PHYSICS 5846: INTRODUCTION TO EXPERIMENTAL TECHNIQUES FALL 1998

Purpose of course:

This course is intended to give an introduction to some of the most important techniques of contemporary experimental physics and provide examples of how they are used in a variety of modern applications. Your knowledge and understanding of these techniques will be further developed and tested via a sequence of homework and laboratory exercises.

Textbook:

There is no textbook for this course. Lecturers will provide lecture notes which will be handed out to students.

Class Meetings

As a rule, class meets Tuesday and Thursday 10:00 to 11:15 in UPL 107. In some cases, time and place will be different. Class periods are used for lectures, to show experimental demonstrations, and to do laboratory exercises. Changes in schedule, place, etc. will be announced by e-mail and on the World Wide Web (the course homepage is `http://www.hep.fsu.edu/~wahl/phy5846/fal98/index.html`.)

Course organization

The course will be team-taught by seven lecturers (Z. Fisk, J.D. Fox, D. Lind, H.B. Prosper, E. Myers, S.v.Molnár, H.D. Wahl = contact person for the course), and will consist of lectures of more or less independent topics that cover major areas relevant in modern experimental physics. The topics covered are governed by the field of interest and expertise of the lecturers that volunteered to contribute to this course. Most of the lectures are augmented by homework, laboratory exercises or demonstrations. In addition, every student has to give one presentation (during the last week of classes) and submit a paper about that same subject. The topics for these papers can be chosen by the students, but are subject to the constraint that the variety of topics should somehow reflect the breadth of topics covered in the course. Approval of the chosen topic by the course convener (HDW) is therefore required.

In a course like this with many different subjects covered by different lecturers, course continuity and coherence can be a problem. Also, in many cases the time alloted to each topic will be too short to allow a full treatment. To alleviate these problems as far as possible, each lecturer will prepare and distribute lecture notes which will at least indicate what are the major points covered in the lectures and what the students are expected to have learned about them. The lecture notes will also include references to sources of further information. It is hoped that these lecture notes will be a useful resource for you.

Topics covered in course:

Here is a preliminary list of topics; the list is possibly incomplete and subject to modifications. The order is arbitrary and does not reflect priority or order in the course.

- **sample preparation** (Zachary Fisk)

- **neutron spallation source and radioactive ion beam** (John Fox)
  In general terms, the lectures would deal with the science, technology, and problems associated with the Spallation Neutron Source being planned at Oak Ridge National Laboratory. This facility will be used mostly for materials science research and applications.

  A tie-in proposal is now being developed by the Oak Ridge nuclear physicists to use a portion of the 1 GeV proton SNS beam as a driver for a radioactive ion beam facility (ISOL - Isotope Separator On Line.) Many aspects of nuclear and materials science are touched by the two projects and the discussion might be interesting to a broad group of students with physics interests. Most nuclear physicists as well as materials science students are unfamiliar with neutron science and only a subset of nuclear physicists know much about ISOL matters.

Topics will include:

- Considerations leading to the SNS
- Types of work to be done at SNS
- Justification for ISOL - how it will work
- How to piggy-back ISOL onto SNS
- Problems associated with spallation/fission radioactive ion beam sources

- **Crystallography and methods of determining crystal structure** (David Lind), including a survey of diffraction based probes (electron diffraction, helium atom diffraction, x-ray diffraction, and neutron diffraction) and microscopy methods (including conventional light microscopy, SEM, HRTEM, and the various scanning probe microscopies such as STM, AFM, NFOM, and MFM, etc.)
  There will be demonstrations of the several examples of these experimental tools that we have here at FSU, and at least one full blown "lab experiment" that the students will have to do for credit involving one of the probes (probably (x-ray diffraction). There will also be several homework problems based on this area.

- **Introduction to lasers and electro-optics**(Ed Myers)
  to provide a basic understanding of laser operation, and briefly survey some important laser systems and electro-optical methods.
  Topics:
  Gaussian beams
  Optical resonators
  Interaction of radiation and atomic systems
  Gain coefficient
  Conditions for laser oscillation
  Saturation characteristics and power output
  Specific systems: Gas, dye, solid state, semiconductor
  Frequency stabilization of single mode lasers
  Electro-optic and acousto-optic modulation
  Q-switching and mode-locking
  Harmonic generation and parametric amplification

  There will be a lab. demonstration and a homework assignment.

- **Beam sources** (Ed Myers)
  - General concepts:
    Emittance and brightness
    Effects of space charge in charged particle sources
    Problems of extraction
  - Survey of beam sources and some applications:
    positive ion sources,
    negative ion sources
    atomic/molecular beam sources

  There will be a homework assignment.

- **Introduction to statistical methods** (Harrison Prosper)
  To introduce students to some of the basic ideas and methods of "classical" and "modern" (read Bayesian) statistics. I plan to use real examples from the physics literature. (Necessarily, this will come from areas with which I am most familiar.) I shall avoid using the Gaussian distribution in my examples so that certain ideas remain distinct - e.g., standard deviation and confidence interval. My aim is to provide the student with a firm grounding in useful statistical ideas.
  Topics or concepts to be discussed:
  - *Basic notions:*

    * decision function, estimator, loss and risk functions (in particular, the mean squared error)
    * bias, variance, efficiency of an estimator, consistency
    * covariance, correlation, and independence
  - *Classical statistics:*
    * The method of maximum likelihood; the method of moments; sampling theory. Use as an example: estimating the mean lifetime of an exponentially decaying system. Also measuring the top quark mass using the method of moments.
    * confidence intervals (both for continuous and discrete distributions). (In spite of the lore to the contrary a confidence interval does have a precise meaning. I hope to get that message across to the students, especially those who wish to do experiments.) Use the Poisson distribution as an example.
    * approximate methods, the likelihood ratio and its relationship to the χ^2-distribution. What to do about unphysical regions: use them, or lose them?
    * fitting: χ^2 method, likelihood method; goodness-of-fit tests (Kolmogorov-Smirnov, Cramér-Smirnov-Von Mises)
  - *Bayesian statistics:*
    * Bayes' theorem
    * hypothesis testing using bayesian probability
    * parameter estimation
    * confidence intervals
    * treating systematic errors and uncertainty
    * unfolding spectra
    * connection to neural networks

- **Magnetometry** (Stephan von Molnár)
  Topics:
  - overview of magnetometers
    a). Induction methods
    b). Force methods
    c). Vibrating sample magnetometer
    d). SQUID magnetometer
    e). Torque magnetometer
  - Novel techniques for special purposes
    a). Hall gradiometer
    b). Cantilever magnetometer

  There will be a lab which will involve the observation of preparation and mounting of a magnetic sample onto the sample holder of a commercial SQUID magnetometer. The data, which will be collected automatically by the SQUID as data points of magnetization vs. temperature and field, will then need to be analyzed by each student. This will permit the student to become familiar with:
    a). various methods of plotting magnetic data to extract significant constants
    b). experimentally defining a second order phase transition.

- **Accelerators** (Horst Wahl)
  The goal is to acquaint the student with basic concepts of the physics of accelerators used in nuclear and particle physics.
  Subjects to be covered:
    Overview of accelerator types
    beam manipulating elements
    beam acceptance, emittance
    betatron motion
    lattice functions, tune
    phase stability

synchrotron radiation
luminosity
beam cooling
representative examples of accelerators

There is no laboratory accompanying this section of the course, but there is homework.

- **Particle detection techniques** (Horst Wahl)
  Subjects to be covered:
  - Interaction of particles with matter
    - cross section, survival probability, free pathlength..
    - energy loss of heavy particles, electrons
    - electromagnetic interactions, strong interactions
    - interactions of photons
    - bremsstrahlung, pair production, electromagnetic showers
    - Cherenkov radiation, transition radiation
  - detector characteristics (sensitivity, response, efficiency, deadtime..)
  - gas detectors (ionization chambers, prop. counters, wirechambers, drift chambers,..)
  - calorimeters
  - semiconductor detectors
  - Cherenkov counters
  - scintillators, scintillating fibers
  - detector systems
  - typical experiments in particle physics

Lecturers:

Lecturer	office	phone	e-mail	office hrs
Zachary Fisk	409 Keen	644-2922	fisk@magnet.fsu.edu	Mo 09:00 - 10:00 We 09:00 - 10:00 or by appt.
John D. Fox	217 Keen	644-2066	fox@mail.phy.ornl.gov	Tu 14:00 - 15:30 Th 14:00 - 15:30 or by appt.
David Lind	412 Keen	644-1576	lind@magnet.fsu.edu	Mo 09:00 - 10:00 We 09:00 - 10:00 or by appt.
Ed Myers	115 NRB	644-4040	myers@nucmar.fsu.edu	Mo 09:00 - 10:00 We 09:00 - 10:00 or by appt.
Harrison Prosper	514 Keen	644-6760	harry@hep.fsu.edu	Tu 09:00 - 10:00 Th 09:00 - 10:00 or by appt.
Stephan von Molnar	406 Keen	644-5075	molnar@magnet.fsu.edu	Mo 09:00 - 10:00 We 09:00 - 10:00 or by appt.
Horst D. Wahl	512 Keen	644-3509	wahl@hep.fsu.edu	Mo 08:30 - 10:00 We 08:30 - 10:00 or by appt.

Course grading

There will be no exams in this course, only graded homework assignments and lab. exercises, as well as presentations and papers on subjects chosen by the students The course grade will be calculated using the sum of normalized grades from the homework, lab. assignments, presentation and paper, normalized to a total of 100 points. The following table contains the range in number of points (for 100 points maximum) necessary to achieve a given letter grade:

grade	points
A	≥ 75
B	< 75, ≥ 50
C	< 50

CLASS SCHEDULE

Week No.	Dates Tu - Th	Subject *Lecturer*	Assignment
1	25 Aug.	Organizational meeting	
2	1 Sep.	Statistical methods *Harrison Prosper*	homework
2	3 Sep.	Accelerators (1) *Horst Wahl*	homework
3	8 Sep. 10 Sep.	Statistics cont'd *Harrison Prosper*	homework
4	15 Sep. 17 Sep.	Statistics (cont'd) *Harrison Prosper*	
5	22 Sep. 24 Sep.	Magnetometry *Stephan von Molnár*	lab.
6	29 Sep. 1 Oct.	Lasers *Ed Myers*	lab. and homework
7	6 Oct. 8 Oct.	Beam sources *Ed Myers*	lab. and homework
8	13 Oct. 15 Oct.	Sample preparation *Zach Fisk*	
9	20 Oct. 22 Oct.	Crystallography (1) *David Lind*	homework
10	27 Oct. 29 Oct.	Crystallography (2) *David Lind*	lab.
11	3 Nov.	Accelerators (2) *Horst Wahl*	
	5 Nov.	Particle detection (1) *Horst Wahl*	homework
12	10 Nov. 12 Nov.	Spallation neutron source *John Fox*	reading ass.
13	17 Nov. 19 Nov.	radiaoactive ion beams *John Fox*	reading ass.
14	24 Nov.	Particle detection (2) *Horst Wahl*	
	26 Nov.	Thanksgiving	
15	1 Dec. 3 Dec.	Student presentations Student presentations	