



*Physics/Department of Physics and Astronomy
Online Syllabus
August 7, 2020*

Part 1: Course Information

Course title: Advanced Accelerator Physics

Course catalog # and section: PHY564

Credit hours: 3

Semester: Fall 2020

General education designation(s) (SBC) (undergraduate only):

Prerequisites: Classical Mechanics, E&M, Linear Algebra (desirable but not obligatory)

Instructor name: Vladimir N Litvinenko

Instructor's Stony Brook email, phone number, and time zone:

vladimir.litvinenko@stonybrook.edu, 631-632-8093, EST

Office hours: Monday, Wednesday 4-5 pm (via BlueJeans, will be opened for all students signed for the course)

TA Information: N/A

Course Description: This graduate level course focuses on the fundamental physics and explored in depth advanced concepts of modern particle accelerators and theoretical concept related to them.

Required Course Textbook and Materials: Lecture notes presented after each class should be used as the main text. Presently there is no textbook, which covers the material of this course. Additional material can be found in:

Recommended Readings/Bibliography:

H. Wiedemann, "Particle Accelerator Physics" Springer, 2007

S. Y. Lee, "Accelerator Physics", World Scientific, 2011

L.D. Landau, "Classical theory of fields"

Course Delivery Mode and Structure:

This is a live online course, delivered using BlueJeans web conference software (provided by CASE, free for users). All lectures, weekly home-works and solutions will be posted that the CASE website: <http://case.physics.stonybrook.edu/index.php/CASE:Courses>. Students must be mindful of all course expectations, deliverables and due dates, especially because the online portion of the course requires significant time management. All assignments and course interactions will utilize internet technologies. See "Technical Requirements" section for more information.

How We Will Communicate:

Course-related questions should be asked during the online lectures using your microphone or posted in chat section of the session. You also can email me both the course and home-works related questions. For personal/private issues, email me directly. **Please allow between 24-48 hours for an email reply.** Your Stony Brook University email must be used for all University-related communications. You must have an active Stony Brook University email account and access to the Internet. All instructor correspondence will be sent to your SBU email account.

Plan on checking your SBU email account regularly for course-related messages. To log in to Stony Brook Google Mail, go to <http://www.stonybrook.edu/mycloud> and sign in with your NetID and password.

Regular announcements will be posted in the course site and may or may not be sent by email. Your home-works should be sent as email attachments. PDF format is preferred. Regular communication is essential in online classes. Logging in once a day, checking the course site and participating with your peers ensures that you are able to remain an active member of the class and earn full points for participation.

Technical Requirements:

This course uses BlueJeans which can be uploaded free-of-charge from <https://bluejeans.com>. Invitations for each session – either class or “office hours” will be sent to the class two days prior to the event. Cancellations will be sent by email.

If you are unsure of your NetID, visit <https://it.stonybrook.edu/help/kb/finding-your-netid-and-password> for more information. You are responsible for having a reliable computer and Internet connection throughout the term. **Caution!** You will be at a disadvantage if you attempt to complete all coursework on a smart phone or tablet. It may not be possible to submit the files required for your homework assignments.

Students should be able to use email, a word processor, spreadsheet program, and presentation software to complete this course successfully.

The following list details a minimum recommended computer set-up and the software packages you will need to have access to, and be able to use:

- PC with Windows 10 or higher (we recommend a 3-year Warranty)
- Macintosh with OS 10.11 or higher (we recommend a 3-year Warranty)
- Intel Core i5 or higher
- 250 GB Hard Drive
- 8 GB RAM
- Latest version of Chrome or Firefox; Mac users may use Chrome or Firefox. (A complete list of supported browsers and operating systems can be found on the My Institution page when you log in to Blackboard.)
- High speed internet connection
- Word processing software (Microsoft Word, Google Docs, etc.)
- Headphones/earbuds and a microphone
- Webcam (recommended)
- Printer (optional)
- Ability to download and install free software applications and plug-ins (note: you must have administrator access to install applications and plug-ins).

Technical Assistance:

If you need technical assistance at any time during the course you can:

- Phone: 631-632-9800 (client support, Wi-Fi, software and hardware)
- Submit a help request ticket: <https://it.stonybrook.edu/services/itsm>
- If you are on campus, visit the Walk-Up Tech Support Station in the Educational Communications Center (ECC) building.

Part 2: Course Learning Objectives and Assessments

Upon completion of the course, students will be able to:

1. Have a full understanding of transverse and longitudinal particles dynamics in accelerators
2. Being capable of solving problems arising in modern accelerator theory

3. Understand modern methods in accelerator physics
4. Being capable to fully understand modern accelerator literature

How to Succeed in this Course:

- Actively participate in classes: ask questions, request clarifications and make comments
- Complete all home-works in time, make them readable
- Prepare for your final exam: pick interesting project, read necessary papers and books, make clear and thoughtful presentation, practice you talk
- You expect to follow live presentation of each lecture and follow up each class with refreshing your memory by reviewing class notes on the course website and solving home-work problems. You expected to spend about 45 hours of your time participating in the live online lectures and 90 hours for work/study out of class

Part 3: Course Schedule

Week or Learning Module	Topic and Student Learning Outcomes	Readings, videos, podcasts, etc.	Activities, assignments, assessments, etc.	Due Dates and Points
1. Relativistic mechanics and E&D. Linear algebra.	This will be a brief but complete rehash of relativistic mechanics, E&M and linear algebra material required for this course.	Lectures 1-3	Home-works 1,2	Home-works are due in one week after posting
2. N-dimensional phase space, Canonical transformations, simplecticity, invariants	Canonical transformations and related to it simplecticity of the phase space are important part of beam dynamics in accelerators. We will consider connections between them as well as derive all Poincare invariants (including Liouville theorem). We will use a case of a coupled N-dimensional linear oscillator system for transforming to the action and phase variables. We finish with adiabatic invariants.	Lecture 4-5	Home-works 3,4	Home-works are due in one week after posting
3. Relativistic beams, Reference orbit and Accelerator Hamiltonian	We will use least action principle to derive the most general form of accelerator Hamiltonian using curvilinear coordinate system related to the beam trajectory (orbit)	Lecture 6	Home-work 5	Home-works are due in one week after posting

4. Linear beam dynamics	This part of the course will be dedicated to detailed description of linear dynamics of particles in accelerators. You will learn about particles motion in oscillator potential with time- dependent rigidity. You will learn how to calculate matrices of arbitrary element in accelerators. We will use eigen vectors and eigen number to parameterize the particles motion and describe its stability in circular accelerators. Here you find a number of analogies with planetary motion, including oscillation of Earth's moon. You will learn some "standards" of the accelerator physics – betatron tunes and beta-function and their importance in circular accelerators	Lectures 7-10	Home-works 6-9	Home-works are due in one week after posting
5. Longitudinal beam dynamics	Here you will learn about one important approximation widely used in accelerator physics – "slow" longitudinal oscillations, which are have a lot of similarity with pendulum motion. If you were ever wondering why Saturn rings do not collapse into one large ball of rock under gravitational attraction – this where you will learn of the effect so-called negative mass in longitudinal motion of particles when attraction of the particles cause their separation.	Lectures 11-12	Home-works 10,11	Home-works are due in one week after posting
Selecting research topic	Students should select research topic for their final exam	List of relevant papers and book will be provided by the instructor	Start studies for the final exam	September 30
6. Invariants of motion, Canonical transforms to the	In this part of the course we will remove "regular and boring" oscillatory part of the	Lectures 13-15	Home-works 12,14	Home-works are due in

action and phase variables, emittance of the beam, perturbation methods, perturbative non-linear effects	particle's motion and focus on how to include weak linear and nonlinear perturbations to the particles motion. We will solve a number of standard accelerator problems: perturbed orbit, effects of focusing errors, "weak effects" such as synchrotron radiation, resonant Hamiltonian, etc. We will re-introduce Poincare diagrams for illustration of the resonances. You will learn how non-linear resonances may affect stability of the particles and about their location on the tune diagram. You will learn about chromatic (energy dependent) effects, use of non-linear elements to compensate them, and about problems created by introducing them.			one week after posting
8. Vlasov and Fokker-Plank equations	This part of the course is dedicated to the developing of tools necessary for studies of collective effects in accelerators. We will introduce distribution function of the particles and its evolution equations: one following conservation of Poincare invariants and the other including stochastic processes.	Lecture 16	Home-work 15	Home-works are due in one week after posting
9. Radiation effects, beam emittance and kinematic invariants	You will learn how to use the tools we had developed in previous lectures (both the perturbation methods and Fokker-Plank equation) to evaluate effect of synchrotron radiation on the particle's motion in accelerator. You will see how the effect of radiation damping and quantum excitation lead to formation of equilibrium Gaussian distribution of the particles.	Lectures 17-19	Home-works 16-18	Home-works are due in one week after posting

10. Collective phenomena	Intense beam of charged particles excite E&M fields when propagate through accelerator structures. These fields, in return, act on the particles and can cause variety of instabilities. Some of these instabilities – such as a free-electron lasers (FEL) – can be very useful as powerful coherent X-rays sources. Others (and they are majority) do impose limits on the beam intensities or limit available range of the beam parameters. You will learn techniques involved in studies of collective effects and will use them for some of instabilities, including FEL. The second part of the collective effect will focus on how we can cool hadron beams, which do not have natural cooling.	Lectures 20-24	Home-works 19-23	Home-works are due in one week after posting
11. Non-linear effects, Lie algebras and symplectic maps	This part of the course will open you the door into and complex nonlinear beam dynamics. We will introduce you to non-perturbative nonlinear dynamics and fascinating world of non-linear maps, Lie algebras and Lie operators. These are the main tools in the modern non-linear beam dynamics. You will learn about dynamic aperture of accelerators as well as how our modern tools are similar to those used in celestial mechanics	Lectures 25-26.	Home-works 24,25	Home-works are due in one week after posting
12. Accelerator application, colliders	We will finish the course with a brief discussion of accelerator application, among which are accelerators for nuclear and particle physics, X-ray light sources, accelerators for medical uses, etc. You will also learn about future accelerators at the energy and intensity frontiers	Lectures 27-28.		Home-works are due in one week after posting

	as well as about new methods of particle acceleration.			
Optional class: Spin dynamics	If time allows – we will add this lecture. Many particles used in accelerators have spin. Beams of such particles with preferred orientation of their spins called polarized. Large number of high energy physics experiments using colliders strongly benefit from colliding polarized beams. You will learn the main aspects of the spin dynamics in the accelerators and about various ways to keep beam polarized. One more “tunes” to worry about - spin tune.			Home-works are due in one week after posting
Final Exam	Students present results of their research on selected topic			December 11

Part 4: Grading, Attendance, and Late Work Policies

Assessment and Grading: Students will be graded for the following activities: participation in class (20% of the final grade), home-works (40% of the final grade) and the research project presented at the final exam (40% of the final grade). Each home-works (HW) will have points assigned for each problem (typically 10 point per HW). The HW score will be provided to each student with a copy of the checked HW in the individual email, one week after the home-ward is due. Homework returned after the due date could be accepted with reduced grading - 15% per day. Failure to return HW one week after it is due would result is zero score. Solution of each HW will posted on the course website for student to compare with their solutions. The overall accumulated HW score for each will be divided by the total sum of HW points. Scores for class participation and the final exam will be send to students in the individual email one week after the final exam.

Activity/Assignment	Points	Due Date
Class participation – questions, comments, answer to teacher’s questions	20	All lectures, office hours
Home-works	40	All course
Final exam	40	End of classes (December 11)
Total	100	

Letter Grades:

Final grades assigned for this course will be based on the percentage of total points earned and are assigned as follows:

Letter Grade	Points or Percentage
A	95
A-	90
B+	85
B	80
B-	75
C+	70
C	65
C-	60
D+	55
D	50
F	<50

- Additional information
 - [Undergraduate Grading System](#)
 - [Graduate Grading System](#)

Part 5: University and Course Policies
University Policies:**Student Accessibility Support Center Statement:**

If you have a physical, psychological, medical, or learning disability that may impact your course work, please contact the Student Accessibility Support Center, 128 ECC Building, (631) 632-6748, or at sasc@stonybrook.edu. They will determine with you what accommodations are necessary and appropriate. All information and documentation is confidential.

Students who require assistance during emergency evacuation are encouraged to discuss their needs with their professors and the Student Accessibility Support Center. For procedures and information go to the following website: <https://ehs.stonybrook.edu/programs/fire-safety/emergency-evacuation/evacuation-guide-people-physical-disabilities> and search Fire Safety and Evacuation and Disabilities.

Academic Integrity Statement:

Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty is required to report any suspected instances of academic dishonesty to the Academic Judiciary.

Faculty in the Health Sciences Center (School of Health Technology & Management, Nursing, Social Welfare, Dental Medicine) and School of Medicine are required to follow their school-specific procedures. For more comprehensive information on academic integrity, including categories of academic dishonesty please refer to the academic judiciary website at http://www.stonybrook.edu/commcms/academic_integrity/index.html

Important Note: Any form of academic dishonesty, including cheating and plagiarism, will be reported to the Academic Judiciary.

Critical Incident Management:

Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of University Community Standards any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn. Faculty in the HSC Schools and the School of Medicine are required to follow their school-specific procedures. Further information about most academic matters can be found in the Undergraduate Bulletin, the Undergraduate Class Schedule, and the Faculty-Employee Handbook.

Course Policies:

Understand When You May Drop This Course:

It is the student's responsibility to understand when they need to consider withdrawing from a course. Refer to the Stony Brook Academic Schedule for dates and deadlines for registration: http://www.stonybrook.edu/commcms/registrar/calendars/academic_calendars.

- [Undergraduate Course Load and Course Withdrawal Policy](#)
- [Graduate Course Changes Policy](#)

Incomplete Policy:

Under emergency/special circumstances, students may petition for an incomplete grade. Circumstances must be documented and significant enough to merit an incomplete. If you need to request an incomplete for this course, contact me for approval as far in advance as possible.

Course Materials and Copyright Statement:

Course material is posted on CASE website and has free access – no copy right protection is expected.

Online Communication Guidelines and Learning Resources:

Maintain professional conduct both in the classroom and online. The classroom is a professional environment where academic debate and learning take place. I will make every effort to make this environment safe for you to share your opinions, ideas, and beliefs. In return, you are expected to respect the opinions, ideas, and beliefs of other students—both in the face-to-face classroom and online communication. Students have the right and privilege to learn in the class, free from harassment and disruption. The course follows the standards set in the Student Code of Conduct, and students are subject to disciplinary action for violation of that code. If your behavior does not follow the course etiquette standards stated below, the grade you receive for a posting may suffer. I reserve the right to remove any discussion messages that display inappropriate language or content.

Online Etiquette:

- Offensive language or rudeness will not be tolerated. Discuss ideas, not the person.

- Avoid cluttering your messages with excessive emphasis (stars, arrows, exclamations).
- If you are responding to a message, include the relevant part of the original message in your reply, or refer to the original post to avoid confusion;
- Be specific and clear, especially when asking questions.
- Use standard punctuation and capitalization. Using all UPPERCASE characters gives the appearance of shouting and makes the message less legible;
- Remember that not all readers have English as their native language, so make allowances for possible misunderstandings and unintended discourtesies.

Online Classes Require Better Communication:

It is important to remember that we will not have the non-verbal cues that occur in a face-to-face classroom. I cannot see the confused, frustrated, or unhappy expressions on your face if you encounter problems. You **MUST** communicate with me so that I can help. To make the experience go smoothly, remember that you're responsible for initiating more contact, and being direct, persistent, and vocal when you don't understand something.

My Role as the Instructor:

As the instructor, I will serve as a "guide" in our online classroom. While I will not respond to every post, I will read what is posted, and reply when necessary. When necessary, I'll allow students to ask question using their microphones – otherwise students should turn them off. Expect instructor posts in the following situations:

- To assist each of you when it comes to making connections between discussion, lectures, and textbook material.
- To fill in important things that may have been missed.
- To re-direct discussion when it gets "out of hand."
- To point out key points or to identify valuable posts.

Part 6: Student Resources

Academic and Major Advising (*undergraduate only*): Have questions about choosing the right course? Contact an advisor today. Phone and emails vary-please see website for additional contact information; website: <https://www.stonybrook.edu/for-students/academic-advising/>

Academic Success and Tutoring Center (*undergraduate only*):

<https://www.stonybrook.edu/tutoring/>

Amazon @ Stony Brook: Order your books before classes begin. Phone: 631-632-9828; email: Bookstore_Liaison@stonybrook.edu; website: <http://www.stonybrook.edu/bookstore/>

Bursar: For help with billing and payment. Phone: 631-632-9316; email:

bursar@stonybrook.edu; website: <http://www.stonybrook.edu/bursar/>

Career Center: The Career Center's mission is to support the academic mission of Stony Brook University by educating students about the career decision-making process, helping them plan and attain their career goals, and assisting with their smooth transition to the workplace or further education. Phone: 631-632-6810; email: sbucareercenter@stonybrook.edu; website:

<http://www.stonybrook.edu/career-center/>

Counseling and Psychological Services: CAPS staff are available by phone, day or night.

<http://studentaffairs.stonybrook.edu/caps/>

Ombuds Office: The Stony Brook University Ombuds Office provides an alternative channel for confidential, impartial, independent and informal dispute resolution services for the entire University community. We provide a safe place to voice your concerns and explore options for productive conflict management and resolution. The Ombuds Office is a source of confidential advice and information about University policies and procedures and helps individuals and groups address university-related conflicts and concerns. <http://www.stonybrook.edu/ombuds/>

Registrar: Having a registration issue? Let them know. Phone: 631-632-6175; email: registrar_office@stonybrook.edu; <http://www.stonybrook.edu/registrar/>

SBU Libraries: access to and help in using databases, ebooks, and other sources for your research.

- Research Guides and Tutorials: <http://guides.library.stonybrook.edu/>
- Getting Help: <https://library.stonybrook.edu/research/ask-a-librarian/>

Student Accessibility Support Center: Students in need of special accommodations should contact SASC. Phone: 631-632-6748; email: sasc@stonybrook.edu;

<https://www.stonybrook.edu/sasc/>

Support for Online Learning: <https://www.stonybrook.edu/online/>

Writing Center: Students are able to schedule face-to-face and online appointments.

<https://www.stonybrook.edu/writingcenter/>