Mechanical Universe Laboratory
PHY-206 Spring 2019
Gustavus Adolphus College

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Course Objectives

- Explore physical laws applicable to motion, energy, oscillations, waves, thermodynamics, and fluid dynamics.
- Learn to formulate and test qualitative and quantitative hypotheses for physical systems
- Acquire experience and skills in making measurements, collecting and analyzing data, and reporting results
- Learn to apply basic error analysis and error propagation techniques
- Learn how to keep a good laboratory notebook
- Learn the basics of scientific writing

Course Policies and Evaluation

Lab Materials:

- Lab manual: Mechanical Universe Laboratory Manual.
- Two quad-ruled laboratory notebooks (Ampad #26-251 or equivalent).
- A calculator.
- A flat straight edge or ruler for making charts and tables (optional).

Pre-Lab Exercises: Moodle pre-lab quizzes will be assigned for the first half of the semester. Eventually, will replace the. After the first week, students will complete the introduction, theory, and a sketch of the procedure (as assigned) directly in the lab notebook before coming to lab. Both the moodle quizzes and notebook pre-labs engage the student in the material so that they are prepared when beginning the lab. The notebook pre-lab also teaches and models best practices for real scientific research. The notebook pre-labs will be checked by the instructor and/or lab assistants at the beginning of each lab session.

Lab notebooks and reporting: In the laboratory, the lab notebook becomes a sequential journal of data collection procedure, observations, calculations, and any analysis that is done. In it you will record everything of significance that you do and observe. What does this mean? While it may be appropriate to record the fact that your lab partner sneezed if you were preparing a culture in a biology lab, it probably does not matter in the physics lab, unless it results in the equipment being knocked over. You will need to decide what is significant. And we will help you with that, particularly early in the semester when the instructor and lab assistants will make frequent checks of what you are recording in your notebook.

The in-lab journal component answers two questions:
What data did you collect?

- Data that is collected by hand should be recorded by hand and sufficiently annotated to be understood.
  - Numbers need to have units and short descriptive phrases that act as labels.
  - Sets of data are organized into tables with columns labeled and with units.
  - Uncertainty estimates should be given for all measurements.
- Data (charts and tables) that are collected via computer can be taped into the notebook. Again, descriptive information and units are essential. Data should be saved for future analysis and the location and filename recorded in your notebook.
- Often observations are not simply a number and need to be represented qualitatively by a short piece of descriptive prose.

How did you collect it?

- Record the procedure step by step as you do it.
- Sketches are essential in conveying procedural information. Make a sketch of everything that is important.
- Procedure and data may be intermixed. It is most appropriate to record the procedure, then the data, or vice versa, as long as it is clear.
- Data and procedure for each section should be kept together. If any calculations are done during the lab, they should be with the data and procedure. The same is true of any graphs you create as you are doing the lab.
- Deviations should be discussed. For example, equipment malfunctions, mishaps, or procedural stumbles.

The lab notebook also serves as a container for analysis, results, and answers to questions that come after the laboratory session is completed. This material should be entered in hand written form. In most cases, you will need to perform some calculations using the data you collected, make graphs, and fit the data to a model to test a particular theory. You will record this in a step by step manner in your notebook, just as you did the procedure and data in lab. Printed graphs must be taped into the lab notebook and annotated appropriately.

Conclusions are an important part of hypotheses testing. Did your measurements agree with the theory (within the estimated uncertainty)? If not, what is behind the difference? (Do you think there might be characteristics of the physical system that the theory is not accounting for? Are there systematic measurement errors or shifts caused by limitations of the measurement method?) Depending on the lab, a question from the manual may ask you to make such a comparison; you can refer to your answer instead of repeating it in the conclusion. Generally, the conclusion is a spot where you can summaries how things went.

We will spend some time in class discussing how to do the analysis, discuss results, and write an appropriate conclusion.
Each lab report in the lab notebook (journal) should roughly follow this basic outline. Sections 1-4 will be done in advance (the pre-lab as discussed above). Sections 6-8 will often be done after lab, but there may be time in some labs to do portions of these.

1. Title, date, student name, and lab partner name
2. A one or two paragraph introduction of the principles to be explored and why it is interesting
3. Theory to be tested
4. A one or two paragraph description of the methods to be used
5. Detailed procedure, data, and observations
6. Analysis and answers to questions
7. Results (summary of findings)
8. Conclusions (Did it agree? If not, why?)

Each student will prepare his/her/their/zir own lab report, even though the experiments were performed with a partner. Reporting is an individual task and responsibility. We encourage cooperative exchange, discussion, and sharing of ideas (and struggles) outside of lab. But we do not want to see duplicated reports. Reports should reflect your individual effort (wording, answers, analysis, and derivations).

Reports are due in class on the Friday or Monday following the completion of the lab. A penalty of 10% per day will be assessed each late lab report. They will be graded and returned at the beginning of the next lab period.

TA Grading: TAs are given the following outline for grading:

Lab (10 points, use fractional (tenth point) values where needed)

- (0.1 pt) **Heading** (title, date, your name, **partner names**),
- (0.6 pt) **Theory and purpose**: a paragraph or two on the purpose of the lab.
- (0.3 pt) **Rough Sketch of Procedure**:
- (5.5 pt) **Detailed Procedure and Data collection**
    - (2.5 pt) **General technique**: Proper use of significant figures, columns are labeled. All measurements have some estimate of uncertainty. Charts have title, axes labeling, error bars, units, etc…
    - (0.5 pt) **Quality of their data**: Are their results within reason or is there clear evidence of careless technique?
    - (2.5 pt) **Charts, data tables…**: Check for completeness.
- (2.0 pt) **Analysis**:
    - (0.5 pt) **Data calculations**: Can you figure out what they did? Did they make an effort to put together a coherent report? Can you follow their write-up?
    - (1.0 pt) **Questions from manual**: Check for completeness and reasonable answers to questions in the manual.
- (0.5 pt) **Results** (Summary of findings AND discussion):
  State the outcome of the lab. Reflect on the objective of the lab. List (or

summary tables can work well here) key results including theoretical predictions and corresponding measurements (with uncertainty).
Some sort of synthesis is good here, especially if there are different approaches used to determine the same characteristic (like the spring constant in the oscillations lab); which approach did they think was best and why. Pull it all together in a discussion. Critical thinking about procedure and methodology is great here.

Note that some students may not have a separate results section. "Results/Findings" may be part of the conclusions (or even analysis). That is ok too. Just so it is somewhere!

- (1.0 pt) **Conclusions:**
    - Comparisons between measurement and theory; try to explain the difference (it is fine if they references answers they have written to questions from the manual):
        - Measurements:
            - Random **uncertainty**: is the difference (from theory) within the uncertainty range on the measurement?
            - **Systematic error**: is there some problem or limitation with the measurement system that causes a **shift** in the data.
        - Theory:
            - Is the theory too simple? Is there some change we could make to our model to make it better represent the physical system we are observing.
    - Lessons learned or interesting observations. Something beyond the obvious is great here…
    - Did they make an effort in writing this conclusion (something beyond a placeholder)?

Writing Assignments: Writing assignments will be given throughout the semester. Assignments will be due one week after the lab is performed and will be graded on a 20-point basis. All assignments should be double spaced on white 8.5" x 11" paper using a 12-point font. Figures should be generated by computer (using Sigmaplot or Logger Pro). All formulas, equations and algebraic expressions should be entered using the Equation Editor. A style reference will be given at the time of the first lab. Grading will focus on adherence to style requirements, clarity of writing, and effort given to methodology, lab technique, and data analysis.

Lab Groups: Students will work in groups of 2 (maximum of 3). It is essential that all members of the group share in the different aspects of the lab and become completely familiar with operating the equipment and computer, taking the measurements, and analyzing the data. It is best if student roles are changed from week to week; this will insure that you are prepared for the lab final.

Preparation for Laboratory: Advance preparation is essential for the efficient use of the limited lab time. Students are expected to be thoroughly familiar with the purpose and general procedures of the experiment before coming to lab. The primary purpose of the Pre-Lab exercise is to encourage and reward preparation for lab (both in grade and ease of carrying out the experiment). Each student must bring his/her lab manual to lab.

Attendance: Students must arrange in advance to attend a lab at other than their scheduled time. It is the responsibility of the student to consult with the instructor during the first week of the semester regarding any anticipated absences due to field trips, athletic events, musical performances, or other activities. Because of equipment conflicts and other logistical reasons, in general it will not be possible to make up a lab outside of a scheduled lab session. Lab equipment is dismantled and next weeks lab is set up typically on Friday afternoon.

Disability Services: Section 504 of the Rehabilitation Act of 1973 and the Americans with Disabilities Act (1990) work together to ensure "reasonable accommodation" and non-discrimination for students with disabilities in higher education. A student who has a physical, psychiatric/emotional, medical, learning, or attentional disability that may have an effect on the student's ability to complete assigned course work should contact the Disability Services Coordinator in the Advising Center (x6286). No accommodations can be made without review by the Disability Services Coordinator.

Honesty: Students are expected to follow the Gustavus honor code.
On my honor, I pledge that I have not given, received, or tolerated others' use of unauthorized aid in completing this work.
Please ask if you have any questions about the appropriate use of another student's work.

Evaluation: Pre-Lab Exercises 10%, Lab Notebooks 65%, Writing assignments 25%

Incompletes: A grade of incomplete will only be given for work not completed due to circumstances beyond the control of the student. [College policy.]

Final Grades: Final course grades will be assigned using the following scale as a guide only:

A	94-100	A-	90-94	B+	86-90
B	82-86	B-	78-82	C+	74-78
C	70-74	C-	66-70	D+	62-66
D	58-62				

Final grades may also take into account the instructor's evaluation of the student's attendance, participation, effort, and evidence of improvement or regression.