PHYS4007 Winter 2026

Fourth Year Physics Laboratory

Selected Experiments and Seminars

Department of Physics, Faculty of Science, Carleton University

Carleton University acknowledges that its campus is located on the traditional, unceded territories of the Algonquin Anishinaabeg people. We recognize our responsibility to the natural environment and to reconciliation with Indigenous peoples.

Course Instructors:

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Brightspace Link:
https://brightspace.carleton.ca/d2l/home/367278

Class Times: Tuesday & Thursday, 8:35 – 11:25 am

Student Hours: Tuesday & Friday, 1:30 – 3:00 pm

If you have a question or would like to talk with us, you can send an email, visit us during student hours, or approach us after labs.

Learning Objectives

The major goal of this laboratory course is to help students enhance their ability to work independently in solving experimental problems, to learn new data analysis methods, and to develop oral and written presentation skills. Standard experimental methods and procedures that are used in research laboratories will be introduced, and therefore certain new material will be presented that is not normally encountered in first- and second-year labs.

Students will work independently completing the hands-on setup and data collection individually or in a group of two. The most important component is experiential learning through trial and error.

At the end of the fourth-year laboratory course students will be able to:

- Apply theoretical knowledge to complex physics experiments
- Demonstrate knowledge of the underlying physics principles for each experiment
- Solve technical problems encountered in experiments independently
- Develop modeling and designing skills for each experiment
- Apply various software packages and statistical tools in data analysis
- Demonstrate knowledge of safety procedures in the laboratory environment
- Use analysis techniques independently

- Select and apply error analysis methods based on each experiment requirements
- Develop skills of using a logbook for data collection and experiments preparation
- Write lab reports complying with scientific journal formats
- Enhance oral communication skills through presentations

These objectives will be reinforced through discussions, questions, tests, laboratory reports, oral presentations, and logbook records.

Rules of Conduct

We are committed to fostering an environment for learning that is inclusive for everyone regardless of gender identity, gender expression, sex, sexual orientation, race, ethnicity, ability, age, class, etc.

- All students in the class, the instructors, staff members, and TAs must be treated with respect during all interactions.
- Disrespect to TAs, other students or the lab supervisor in the labs will not be tolerated. Crossing personal boundaries can be considered as a harassment.
- Discussions about the experiment or any disagreements about work must fall on reasoned arguments about physics principles, the data, or acceptable procedures.
- Disruptive behavior (that may include interfering with other students' work or expecting someone else to do their experimental work) will not be tolerated and lab rules will be strictly enforced.
- The learning process involves making mistakes and learning from them. Respect that and be prepared to repeat measurements.

Attendance

- Attendance to the lab sessions is mandatory. Labs start on the first week of classes, on **Jan 6th**. Lab sessions will be held twice a week. Please check Carleton Central for lab location.
- Each student is expected to come to the lab on time for each lab period. If you are unable to come to the lab (or will be late) on a certain day, inform the instructors as soon as possible. Make sure to include an Academic Consideration for Coursework Form to explain your absence. If the reason for missing the lab is accepted by the Lab instructors, then arrangements to make up for the lost time may be made. This will be scheduled outside of the scheduled lab time (during working hours) when staff are available to supervise and help.

  Note:
  - One missed lab session must be re-done within the following 2 labs sessions.
  - The second missed lab session (again, with the academic consideration form to explain absence) would require a conversation with the Registrars' Office / Student Care and Support Team.
  - If a student were to miss a third lab session (or more), the student may not be granted permission to continue with the course.

Organization

- Students will perform the experiments individually or in teams of two. The groups and experiments are pre-assigned, and they will be discussed during the first lab session.
- Each student will perform two experiments (see schedule). Complete individual lab reports are expected for each. While the data may be shared between partners, the analysis must be done individually.
- Each student will keep a physical or electronic logbook record using OneNote or other type of electronic record keeping notebook. The progress of the record keeping will be formally evaluated.
- An outline of each experiment's details, measurements, and analysis is posted on Brightspace along with a set of recommended readings relevant to each experiment. Read the provided materials prior to each experiment and write notes in the logbook. As part of your preparation and your logbook evaluation, outline a detailed plan of how the experiment will be conducted (calibration runs, measurement techniques, etc.). Be prepared to answer questions about the experiment's underlying physics motivation and procedure during the first period scheduled for each experiment. Discussions on the progress will be formally evaluated.
- Students are expected to work on the experiments and analysis during the scheduled lab period. Working outside lab hours is possible, but this work is additional to the scheduled lab sessions and up to the student. Students working on other courses during the lab sessions will be asked to leave and the session will need a make-up.
- A copy of the original data recorded in the logbook must be presented for review to the lab supervisor or TA at the end of the data taking period. While in some cases the data might be shared between the members of a group, some experiments will require a set of data for each individual.
- All the lab reports are due at the time of the start of a new experiment, before the lab starts that day (the due dates are indicated in the lab schedule). Each student will write his/her own lab report. No shared formatting of tables or graphs will be allowed. Late penalties will be applied as soon as the due date and time has passed.
- Each student will give a 10-minute presentation (plus 3 minutes for questions) for each of the long experiments. All the presentations will be given in person in the lab (see lab schedule for the exact dates). The time limit will be strictly enforced.
- All logbook records, lab reports, and presentation documents are to be submitted online via Brightspace by the due dates indicated in the schedule.
- To pass the lab course, all components of the experimental work must be completed and a lab report for each experiment must be submitted.
- The final grade is a weighted average of the written reports, the oral presentations, the logbook record and your performance during the lab sessions.

- For safety reasons, experiments may not be carried out if you are alone. The lab will be accessible outside of class times to do analysis, to access data files, but not to perform experiments. Access to the lab outside regular lab times might be granted upon request.

Computer Use Rules

Most of the computers in the advanced lab are connected to the network and you can log on with your Carleton account to use them.

- Use your Brightspace credentials (username and password) to log on or use the student account specified in the computer.
- It is the student's responsibility to save their work before logging off. Save your collected data and files on a USB key, or on the P: drive, or e-mail them to yourself for analysis at home.
- The data may be lost once you log off from the computer.
- If you are collecting data for a long period of time, you will still be connected to the machine on the next day but will be asked to type your password again.
- If experimental data or a file is not saved and it is lost, the student will have to collect the data again.

Experimental Procedures

When performing an experiment there are several aspects to factor in; how to use the equipment in the best possible way to give you accurate results, what techniques to use for the analysis, and how to communicate to the reader that your results are meaningful.

Follow these steps when approaching an experiment or the analysis of provided data:

- Read the instruction materials AND the recommended resources relevant to each experiment. NOTE: the instruction materials are on their own insufficient for you to understand the underlying physics and goals of your experiment and develop a successful experimental procedure and data analysis strategy that will ultimately result into good quality data.
- Conduct background research and understand the goals and physics motivation of the experiment. Enter these in your logbook.
- Work out a technique for taking all the measurements (or review the literature about the details of already collected data). Write the process in your logbook record, it will help you when you write the procedure in the report later. Think of ways to double-check your results and ensure that you are not making mistakes.
- Discuss the procedure and safety handling of the equipment with the lab instructors before turning any equipment on and taking any measurements.
- Organize your measurements in proper formatted data tables and produce preliminary plots of the data. Identify trends and anomalies in the data and write reflections on your observations.
- Regularly update your logbook with your progress in the experiment (i.e. theory derivations, equipment characteristics and limitations, the set-up, trial runs, the data analysis, assessment of uncertainties, etc.)

Experiment Schedule

Week	Date	Experiment	Lab Work Due*
1	06-Jan	Introduction	Logbook 1
	08-Jan	Experiment I	
2	13-Jan		Logbook 2
	15-Jan		
3	20-Jan		Logbook 3
	22-Jan		**Discussion I**
4	27-Jan		
	29-Jan		*Theory Draft*
5	03-Feb		Logbook 4
	05-Feb		*Presentation Draft*
6	10-Feb		
	12-Feb	Oral Presentations	
7	17-Feb	Fall Break	
	19-Feb		
8	24-Feb	Experiment II	**Exp I Lab Report**
	26-Feb		Logbook 5
9	03-Mar		
	05-Mar		Logbook 6
10	10-Mar		**Discussion II**
	12-Mar		
11	17-Mar		*Theory Draft*
	19-Mar		
12	24-Mar		Logbook 7
	26-Mar		*Presentation Draft*
13	31-Mar		
	02-Apr	Oral Presentations	
	07-Apr		**Exp II Lab Report**

*Logbook record uploads will be due at the end of the session on the specified dates. Lab report submissions will be due at the start of the lab period on the specified dates.

The available experiments are listed below. For more information on each, see the summary of experiments (provided as a separate document).

Experiment I	Experiment II
X-Ray Fluorescence	X-Ray Diffraction
Laser Doppler Velocimetry	Mach-Zehnder Interferometer
Normal Zeeman Effect	Silicon Photomultiplier Characterization
Pulsed Nuclear Magnetic Resonance	Muon Lifetime (+ Monte Carlo simulation)
Alpha Spectroscopy	Lock-in Amplifier Detection
Beta Spectroscopy	Fourier Optics

Grade Breakdown

To pass the lab course, all components of the experimental work must be completed and a lab report for each experiment must be submitted. The final grade is a weighted average of the introductory work, the written reports, the oral presentations, the logbook record and your performance during the lab sessions.

COMPONENT	GRADE VALUE
EXPERIMENTAL CLASSWORK	20% (attendance and in-lab work 10%, logbook record worth 10%)
FORMAL DISCUSSIONS	10% (two discussions with lab instructors/TA about the progress of each experiment)
LAB REPORTS	50% (two lab reports completed on an individual basis, each worth 25%)
ORAL PRESENTATIONS	20% (two presentations, each student will be assessed separately)

Course instructors and TAs will keep a record of your arrival and dismissal time, your work during the lab sessions, and will ask you questions about your experiment.

Late reports will incur a penalty of 10% for every 24 hours after the due date and time. Reports that are more than two weeks late will not be graded (they still must be submitted to show that the experiment was performed, and it is required for the student to pass the course).

If a request is made for a grade adjustment in a lab report, the full lab report will be reevaluated by the instructors, and the new awarded mark will be considered final.

Assessment in this Course

In evaluating a student's work, the following aspects of his or her performance will be considered:

Experimental Preparation: The student must study the physics literature to the extent that they acquire an understanding of the theory and instrumentation relevant to their experiment. Notes of the relevant theory recorded in the logbook together with reflections and questions asked during class will be graded for each experiment.

Attendance & Lab Work: Students will work independently completing the hands-on setup, data collection, and respective literature review and analysis of results. The most important component is experiential learning through trial and error.
In-class quizzes, tests, and discussions will be part of the in-lab work. Lateness and how well the lab time is used to work on experiments and analysis will also be considered.

Discussions: There will be two formal in-lab evaluations for each student covering each experiment. The times will be decided based on the progress of the experiment but likely will be scheduled for the third week of each experiment.

Logbook Records: The logbook is a record of your work for each experiment. OneNote can be used or any other software that you are comfortable with and allows for continuous entries. For each experiment, it should include:

- date of entry
- objectives of the experiment (described in your own words)
- underlying physics, including references for later use
- tasks as they are completed – discuss outcomes, failures and how you overcame them
- new tasks and questions for next week
- preliminary plots
- results and calculations as the progress of the experiment is followed
- reflections of how well the equipment works, and difficulties encountered while working with the apparatus or during data analysis and how you went about overcoming them.

The log entries should be uploaded on Brightspace as per the schedule. They will be checked, marked, and discussed during the scheduled lab sessions. The logbook record keeping should make sense if you come back in a few months. There should be enough information that allows you to complete the experiment analysis and a write up as if starting again. The logbook record should provide valuable input to the reports and presentations.

Lab reports: The results of scientific research are usually published in scientific journals. In this course, you will present your experimental results in the form of laboratory reports. By doing so, you will develop

skills in scientific writing and will get to thoroughly understand the theory and data analysis involved in the experiments, gaining a better insight for the arguments supporting their validity.

The format to follow for a scientific report is listed below.

- Abstract (5%)
- Theory (20%)
- Apparatus/Procedure (15%)
- Analysis and Results (40%)
- Discussion (20%)
- References
- Appendices

When formatting the report make sure to use clear and short sentences. Make sure that the document is organized and that it is easy to find information in it. Give reasons for your calculations in order to validate a conclusion at the end. Present in detail your apparatus, provide a schematic (not a photo!) and motivate its use; just providing a list of the equipment used is insufficient and will be evaluated as such. Discuss your results, how they compare to other published measurements in literature, their quality and precision, any potential limitations of your apparatus that may have compromised the quality of your results. A good report can be written regardless of the quality of the result of the experiment.

Penalties (up to 10%) will be applied for lack of neatness and professionalism (ex. information missing, grammatical mistakes, unordered pages, etc.). Data acquisition and analysis files must be included as part of the submission, otherwise the report won't be graded.

Any lab report copied in whole or in part from another source will automatically receive a grade of zero. If another student is involved, both parties will be penalized.

Oral Presentations: The last two experiments will require a 10-minute presentation. This will allow you to develop skills on how to give a talk and help you prepare for future presentations at conferences. It might be presented as a group work, but each student will be individually graded.

The presentation at the end of each experiment should be prepared in PowerPoint. Before all the presentations start, please have your presentation file uploaded on Brightspace. Include the following slides:

- Title, author, and an outline specific to the experiment; 2 slides, one for the title page and one for the outline
- Introduction (15%), should include short history, the physics motivation and theory, the interest and practical applications; 3-4 slides

- Body of the talk (50%), experimental set-up and method, data collection, data analysis (graphs, tables), sources contributing to statistical and systematic uncertainties and how they were evaluated; 4-6 slides
- Results (30%), results and uncertainties, interpretation of results, connection of experiment with theory; 2-3 slides
- Short conclusion and a discussion on the method and errors (5%); 1 slide
- Diagrams (not photos!) should be used when appropriate to clearly illustrate the experimental setup and the underlying physics that is being addressed.

Instruction Materials

Excerpts from relevant resources specific to each experiment are available on Brightspace. A limited number of resources will be available for the students to borrow from the lab. Let the lab supervisor know if you intend to do so. Some useful textbooks are listed below:

Hughes, I., & Hase, T. P. A. *Measurements and their uncertainties: A practical guide to modern error analysis*. Oxford: New York, 2010.

Barford, N.C., *Experimental Measurements: Precision, Error and Truth*, John Wiley and Sons, 1985

Bevington, P., *Data Reduction and Error Analysis for the Physical Sciences*, New York, McGraw-Hill., 1992

Taylor, John R. *An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements*. Mill Valley, Calif: University Science Books, 1982.

Melissinos, A.C. *Experiments in Modern Physics*. Academic Press, 1966

Evans, *The Atomic Nucleus*, 1955

Haken, H., Wolf, H. C., *The physics of the atoms and quanta*, Springer, 2004

Dunlap, R.A., *Experimental Physics*, Oxford University Press, 1988

Preston, Daryl W. and Eric R. Dietz. *The Art of Experimental Physics*. New York: Wiley, 1991

G. F. Knoll. *Radiation Detection and Measurement.* John Wiley & Sons, New York, 2010

Safety in the Laboratory

Various hazards are present in the physics laboratory due to the use of sophisticated equipment and techniques. Prevention of injury, to students and staff, is a matter of being aware of, and treating with respect apparatus and materials which may be potentially hazardous. One of the goals of this physics

laboratory is to instruct students in the safe use of equipment and materials commonly encountered in research and industrial laboratories. We have endeavored to make the lab as safe as possible for students, but ultimately it is students' responsibility to ensure their own safety and that of others.

The following is a summary of the most basic rules and points:

- If an accident does occur, notify the lab supervisor or the lab technician immediately.
- In case of a fire alarm, evacuate the building in an orderly fashion, via the nearest fire stairs or exit (do not use the elevators), and meet in front of the Herzberg building.
- For detailed safety instructions on individual experiments, particularly those involving lasers and radioactive sources, consult the experiment notes and the provided references.
- Before starting any experiment always check for any potential hazards relating to the experiment and how to deal with them. Ask for help if in doubt.
- Carefully follow the instructions when assembling your circuit to prevent any short circuit.
- Practice good housekeeping. Clean-up your workstation and store any unused instrument.
- Food and drink are not to be consumed at the experimental benches.
- Never work alone in the laboratory.
- Understand the limitations of each instrument. Do not modify any instruments, use a damaged instrument, or use it in any unintended way.
- When using lasers wear appropriate eye protection. Never look directly into the laser output and beware of stray reflections.
- Maintain experimental setups at low height to prevent inadvertent scattering of light into your colleague's eyes.
- When working with radioactive sources, minimize your exposure by maximizing your distance to it.
- Never eat or drink when using radioactive sources and always wash your hands after handling the radioisotopes.
- Be aware of High Voltage power supplies and take the necessary precautions
- For details of the hazards associated with, and precautions for the safe handling of, the various chemicals and substances used in the laboratory, consult the relevant Material Safety Data Sheet (MSDS) folder on the laboratory's bookshelf.

For further reading on safety, consult the University website: https://carleton.ca/ehs/resources/

Plagiarism and Academic Misconduct

Sharing data information and exchanging ideas with your colleagues is expected, however every student has to come up with their own effort on how to resolve problems and suggest solutions. This exchange of ideas helps in the learning process. Sometimes you will get things wrong because of an error in the manipulation of apparatus or malfunction of the equipment. The lab supervisor will help you figure out

the problem or in the case that you can not get your own data, you may use someone else's (with the permission of the lab supervisor), provided you acknowledge it.

Both the substance and text of scientific reports must be one's own, and all sources of information must be stated. Fabrication or falsifications of data or using results of another student's work without acknowledgment is a serious plagiarism offense. In some cases, it can lead to the loss of academic status and will be addressed in a case-by-case manner.

In this course, independent work is required and there is a **zero-tolerance policy** on cheating. All violations of the Academic Integrity Policy will be reported the Dean's Office, and students will be sanctioned.

Here are some extracts from the ***Carleton University Academic Integrity Policy:***

"Students are responsible for being aware of and demonstrating behavior that is honest and ethical in their academic work. Such behavior includes:

- Following the expectations articulated by instructors for referencing sources of information and for group work.
- Submitting original work, citing sources fully, and respecting the authorship of others.
- Asking for clarification of expectations as necessary. Students who are in doubt as to whether an action on their part may be viewed as a violation of the standards of the academic integrity should ask their instructors, lab assistant and/or advisers.
- Identifying testing situations that may allow copying.
- Preventing their work from being used by others, e.g. protecting access to computer files, etc.
- Adhering to the principles of academic integrity when conducting and reporting research."

"Plagiarism includes reproducing or paraphrasing portions of someone else's published or unpublished material, regardless of the source, and presenting these as one's own without proper citation or reference of the original source."

Examples of appropriate peer-to-peer sharing/learning: identifying an incorrect or missing step in your lab partner's work, brainstorming potential reasons behind the results of the experiment with your lab partner, suggesting helpful modifications to improve the outcome of your experiment with your lab partner

Examples of unacceptable peer-to-peer sharing: Collaborating to write up reports with your lab partner or members of another group, sharing the experiment measurements, results, calculations, and analysis with other lab groups either in person or posting any of the above on social media platforms/homework help websites, use of generative AI tools for computational or writing purposes, sharing any part of your written report with your lab partner and other groups in person or posting any of it online

Students are expected to familiarize themselves with and follow the Carleton University Academic Integrity Policy. The Policy is strictly enforced and is binding on all students. Misconduct in scholarly activity will not be tolerated and may be subject to one of several sanctions.

Student Rights & Responsibilities

Students are expected to act responsibly and engage respectfully with other students and members of the Carleton and the broader community. See the Student Rights and Responsibilities Policy for details regarding the expectations of non-academic behaviour of students. Those who participate with another student in the commission of an infraction of this Policy will also be held liable for their actions.

If any student witnesses or experiences harassment, bring it up to the lab supervisor and contact Ombuds Services or Carleton Equity and Inclusive Communities.

If you are concerned, confused, or conflicted over something, please reach out to the lab supervisor through email for help. Let's do our best to support one another in this class and keep the lab environment a safe, inclusive, and positive experience for everyone.

Academic Accommodations

Carleton University is committed to providing academic accessibility for all individuals. You may need special arrangements to meet your academic obligations during the term. The accommodation request processes are outlined on the Academic Accommodations website.

Academic accommodation refers to educational practices, systems and support mechanisms designed to accommodate diversity and difference. The purpose of accommodation is to enable students to perform the essential requirements of their academic programs. At no time does academic accommodation undermine or compromise the learning objectives that are established by the academic authorities of the University.

Pregnancy Accommodations: Write any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist.

Religious Accommodations: Write any requests for academic accommodation due to religious obligations during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist.

Students with Disabilities: If you have a documented disability requiring academic accommodations in this course, please contact the Paul Menton Centre for Students with Disabilities (PMC) at 613-520-6608 or pmc@carleton.ca for a formal evaluation or contact your PMC coordinator to send your instructor your Letter of Accommodation at the beginning of the term. After requesting accommodation from PMC, meet with your instructor as soon as possible to ensure accommodation arrangements are made.

Participation in activities beyond the classroom experience. Reasonable accommodation must be provided to students who compete or perform at the national or international level. Any requests for academic accommodation must be submitted during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist.

Accommodations for missed work. Carleton recognizes that students may experience unexpected, temporary incapacitation (i.e., illness, injury, or extraordinary circumstances outside of a student's control). Accommodations for missed work must be requested via a written email to the lab supervisor along with an Academic Consideration for Coursework Form.

Note that these forms should be used for short-term concerns related to missed work; if you are experiencing chronic, ongoing challenges which necessitate a broader solution, reach out to the Paul Menton Centre and/or the Care Support team.

Freedom and Privacy Protection Act (FIPPA)

All students have the right to confidentiality in all aspects of their grades and performance in the courses taken in the Physics department. For more information, see Freedom and Privacy Protection Act

University Resources

Academic Support: Student Academic Success Services (SASS) at Carleton offers course-targeted study groups and supports and the Science Student Success Centre (SSSC) provides help with study skills.

Mental Health: If you are struggling, please do not hesitate to reach out. Carleton also offers an array of mental health and well-being resources, which can be found at https://carleton.ca/wellness/

Human Rights: The University and all members of the University community share responsibility for ensuring that the University's educational, work and living environments are free from discrimination and harassment. Should you have concerns about harassment or discrimination relating to your age, ancestry, citizenship, colour, creed (religion), disability, ethnic origin, family status, gender expression, gender identity, marital status, place of origin, race, sex (including pregnancy), or sexual orientation, please contact the Department of Equity and Inclusive Communities at equity@carleton.ca

Sexual Violence: As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and where survivors are supported through academic accommodations as per Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: https://carleton.ca/sexual-violence-support/

Other resources,

Academic and Career Development Services: http://carleton.ca/sacds/

Writing Services: http://www.carleton.ca/csas/writing-services/

Peer Assisted Study Sessions (PASS): https://carleton.ca/csas/group-support/pass/

Math Tutorial Centre: https://carleton.ca/math/math-tutorial-centre/

Science Student Success Centre: https://sssc.carleton.ca/