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<head>

<title>PHY 905: Fundamental of Accelerator Physics</title>

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<h1> Syllabus and Course Web Site <br>

PHY 905: Accelerator Physics</h1>

<!-- <h1><font color = "red">Under Construction</font></h1> -->

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<h2>

Michigan State University <br>

Spring Semester, 2018 <br>

3 credits <br>

Tuesday, Thursday, 4:10 pm - 5:30 pm <br>

National SuperConducting Cyclotron Lab (NSCL) Lecture Hall 1200 <sup>\*</sup>

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<blockquote>

<sup>\*</sup> Ask NSCL main desk reception for lab entry and directions to attend.

</blockquote>

<h3> Instructors:</h3>

<blockquote>

Prof. Steven M. Lund <br>

Michigan State University <br>

Physics and Astronomy Department <br>

Facility for Rare Isotope Beams (FRIB) <br>

640 South Shaw Lane <br>

Room 5302 <br>

517-908-7291 (office) <br>

510-459-4045 (mobile) <br>

Lund@frib.msu.edu <br>

<!-- <a href="https://people.nscl.msu.edu/~lund/">Web Page</a> -->

</blockquote>

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Prof. Yue Hao <br>

Michigan State University <br>

Physics and Astronomy Department <br>

National Superconducting Cyclotron Laboratory (NSCL) <br>

640 South Shaw Lane <br>

Room 5301 <br>

517-908-7524 (office) <br>

HaoY@frib.msu.edu <br>

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<h3> Course Web Site:</h3>

<blockquote>

https://people.nscl.msu.edu/~lund/msu/phy905\_2018/

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<h3>Purpose:</h3>

<p>

The purpose of this course is give a theoretical foundation to the

physics and technology of charged particle accelerators. This course

is suitable for graduate students from physics and engineering who

are interested in accelerators as part of their research or career

goals, or scientists and engineers who want more detail on the physics

of accelerator systems.

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<h3>Prerequisites:</h3>

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It is the responsibility of the student to ensure that

he or she meets the course prerequisites or has equivalent experience.

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<td>&bull; Required: Undergrad Electricity and Magnetism: level Griffiths, Intro to Electrodynamics (including special relativity) </td>

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<td>&bull; Required: Undergrad Classical Mechanics: level Taylor, Classical Mechanic (including Hamiltonian formulation of dynamics) </td>

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<td>&bull; Recommend: Undergrad Accelerator Physics: exposure at an elementary level </td>

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<td>&bull; Recommend: Graduate Electricity and Magnetism: level Jackson, Classical Electrodynamics </td>

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<td>&bull; Recommend: Graduate Classical Mechanics: level Goldstein, Classical Mechanics </td>

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<h3>Objectives:</h3>

<p>

On successful completion of this course, students should attain a basic understanding

of the physics of charged particle accelerators. Emphasis is on theoretical and analytical

methods of describing the focusing and acceleration of charged particle beams. Some aspects of

numerical and experimental methods will also be covered. Topics are systematically covered to

provide a foundation to designing a diversity of linear and circular machines. Example

applications are highlighted to attain a better understanding of accelerator systems used in

a plethora of fields such as high energy and nuclear physics, light sources for materials

science, medical technology, and industrial applications.

</p>

<h3>Instructional Method:</h3>

<p>

Lecture notes/slides complied by the instructor will serve as the "text"

for the course. These are given in the linked directory below. These include: notes developed by the

lecturer based both on materials from his courses in the US Particle Accelerator School and materials developed specifically

for this class, introductory overview material generously

provided by Prof. Mike Syphers (Northern Illinois U., former MSU) from

teaching a similar course in the <a href=" [http://uspas.fnal.gov](view-source:http://uspas.fnal.gov/)">US Particle Accelerator School</a>, and referenced material taken from

various textbooks. Lectures will augment and clarify these notes.

Textbooks (see below) are recommended,

but not required, for supplemental reading. Weekly problem sets (total 70% grade) will be

assigned which will be expected to be completed outside of scheduled class sessions. An overnight take home

final (30% grade) due the next day will be given during the finals period. The specific schedule will be determined on

consultation with the students for minimal conflict with other exams.

Points for all problems will be

specified. Problem set grades will be computed as a percentage of points scored relative to

points possible on all problem sets. Final exam grades

will be computed as a percentage of points scored relative to points possible on the final.

The problems are designed to reinforce and extend lecture presentations and will follow directly from materials covered.

Students are encouraged

to discuss the problem sets with other students and the lecturers/graders, but are required to turn in their

own solutions. On the final exam, both course lecture

notes and the student's own personal notes can be used, but all work must be independent. Clarification

questions to the lecturers are allowed.

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<h3>Course Content:</h3>

<p>

See topics on the course schedule below for the specific progression of topics. This

course provides a systematic introduction to the physics of charged particle beam

accelerators. Topics include: particle sources and injectors, field calculations

of magnetic and electric focusing and bending optics, particle equations of

motion, multipole descriptions of applied focusing and bending fields, thin-lens

and quadrupole focusing, edge focusing, solenoid focusing and beam canonical

angular momentum, phase amplitude methods and Hill-F¢s equation to describe

linear focusing, phase advance in periodic focusing lattices, the Courant-Snyder

invariant and beam emittance, dispersive and chromatic effects, momentum compaction

in rings, acceleration induced effects on beam emittance, resonance effects,

longitudinal particle acceleration with emphasis on RF technology, RF cavities

and traveling wave structures, Panofsky¢s equation describing longitudinal RF focusing,

longitudinal beam dynamics in linacs and rings, beam cooling, and space-charge

effects, and advanced acceleration techniques. Concepts are illustrated by brief

application sketches applying to a variety of linear and circular architecture

machines including synchrotrons, electron storage rings, and light sources.

Application lectures will cover a variety of machines.

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<h3>Schedule:</h3>

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The schedule below will be adjusted as the course progresses.

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<tr>

<td><a href="[schedule/schedule.htm](view-source:https://people.nscl.msu.edu/~lund/msu/phy905_2018/schedule/schedule.htm)">Schedule</a></td>

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<h3>Lecture Notes:</h3>

<p>

Lecture notes will be periodically posted on the course web site under the linked directories below for Prof. Lund and Hao.

Paper copies of lecture notes will be handed out in class to aid note taking.

When possible, corrections and additions will be posted on the course web site subsequent to lectures.

Materials are organized by lecture. Postings will be in pdf format. In some cases, notes are posted in both one slide per page (for presentation; e.g., 01.lecture.pdf)

(presentation) and 4 slides per page (handouts, for more compact printing; e.g., 01.lecture\_ho.pdf) formats. Notes will be maintained on this

on this web site after the course with occasional updates, corrections, and extensions until a next version

of the course is given. At that time, the web site will be frozen with a link to the newer version.

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<td><a href="[lec\_lund/](view-source:https://people.nscl.msu.edu/~lund/msu/phy905_2018/lec_lund/)">Lund Lectures</a></td>

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<td><a href="[https://people.nscl.msu.edu/~haoy/P905/](view-source:https://people.nscl.msu.edu/~haoy/P905/)">Hao Lectures</a></td>

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<h3>Supplemental Texts:</h3>

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The following optional texts can be used for additional background information but are not required for

the course:

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<tr><td>&bull; Wangler, <a href="[https://www.amazon.com/RF-Linear-Accelerators-Thomas-Wangler/dp/3527406808/ref=sr\_1\_1?ie=UTF8&qid=1515483987&sr=8-1&keywords=wangler+accelerators](view-source:https://www.amazon.com/RF-Linear-Accelerators-Thomas-Wangler/dp/3527406808/ref=sr_1_1?ie=UTF8&qid=1515483987&sr=8-1&keywords=wangler+accelerators)">

"RF Linear Accelerators"</a></td></tr>

<tr><td>&bull; Conte and MacKay, <a href="[http://www.worldscientific.com/worldscibooks/10.1142/6683](view-source:http://www.worldscientific.com/worldscibooks/10.1142/6683)">

"An Introduction of the Physics of Particle Accelerators"</a></td></tr>

<tr><td>&bull; Edwards and Syphers, <a href="[http://onlinelibrary.wiley.com/book/10.1002/9783527617272](view-source:http://onlinelibrary.wiley.com/book/10.1002/9783527617272)">

"An Introduction to the Physics of High Energy Accelerators"</a></td></tr>

<tr><td>&bull; Wiedemann, <a href="[http://www.springer.com/us/book/9783540490432](view-source:http://www.springer.com/us/book/9783540490432)">

"Particle Accelerator Physics"</a></td></tr>

<tr><td>&bull; Wille, <a href="[https://global.oup.com/academic/product/the-physics-of-particle-accelerators-9780198505495?cc=us&lang=en&](view-source:https://global.oup.com/academic/product/the-physics-of-particle-accelerators-9780198505495?cc=us&lang=en&)">

"The Physics of Particle Accelerators An Introduction"</a></td></tr>

<tr><td>&bull; SY Lee, <a href="[http://www.worldscientific.com/worldscibooks/10.1142/8335](view-source:http://www.worldscientific.com/worldscibooks/10.1142/8335)">"Accelerator Physics"</a></td></tr>

<tr><td>&bull; Berz, Makino, and Wan, <a href="[http://www.crcpress.com/product/isbn/9780750302630](view-source:http://www.crcpress.com/product/isbn/9780750302630)">

"An Introduction to Accelerator Physics"</a></td></tr>

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<p>

Several of these are available online via the MSU library.

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<h3>Problem Sets (70% Course Grade):</h3>

<p>

Problem sets will be handed out in class and subsequently posted below in pdf format on the course web site in the linked directory below.

The problem sets are due at the start of lectures on the day specified on the problem sets and schedule. Solutions will not be posted on this web site,

but paper copies of solutions will be handed out in class.

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<td><a href="[problems/](view-source:https://people.nscl.msu.edu/~lund/msu/phy905_2018/problems/)">Problem Sets</a></td>

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<!-- <tr><font color = "red">To be added during course</font></tr> -->

<!-- Comment out section ... add when ready

<tr>

<td><a href="problem\_sets/ps01.pdf">Problem Set 01</a></td>

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<td><a href="problem\_sets/ps02.pdf">Problem Set 02</a></td>

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<td><a href="problem\_sets/ps03.pdf">Problem Set 03</a></td>

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<h3>Final Exam (30% Grade):</h3>

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A take home final exam will be handed out at the end of the last lecture and subsequently posted

in pdf format on the course web site in the directory below. The final exam is due at the time specified on the exam and will likely have a duration of

one to two days.

Solutions will not be posted on this web site,

but paper copies of solutions will be handed out when the exam is returned.

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<td><a href="[final/](view-source:https://people.nscl.msu.edu/~lund/msu/phy905_2018/final/)">Final Exam</a></td>

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<!-- Comment out section ... add when ready

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<td><a href="final\_exam/final\_problems.pdf">Final Exam</a></td>

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<h3>Previous and Related Versions of This Course:</h3>

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This course will be given at MSU, depending on demand and needs, either every other year or every year during

Spring semesters. Also, a version of the course will be taught at the US Particle Accelerator School (USPAS) using essentially

the same materials in an compressed two-week intensive school format. The USPAS version will be taught in a

two to three year repetition cycle at locations around the country where the USPAS sessions are held. MSU graduate credit can

be given for MSU students taking the class at USPAS. Contact the instructors for more information.

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<td><a href="[http://uspas.fnal.gov/programs/2018/msu/courses/accelerator-physics.shtml](view-source:http://uspas.fnal.gov/programs/2018/msu/courses/accelerator-physics.shtml)">June 2018: USPAS Intensive School Version</a></td>

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<td><a href="[https://people.nscl.msu.edu/~lund/msu/phy905\_2016/](view-source:https://people.nscl.msu.edu/~lund/msu/phy905_2016/)">Spring 2016: PHY 905 Fundamentals of Accelerator Physics</a></td>

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