SYLLABUS 2002
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 by arrangement throughout the week.
Lab room key issue:	See Annette Ross, physics receptionist, 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 small bound, quadrilled lab notebook for recording activities and data. One 3-ring binder to archive finished lab reports.
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:	Slade Jokela, Webster 332, 432-9557 (cell), mailto:sjokela@wsunix.wsu.edu
Course home page:	http://www.wsu.edu/~collins/415-02/

OVERVIEW

Physics 415 is an advanced laboratory in quantum or modern physics approached through detection of nuclear radiations. Elementary experiments probe basic interactions of radiations with matter. Advanced experiments explore properties of condensed matter. Research-grade instrumentation is used throughout. Physics 415 is required for undergraduate physics majors and is a writing-in-the-major course (M). Graduate students and other undergraduates in science, math and engineering are also encouraged to enroll. Prerequisites are familiarity with basic quantum concepts such as provided by Physics 303-304 and familiarity with an oscilloscope. Knowledge about atoms, nuclei, solids and radiation that you will need to interpret the experiments is provided in the course.

GOALS

- To deepen your understanding of the quantum behavior.
- To develop research skills: keeping a lab notebook, independent design and execution of experiments, proper treatment of statistical and systematic errors.
- To become versed in the 'cultural norms' for communicating research results in physics through
  - careful recording of measurements in your lab notebook
  - well-written laboratory reports with effective presentation of data using tables and graphs.
  - oral discussion of progress in experiments in seminar-style group meetings.
  - formal presentations of reports in a 15-minute talk and in a poster paper.
  - preparation of a manuscript in format sutiable for submission to a scientific journal for publication. The script will go through a review and revise cycle with me acting as editor.

COURSE ELEMENTS

A. Class meetings. We meet collectively twice each week for three purposes.

(1) Presentation of background information and discussion.

(2) Introduction to upcoming experiments, including orientation to instrumentation and methods. *Students should come prepared by studying available writeups for experiments*. When underlying concepts are unfamiliar, students should review background material (e.g., in texts for Physics 303-304 or 450). Since some writeups describe more activities than may be required, pay close attention to instructions about specific activities you are expected to complete.

(3) 'Roundtable' discussion of experiments in progress. Students describe progress in their individual experiments, followed by informal discussion. *All students are strongly encouraged (and expected) to participate in a lively way!* Interactions are similar to what students may experience elsewhere as members of a research team.

B. Experiments. Students are expected to exercise initiative to get experimental work done in a timely manner. Students should complete 7-8 experiments during the semester. Writeups for many experiments may be found in a sketchy format at http://www.wsu.edu/~collins/Phys415/ Normally, the first 6 are "core" experiments in which basic skills are developed. Students are encouraged to work in pairs, with each should produce his/her own lab report. Each student should maintain his/her own data. If data is taken by a pair, then it is acceptable to paste a photocopy of original data tables and figures from one student's notebook into the other's. Students normally carry out core experiments early in the semester in the same time-frame so that they can benefit from discussions with fellow students. The last 1-2 experiments are "advanced" experiment(s) selected in consultation with the instructor and typically carried out toward the end of the semester.. A schedule of experiments and activities is provided separately.

Laboratory hours. Lab times may be scheduled at all hours. Keys to the building and lab room will be issued to each student by Annette Ross, the receptionist in the Physics Department Office (335-1698). Please reserve lab hours during the week in morning, afternoon, or evening time-blocks using the ongoing schedule posted on the blackboard. Scheduled students have "first dibs" on instrumentation and computers. Other students may work at the same time if there is no interference. Please note that you will most often be working in the lab without an instructor present. Therefore come well-prepared and cognizant of safety concerns. There is a phone in the lab (335-3866) from which you may make outside local calls, including emergency calls. Dial prefix "9" before an outside numbers. Do not hesitate to call me or Slade at work or home if you have safety concerns. Phone numbers are on the front page and posted in the lab room. To avoid theft, please ensure that the lab room is locked whenever the room is vacated. The lab room is used only by you and your fellow students.

Laboratory notebook. Your bound lab notebook should be a journal of lab activities and methods and an archive of your data. Strive to organize it well so that it will be useful to you (and others) later on. The notebook must have bound, quadrilled, numbered pages (e.g., National 53-108 or 53-110.) Use the quadrilled pages encourage neat, hand-drawn figures, tables, notes and paste-ins.

Pages should be numbered. 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 permanent ink and dated. Photocopies of figures or computer output may be carefully pasted in. Learn from your mistakes: identify and document problems and solutions that you find. Record other information liberally (e.g., room temperature, phase of the moon, ...) as well as unusual or qualitative observations because they often turn out to be useful. *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. As always, know your audience!* Notebooks will be collected for review and comment periodically..

Laboratory reports. Reports will be prepared based on measurements recorded in your lab notebook. They may be prepared using a word-processor. Reports should be organized according to conventions generally used in physics journal articles. Suggesed elements are as follows:

1. *TITLE. Author, dates of activity, and partner (if any).*
2. *ABSTRACT. Summarize the results (not the goals) in one or two sentences. Include principal numerical results where appropriate. (This is often best written last).*
3. *INTRODUCTION. What are the goals of the experiment? What hypothesis or theory was tested? What is the relationship to physics at large? Why should the reader care? How did you design an experiment to achieve your goals?*
4. *MEASUREMENTS. Describe experimental apparatus, materials, methods of measurement and other relevant information concisely. Use diagrams (a copied figure from a writeup, text or web-page is acceptable when properly referenced.) Clearly describe procedures and emphasize deviations from "standard" procedures.*
5. *RESULTS. Present your results. Strive for an effective presentation.*
   - (a) *TABLES AND GRAPHS. Summarize your results using tables and graphs. Label clearly. Indicate if raw data is archived in your notebook. Include sample calculations, 'seat of pants' estimates, and units. Always estimate errors. A measured value without an extimate of uncertainty is meaningless!*
   - (b) *NARRATIVE. Describe in plain terms what your results mean with a minimum of interpretation. Leave interpretation to the discussion section that follows. Never underestimate a reader's inability to read your mind: work hard for clarity.*
6. *DISCUSSION. Interpret the results. Draw reasonable conclusions based on the above results. Here is the place for controversy. Do results agree with a theoretical prediction, measurement or claim in the 'literature'? Are results physically reasonable? Are they convincing? Would you eat your hat if they were wrong? Has something completely unexpected and novel been observed? Persuade the reader that your assessment is valid and that you have adequately considered alternate explanations, especially errors in methodology. If results are 'new', explain. Finally, note what changes in experimental approach might better support or refute the hypothesis or lead to a more accurate measurement.*
7. *ANSWERS TO QUESTIONS IN THE WRITE-UPS. Place in a final section at the end of the report.*

And, of course, always cite references you consulted from which you benefitted in 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.

Grading lab reports. A written report for each experiment will be due at a specified date. *Reports for all experiments must be completed and turned in on time to pass the course.* Grading will take into account the following criteria:

1. Validity of results and interpretation (essential)
2. Quality of measurements and analysis
3. Clarity
4. Organization of ideas
5. 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...)
7. Spelling, punctuation, grammar (“minimal marking” method)

Reports will be evaluated with one of three outcomes: (1) a letter grade may be assigned immediately; (2) a *provisional* letter grade may be assigned that can be improved optionally by correcting minor errors that are specified (e.g., minimal marking errors), or (3) the report will be returned ungraded if there are major deficiencies such as blunders, invalid conclusions, or very poor presentation. A clear recommendation will be guveb for action to improve the report.

Late reports. Report grades will be reduced by a full grade for each full week they are late.

C. Professional presentations of research results: The 'cultural norms' of each scientific discipline define how we 'do science' and present it to others. A quality presentation advertises and promotes your work, attracts interest, and may impress potential employers or experts in the field. In this course you will practice preparing poster papers, short oral presentations and scripts for publication.

1. Poster paper. Scientific meetings frequently include 'poster paper' sessions in the scientific programme. Typically covering a *1m x 1m* wall area, a good poster is a succinct pictorial summary of the goals, methods and results of an experiment. During scheduled times, attendees circulate in a hall full of poster boards, with poster-presenters 'on call' at their posters to discuss their research and answer questions. This meeting format helps persons interested in particular posters get together with authors for a fruitful discussion. Effective posters do not simply rehash the written report or papers but stimulate questions and interaction. For Physics 415, each student will prepare a poster paper based on a core experiment written up already as a report. Poster papers will be presented at about the time of the spring vacation break.

2. Oral presentation. Scientific meetings frequently have sessions of 10-15 minute talks on related research given to an audience in a hall. Time for questions is limited to a few minutes at the end. Practice is necessary to say it all in 10 minutes. At the end of the semester, each student will make a short oral presentation on an advanced experiment that also will be written up 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 replaces a regular written lab report. The script will pass through a review/edit cycle in which the instructor will act as journal editor and make recommendations for revisions to a first draft. The final draft should be in “camera-ready” form suitable for submission to a scientific journal for publication. Formatting should follow the style manual of the American Institute of Physics..

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

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

<u>Oral final examination</u>. Understanding of the experiments, instrumentation and methods used will be evaluated during final exam week. As part of the exam, suggestions will be solicited for ways to improve existing experiments or for entirely new ones. *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 final 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
Core lab reports (6 labs x 7%)	45%
Advanced lab(s), including camera-ready written report (1-2 labs, by agreement)	12%
Homework	10%
Mid-term examination	8%
Poster-paper	5%
Oral presentation	5%
Oral final examination	5%
Class participation grade	10%

STUDENTS WITH SPECIAL NEEDS

Reasonable accommodations will be made 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 into the habit of making preliminary analyses of your measurements using graphs and sample calculations as you proceed. This can help as a check that useful measurements are being made and point the way to problems that can dealt with before a lot of time is wasted taking useless data. Finally, read the instructions and think!

ETIQUETTE

As a courtesy to classmates, please notify an instructor immediately if there appears to malfunctioning instrumentation or something misplaced. We will try to remedy the problem fast. Also, if you know ahead of time that you will miss a reserved lab time, please note it on the blackboard so that another student might make use of the time. Finally, please tidy up when finished.

LABORATORY SAFETY

You will often work without presence of an instructor. You therefore have a special responsibility to be cognizant of 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! <u>Always</u> lock the lab room door when you leave to avoid theft, even if you are only going to the lavatory. The lab room is not used by students in any other course, so never admit any students unknown to you. Two particular safety concerns are as follows.

1. <u>RADIOACTIVE SOURCES</u>

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. <u>*Individual dosimeters*</u>. 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. <u>*Portable dosimeter*</u>. 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. <u>*Storage of radioactive sources*</u>. 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. <u>HIGH VOLTAGES</u>

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.. However, if you must disconnect high-voltage cables, take care that equipment is completely turned off and fully discharged before attempting to detach or attach high-voltage connectors. <u>If you have any doubts at all, call an instructor before you do anything</u>!

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 most function like more modern counterparts. There is a good discussion of statistics and error analysis 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/415-02 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 download writeups and other material in HTML or PDF. 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 some modern Wintel PC's as well as an older 486DX Windows 95 PC and a 386SX DOS PC that house data acquisition modules. The computers are installed with general-purpose applications that include Microsoft Word, Microsoft Excel, and Origin graphics software. Students will be given subdirectories as needed in which to work or save data files. Students are welcome to use the machines to analyse data and prepare reports.

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 available 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. Other ideas are also listed.

Core experiments

1. Statistics of counting experiments
2. Gamma-ray energy spectroscopy
3. Beta-ray absorption (less recommended)
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

Advanced experiments

9. Scanning tunnelling microscopy of surfaces.
10. Absolute measurement of Compton Scattering crosssection.
11. Energy loss of electrons in aluminum or other material.
12. Lifetime of the isomeric level of ^{137}Ba
13. Decay scheme of ^{116}In produced by neutron activation
14. Fermi-energy of conduction electrons measured by positron annihilation (follows lab 7).
15. Nuclear relaxation (pulsed nuclear magnetic resonance). Relaxation of paramagnetic ions in liquid solutions; correlation with viscosity.
16. Heisenberg uncertainty principle: lifetime of nucleus and eenergy width. (Mössbauer effect)
17. Internal magnetic fields in solids (Mössbauer spectroscopy) (follows Heisenberg lab.)
18. Perturbed angular correlation of gamma-rays (using Collins's lab spectrometer)

Other possible experiments

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