SYLLABUS
JANUARY 19, 2000
DEPARTMENT OF PHYSICS
WASHINGTON STATE UNIVERSITY

QUANTUM PHYSICS LABORATORY 415

Meeting times: Tuesdays and Thursdays, 10:35-11:50 am, Webster 249, 335-3866.
Laboratory times are by arrangement throughout the week.

Lab room key: See physics receptionist, Annette Ross, Webster 1245.

Texts and notebook: *Experiments in modern physics*, Adrian Melissinos (Academic 1966);
Data analysis for physical science students, Louis Lyons (Cambridge 1991);
Communicating in Science, Vernon Booth (Cambridge, 2nd ed., 1993);
One lab notebook with bound, quadrilled pages.

Instructor: Professor Gary Collins, Webster 554, 335-1354, mailto:collins@wsu.edu, (home) 332-8639. Office hours: when my door is open or by appointment.

Teaching Assistant: Dana Franz, Webster 548, mailto:vladimir@wsu.edu, (home) 338-4551

Course home page: http://www.wsu.edu/~collins/Phys415/ . Includes schedule and writeups.

OVERVIEW

This is an advanced laboratory in quantum physics approached by detection of nuclear radiations. Elementary experiments that explore basic interactions of radiations with matter are followed by design and completion of advanced experiments. Research-grade instrumentation is used made possible in part by an instrumentation grant from the National Science Foundation.

Physics 415 is a writing-in-the-major course (M) required for undergraduate physics majors. However, other undergraduates in science, math and engineering and entering graduate students will also find it an appropriate, engaging lab experience and are encouraged to enroll. The only prerequisites are familiarity with basic quantum concepts such as provided by Physics 303-304 and with the use of an oscilloscope. Knowledge about atoms, nuclei, solids and radiation that you will need to interpret the experiments is provided within the course.

GOALS

Knowledge goals

- Deepening your understanding of the quantum behavior of nuclei, atoms and solids.
- Improving research skills: Learning how to keep a lab notebook and design experiments.
- Properly treating statistical and systematic errors.
- Becoming versed in the ‘cultural norms’ of physics and similar disciplines.

Communication goals

- Communicating your experimental results orally in informal seminars.
- Evaluating results of others in a fair-minded way in seminars and in informal settings.

- Synthesizing and presenting results effectively and concisely in the contexts of a written lab reports, poster paper, oral presentation, and 'camera ready' manuscript.

COURSE ELEMENTS

A. Class meetings. We will all meet for 75 minutes twice each week for three activities.

(1) Presentation of background information by the instructor.

(2) Introduction to upcoming experiments by the instructor. A practical orientation will be given to instrumentation and methods. Students should come prepared by studying available writeups. When underlying concepts are unfamiliar, students should review background material (e.g., in texts for Physics 303-304 or 450). Some writeups describe more activities than may be required, so pay attention to instructions about those activities you will be expected to complete.

(3) 'Roundtable' discussion of experiments in progress. Students make informal progress reports that are subject to feedback and constructive criticism by other class members. All students are expected to participate in these seminar-style discussions. Interactions are cooperative, similar to what students may experience as members of a research team in their later careers.

B. Experiments. Students are expected to complete 7 experiments during the semester. The first 6 are “core” experiments in which basic skills are developed. Students are encouraged to work in pairs, but each should produce his/her own lab report. If data is taken by a pair, it is acceptable to paste photocopies of original data tables and figures from one student’s notebook into the other’s. Depending on abilities, the last 1-2 experiments are “advanced” experiments selected in consultation with the instructor and carried out toward the end of the semester. Writeups for many experiments can be found at http://www.wsu.edu/~collins/Phys415/.

Laboratory hours. Lab times may be scheduled at all hours. Keys to the building and lab room will be issued to you by Annette Ross, the receptionist in the Physics Department Office (335-1698). Reserve lab hours during the week in morning, afternoon, or evening time-blocks using a schedule posted on the blackboard. Scheduled students have "first dibs" on instrumentation. Students are expected to carry out core experiments early in the semester in the same time-frame so that they can benefit from discussions of methods and results with fellow students. A schedule is provided below. Please note that you will frequently be working in the lab without an instructor present. You should therefore come to the lab well-prepared and cognizant of safety concerns. There is a phone in the lab (335-3866) on which you may make outside local calls, including energency calls. Dial prefix “9” before outside numbers. Do not hesitate to call an instructor at work or home if you have safety concerns. Phone numbers are on the front page.

Laboratory notebook. Your notebook should be a journal of lab activities and methods and an archive of your data. A well-organized lab notebook betrays a well-organized mind. The notebook must have bound, quadrilled, numbered pages. Binding keeps pages from falling out. Quadrilled pages encourage neat, hand-drawn figures, tables, and paste-ins. The first 3 pages should be reserved for filling in a table of contents that eventually will list experiments completed, with dates of activity, and other important contents. Notebook entries such as experimental details, graphical and tabular data and preliminary results should be clearly labelled and carefully recorded in ink and dated.

Photocopies of figures or computer output may be carefully pasted in. One should learn from one's errors: Procedural errors should be identified and carefully documented, and improved methods described. Other remotely relevant information (e.g., room temperature, phase of the moon, ...) and unusual observations should be recorded. Notes should be legible and detailed enough so that another member of the class could reproduce your procedures solely from your report. However, notes need not be verbose: know your audience. Notebooks may be collected for review and comment.

Laboratory reports. Reports will be submitted separately from the notebook. They may be prepared by hand or using a word-processor. Original data collected should still be archived and labelled clearly in the notebook. Reports should be organized according to the conventions generally used in physics journal articles. Recommended elements are as follows:

1. *TITLE. Author, dates of activity, and partner (if any).*
2. *ABSTRACT. Summarize the results (not just the goals!) in one or two sentences. Include numerical results where appropriate. (This is often best written last).*
3. *INTRODUCTION. What are the goals of this experiment? What hypothesis or theory was tested? What is the relationship of this experiment to physics at large, and the broader significance? How did you propose to reach your goals?*
4. *MEASUREMENTS. Describe experimental apparatus, materials, methods of measurement and other relevant information concisely. Use diagrams (a xeroxed figure from a writeup or text is acceptable if properly referenced) to communicate information about setups, etc. Clearly describe deviations from "standard" procedure.*
5. *RESULTS.*

   (a) TABLES AND GRAPHS. Summarize data succinctly using tables and graphs. Label them clearly. Indicate where in your notebook raw data is located. Include sample calculations, 'seat of the pants' estimates, and units. Include error estimations: A measured value without an extimate of its uncertainty is meaningless! Always evaluate statistical and systematic uncertainties of the data and derived results.

   (b) NARRATIVE. Describe in plain terms what your results should indicate to a fair-minded reader. Leave interpretation to the discussion section that follows. Never underestimate a reader's inability to read your mind: make clear to the reader what you want him/her to understand from your graphs and tables.
6. *DISCUSSION. Interpret the results. Draw reasonable conclusions based on the above results. Here is the place for controversy, if any. Do results agree with predictions of some theoretical model or claim in the 'literature'? Are results physically reasonable? Are they convincing? Has something completely unexpected on the basis of present knowledge been observed? Persuade the reader that your assessment is valid and that you have adequately considered alternate explanations, especially possible errors in methodology. If results are 'new', explain why. Here is one way to organize the discussion:*

   (a) Give your interpretation of your results.
   (b) Explain how reliable you think the results are. Do the results suggest unrecognized systematic errors? If so, what are possible sources? Do the errors have an important or unimportant effect on your conclusions?
   (c) Do the findings support your initial hypothesis?
   (d) What changes in methods and/or additional measurements might better support or refute the hypothesis?
7. *ANSWERS TO QUESTIONS IN THE WRITE-UPS. Place them in this final section.*

And, of course, always cite references you consulted and from which you benefitted, either as endnotes or footnotes.

Final versions of reports may be typed with 1.5 or 2-line spacing on white paper using a word-processor. Figures should be drawn in ink or generated using graphics programs and a good-quality printer.

Criteria for grading lab reports. A written report for each experiment is due at a specified date in a separately circulated schedule. Report grades will be reduced by a full grade for each week they are late. All reports must be completed to pass the course. Grading will take into account:

1. Validity of results and interpretation (essential)
2. Quality of measurements and analysis
3. Organization of ideas.
4. Clarity of expression and conciseness.

About 20% of the grade will be based on the quality of writing and presentation as follows:

6. Presentation (neatness, clarity of figures, tables, captions...)
7. Spelling, punctuation, grammar (“minimal marking” method)

Reports will be evaluated with either of three outcomes: (1) a letter grade will be assigned immediately; (2) a provisional letter grade will be assigned contingent on correcting specified minor errors (e.g., minimal marking errors), or (3) the report will be returned ungraded if there are significant deficiencies (e.g., blunders, invalid conclusions, exceedingly poor presentation), with a clear recommendation for action to improve the data, analysis or report. There is no grading penalty if reports are turned back for more work.

C. Professional presentations of research results: A quality presentation of your research results will advertise and promote your work, attract attention and interest, and impress potential employers and established experts in the field. You will gain practice preparing poster papers, short oral presentations and scripts for publication.

1. Poster paper. Scientific meetings nowadays commonly include 'poster paper' sessions. Typically covering a *1m x 1m* wall area, a poster should be a succinct pictorial summary of the purpose, methods and results of an experiment. During scheduled poster session times, attendees circulate in a hall filled with posters and poster-presenters are 'on call' at their posters to answer questions. Poster sessions give persons interested in particular posters the opportunity to converse at length with the presenter. Effective posters are not rehashes of written papers but attractive presentations that stimulate viewers to ask the presenter questions. For Physics 415, each student will prepare a poster paper based on a core experiment that has been written up separately as a report. Poster papers will be presented soon after the spring vacation break.

2. Oral presentation. The American Physical Society, for example, has many sessions at meetings in which are presented a group of related 10-15 minute talks. Time for questions is limited to a few minutes at the end. An effective presentation can attract interest and stimulate contacts. For Physics 415, each student is to make a short oral presentation on an advanced experiment at the end of the semester that has been written up separately as a report.

3. 'Camera-ready' report on an advanced experiment. Students will prepare a polished report in a format suitable for submission to a scientific journal. This report will be in stead of one regular written lab report. The script will pass through a review/edit cycle with the instructor acting as journal editor and making recommendations for revisions to a first draft. The final draft should be in “camera-ready” form. Additional formatting instructions will be provided later.

Homework. Problems on error and data analysis from Lyon's text will be assigned, collected and graded.

Mid-term examination. A written examination will cover basic interactions of radiations with matter, how radiation detectors work, and statistics of counting experiments.

Oral final examination. Understanding of the experiments, instrumentation and methods used will be evaluated in an exam about 1-hour long. As part of the exam, suggestions will be solicited for ways to improve existing experiments or for entirely new ones. You should think about such improvements throughout the semester, record your 'ideas' in an indexed place in your lab notebook, and bring a one-page summary of suggestions to the exam.

GRADING

Letter-grades will be assigned for each activity shown in the table below. The course grade will be the average letter-grade calculated following the table below fiarly closely. The participation grade will recognize meritorious participation, such as in the meetings.

Activity	Contribution to Final Grade
Regular lab reports (6 x 7%)	42%
Camera-ready written report	16%
Homework	10%
Mid-term examination	8%
Poster-paper	6%
Oral presentation	6%
Oral final examination	6%
Participation grade	6%

STUDENTS WITH SPECIAL NEEDS

Reasonable accommodations are available for students with documented disabilities. Please notify the instructor during the first week of class of any accommodations needed. Late notification may cause the requested accommodations to be unavailable. All accommodations must be approved through the Disability Resource Center (DRC) in Administration Annex 206, 335-1566.

GOOD LABORATORY PRACTICE

You should get in the habit of making preliminary analyses of your measurements 'on the go'. This will help you check that the experimental design is working and help identify experimental problems before a lot of time is wasted taking useless data.

ETIQUETTE

As a courtesy to your classmates, please notify an instructor immediately if there appears to malfunctioning instrumentation or something misplaced so that we can get it fixed fast for you. Also, if you know ahead of time that you will miss a normally reserved lab time, please note it on the blackboard so that another student can make use of that time. Finally, please put things away when you are finished and leave the lab room and tables as tidy or tidier than you found it.

LABORATORY SAFETY

You will often work without presence of an instructor. You therefore have a special responsibility to yourself to be attentive to safe laboratory procedure and operation of instruments. Be gentle with the instruments. Be gentle when attaching or detaching coaxial cables, which look thick but are made to conduct signals, not for strength! Always lock the lab room door when you leave to avoid theft, even if you are only going to the lavatory. You should know everyone who visits the lab room since it is not used by any other students. There are two special safety concerns as follows.

1. RADIOACTIVE SOURCES

Most radioactive sources you will be using are weak, but you should still use them in such a way as to avoid unnecessary exposure. Safety involves reducing exposure to radiation by shielding and/or distance ($1/r^2$). You will complete WSU's radiation safety course early in the semester, for which you should read ahead in Melissinos on pages 137-149. Women who are or may become pregnant need to read additional information that will be provided about hazards of radiation to a fetus. *Individual dosimeters*. Individual dosimeters will be distributed to students upon completion of the safety course and an application form you will fill out. They should be worn when working near radiation sources. They will be collected once a month and returned to a central site for measurement of radiation exposure. *Portable dosimeter*. A portable dosimeter with real-time readings is available for use in the lab. It is located near the source checkout notebook. When activated, it measures exposures with a digital readout in units of mrem. Audible "beeps" are emitted after each incremental exposure of 1/40 millirem. *Storage of radioactive sources*. There is a strong ^{137}Cs source used in the Compton scattering experiment that is normally not moved. Other sources, all weak, are stored in a lead cistern located on a table near the sink. Entries should be recorded in a notebook when sources are checked out and returned to the cistern.

2. HIGH VOLTAGES

Radiation detectors in the laboratory often use biasses of 1000 volts or more. Normally, high-voltage cables are left connected and biasses left on, so that you should not need to connect or reconnect detectors.. If you must disconnect high-voltage cables, take care that equipment is completely turned off and fully discharged (e.g, filter capacitors) before attempting to detach or attach high-voltage connectors. If you have any doubts, call an instructor before you do anything!

RESOURCES

Experiments in modern physics, Adrian Melissinos (Academic, 1966), required text. A great deal of useful information is contained in this text. Results of experiments similar to some Physics 415 experiments are presented. The circuits are antiquated, but function like modern counter-parts. There is a good discussion of distribution functions, statistics, and errors in Chapter 10.

Data analysis for physical science students, Louis Lyons (Cambridge, 1991), required text. A clear, practical introduction to statistical analysis as applied in pulse-counting experiments.

Communicating in Science, Vernon Booth (Cambridge, 2nd ed., 1993). A practical guide to effective oral and written communication.

Physics 415 home page. At the URL http://www.wsu.edu/~collins/Phys415 are postings of the course syllabus and schedule, lab write-ups, and links to useful information elsewhere. Students are expected to be able to access the home page and to download writeups and other material in HTML or PDF files. Contact an instructor if you need help.

Handbook of Chemistry and Physics. Contains useful tables, such as a table of isotopes with information on nuclear properties and decay radiations, tables of x-ray wavelengths and energies, and tables of x-ray and gamma-ray absorption coefficients. Copies are in the lab room.

Table of isotopes (General Electric wall chart). Summarizes much nuclear data, in particular decay modes of isotopes. Mounted on the back wall and partly available over the web.

COMPUTING FACILITIES

Lab computers include a 486DX Windows 95 PC and a 386SX DOS PC, each with data acquisition modules. General-purpose applications are installed, including Microsoft Word, Microsoft Excel, and PSI-Plot. The Windows PC has an internet connection. Each student will be given a subdirectory on each machine in which to work or save data files. Students are welcome to use the machines to analyse data and prepare reports, and to use an attached laserjet printer

ACKNOWLEDGMENT

Elements of the outline for preparing and grading lab reports were adapted from Successful Lab Reports, by C. S. Lobban and M. Schefter (Cambridge, 1992).

LIST OF EXPERIMENTS

A list of experiments with links to writeups can be found at http://www.wsu.edu/~collins/Phys415/writeups.htm. Experiments are divided among core experiments, that are simpler in concept and scope, and advanced experiments.

Core experiments

1. Statistics of counting experiments
2. Gamma-ray energy spectroscopy
3. Beta-ray absorption
4. Gamma-ray absorption
5. X-ray energies of the elements (Moseley's law)

6. Compton scattering of gamma-rays
7. Angular correlation of positron annihilation radiation
8. High-resolution gamma and x-ray spectroscopy

<u>Advanced experiments</u>

9. Lifetime of the isomeric level of ^{137}Ba
10. Decay scheme of ^{116}In produced by neutron activation
11. Fermi-energy of conduction electrons measured by positron annihilation (follows lab 7)
12. Nuclear resonant fluorescence (Mössbauer effect)
13. Internal magnetic fields in solids (Mössbauer spectroscopy) (follows lab 12)
14. Nuclear relaxation (pulsed nuclear magnetic resonance)
15. Perturbed angular correlation of gamma-rays (using Collins's spectrometer)

<u>Other possible experiments</u>

16. Angular correlation of ^{60}Co gamma-rays
17. Charged particle spectroscopy (beta and alpha)
18. Muon detection and lifetime
19. Positron lifetimes in solids
20. Short-lived nuclear lifetimes measured using coincidence techniques