tools for this purpose, not continuous pages of lists of numbers. Other appropriate methods are possible. Failure to analyze the data numerically will result in severe penalties.
   2. Appropriate discussions and conclusions are expected to be noted explaining results, agreement/disagreement with expectations, and other phenomena observed. Discrepancies between data from different sources must be discussed. All this should be done within the framework of the experimental objectives.
   3. Appropriate technical report writing rules should be followed. If help is needed in finding these rules, the instructor should be consulted. Extra adjectives and all informal statements should not be used. For every experiment, a group of students might be selected randomly to submit the full report of the experiment.

### LAB DOCUMENTS

Lab documents are considered a critical professional and legal instrument in the context of scientific and engineering work. Students will become acquainted with the use of lab documents during this course. Lab books, worksheets, and Pre-lab sheets, are expected to be used professionally, and to be maintained by the students on a regular basis. Technical writing standards should be followed closely in lab documents. These guidelines are provided in Appendix A. Lab documents start with a Pre-lab including data and observations sheets. A sample document is provided in Appendix B. For every experiment, a Pre-lab and set of data sheets should be prepared and made ready to receive data and observations, data and observations should be collected on the sheets, and post-lab work should be completed and included with this same set of documents. Post-lab work is explained in section 1.3, part 3 of this document. It includes analysis of results as well as relevant concluding remarks about the experiment, amongst other items. This set of documents should be included in the lab binder or part of the lab book and might be checked by the instructor during the following lab session. If a full report is required, it should be produced based on this set of documents.

To understand what lab documents should contain regarding each individual experiment, the student should try and answer the following question: based on the written information, can someone duplicate the experiment and obtain the same results that were obtained when this experiment occurred?

Also, to understand what to have prepared for an experiment, the following four questions should guide the work: what is the experiment about (title and background), what is to be done, how is it going to be done (procedure, setup, tools, etc.), and what data is to be collected and how should it look like?

The following list should help:

1. Use past tense, third-person, passive voice in writing about experiment.
2. After data is collected, extract key numerical results.
3. Comment all code.
4. Figures should be numbered with titles below the figures.
5. Tables should have be numbered with titles above the tables.
6. All relevant documents for a particular lab should be attached and filed together as one set. A lab book is recommended, but not required. If not using a lab book, a binder should include all lab documents related to the lab throughout the semester.
7. Outline form must still use full sentences.
8. When using “counts” convert the numbers to real units.
9. **Do not copy the procedure and background from the lab guide verbatim. Summarize it**.
10. The conclusions should address the purpose using numerical values derived from the experimental data.
11. Use numbered steps for procedures.
12. When using software to draw graphs do not use smooth curve fits for experimental data. For theoretical curves, do not include discrete data points on the lines.
13. When unexpected or notable events occur during the lab they should be noted in the lab notes.
14. Additional data points should be collected in areas of rapid change.

### SAFETY RULES

Qualification Training Required: Machine Shop Safety and Welding

1. Failure to follow these safety rules, as well as the abuse and/or misuse of any equipment in the lab, including messing up the order and arrangement of the lab, will result in one or more of the following:
   1. Removal of the student from the lab.
   2. Revocation of after hour lab privileges.
   3. Removal of the student from the course.
   4. Referral of the student to the appropriate school committee for possible further action.
2. If you have not finished the qualification training required for operating the equipment in this lab:
   1. You are not allowed to operate the equipment in this lab.
   2. Seek help from a faculty or staff member as soon as possible.
   3. If you operate equipment in the lab without proper training, you will be committing a violation of the safety rules. This will result in item (1) being applicable.
3. Professional behavior and courtesy are expected in the lab. While in the lab operating equipment, students are responsible for their own safety and the safety and security of all equipment in the lab. Eating and drinking in the lab are strictly prohibited. Students should also report to faculty and/or staff any violations of the rules mentioned in this document.
4. When operating the equipment in this lab:
   1. There should always be more than one person in the lab space.
   2. In addition, a faculty or staff member should be aware that you are working in the lab.
5. Power to the lab equipment must be turned off unless a faculty or staff member is present in the building and aware of the use of the equipment.
6. Any changes to the setup or wiring or air supply of the equipment must be approved by a faculty or staff member and checked off by a faculty or staff member before the power is turned on.
7. Machines in motion can be dangerous, especially during training, programming, and testing. When working with moving equipment, take extra precaution to ensure that:
   1. Nobody is in machine’s reach
   2. An emergency stop button (E-Stop) or a similar switch is within reach of yourself or a partner working with you and paying attention to what you are doing
8. **Note that: Even though you have received information regarding lab safety regulations and proper training on all equipment, the responsibility of following the safety regulations and using the equipment in a safe manner falls entirely upon you.**

**Appendix A: Technical Writing Guidelines Prof. Nael Barakat**

For more information, refer to: [http://www.gvsu.edu/wc/writing- in-your- major-49.htm](http://www.gvsu.edu/wc/writing-in-your-major-49.htm)

Technical writing is both a science and art. No matter how good an experiment or how brilliant a discovery is, it is worthless unless the information is communicated to other people. This communication must be as clear and unambiguous as possible. Usually, the general objective of a report, or a technical paper, in Engineering and Science is to communicate the ideas and information gained in the experimental work. The care and skill with which the discussion and conclusion are drawn will determine the overall success of the report. An old rule in army communication always applies in report writing which is: Tell them what you are going to tell them, tell them, and then tell them what you have told them.

There are many methods and techniques available and accepted for technical writing. The method provided in this document is a very common one and is recommended as a method for technical report writing. This document will refer specifically to parts of a technical report or write-up. There can be other formats and methods for technical writing based on the requirements of the organization receiving or sponsoring the written material. In that case, the writer should follow the writing guidelines set by the relevant organization or journal to which the communication material is intended. *In addition, a course instructor might choose to keep or eliminate portions of this document, or select a completely different method, as a requirement in written material submitted by students in that particular course.*

**Report Contents:**

1. **Memo:** Also known as a letter of transmittal. The memo should be attached on top of the report. A memo can be as short or as long as needed, and should include the following general elements:
   1. First four lines should be [To:], [From:], [Date:], and [Subject:]. Make sure you **address people with their appropriate titles, and correct name spelling!**
   2. Organizational Problem (OP): This is the part where an explanation of the big picture, the problem, and a frame work of context are provided.
   3. Technical Task (TT): In this part, the technical details and the completed task to solve the problem are detailed.
   4. Rhetorical Purpose (RP): This is the last part of the memo where the writer describes the specific reaction required of the reader in response to the memo. Be professional and polite when asking for a response (e.g. **Do not use** a statement like: Please grade appropriately. **Instead, use** something like: Your feedback and comments would be greatly appreciated!).
   5. Initial(s) by the name(s) in the [From:] part. Memos are not normally signed, but the rules might be different in certain organizations.
   6. List of attachments to the memo.
2. **Front matter:** Front matter includes the title page, with author affiliation(s), sponsor of report activity (if any), table of contents, list of nomenclature, list of figures, preface (if any), and a letter of transmittal (memo). Not all these elements have to be included in every technically written report. Only the elements that are relevant should be considered.
3. **Executive Summary (ES):** This is a brief overview of the entire laboratory experiment or technical topic discussed. This should contain a statement of the overall purpose of the laboratory experiment, a statement of the objective and tasks performed, and a statement of the **major/significant** results with a quick comparison between the theory and measured results. It should also contain the inferences that could be drawn from the whole experiment. The ES should stand alone as an explanation of the report! **This is the most important part of the report**. Some people receiving the report will have time only to read this part. In physical sciences this is called an Abstract[[1]](#footnote-1). The difference is that in Engineering, the ES is expected to be more object oriented.
4. **Introduction:** In the introduction, lay the groundwork for the more detailed discussion in the body of the report. Include a review of previous work if necessary. In addition, use the introduction to state the motivation of the work and define the problem. This part should **ramp-up the reader’s** frame of context to a level sufficient to view the big picture of the report. Provide a **forecast** of the following sections of the report.
5. **Theory:** This section contains an explanation of the concepts and equations used to conduct and analyze the experiment. It enables the reader to understand the implications of the experimental work and aids in proper interpretation of the data. Detailed derivations should be relegated to the appendices.
6. **Experimental Apparatus and Procedure:** This part should include lists and figures showing the equipment used, the specifications or accuracy of the equipment, etc. Details covering how the experiments were performed, difficulties that were overcome, and demonstration that care was taken to be accurate and consistent should be included here. All of the steps taken to carry out the experiment as precisely as possible should be shown in this part.
7. **Results and Discussion:** In this section results of the work are presented and logically linked to the theory, previous work, and predictions. Clear tabular and graphical presentations of results should be used. Some verbal discussions of the graphs and tables should be given, but only to focus the reader’s attention on salient features of the data. Moreover, the writer of the report has the responsibility of interpreting the results in light of the theoretical background and previous work in the area. “Bad” results are only bad if you fail to give a reason why your theory and experiments do not match up well.
8. **Conclusions and Recommendations:** By the time the reader has reached this part, most of the conclusions should have been drawn. Never mention anything new or unexpected at this part of the report. This part is where you wrap up the report with a summary of all the important results and interpretations. It is always helpful to show a clear quantitative comparison of the different results, as well as a percentage error. **This is the second most important part of the report next to the ES**. When you are done with your report, check that the Executive Summary and Conclusion are consistent. Have you “promised” anything in the Executive Summary that you have not delivered in the report?
9. **References:** References should be cited in the report and listed in this section. Citation and listing can be of many styles, just make sure you are consistent. Two examples of citation are by number *e.g. [5], or by name and year (Frank et. al., 1999).* The reference should show in this section as follows:

*[5] Frank A., et. al. (1999), “title….” Publisher, and pages.*

References from the internet should include the title of the referenced article or part, site address, author name and affiliation, and the sponsor of the site. The following is an example:

*Armstrong, J., “writing guide,” Version 3, Retrieved from the Web 9/1/98,* [*http://www.uwsp.edu/psych/apa4b.h*](http://www.uwsp.edu/psych/apa4b.htm)*tm, U.S. Department of Health, Education, and Welfare.*

1. **Appendices:** Wide latitude is available on what to include as an appendix. The writer may choose not to include any appendices. However, appendices should always be referenced in the body of the report. Some examples of material that should be in the appendices are: detailed mathematical derivations, tables of raw experimental data, calibration information for instruments, uncertainty analysis of the experiment, material property tables and graphs, calculations charts, and computer code and programs. Irrelevant material or appendices and content that is not used or referenced in the main report should not be included in this part.

**General Guidelines:**

1. **Be specific** and straight to the point. Extra wordiness is as destructive as the lack of explanations. Ensure **consistency and logical flow** of the complete report as well as each paragraph individually. In the report, and each individual part, ideas should flow from **general to specific** and tie up to the parts preceding and succeeding it.
2. Use third person, passive voice.
3. **Check** the spelling, grammar, punctuation, and upper/lower case letters in your written material. Such mistakes are very irritating and confusing to the reader.
4. **Equation Presentation:** Equations should be written in the report as they are presented in any text, and with a reference number. Computer jargon and awkward type equations should be avoided. The general rule for use of brackets is to move outward from parentheses to brackets to {} signs. If more than three levels is required, it is best to define new variables. A multiplication sign after variables is not necessary, except to avoid confusion. The two following examples acceptable:

(1)

*S*  *P*{1 *I* *N* 1/ *I*} (2)

1. **Graphs, Figures, and Tables presentation:** Ensure that any figures in the reports are relevant and referenced in the text of the report. Reference to figures and tables should precede them. Each graph and figure should have a number and title under it. Label the graph and coordinates consistently. Each coordinate should have a scale markings and units for each variable labeled. Numbers and titles for tables should go on top of them. Use full names and units for variables as possible. Make sure you abide by the significant figures rule and that less than unity numbers are written properly written by adding a zero preceding the decimal point.
2. **Any Questions** asked in the handout or by the instructor should be specifically answered with facts, figures, and references in the discussion part.
3. **Format:** Your report should be visibly organized. Balance the amount of ink on the page between not leaving extra white space and not cluttering the page. As a nominal format use single space, 12.0 true type font (e.g. Garamond or Times New Roman), 1.0 inch margin from each edge of the page, and boldface for titles. Indent each paragraph and make sure that your numbering system flows consistently. Also make sure that the same set of variables is used throughout the report.

**Appendix B: Sample Pre-lab and data sheet**

**Name:**  John Barkley

**Course and Section #:** EGR 346 - 901

**Number and title of the experiment:** Experiment # 3: Measuring the value of gravitational acceleration.

**Date/ time:** Aug. 24, 2015 – started at 9:00 AM.

**Purpose:** The purpose of this experiment is to measure and verify the value of the gravitational acceleration.

**Equipment and materials:**

1. Metal balls of known mass and size.
2. Solid aluminum ramp at a 45 degrees inclination.
3. Stop watch # 0000
4. Measuring tape brand KKKKK.

**Experimental Setup:** The ramp will be setup as shown in figure 1.

**Figure 1: Ramp setup for experimental verification of gravitational acceleration.**

**Procedure:**

1. Set ramp to do test.
2. Start timer simultaneously with the release of the metal ball from the top of the ramp
3. Etc!

**Data to be collected and tables:**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Test # | Ball weight  (g) | Ball diameter  (m) | Ball type | Start time  (S) | End time  (S) | Distance  crossed (m) |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

**Expected results:** Time needed for the balls to roll down the ramp over a constant distance should be same. Calculation of the value for gravitational acceleration can be performed using Newton’s law.

1. **Abstract**: Some engineering reports are required to have an abstract replacing the ES. **The rule is: there can be either an ES or an Abstract in the report but not both**. The abstract describes the nature of the project/experiment, major tasks and outcomes. It should include some background information and the circumstances leading to the project/experiment. The memo format should not be used, and the narrative should not include a rhetorical purpose. The abstract needs to be written carefully because it will be the only piece of text that will be read by multiple technical and non-technical audiences. In addition, the writer will have no control over who reads the abstract, and thus should be sensitive to proprietary or confidential information. The abstract should avoid negative words such as inferior, failure, sub-standard, etc. Note that the abstract is different from the executive summary style of a document. A well- written abstract requires time and several drafts to complete. [↑](#footnote-ref-1)