SYLLABUS

PHYS-2350
Experimental Physics
SUMMER 2024
Lab Location: J-ROWL 3C14

Sections	**01** (Tuesday morning)/**02** (Wednesday afternoon)
Instructor:	Prof. D. Michael
Email:	michaj2@rpi.edu
Virtual:	https://rensselaer.webex.com/meet/michaj2
Office:	J-ROWL 1C36
TAs:	Joseph Daafour/Adam Tidball

Section 1: Tuesday 8:00am – 11:50am
Section 2: Wednesday 12-3:50pm

Instructor: Prof. D. Michael
Office Hrs by appointment only (In person(JROWL 1C36) or Virtual)

TA: Joseph Daafour (email: *daafoj@ rpi.edu*)
Office Hrs (Virtual:) https://rensselaer.webex.com/meet/daafoj
Tuesday: (1:30pm-5pm) (Virtual or In person (HBH))
Saturday: 9:30am- 11AM (or by appointment)

TA: Adam Tidball (email: *tidbaa@rpi.edu*)
Office Hrs (Virtual:) https://rensselaer.webex.com/meet/tidbaa
Wednesday: (9am -Noon) (In person (JROWL 2W08)
Sunday: 9am- 11am (Virtual or by appointment)

Objective:
The objectives of this course are designed to apply techniques in experimental physics to acquisition and manipulation of large data sets and to perform sophisticated data analysis. These objectives include:

1. Observation and collection of experimental data;
2. Practical experience in working with and manipulating common laboratory equipment;
3. Fundamentals of error and uncertainty in scientific measurements;
4. Computational skills for basic data analysis
5. Written and oral presentation of results

Prerequisites:

- PHYS-2220

Required Course Materials:

- "Experiments in Modern Physics" by A. C. Melissinos and Jim Napolitano.

- Physics Carbonless Lab Notebook (SKU# LAB-050-7GW-D(PHYSICS)) from **bookfactory.com**.

Recommended Textbooks:

- "An Introduction to Error Analysis" by John Taylor.
- "From Research to Manuscript, A Guide to Scientific Writing" by Michael Jay Katz.
- We will also use "Experimental Physics 78235 Course Notes" by Jim Napolitano (1999).
- "Quantum Physics: A Fundamental Approach to Modern Physics" by Townsend.

Other required tools:

- Computer: It is necessary for each student to bring a laptop computer to the laboratory. Laptops are an integral part of data acquisition for several experiments.
- Plotting and analysis software: All data analysis, plots, and figures must use Jupyter Notebooks with Python (what is used in PHYS-2220). You should install this software ahead of time so that you don't lose time on the first day of class. The easiest way is using Anaconda.
- You are expected to have basic proficiency with Python and Jupyter notebooks. If you are uncomfortable with either of these, you should seek help from the Teaching Assistant or consider dropping the course.

COVID-19 Safety Requirements for Experimental Physics Laboratory Work

Rensselaer is committed to the health and safety of all students.

Masking Requirements

Rensselaer will link masking protocols to the CDC's recommendations, with the same reservation of flexibility as with testing. Any individual who prefers to wear a mask, indoors or outdoors, may wear a mask even in Green and Yellow Tiers.

- Green/Yellow Tier (Low and Intermediate Community Transmission): No outdoor or indoor masking required.
- Red Tier (High Community Transmission): Indoor masking required, but outdoor masking not required.

Individuals in a classroom or office setting may request that classmates or co-workers wear a mask out of concern for their personal health. We encourage members of the community to consider these requests seriously as a show of support for our colleagues.

Social Distancing in Labs:

Students and the instructor will respect the need for social distancing to the degree possible by the lab setting. The instructor will provide appropriate direction should students face issues with social distancing within the lab area.

Cleaning of Spaces:

Students are encouraged to clean the surfaces of the chairs/tables/desks they occupy before they sit down and as they prepare to leave. Where appropriate, students will be advised to clean equipment that was used during the experiments.

Student Health:
Students who are ill, under quarantine for COVID-19, or suspect they are ill will report that to Student Life. Student Life will verify and notify all faculty who have that student. Once notification is made, all faculty will make every reasonable effort to accommodate the student's absence and will communicate that accommodation directly to the student. Failure to make an appropriate accommodation for a verified or reasonably suspected case of illness may be appealable under the student grade appeal process. Students who need to report an illness should contact the Student Health Center via email or call 518-276-6287. For students staying off campus, a student may request an excused absence via www.bit.ly/rpiabsence with an uploaded doctor's note that excuses them.

Refusal:
Refusal to comply with any appropriate request, e.g. Red Tier compliance, will be treated as would any classroom disruption. Disciplinary actions and sanctions will be taken through the judicial process in the Rensselaer Student Handbook (request to change the behavior; request to leave the class; dismissal of the class and referral to Student Life and the Dean of Students.)

Diversity: We value the voice of every student in the course. Our diversity as a class—in race, gender, sex, religion, language, ability, veteran status, place of origin—is an asset to our learning experience. As a result, we will design inclusive lessons and assignments that provide you with the opportunity to speak and be heard, explore your own understanding, and encounter each other.

Course structure:

This course consists of one lecture on the first day, hands-on experience of physics experiments, and preparation and presentation of written and oral reports. This course is taught differently than most other courses at RPI in that it stresses independent work and self-motivation. The written instruction covers the minimum necessary instruction to conduct the experiments, and student-initiated gathering of further information is expected.

A group of two will complete five experiments (Electronics Lab + 4 Experimental Labs) over the term. You must select lab partners before or during the initial class meeting. You are expected to work together on the Electronics Lab, then complete all labs together in subsequent class meetings. Before you come into the classroom, you are expected to finish reading all pre-lab materials, including the lab instructions and theory. There will be a pre-lab quiz before each experiment with four questions, that will count for 10% of your final grade.

The instructions on the lab notes are a minimum requirement of the labs. Exploring further steps of each experiment beyond the instructions in the notes is expected. **During the experiments, we will instruct more about "what" to do (e.g. principles), but much less about "how" to do it (e.g. which button to push and why).** It is an important problem solving training to find a way to take the desired data based on the information you have and through the logical thinking process when you are in the situation where you have never been before. A separate document that will accompany the Instructions Manual will describe the theory behind the experiment. This is a concise write up but has sufficient information to guide you to an understanding of the experiment. The course text, "Experiments in

Modern Physics" by A. C. Melissinos and Jim Napolitano, is a very useful reference and will complement the documentation found in the LMS site.

Academic Honesty:
You are expected to collaborate with your lab partners on all aspects of this course. Collaboration means working with your partner: performing your share of the work, preparing properly so as not to disadvantage your partner, and discussing your ideas openly. The majority of the grade involves experiments performed with partners. You are permitted to discuss any aspect of your work with anyone, but what you hand in must clearly be your own work. All work must be handed in individually. Partners must hand in separate and different write-ups. Simply copying your partner's notes or copying from the internet or an existing reference is cheating. This includes data, analysis, and writing. **Turning in work or data that is not yours will result in 0 (zero) points for that report!**

However, in the unfortunate case where there was a serious issue with the data (e.g. it was later discovered that a power supply was not turned on when the data was being recorded) and the analysis proves fruitless, you will be allowed to use data from another source, provided this is cited appropriately in the text. In this case, the maximum grade you can get on the report will be **75 points**. You will need to include in the Appendix portion of the report, the original erroneous data and the accompanying analysis to provide to the grader a convincing "paper trail" of the original experiment.

Using artificial intelligence (AI) to generate text or problem solutions is prohibited. Submission of work generated by AI will be considered a violation of academic ethics for this course. When we detect the use of AI in your work, you will be given a warning. Subsequent violations will result in points being deducted from the assignment. The total points deducted will depend on the severity of the violation.

Prelab Preparation:

Prior to arriving for class each week, you must prepare for the experiment by reading the relevant background material provided on LMS and the course text. At the beginning of each experiment, you must complete a short prelab quiz. These quizzes will count for 10% of your final grade for the course. You cannot collaborate with your lab partner on these quizzes, and you will be given about 10 mins to complete the quiz at the beginning of the class. Do not take digital images of these quizzes with your smartphones/notepads/cameras etc.

Lab Notebooks:

Jupyter Notebooks:
All work for every lab will be presented in Jupyter Notebooks. These are intended to be a semi-formal lab report, containing a detailed study and analysis of everything to be presented, but without the excessive time demand of preparing a formal lab report. Every student must complete a notebook, even though the lab will be performed as a team.

The Jupyter Notebook reports will be graded out of 100 points each. The report should not be lengthy, rather, the focus should be on analyzing data and preparing a notebook that describes what was done to someone that has not done the lab but understands all of the principles in it (e.g. the TAs). This is how Jupyter Notebooks are used in physics labs, and in tech and data science jobs. The reports will be written according to the following rubric:

Introduction – A brief introduction to the physics and measurements for the lab.
Procedure – Describe the experimental procedure for each section of the experiment.
Analysis – Give a quantitative discussion of how you treat your data to derive results, including error analysis.
Discussion – Briefly discuss any challenges you encountered when you did your experiment. Propose reasons why these occurred and how these could be addressed in the future. (*new*)
Conclusion – List all qualitative and quantitative results, along with the uncertainty.

Failure to follow significant figure and error propagation rules will result in 0.5 – 1 point loss, for each instance of not adhering to these rules.

The LMS site has sample Jupyter Notebooks of experiments in this course.

Notes on Jupyter Notebook:

- *If you are granted an extension for handing in your Jupyter Notebook due to a valid reason after a discussion with the Instructor, an email will be issued to both you and your TA regarding this decision. This will avoid any issues in grading.*
- *Jupyter Notebooks that use data stored in external files should have these files included with the Jupyter Notebook as a *.zip file when uploaded to the LMS site.*
- *A line of code will be included at the beginning of the Jupyter Notebook to enable the reader to view the Jupyter Notebook with or without the embedded code for the sake of readability. An example of how this is done will be found in the LMS site. Check with your TA to make sure you know how to do this.*
- ***IMPORTANT:*** *A PDF version of the Jupyter Notebook will also be uploaded to LMS in addition to the original Jupyter Notebook. The PDF version will provide a mechanism of feedback via embedded annotations within the file. This feedback should be used to improve the quality of each subsequent submission.*

Written Laboratory Notebook:
Additionally, all experimental procedures must be logged in a physical, quad-ruled notebook that can be purchased from the Rensselaer Store (PHYSICS CARBONLESS LAB NOTEBOOK (SKU# LAB-050-7GW-D(PHYSICS) from **bookfactory.com**) and should be specified in the Course Materials. Every student must complete the written notebook and each lab must be clearly labeled. An example of a written lab notebook is posted in LMS together with the format of what your notebook should contain. The expected format for the written laboratory notebook is also posted in the LMS site together with a grading rubric for the first four pages (which includes the cover) and the pages that record details of the experiment. You must have your notebook signed by the instructor at the completion of each lab – points will be deducted if this is not done. If you need extra time to finish a lab (e.g. completing sketches of schematics or graphs), discuss this with the instructor and you must complete this using the extra time before obtaining a signature. Constructive comments will be made either verbally and/or written regarding the quality of the writeup for each experiment to point out potential areas of improvement. **Points will be deducted for poorly written sections**. The written notebook will be turned in on or before **8/12/24** and graded out of 100 points toward the notebook portion of the grade.
Examples of a well-maintained laboratory notebook can also be found in the LMS site. Please take time to read through these to orient yourself regarding use of the notebook in recording each experiment.

This means that the total # of points for the notebooks, both electronic and written, will be 600 (1 Electronics Lab + 4 Labs + Physical Lab Notebook) for the semester.

Formal Written Lab Report:
One formal lab report will be prepared at the end of the course. This report will mimic turning an internal report to a paper for publication. Students will choose one of four labs from the semester (the Electronics Lab is excluded) to present in the Final report, then take the information from the relevant Jupyter notebook and expand this into a formal report.

Formal Written Lab reports have the following requirements:

- 5 page limit, including bibliography
- 12 pt Liberation Serif font
- Single spaced
- Contain sections clearly labeled:
  - **Abstract** – concise summary of the work covered in the main body which includes final results
  - **Introduction** – introduce physical phenomenon and what hypothesis is being tested
  - **Experimental setup** – description of how test is performed
  - **Analysis** – detailed description of how data are handled and manipulated, including uncertainty
  - **Discussion** – communicating to the reader challenges in the experiment and how these were addressed
  - **Conclusion** – discussion of conclusions drawn from data and what they infer about hypothesis. Recommendations for improving the accuracy/precision of the experiment.
  - **Bibliography** – list of references cited in text
    - All references must be cited inline in the text with a number in brackets in the order they appear, then listed in the bibliography

There will be one class period – the Prep Session (8/6/24 for Sec. 1 and 8/7/24 for Sec. 2) - dedicated to preparation of the formal reports. Here you will be guided through an Overleaf template for preparing the report in Latex. An example of a report based on an experiment is also found on the LMS site.

Oral Report:

You will create an oral report via a Webex recording from your final report. The PowerPoint template for this may be found in the LMS site and we will go over this template during the Prep Session (8/6/24 for Sec. 1 and 8/7/24 for Sec. 2). The presentation will be maximum of 8 minutes sharp (video after the 8 minute mark will not be considered for grading purposes). Please upload the presentation as a Webex link (of your video) to the LMS site.

This presentation needs to be uploaded on the specified day according to this schedule:
Section 1 – the file should be sent by **10:00 am** on the due date (8/15/24)
Section 2 – the file should be sent by **2:00 pm** on the due date (8/16/24)

Late submissions of the Oral Report will have a mandatory 10pts deduction.

Presenting Data:

Experimental data presented in plots, either in Jupyter notebooks, formal lab report and in the Oral presentation slides MUST adhere to these guidelines:

- All axes must have labels. Points will be deducted from a plot missing axis labels.
- Every plot must be clear and legible, illegible plots will receive no credit.
- Plots with multiple data sets must include a legend, clearly denoting the different sets.
- All figures must be labeled with figure numbers and must be described and referenced in the text.
- Each figure must include a caption with a description of what is presented.

Excused absences:
The only makeup work that will be allowed is for an absence with a dean's excuse. **All makeups must be discussed and approved by the instructor prior to the beginning of class, you will not be permitted to just "show up" and join a group**.

Late Policy:
Late arrival hurts both you and your lab partner. It is disrespectful to take precious time away from your lab partner or to force them to get the lab started on their own. **Arriving later than 15mins from the start of class will not be tolerated. This will result in a 10 point deduction from that lab**. The first time this occurs, a warning will be given to you. Subsequent occurrences will incur the penalty of the 10 point deduction from the lab.

"Lack-of-Participation" Policy:
We expect the workload of the experiment during class be equally shared between both lab partners. We - the course instructor, TA and lab supervisor - will note down if this is not the case for an experiment. **This will result in a maximum 10 point deduction from that lab for the student that is involved in not participating equally in the lab**. The first time this occurs, a verbal warning will be given. Subsequent occurrences will incur the penalty. The reason for the additional deduction will be noted in feedback of the graded lab.

Office Hours with TAs Policy:

You can go to **either** TA for help with your work. They can help you with challenges in the course which includes and is not limited to: understanding error propagation and how to reduce it in practice, graphing data, proper use of ODR, getting clarity on the physical concepts in the experiment, etc.

However, students cannot use the assigned office hours for debugging an entire code. This consumes an enormous amount of time and takes away the TAs interaction time with other students. **TAs have the right of refusal if a student attempts to do this during regular office hours**. The accepted approach for code debugging efficiently is to send an email to the TA with the code - as an attachment or link - describing the issue. It is best to do this several days before the report is due.

Communication intensive course:
This course is communication intensive, in that it addresses several aspects of interpersonal scientific communication. First, you must learn to communicate clearly with your lab partners, prior to, during, and after each experiment. You cannot do these assignments on your own. You will also learn to communicate your results to the outside world in three different ways. The lab notebooks, formal lab report, and final oral presentation are the metric for this. You will receive feedback on what you present that will teach you how to effectively present scientific measurements to peers.

Grades: Your course grade will be determined as follows.

- Statistics based HW problem: 5%
- Electronics based HW problem: 5%
- Prelab quizzes: 10%
- Jupyter Notebooks: 55% - 6 reports plus written lab notebook
- Final Lab Report: 15%
- Oral Report: 10%

Grade Assignment:

- A 92-100
- A- 90-91.99
- B+ 87-89.99
- B 82-86.99
- B- 80-81.99
- C+ 77-79.99
- C 72-76.99
- C- 70-71.99
- D+ 67-69.99
- D 60-66.99
- F <60

Course Schedule:
All students will perform in the first two weeks a statistics-based problem set and an electronics-based problem set, in addition to an introductory electronics lab. At the first class meeting, short lectures on statistics and circuit theory will be given prior to students working on the statistics based problem set and electronics HW set. **The skills taught in the first two weeks are mandatory for each subsequent experiment and report in the course.** Groups will then rotate through the remaining labs, performing 4 of the 10 available labs. You will choose a lab partner prior to the first week of classes, failing which one will be chosen for you. **Each lab (including the Introduction to Electronics Lab) will last two weeks, and the Jupyter notebook for that lab must be uploaded to LMS within a prescribed number of days from completion of the lab. The schedule for each section is shown below.** LMS will be setup to reflect this schedule. Late notebooks will be subject to a weighting factor specified later in this syllabus.

Resources:
Documentation for each lab is collected on LMS, which includes theoretical material and instructions for each experiment. Computing resources are posted on LMS. The assigned Statistics based HW problem that will be graded will help you learn the data analysis skills needed for the Jupyter notebooks and Final Report.

List of experiments in this course:

I. Electronics Lab & Statistics & Electronics HW (week 1 & 2 for everyone)
II. List of available experiments:

1. Magnetic Moment
2. Compton Scattering
3. Earth Field NMR
4. Faraday Rotation (AC/DC)
5. Optical Pumping
6. Analog Computing
7. Johnson Noise
8. Hall Effect
9. Muon Decay
10. Magnetic Levitation

Schedule:

		SECTION 1	
Week #	Date	Activity	Due date
1	21-May	Lecture/Stats - ODR HW Problem	10-Jun
1	21-May	Lecture/Electronics HW	10-Jun
1	21-May	Electronics Lab	
2	28-May	Electronics Lab	10-Jun
3	4-Jun	Lab 1	
4	11-Jun	Lab 1	17-Jun
7	18-Jun	Lab 2	
8	25-Jun	Lab 2	15-Jul
9	1-Jul	SUMMER BREAK	5-Jul
10	9-Jul	Lab 3	
11	16-Jul	Lab 3	22-Jul
12	23-Jul	Lab 4	
13	30-Jul	Lab 4	5-Aug
14	6-Aug	Oral Presentation/Final Term Report Prep	
15		Final Report Due	13-Aug
16		Oral Presentations Due	15-Aug

Note:

- *The Oral Presentation (Webex Link – posted in LMS) is due by 10:00am for Section 1*

Grading Rubric:

How to read the rubric below:

Example: Section 1 (8:00am-11:50am session) – grading related to Lab 1

If the Jupyter Notebook is handed by 7:59pm on 6/17– the scaling factor for the Notebook is 1.
If handed late, between 8:00pm of 6/17 and 7:59pm of 6/18 – the scaling factor for the Notebook is 0.9.

If handed in between 8:00pm of 6/18 and 7:59pm of 6/19 – the scaling factor for the Notebook is 0.8.
If handed in between 8:00pm of 6/19 and 7:59pm of 6/20 – the scaling factor for the Notebook is 0.7.
If handed in between 8:00pm of 6/20 and 7:59pm of 6/21 – the scaling factor for the Notebook is 0.6.
If handed in between 8:00pm of 6/21 and 7:59pm of 6/22– the scaling factor for the Notebook is 0.5.
If handed after 8:00pm of 6/22 – the scaling factor for the Notebook is 0 and the grade is 0.

Statistics HWElectronics HW	6/10	6/11	6/12	6/13	6/14	6/15	6/15 (>7:59pm)
	1	0.9	0.8	0.7	0.6	0.5	0
Electronics Lab	6/10	6/11	6/12	6/13	6/14	6/15	6/15 (>7:59pm)
	1	0.9	0.8	0.7	0.6	0.5	0
Lab 1	6/17	6/18	6/19	6/20	6/21	6/22	6/22(>7:59pm)
	1	0.9	0.8	0.7	0.6	0.5	0
Lab 2	7/15	7/16	7/17	7/18	7/19	7/20	7/20(>7:59pm)
	1	0.9	0.8	0.7	0.6	0.5	0
Lab 3	7/22	7/23	7/24	7/25	7/26	7/27	7/27(>7:59pm)
	1	0.9	0.8	0.7	0.6	0.5	0
Lab 4	8/5	8/6	8/7	8/8	8/9	8/10	8/10(>7:59pm)
	1	0.9	0.8	0.7	0.6	0.5	0
Final Report	8/13	8/14	8/15	8/15 (>7:59pm)			
	1	0.9	0.8	0			

		SECTION 2	
Week #	Date	Activity	Due date
1	21-May	Lecture/Stats - ODR HW Problem	11-Jun
1	21-May	Lecture/Electronics HW	11-Jun
1	21-May	Electronics Lab	
2	5/28-5/31 (Sign up)	Electronics Lab	11-Jun
3	5-Jun	Lab 1	
4	12-Jun	Lab 1	18-Jun
7	6/17-6/21 (Sign up)	Lab 2	
8	26-Jun	Lab 2	16-Jul
9	1-Jul	SUMMER BREAK	5-Jul
10	10-Jul	Lab 3	
11	17-Jul	Lab 3	23-Jul
12	24-Jul	Lab 4	
13	31-Jul	Lab 4	6-Aug
14	7-Aug	Oral Presentation/Final Term Report Prep	
15		Final Report Due	14-Aug
16		Oral Presentations Due	16-Aug

Note:

- *The Oral Presentation (Webex Link – posted in LMS) is due by 2:00pm for Section 2*

Grading Rubric:

How to read the rubric below:

Example: Section 2 (noon -3:50pm session) – grading related to Lab 1

If the Jupyter Notebook is handed by 11:59pm on 6/18– the scaling factor for the Notebook is 1.
If handed late,between midnight of 6/18 and11:59pm of 6/19 – the scaling factor for the Notebook is 0.9.
If handed in between midnight of 6/19 and 11:59pm of 6/20 – the scaling factor for the Notebook is 0.8.
If handed in between midnight of 6/20 and 11:59pm of 6/21 – the scaling factor for the Notebook is 0.7.
If handed in between midnight of 6/21 and 11:59pm of 6/22 – the scaling factor for the Notebook is 0.6.
If handed in between midnight of 6/22 and 11:59pm of 6/23– the scaling factor for the Notebook is 0.5.
If handed after midnight of 6/23 – the scaling factor for the Notebook is 0 and the grade is 0.

Statistics HWElectronics HW	6/11	6/12	6/13	6/14	6/15	6/16	6/16 (>11:59pm)
	1	0.9	0.8	0.7	0.6	0.5	0
Electronics Lab	6/11	6/12	6/13	6/14	6/15	6/16	6/16 (>11:59pm)
	1	0.9	0.8	0.7	0.6	0.5	0
Lab 1	6/18	6/19	6/20	6/21	6/22	6/23	6/23(>11:59pm)
	1	0.9	0.8	0.7	0.6	0.5	0
Lab 2	7/16	7/17	7/18	7/19	7/20	7/21	7/21(>11:59pm)
	1	0.9	0.8	0.7	0.6	0.5	0
Lab 3	7/23	7/24	7/25	7/26	7/27	7/28	7/28(>11:59pm)
	1	0.9	0.8	0.7	0.6	0.5	0
Lab 4	8/6	8/7	8/8	8/9	8/10	8/11	8/11(>11:59pm)
	1	0.9	0.8	0.7	0.6	0.5	0
Final Report	8/14	8/15	8/16	8/16 (>11:59pm)			
	1	0.9	0.8	0			