US Particle Accelerator School

Sponsored by Yale University

to be held in New Haven, Connecticut, June 10 – 21, 2002

COURSE DESCRIPTIONS

Two-week full courses (June 10-21, 2002)

Accelerator Fundamentals

1 Yale graduate credit (the equivalent of 3 semester hours; undergraduate degree required for Yale credit)

Carol Johnstone, Fermi National Accelerator Laboratory

The course will begin by reviewing the basic physical laws and equations of motion that underlie the field of accelerators. Concepts, parameters, and approximations commonly used in describing the transport and acceleration of ensembles of particles, or particle beams, will be introduced. Methods of acceleration and their application in existing machines will be covered, highlighting differences and challenges in technique and technology depending on the energy and type of particle accelerated. Along with the examples of accelerators, important principles of optics, lattice design, devices, and advanced simulation tools available will be emphasized. *Prerequisites: College Physics and first-year Calculus.* [IU/USPAS P470]

Accelerator Physics

1 Yale graduate credit (the equivalent of 3 semester hours; undergraduate degree required for Yale credit)

Waldo MacKay, Brookhaven National Laboratory

This course will cover the fundamental physical principles of particle accelerators, with a focus on high-energy accelerators. It will include magnets, beam optical design, the single-particle dynamics of transverse motion, lattice design, single particle acceleration and longitudinal dynamics, rf systems, synchrotron radiation, nonlinear effects, linear coupling, emittance growth and beam cooling, collective effects. *Prerequisites: Electromagnetism and Classical Mechanics.* Textbook to be provided: *An Introduction to the Physics of Particle Accelerators,* by M. Conte and W. W. MacKay (World Sci., 1991). Other suggested references: *An Introduction to Particle Accelerators,* by E. J. N. Wilson (Oxford, 2001); *An Introduction to the Physics of High Energy Accelerators,* by D. A Edwards and M. J. Syphers (J. Wiley, 1993); *Accelerator Physics,* by S. Y. Lee (World Sci., 1999); *Particle Accelerator Physics I,* by Helmut Wiedemann (Springer Verlag, 1993). [IU/USPAS P570A]

Classical Mechanics and Electromagnetism in Accelerators and Beams

1 Yale graduate credit (the equivalent of 3 semester hours; undergraduate degree required for Yale credit)

Richard Talman, Cornell University

Topics will alternate each day between Electromagnetism and Classical Mechanics. Topics on electrodynamics include Maxwell's equations, units; static 2D fields and end effects; plane waves, impedance; transmission lines, impedance matching; wave guides and resonators; electron linac; retarded time formalism, radiation; synchrotron and undulator radiation; beam instruments: pick ups, current transformers; resistive wall wake fields. Topics on Mechanics include relativistic mechanics; linear oscillators, Laplace transform; Hamiltonian formalism, adiabatic invariance; synchrotron oscillations; transfer matrices, symplectic requirements; nonlinear oscillators, method of Bogoliubov and Metropolsky; method of difference equations (maps); Z-transform; resonance and chaos; beam-beam interaction; beam diagnostics and FFT. *Prerequisites: intermediate-level courses in Classical Mechanics and Electromagnetic Theory.* [IU/USPAS P570B]

Computational Methods in Electromagnetism

1 Yale graduate credit (the equivalent of 3 semester hours; undergraduate degree required for Yale credit)

Kwok Ko, SLAC

Numerical simulation has become an integral part of any accelerator design and in particular, electromagnetic (EM) modeling is now a routine procedure for prototyping accelerator components. In this course, we will present the computational methods that form the basis for many of the numerical modeling tools in electromagnetism as applied to accelerator design. Topics in electro- and magneto-statics, eddy currents, electromagnetic as well as space charge and wakefield effects will be covered, and the numerical algorithms (e.g. finite difference, finite element) pertinent to each of these areas will be examined. We will describe the main components of a typical modeling tool: mesh generator, field solver and post-processor, and will compare their specific features in available code packages such as MAFIA, HFSS and others. Students will gain hands-on experience with EM software by designing accelerator components typical of those currently being considered for use in next-generation linear colliders and storage rings. The computer exercises will include discussions on the design principles and computational techniques that are applicable to the problem at hand. We will use codes developed at SLAC to introduce advanced topics such as parametric optimization and parallel processing as ways to tackle more complex designs with stringent requirements in resolution and accuracy. *Prerequisites: Electromagnetism and Accelerator Physics, familiarity with numerical analysis and computers.* [IU/USPAS P571A]

<u>One-week half courses (June 10-14, 2002)</u>

Students must take one course each week to earn Yale University credit

Magnetic Systems: Insertion Devices

Graduate credit (the equivalent of 1.5 semester hours; undergraduate degree required for Yale credit)

Ross Schlueter, Lawrence Berkeley National Laboratory

This course introduces the fundamentals of the design of electromagnet, pure permanent magnet, superconducting, and hybrid iron/permanent magnet systems with special attention and application to insertion devices for synchrotron storage rings. Emphasis is on practical engineering and magnetics issues, after the stage has first been set with the magnetics fundamentals, beginning with a review of Maxwell's Equations. Topics included are: (1) theory of electromagnet, pure permanent magnet, and hybrid magnet design, (2) wiggler and undulator requirements and performance, (3) field strength and quality issues, (4) polarization, (5) magnetic forces, (5) coil construction and cooling; permanent magnet sorting and quality, (6) field errors in insertion devices, (7) pitfalls in design and construction, (8) novel insertion devices. *Prerequisites: graduate-level Electricity and Magnetism.* [IU/USPAS P671A]

Accelerator Vacuum System Design

Graduate credit (the equivalent of 1.5 semester hours; undergraduate degree required for Yale credit)

Louis R. Bertolini, Lawrence Livermore National Laboratory

This course is an introduction to the engineering, design, and testing of high vacuum and ultra-high vacuum systems for accelerators. Topics include a survey of vacuum pumping schemes, design of custom vacuum pumps, vacuum diagnostics, materials, methods of vacuum chamber construction, handling, and vacuum processing. We will discuss the role of gas desorption and pump speed experiments in the design process. Vacuum system supports and alignment techniques will also be described. A variety of computational tools will be described and utilized in classroom design exercises. *Prerequisites: some familiarity with Thermodynamics and Material Science.* [IU/USPAS P671B]

Particle Beam Optics Using Lie Algebra Methods

Graduate credit (the equivalent of 1.5 semester hours; undergraduate degree required for Yale credit)

John Irwin, SLAC

Lie operator methods have proven to be powerful tools in designing beamlines with strong nonlinearities, and were employed in the design of the PEP-II B-factory and Final Focus Test Beam beamlines at SLAC. The goal of this course will be to build an intuitive understanding of the meaning and use of these tools. The curriculum will begin with a thorough introduction to advanced classical mechanics concepts and Lie operator fundamentals, and continue with a detailed description of their application to the easy and difficult aspects of beamline design. In particular the course will include: truncated power series algebras (TPSA), canonical dynamics and symplecticity, Poisson bracket basics, Lie operator basics, representation of simple and difficult beamline elements, representation of beamline modules, factorization methods, resonance basis and normal forms, and fields (non-Hamiltonian Lie operators) for synchrotron radiation. *Prerequisites: a course in Accelerator Physics.* [IU/USPAS P671C]

One-week half courses (June 17-21, 2002)

Students must take one course each week to earn Yale University credit.

Applications of Synchrotron Radiation in Materials Science

Graduate credit (the equivalent of 1.5 semester hours; undergraduate degree required for Yale credit)

Denis B. McWhan, Brookhaven National Laboratory (Retired)

The use of synchrotron radiation is no longer just the province of the experts; it has become ubiquitous as a tool for the study of materials. This survey course will present the fundamental properties of synchrotron radiation and describe the sources that are available to universities, industry and government laboratories in the U.S. The course will then cover the wide range of different synchrotron experiments that can be used to characterize materials. The unifying theme will be "what can one learn about Si, SiO2 and products derived from them using synchrotron-based experiments". How does one understand both the atomic and electronic structure of different phases; the role and control of impurities and defects, and how surfaces differ from the bulk? These properties can be studied using diffraction, spectroscopic, and imaging techniques. The structure of powders, single crystals, surfaces, and various synthetic multilayers are determined using x-ray diffraction. Chemical and near neighbor information is obtained from X-ray absorption spectroscopy, and the electronic structure is probed using angle resolved and spin polarized photoemission and various core level spectroscopies. Imaging techniques include x-ray topography, x-ray microtomography, scanning x-ray microscopy and infrared spectromicroscopy. The objective of this course is to provide a materials scientist, at the graduate student-level and above, with the basic information needed to use synchrotron-based experiments in their research. *Prerequisite: familiarity with Condensed Matter Physics and Materials Science at the undergraduate level.* Text to be provided: *Elements of Modern X-Ray Physics* by Jens Als-Neilson and Des McMurrow, (Wiley NY, 2001). [IU/USPAS P671D]

Medical Applications of Accelerators and Beams

Graduate credit (the equivalent of 1.5 semester hours; undergraduate degree required for Yale credit)

Jacob Flanz, Massachusetts General Hospital and Harvard University

This course discusses the applications of beams in medicine and explores the accelerator designs used to produce them. The relevance of beams to medicine has been recognized from the time that particles were discovered. We will discuss how to prepare these beams appropriately for a variety of clinical uses, including the flow down from the application specifications to the parameters of the accelerator and beam delivery equipment. Machine design parameters and tolerances will be derived for linacs, rings, cyclotrons and beamlines. Applications include diagnostic medicine, medical radiation oncology, and material process for medical uses. Some introductory familiarity with accelerator systems will be assumed. *Prerequisites: a course in Accelerator Fundamentals or Accelerator Physics.* [IU/USPAS P671E]

Applications of MATLAB in Accelerator Physics and Engineering

Graduate credit (the equivalent of 1.5 semester hours; undergraduate degree required for Yale credit)

Andrei Terebilo, SLAC

Many common problems in accelerator physics can be formulated in matrix notation and analyzed using linear algebra tools. Problems of this kind are ideally suited for solving with MATLAB. The course will give a brief (one-day) introduction of the tools available in MATLAB and the possibilities for bringing the accelerator simulation data into MATLAB: formatting the input and reading the output of accelerator codes or performing the simulation in MATLAB using Accelerator Toolbox framework. Then the course will concentrate on a few practical examples from the physics of storage rings. The examples will include: closed obit control, linear optics correction, and transverse coupling analysis. They will use as inputs, the real measured data sets as well as numerical simulations. *Prerequisites: graduate courses in Accelerator Physics, Linear Algebra, and Numerical Methods. Some exposure to accelerator modeling codes is beneficial.* [IU/USPAS P671F]