Syllabus for PHYS 790-D

Last Updated: 2019-04-30

PHYS 790-D Special Topics in Physics – Beam Physics

- *"Essential Beam Physics Calculations"*

Cross Reference: PHYS 459 Special Problems in Physics (by permission)

** Details:**

- *Fall Semester 2019*
- *Credits: 3*
- *Meeting Time:* Tuesday/Thursday 2:00-3:15
- *Class Room:* FR238
- *Instructor:* Prof. M.J. Syphers
  + La Tourette 204
  + msyphers@niu.edu

- *Office Hours:* Tuesday 10:00-11:00 a.m. or by appointment
- *Prerequisites:* Consent of Department

Textbooks and Software

Primary Textbook (pdf version provided by instructor):

- Edwards, D.A., and M.J. Syphers, *An Introduction to the Physics of High Energy Accelerators.* 2nd ed. New York, New York: Wiley (1993). http://onlinelibrary.wiley.com/book/10.1002/9783527617272.

Recommended Textbooks:

- S.Y. Lee, *Accelerator Physics* (Fourth Edition), Singapore: World Scientific (2019). https://doi.org/10.1142/11111
- M. Conte and W. Mackay, *An Introduction to the Physics of Particle Accelerators* (Second Edition), Singapore: World Scientific. https://doi.org/10.1142/6683.

Software to be used in class (freely available online):

- R (R Core Team 2016), https://www.r-project.org/
- Rstudio (Rstudio 2019), https://www.rstudio.com
- FEMM (David Meeker, 2018), http://www.femm.info
- MADX (Laurent Deniau 2017), http://mad.web.cern.ch/mad/
- G4beamline (Muons, Inc. 2017), http://public.muonsinc.com/Projects/G4beamline.aspx

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Accessibility Statement:

Northern Illinois University is committed to providing an accessible educational environment in collaboration with the Disability Resource Center (DRC). Any student requiring an academic accommodation due to a disability should let his or her faculty member know as soon as possible. Students who need academic accommodations based on the impact of a disability will be encouraged to contact the DRC if they have not done so already. The DRC is located on the 4th floor of the Health Services Building, and can be reached at 815-753-1303 (V) or drc@niu.edu.

Overview

This course will provide to the student an introductory overview of fundamental physics and computational techniques basic to the study of particle beam acceleration and transport. While many highly specialized codes and advanced techniques exist to produce precision results of the many detailed problems in particle accelerator design and application, this course sets out to introduce the student to programming procedures and methods for the calculation of many situations found in the dynamics of charged particle beams. Such problems may involve simple coding, specialized plotting and fitting, the use of simple solvers and minimization routines, Monte Carlo-style modeling with ensuing data analyses, essential matrix methods, and more, but will also include introductions to field/potential solvers and optics design codes used in the practice of magnet, cavity, and beam transport system design.

The student in this course will be guided in studies of particle beam transport, beam optical systems, particle acceleration, particle interactions with matter, and particle spin dynamics with emphasis on sensitivity analyses and elements of system design for various beam transport systems and electromagnetic elements routinely found in high energy and nuclear physics facilities.

By the end of the course the student should be able to demonstrate sufficient knowledge and skills to perform basic analyses of lowest-order beam optical systems in terms of stable beam transport, control of beam quality (emittance, energy spread, polarization, etc.), as well as basic estimations of hardware requirements.

In addition to the physics, the student will be introduced to basic tools and techniques for producing reproducible research, such as the use of the R/python programming languages, markdown documents, and LaTeX typsetting to generate scientific notebooks and make quality reports.

Topics

Topics to be covered in this course include (order may vary):

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- intro/review of fundamental beam physics
- reproducible research techniques (R/python, markdown, notebooks, LaTeX)
- essential modeling and data analysis techniques (using R/python)
- particle beams and phase space analyses
- basic field calculations in magnets and cavities (using FEMM)
- basic beam optics calculations (using MAD-X)
- beam interactions with materials (using g4beamline)
- application to special topics, such as:
    + sensitivity analyses
    + nonlinear particle motion
    + diffusive effects
    + space charge and beam-beam interactions
    + synchrotron radiation
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The above list and the course timeline will evolve as the time of the course approaches.

Grading (tentative) and Timeline:

Student evaluation will be performed through a set of homework assignments and computational projects. The final evaluation will also include the student's development of an electronic notebook of the course's activities, codes, and results.

Time line: August 26, 2019 – December 14, 2019