Physics 3900G
Senior Physics Laboratory
Course Information
Version: January 17, 2021

Calendar Description

Physics 3900 is an advanced physics laboratory course designed to familiarize the student with the basic concepts of modern physics, with emphasis on the development of experimental skills and including an introduction to computer programming and its use in experimental analysis.

Prerequisites: Physics 2910F/G or the former 2900E.

6 hours, 0.5 course.

Instructor: Dr. Lyudmila Goncharova
email: lgonchar@uwo.ca
Office hours: on Zoom by appointment lgonchar@uwo.ca

Staff members: Paul Christiaans, electrical engineer: pchrist@uwo.ca

TAs: Matheus Adam madam28@uwo.ca
Cole Gregg, cgregg2@uwo.ca

C**ourse website:** OWL site for this course: https://owl.uwo.ca/portal
Lab manuals, course materials, and assignments will be posted there. Please check the site often.

Class times: Classes begin: January 11, 2021; classes end: April 5, 2021

MW 2:30-5:30pm, via Zoom at the beginning of the Winter term
with some activities in-person in PAB 130 after January 25, 2021.
Please refer to the schedule in **Appendix I** (page 6).

Textbook. Selected chapters of the following textbooks will be on OWL/Resources/Books

1. P. Horowitz, W. Hill, The art of electronics (3rd ed.), Cambridge University Press, New York, 2015 – ISBN 978-0-521-80926-9.
2. Adrian C. Melissinos and Jim Napolitano, *Experiments in Modern Physics*, 2nd edition (Elsevier, 2003)
3. John R. Taylor, *An Introduction to Error Analysis*, 2nd edition (University Science, 1997).
4. Yaakov Kraftmakher, *Experiments and demonstrations in physics*, World Scientific Publishing, 2007.

Introduction:

The main goals of this course are to:

- demonstrate the experimental basis for some of the important concepts of physics
- introduce instrumentation and techniques essential to research and measurement in academic and industrial settings
- develop your experimental skills
- provide training in computerized data acquisition and analysis
- build skills in keeping a record of your activities, data, and results, and in preparing research reports
- develop your data analysis skills
- improve your understanding of the importance of experimental uncertainties in the analysis and interpretation of data

Lab Schedule

Tentative schedule of all experiments can be found in Appendix I.

This year you will be using all experimental setup alone. During the first four weeks of the term, you will perform four labs. These are:

1. **Sound Card Oscilloscope (SCO), on-line**
2. **Software Tools (ST), on-line**
3. **Analog Electronics (AE), in person**
4. **Digital Logic (DL), in person**

Weeks 5 and 6 will be dedicated to nuclear physics experiments, including

5. **Scintillation Counter (SC), on-line**
6. **Multichannel Analyzer (MCA), in person**

In the final five or six weeks of the term, each student will be required to complete one more advanced experiment from the list below.

Lab #7 (one week or 2 3-hour periods experiments):

Quantum Analogs (QA)	**MP**
Chaotic Pendulum (CP)	**OW**
Electronic Properties of Materials (EPM)	**CMP**
Nuclear Magnetic Resonance Spectroscopy (NMR)	**MedP**
Speed of Light (SL)	**O**
Optical Computed Tomography (CT)	**MedP**
Photoluminescence (PL)	**O, CMP**

There is only one set-up available for each of the Lab #7 experiment, they need to be scheduled in advance. Each student must email your lab choice, ranked in order of preference and including one or two "backup" choices, to Dr. Goncharova by Wednesday, January 20, 2021.

Lab #8: Arduino kit and sensor experiment design. This will be take-home experiment, Arduino kit and additional sensors will be provided early in the term, on January 25th, 2021, or by alternative ways provided by instructor.

Evaluation

Your final grade in this course will be calculated *approximately* according to:

Lab notebooks (electronic notes, or hardcopy)	8%
Radiation safety	2%
Evaluation of lab performance	10%
Homework (2)	20%
Short reports (4x5, submitted on OWL)	20%
Long reports and presentations, including	40%
SC (lab #5, 10%) with short presentation on the detector technology	
MCA (Lab #6, 10%)	
Lab # 7(PhUNC Poster presentation, 10%)	
Final presentation (10%)	

Lab notebook: All students are required to keep a record of their work in laboratory notebooks. This year, due to the COVID-19 restrictions, we can use electronic notes, e.g. OneNote via MS Office, or hardcover lab books, if you wish. You will need to upload PDFs from selected pages of your notebooks on OWL two times (initial marking and final assessment). Basic rules outlining what should be in your notes are listed below.

The purpose of the laboratory record is to have a sufficiently detailed record of your experiments that someone else could reconstruct exactly what you did. This is essential in case you – or someone else– have to check or repeat your measurements in the future. In a research laboratory, whether academic or industrial, laboratory notebooks are legal documents that can be important for establishing priority, obtaining patents.

If you use hardcover lab notebooks, the laboratory notebook must be bound, with numbered pages, and all entries must be recorded in ink. The date should be recorded on each page and your book should be signed by a TA or the course instructor at the end of each day when experiments are completed. No pages should ever be removed from this book, and errors should be crossed out with a single line (so that they are clearly rejected, but still legible). If it is useful to add information to this notebook (e.g., a computer-generated plot, or work completed at home), it should be permanently attached to a blank page with an explanatory note and the date, and should not hide any information that is written on the page. Calculations (entered by hand, or attached as printouts) and preliminary conclusions can be included.

Copies from your lab notebooks pages may be checked by the instructors at any time during the lab period to ensure that they are being properly kept, and must be submitted with your final reports on each experiment.

Evaluation of lab performance: 10% of your grade will be based on our observations of your experimental skills and effectiveness in the lab and informal conversations with you about the experiments. Things like falling asleep in the lab, showing up late or unprepared, ignoring safety rules, fighting with your lab partner, or breaking more than your share of equipment will have a negative impact on this component of your grade. Good preparation, initiative, and skill will serve to maximize it!

Radiation Safety Awareness: You will also get marks (2 points) for completing the Radiation Safety Awareness training (via OWL) described below.

Homework (20 points, submit both assignments on OWL). There will be two homework assignments on

data and error analysis (#1), and error analysis and principles of the detectors (#2), due in February. The first will be handed out early in the term, after the lectures on error analysis.

Lab reports are due on the dates listed in **Appendix I**. There will be four short reports, submitted on OWL (**SCO, DL, AE, and ST labs**, 5 % each) and two long **(SC, MCA)** reports and two presentations (PHUNC poster presentation for lab #7, and final talk for lab #8). In some cases, PHUNC poster can be prepared based on MCA lab results. Guidelines for long reports are listed in **Appendix II**. Late reports may be accepted with penalty: the marks will be divided by 2 for reports submitted two week after the deadline. In marking lab reports, graders will consider the scientific quality of the work, including your data and error analysis and the validity of your conclusions, as well as the clarity of the presentation and quality of your writing. Reasonable error analysis will be required to achieve an A, while some effort beyond that prescribed by the lab manual is necessary to reach an A+.

Detector technology presentation: you will learn about several different detector or amplifier technology in this course. You will need to make a short presentation on Zoom (5 minute, February 8, 2021) on the theory and practical aspects of one of the detectors in the following list (feel free to add your favorite detector to this list if you don't see it):

1. Geiger-Muller Counter;
2. Scintillation Detector
3. Photomultiplier
4. CCD
5. CMOS
6. Lock-in amplifier
7. Solid barrier detector
8. HPGe detector
9. Bolometer

PhUNC poster presentation: your project progress will be presented on March 2021 as a poster presentation during virtual PhUNC 2021. Posters will be uploaded on OWL and presented to other class members, faculty members, interested reviewers, course instructors and TAs.

Final Presentation: You will be presenting results of experiment #8 as a final oral presentation. All presentations will be presented on March 31 and April 5, 2021 together with the P4910G class. More instructions will be provided later.

Safety and Security

Please follow these common-sense rules:

- Do not work at any experiment in the lab outside of normal laboratory hours without permission from an instructor.
- Even when you have permission to work in the lab outside normal hours, *never* work alone.
- The rooms are for the use of Physics 3900 students only—no guests without permission.
- No food or drink is permitted next to experimental setups.
- Never remove equipment from the lab or allow anyone else to do so without permission from the instructor.
- Books from the lab collection may be borrowed only with permission from an instructor.

Radiation Safety: Several of the experiments in this course involve radioactive materials.

- *All students must complete Western's Radiation Safety Awareness training before starting any labs that involve radioactive sources.* This is a straightforward do-it-yourself web course. The link is on OWL in the Lab Safety folder, or you can go directly to http://www.uwo.ca/hr/safety/topics/nuclear/radiation.html.

- Please hand your signed Certificate of Completion in to Dr. Goncharova. You get 2 marks for doing this 😊
- Please read and understand the necessary precautions outlined in Appendix D of Melissinos and Napolitano (also in the Lab Safety folder) before attempting experiments the use radioactive sources. When in doubt, ask an instructor!

Accommodation Policies

Students with disabilities work with Accessible Education (formerly SSD) which provides recommendations for accommodation based on medical documentation or psychological and cognitive testing. The Academic Accommodation for Students with Disabilities policy can be found at:
https://www.uwo.ca/univsec/pdf/academic_policies/appeals/Academic Accommodation_disabilities.pdf

Academic Consideration for Student Absence

Students will have up to two (2) opportunities during the regular academic year to use an on-line portal to self-report an absence during the semester, provided the following conditions are met: the absence is no more than 48 hours in duration, and the assessment for which consideration is being sought is worth 30% or less of the student's final grade. Students are expected to contact their instructors within 24 hours of the end of the period of the self-reported absence, unless noted on the syllabus. Students are not able to use the self-reporting option in the following circumstances:

- for exams scheduled by the Office of the Registrar (e.g., December and April exams)
- absence of a duration greater than 48 hours,
- assessments worth more than 30% of the student's final grade,
- if a student has already used the self-reporting portal twice during the academic year

If the conditions for a Self-Reported Absence are *not* met, students will need to provide a Student Medical Certificate if the absence is medical, or provide appropriate documentation if there are compassionate grounds for the absence in question. Students are encouraged to contact their Faculty academic counselling office to obtain more information about the relevant documentation.

Students should also note that individual instructors are not permitted to receive documentation directly from a student, whether in support of an application for consideration on medical grounds, or for other reasons. **All documentation required for absences that are not covered by the Self-Reported Absence Policy must be submitted to the Academic Counselling office of a student's Home Faculty.**

For policy on Academic Consideration for Student Absences - Undergraduate Students in First Entry Programs, see:
https://www.uwo.ca/univsec/pdf/academic_policies/appeals/Academic_Consideration_for_absences.pdf
and for the Student Medical Certificate (SMC), see:
http://www.uwo.ca/univsec/pdf/academic_policies/appeals/medicalform.pdf

Religious Accommodation

Students should consult the University's list of recognized religious holidays, and should give reasonable notice in writing, prior to the holiday, to the Instructor and an Academic Counsellor if their course requirements will be affected by a religious observance. Additional information is given in the Western Multicultural Calendar:
https://multiculturalcalendar.com/ecal/index.php?s=c-univwo

Cheating

University policy states that cheating is a scholastic offence. The commission of a scholastic offence is attended by academic penalty, which may include expulsion from the program. If you are caught cheating, there will be no second warning. Cheating includes having available any other electronic devices than a watch and a calculator during a test or exam. You may not have a cell phone accessible, even to use it as a calculator or watch. Complete information on the University policy on academic offenses can be found at

http://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_undergrad.pdf

Academic Policies

The website for Registrar Services is http://www.registrar.uwo.ca.
In accordance with policy, http://www.uwo.ca/its/identity/activatenonstudent.html, the centrally administered e-mail account provided to students will be considered the individual's official university e-mail address. It is the responsibility of the

account holder to ensure that e-mail received from the University at his/her official university address is attended to in a timely manner.

Contingency plan for an in-person class pivoting to 100% online learning
In the event of a COVID-19 resurgence during the course that necessitates the course delivery moving away from face-to-face interaction, all remaining course content will be delivered entirely online, either synchronously (i.e., at the times indicated in the timetable) or asynchronously (e.g., posted on OWL for students to view at their convenience). The grading scheme will **not** change. Any remaining assessments will also be conducted online as determined by the course instructor.

Plagiarism

Students must write their lab reports, tests and final exam in their own words. Whenever students take an idea, or a passage from another author, they must acknowledge their debt both by using quotation marks where appropriate and by proper referencing such as footnotes or citations. Plagiarism is a major academic offence (see Scholastic Offence Policy in the Western Academic Calendar).

All required papers may be subject to submission for textual similarity review to the commercial plagiarism detection software under license to the University for the detection of plagiarism. All papers submitted will be included as source documents in the reference database for the purpose of detecting plagiarism of papers subsequently submitted to the system. Use of the service is subject to the licensing agreement, currently between The University of Western Ontario and Turnitin.com (http://www.turnitin.com).

Help

Please visit the Science & Basic Medical Sciences Academic Counselling webpage for information on add/drop courses, academic considerations for absences, appeals, exam conflicts, and many other academic related matters: https://www.uwo.ca/sci/counselling/

Please contact the course instructor if you require lecture or printed material in an alternate format or if any other arrangements can make this course more accessible to you. You may also wish to contact Student Accessibility Services (SAS) at (519) 661-2147 if you have any questions regarding accommodations.

Western University is committed to a thriving campus as we deliver our courses in the mixed model of both virtual and face-to-face formats. We encourage you to check out the Digital Student Experience website to manage your academics and well-being: https://www.uwo.ca/se/digital/.

This course has been supported by the Science Student Donation Fund.

If you are a BSc or BMSc student registered in the Faculty of Science or Schulich School of Medicine and Dentistry, you pay the Science Student Donation Fee. This fee contributes to the Science Student Donation Fund, which is administered by the Science Students' Council (SSC). One or more grants from the Fund have allowed for the purchase of equipment integral to teaching this course. You may opt out of the Fee by the end of September of each academic year by completing the online form linked from the Faculty of Science's Academic Counselling site. For further information on the process of awarding grants from the Fund or how these grants have benefitted undergraduate education in this course, consult the chair of the department or email the Science Students' Council at ssc@uwo.ca.

Appendix I Updated: 01/17/2021

All **in-person** activities ae listed in **purple color** below. All students are divided in Stream 1A, 1B, 2A, and 2B, and this information can be found on OWL, under "Resources" folder.

	Monday (2:30-5:30pm)	Wednesday (2:30-5:30pm)
Week 1	11-Jan Zoom, Introduction, COVID 19 procedures	13-Jan Zoom Lab #1 Sound card oscilloscope (SCO)
Week 2	18-Jan Zoom Error and uncertainty, Refresh on op. amps	20-Jan Zoom Lab #4 Software tools (ST) All on Zoom
Week 3	25-Jan Arduino pickup Distribution details will be provided	27-Jan Introduction to Arduino
Week 4	1-Feb HW#1 are due on OWL Lab #2 Analog electronics (AE) All on Zoom	3-Feb Lab #3 Digital logic (DL) All on Zoom
Week 5	8-Feb Lab #2/3 AE and DL All on Zoom SCO and ST reports* are due on OWL	10-Feb (6) Lab #5 Scintillation counter intro
Week 6	February 15-19. No classes, reading week	
Week 7	Feb 22 Zoom Detectors mini-talks Scintillation counter continue/PMT demo	Feb 24 Lab #6 MCA Stream 1A, in person Lab #7 Stream 2A, in person AE and DL reports* are due on OWL
Week 8	Mar 1 Zoom Short meeting on-line (after break) Arduino, more basic projects Lab #5 (SC) reports** are due on OWL	Mar 3 Lab #6 MCA Stream 1B, in person Lab #7 Stream 2A, in person Lab #8 Arduino Zoom for all other
Week 9	8-Mar Lab #6 MCA Stream 2B, in person Lab #7 Stream 1A, in person Lab #8 Arduino Zoom for all other Preparing poster Zoom for all Have poster (lab 6 or 7) ready for OWL	10-Mar Lab #6 MCA Stream 2A, in person Lab #7 Stream 1A, in person March 11: PhUNC poster presentation
Week 10	15-Mar HW#2 are due on OWL Lab #7 Stream 1B, in person Lab #7 Stream 2B, in person	17-Mar Lab #7 Stream 1B, in person Lab #7 Stream 2B, in person
Week 11	22-Mar Lab #7 Makeup time Lab #8 Arduino Zoom for all	24-Mar Lab #8 Arduino Zoom for all
Week 12	29-Mar Lab #8 Arduino Zoom for all Lab #7 reports** are due on OWL	31-Mar Final presentation Zoom (Day 1)
Week 13	April 5 Final presentation Zoom (Day 2)	

*S – short report; **L – long report, see appendix II for guidelines. All reports will be uploaded to OWL in one of the following formats: PDF (preferred) or Word (*.doc, *.docx).

Last day to deliver <u>all</u> lab reports in order to pass the course April 2, 2021 11:55pm

Appendix II

Guidelines for Long Lab Reports

Title Page: The title of the experiment, date, your name, and your lab partner's name are required. Indicate clearly who is the author of the report and who is the lab partner.

Abstract: This is a concise, one-paragraph summary of the basic goal and results of the experiment.

Introduction: This section can be used to describe the background and purpose of the experiment, an outline of the basic techniques used, how your experiment compares to related experiments and methods, etc.

Theory: This section should describe the basic science underlying the experiment. Equations that are used in the interpretation of data should be included, but need not be derived (unless specifically requested in the lab manual). Do not copy derivations found in the lab manual or in a textbook—instead, simply cite the source.

Experimental Details/Method/Procedure/Apparatus: Use one or more of these headings to describe the experimental set-up and how it was used to make measurements. A schematic diagram of the apparatus, accompanied by a few sentences of explanation, is always helpful. Do not reproduce all of the material from the lab manual, but refer to it as necessary. However, any procedures *not* included in the manual should be described.

Results/Measurements and Calculations: Tabulate your measurements. Be sure to include titles, units, and *uncertainty estimates*. Graphs should be properly formatted with captions and labeled axes. It is not necessary to include every last detail in the report. For example, if you take a series of observations (and record them in your lab notebook) to verify that an instrument behaves linearly, it may be sufficient to state in your report that it was linear to within *x*%.

Similarly, it is not necessary to show every detail of your data analysis. For instance, a sample calculation (with error analysis) might be included to provide the details of your method, but only the results are shown for subsequent calculations.

Discussion and Conclusions/Summary: Here you summarize and interpret the results of your experiment. Explain what your data mean. Include a discussion of any peculiar results or inconsistencies. Final results must have error estimates and, if appropriate, a comment on their agreement with theoretical or accepted values.

References: List any papers, books, or websites consulted in the preparation of the report. Note that all references listed must be cited somewhere in the main text in an appropriate format.

As a guideline, the text (not including figures, tables, and references) should not normally exceed 15 double-spaced pages.

Physics 3900/4910G – Senior Physics Laboratory/Advanced Physics Project

Learning outcomes

Students will be able to…

Laboratory and writing skills

- Effectively use oscilloscope, electrical breadboards, function generators, power supplies, multimeters in circuit analysis. Construct filters on breadboards and calculate their characteristics
- Practice skills in keeping a record of your activities, data, and results, and in preparing research reports
- Find different errors associated with laboratory measurements to be able to explain if experimental results are significantly different from calculated or theoretically predicted values
- Improve your understanding of the importance of experimental uncertainties in the analysis and interpretation of data
- Get training in computerized data acquisition and analysis

In various experiments that vary from one student to another students in this course students will

- Apply Kirchhoff's voltage and current laws for linear DC and AC circuits, in op amp analysis cases, such as inverting and noninverting circuits, voltage follower, differentiator and integrator
- Define materials (metals, semiconductors and insulators) by the difference in the band gap and remember few examples and band gap values for each type of material. Explore the electronic properties of conductors and semiconductors and learn about why they are so useful
- Get familiar with the standard components of pulse electronics that may be used with any detector giving a pulse output. Practice working with gamma-ray detectors in Compton scattering experiment.
- Explore behavior of a damped pendulum, both driven and undriven, in the regimes of small amplitude oscillations, with and without damping, steady-state driven motion and elements of chaos
- Determine the speed of light by modulating a light source and observing the phase shift in the modulations as the distance between source and receiver is varied
- Explore the use of vacuum chambers, pumps and gauges, and safe practices for use of radioactive sources.

Last updates: January 13, 2021