UBC PHYS 560-201, UVic PHYS 522
Physics and Engineering of Particle Accelerators
in 2023

Overview:

A 3 credit points course open to domestic and international students, offered by the UBC and UVic Physics Departments in partnership with TRIUMF.

Dates, times, location:

Course duration: Jan. 10 to April 11, 2023 – mid-term break Feb. 20-24, 2023
Course times: Tuesdays and Thursdays 14:00-15:30 PST
Course location: MOB conference room at TRIUMF and online via Zoom

Brief summary of the synopsis:

The course will provide an introduction to the physics, technology and some engineering aspects of particle accelerators with focus on proton and ion accelerator technology.
The course will include a survey of existing accelerator types and an introduction to transverse and longitudinal beam optics. The course will also include an introduction to the physics and technology of ion sources, will give an overview of secondary particle production with focus on radioactive ion beam production, of accelerator radio-frequency principles and more detailed aspects of room temperature and superconducting linear accelerators, as well as high energy circular machines. The course should appeal to students of Accelerator Physics and Physics Engineering, as well as to students of Experimental Nuclear and Particle Physics and other students interested in Particle Accelerators.

Pre-requisites:

Classical Mechanics, Classical Electro-dynamics

Lecturers:

The course will be given by a team of lecturers made up of experts from the TRIUMF Accelerator Division and UVic. Each lecturer is responsible for about 3-5 lectures.

Final Grade:

Weekly homework (due one week after assignment) – 50% (based on completion and quality)
Mid-term exam (March 01, 2022) – 20%
Final Exam (TBA) – 30%

Course Coordinator:

Oliver Kester, TRIUMF okester@triumf.ca

Course outline and lecture synopsis:

Lecture	Date	Lecturer
1	**January 10**	**Rick Baartman** baartman@triumf.ca
Title: Historical overview Linear and Circular accelerators		
Synopsis: Introduction of the basic principles of acceleration and a review of the historical development of accelerators, both linear and circular.		
2	**January 12**	**Rick Baartman** baartman@triumf.ca
Title: Cyclotrons – from Classical to Isochronous pre-reading: Livingood – Principle of Cyclic Particle Accelerators		
Synopsis: The magnetic resonance is the basis of the Cyclotron. An overview of cyclotron principles, technical solutions and applications will be shown.		
3	**January 17**	**Rick Baartman** baartman@triumf.ca
Title: Basics of linear optics of beams - transverse beam dynamics		
Synopsis: Hill's equation, Matrix formalism and beam focusing will be explained.		
4	**January 19**	**Thomas Planche** tplanche@triumf.ca
Title: Beam emittance and TWISS parameters, particle distributions		
Synopsis: Coordinate system (Frenet-Serret coordinate systems) and the concept of beam emittance and phase space is addressed in this lecture. Examples of particle distribution and their beam emittance, as well as the description of the beam emittance via Courant Snyder ellipse concept will be explained.		
5	**January 24**	**Thomas Planche** tplanche@triumf.ca
Title: Basics of longitudinal beam dynamics		
Synopsis: The Equation of motion for particles in the longitudinal direction will be derived. The longitudinal phase space including the separatrix will be introduced. The principle of phase focusing and transit time factor (TTF) will be addressed.		
6	**January 26**	**Thomas Planche** tplanche@triumf.ca
Title: Beam line elements - Magnets (Design and function)		
Synopsis: Magnetic elements are key for particle accelerators and beam line systems. The beam physics sets the requirements for the design of such elements. The electromagnetic principles for dipoles and multipoles of normal and superconducting magnets will be explained.		

7	**January 31**	**Thomas Planche** tplanche@triumf.ca
Title: Physics of space charge dominated beams Pre-reading:		
Synopsis: By transporting charged particles, all of like charge, they naturally repel each other and he repulsion forces can at highest intensities be comparable to the focusing forces of beam line elements, so must be taken into account. The space charge fields of a beam will be presented including relativistic beams. The effect of space charge forces on beam envelope and emittance is explored.		
8	**February 2**	**Friedhelm Ames** ames@triumf.ca
Title: Introduction to electron and ion sources Pre-reading: Ian G. Brown – The Physics and Technology of Ion Sources		
Synopsis: The basics of electron emission processes and ionization will be explained. This will include thermionic emission, photo emission and electron impact ionization. Some examples for electron and ion sources will be presented.		
9	**February 7**	**Friedhelm Ames** ames@triumf.ca
Title: Plasma physics and magnetic confinement		
Synopsis: Electron and ion beam formation will be introduced. Plasma physics and magnetic plasma confinement are key for the operation of plasma ion sources. Fundamentals from plasma physics and the principle of magnetic confinement of plasma will be addressed. The extraction of ions from a plasma will be discussed in more details.		
10	**February 9**	**Friedhelm Ames** ames@triumf.ca
Title: Plasma ion sources for positive and negative ions		
Synopsis: Due to the different types of plasma generation (discharge, RF, laser) and different strategies of magnetic plasma confinement, there are many different types of plasma ion sources available. The most important plasma ion sources as well as sources for negative ions will be presented.		
11	**February 14**	**Friedhelm Ames** ames@triumf.ca
Title: EBIS and ECRIS - sources for highly charged ions		
Synopsis: The principle of highly charged ion generation in electron cyclotron resonance ion sources (ECRIS) and electron beam ion sources (EBIS) will be topic of this lecture. Basics of these ion sources will be discussed, and examples will be presented.		
12	**February 16**	**Tobias Junginger** **junginger@uvic.ca**
Title: Vacuum physics and technology		
Synopsis: All accelerators and beam line systems that accelerate and transport beams of charged particles need evacuated beam tubes and sophisticated vacuum systems to generate low pressure inside the beam tube. The physics of pressure measurements, of gas pumping will be discussed. Modern vacuum components and systems will be introduced.		

13	**March 2**	**Thomas Day Goodacre** **tdaygoodacre@triumf.ca**
Title: Physics of radioisotope production Pre-reading: Introductory Nuclear Physics, Kenneth S. Krane, Chapters 1, 3.1, 3.2, 3.3,		
Synopsis: The basics of interactions of beams with matter will be discussed. The nuclear physics to understand the occurring nuclear reactions that generate secondary particles in accelerator targets will be introduced and their consequences on target design and operation parameters discussed.		
14	**March 7**	**Thomas Day Goodacre** **tdaygoodacre@triumf.ca**
Title: Accelerator based secondary particle production		
Synopsis: The introduction to methods for producing short-lived radioisotopes beams, in-flight separation and Radioisotope Separation Online (ISOL) techniques is foreseen as well as techniques for ion beam purification and selection. An overview of accelerator driven secondary particle production is reviewed in this lecture. The according beam production and target handling technology will be introduced using examples.		
15	**March 9**	**Thomas Day Goodacre** **tdaygoodacre@triumf.ca**
Title: Target and ion sources		
Synopsis: An overview of target materials and target technology for the production of radioisotopes for science, medicine and industry will be given. Chemically selective and high-efficiency ion sources for secondary ion beams are reviewed.		
16	**March 14**	**Oliver Kester** okester@triumf.ca
Title: Beam Instrumentation		
Synopsis: Beam instrumentation and diagnostics is the observation of particle beams with the precision required to tune, operate, and improve the accelerators and their associated transfer lines. The lecture will introduce basic principles of beam diagnostics, destructive or non-destructive for the beam and examples of such beam.		
17	**March 16**	**Oliver Kester** okester@triumf.ca
Title: Synchrotrons and Storage Rings		
Synopsis: The concept of storage rings, synchrotrons and colliders will be explained. The principle of periodic focusing structures will be explained, with the example the FODO lattice. Examples of storage rings and colliders will be discussed, in particular the Large Hadron Collider (LHC). Beam cooling mechanisms will be addressed.		
18	**March 21**	**Oliver Kester** okester@triumf.ca
Title: Numerical simulation of charge particles in electromagnetic fields		
Synopsis: Basics of numerical simulations of electric and magnetic fields and electromagnetic fields in cavities are presented. In addition, basics of numerical integration of the trajectories of charge		

particles in electromagnetic fields are explained. The conceptual treatment of space charge using a self-consistent iterative approach will be addressed.		
19	**March 23**	**Robert Laxdal** lax@triumf.ca
Title: Waveguides and cavities Pre-reading: Thomas P. Wangler – RF-Linear Accelerators		
Synopsis: The key infrastructure elements supporting RF-acceleration are wave guides and RF-resonators or cavities. The fundamentals of wave guides, cavities and standing electromagnetic waves in such devices will be discussed.		
20	**March 28**	**Robert Laxdal** lax@triumf.ca
Title: Fundamental parameters of RF resonators (Q-value, shunt impedance, skin depth, surface resistance)		
Synopsis: The physics of RF-resonators and the fundamental parameters of normal and superconducting cavities will be reviewed in this lecture.		
21	**March 30**	**Robert Laxdal** lax@triumf.ca
Title: RF acceleration in periodic structures – Linear Accelerators		
Synopsis: RF-acceleration in linear accelerators (linacs) is introduced as well as basic parameters are discussed. Different types of linacs are introduced as examples to demonstrate the principles.		
22	**April 4**	**Robert Laxdal** lax@triumf.ca
Title: Hadron accelerators: Radio Frequency Quadrupoles (RFQ), IH-structures, DTLs, SRF cavities		
Synopsis: A review of hadron linear accelerators including RFQs, IH-structures, Alvarez and coaxial cavities and the major operational variants of these structures: pulsed vs CW operation and normal conducting vs SRF technologies.		
23	**April 6**	**Tobias Junginger junginger@uvic.ca**
Title: Modern concepts of ultra-high gradient acceleration		
Synopsis: Present concepts and the future of SRF, Laser Plasma Acceleration and Wake field accelerators will be presented.		