

Instructor
Hossain Ahmed

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Office Location
PSC, 1009

Student Hours
Monday: 9:30 am -10:20
am
Wednesday: 9:30 am –
10:20 am
Thursday: 10:30 – 11:20
am

**Class Time
and Location**
Monday: 12:30 - 1:20 pm
Wednesday: 11:30 –
12:20 pm
Thursday: 1:30 –2:20 pm

Location: NFSC 1096



ST. FRANCIS XAVIER
UNIVERSITY

Subject Name: Phys 303, Winter 2025 Modern Physics: Subatomic Physics and Cosmology

Course Overview

Physics (PHYS) 303 is a third-year elective course in physics. This course aims to acquaint you with the basis of the building blocks of nature. We will start with Nuclear Physics and briefly learn about the atomic nucleus' discoveries and their constituents, X-rays, and radiations by spending about 10% of the total course time. We then move to the particle zoo and their findings with the cutting-edge technologies, e.g., particle accelerators and detectors. Relativistic kinematics, particle symmetries, fundamental forces in nature, particle interaction, the Standard Model (SM) and its limitations, beyond SM and unknown/new physics, are the topics we will cover and spend about 75% of the total course time. St. Francis Xavier (StFX) University is an institutional member of the Belle II experiment at the High Energy Accelerator Research Organization (KEK) in Japan and the BaBar experiment at the SLAC National Accelerator Laboratory in the USA. We will use these experiments for demonstrations and big-data analysis (students are not expected to know any software at this stage). There is a deep connection between the physics of the smallest objects (e.g. Quarks) and the physics of the largest scales (galaxies, clusters of galaxies, the universe itself), which is not entirely understood yet. We will spend about 15% of the course time understanding this connection and current/future research paths. I suppose students are already familiar with Modern Physics (e.g. PHYS 201: Introduction to Relativity and Quantum Physics). Three credits

Additional Course Information

Class participation, textbook consultation, doing assignments, and participating in-class quizzes and presentations are the key to success in this course. Class attendance is strongly recommended, and students are responsible for collecting information from the classes.

Learning Objectives

By the end of this course, students will be able to:

- Distinguish nuclear and subatomic particles that shape our known universe.

- Explain four fundamental forces in nature involved in subatomic particle interaction.
- Demonstrate how subatomic physics research is essential and developed cutting-edge technologies for humankind in 20th and 21st centuries.
- Accurately describe the connection between the physics of the smallest object and the physics of an enormous scale and acquaint a path of new physics search.

Evaluations

Category	Weight
Assignments (3)	15%
Quizzes (3)	12%
Midterm	18%
Research and Class-Teaching	15%
Final	40%
Total	100%

Assignments and Quizzes

There are four assignments and three in-class quizzes throughout the semester. Solving assignment questions and participating in-class quizzes will significantly help you to succeed in the course. Discussion with other students on assignment questions is always welcomed but make sure you can do the problems yourself as all in-class exams are closed books, and you will be working on exams yourself. Late submission without a valid reason will affect your grade, e.g. 10% cost for a single day delay and 100% cost for a week or so delay!

	Assignment	Assignment	
	Handing out	Due	Quiz
01	Jan. 17	Jan. 24	Feb. 03
02	Mar. 06	Mar. 13	Mar. 17
03	Mar. 27	Apr. 03	Apr. 02

Class Teaching

Students are required to do research on a topic below and present their findings in the class for 20-25 minutes. The main objective of this class teaching is to improve students' skills in presentation and research. You can make your .ppt slides for the lecture or use the conventional teaching methods, e.g., whiteboard, markers etc. Students will be questioned and evaluated by peers. Details information are as follows:

Week	Date	Topic	Lecturer
8	Feb. 27, 2025	I	
8	Feb. 27, 2025	II	
11	Mar. 19, 2025	III	
11	Mar. 19, 2025	IV	
12	Mar. 27, 2025	V	
12	Mar. 27, 2025	VI	

Selected topics

I. Electron and Proton

- https://web.archive.org/web/20081203124237/http://nobelprize.org/nobel_prizes/physics/laureates/1922/bohr-lecture.pdf
- <https://web.archive.org/web/20220125001603/https://web.lemoyne.edu/~giunta/thomson1897.html>
- <file:///Users/hahmed/Downloads/MLpr11b.pdf>
- <https://journals.aps.org/prl/pdf/10.1103/PhysRevLett.102.141801>

II. Particle Accelerators and the Big-Bang

- https://cds.cern.ch/record/261062/files/p1_2.pdf
- <https://www.slac.stanford.edu/pubs/beamline/27/1/27-1-panofsky.pdf>
- <https://home.cern/news/series/lhc-physics-ten/recreating-big-bang-matter-earth>

III. Higgs Boson

- <https://atlas.cern/updates/blog/what-should-we-know-about-higgs-particle>
- https://pdg.lbl.gov/2008/reviews/higgs_s055.pdf
- <https://journals.aps.org/prl/pdf/10.1103/PhysRevLett.13.508>
- <https://www.sciencedirect.com/science/article/pii/S037026931200857X?via%3Dihub>

IV. Neutrinos

- <https://pdg.lbl.gov/2016/reviews/rpp2016-rev-neutrino-mixing.pdf>
- <https://web.archive.org/web/20160625002601/http://cerncourier.com/cws/article/cern/28553>
- <https://www.nobelprize.org/uploads/2017/09/advanced-physicsprize2015.pdf>

V. Cosmic Microwave Background (CMB)

- <https://www.space.com/33892-cosmic-microwave-background.html>
- https://www.esa.int/Science_Exploration/Space_Science/Cosmic_Microwave_Background_CMB_radiation
- <https://pressbooks.bccampus.ca/astronomy1105/chapter/29-4-the-cosmic-microwave-background/>

VI. Black Hole: It's formation, evolution, and fate

- <https://science.nasa.gov/universe/black-holes/>
- <https://www.space.com/15421-black-holes-facts-formation-discovery-sdcmp.html>
- <https://arxiv.org/pdf/physics/9912033>

Exams:

Quizzes: In class

Midterm: February 13, 2025 (Thursday) [Time: 1:30 pm – 2:20 pm]

Final: The final exam date will be set by the University registrar.

Method of Instruction

- Face-to-face at PS 1096
- Online (if necessary): <https://calti.bbcollab.com/collab/ui/scheduler/session/settings/e2eb07542ce14479858ef86305dd45f0>

Course Schedule

Note: Based on time and situation, we might include or discard some of the contents in the table below.

Week/Date	Topic	Assignment (Reading, Exercises, Hand-in Assignment) and Quiz
Week 1 – 2 – 3	Module 1: Atom and Nuclei <ul style="list-style-type: none">■ Nuclei and its structure■ X-ray and its applications■ Radioactivity and its importance■ Nuclear decay and half-lives	■ Assignment one
Week 3 – 4 – 5	Module 2: Subatomic particles and the Standard Model <ul style="list-style-type: none">■ Historical Introduction to the Elementary particles■ The Standard Model■ Elementary particle dynamics■ Relativistic Kinematics	■ Quiz one
Week 5 – 6	Module 3: Particle Accelerators and Detectors <ul style="list-style-type: none">■ PEP II■ SuperKEKB■ LHC■ BABAR■ BELLE II	

Week/Date	Topic	Assignment (Reading, Exercises, Hand-in Assignment) and Quiz
Week 7	Study break	
Week 8 – 9 – 10	Module 4 <ul style="list-style-type: none"> ■ Symmetries ■ Bound States ■ The Feynman Calculus ■ QED and QCD 	■ Assignment two
Week 11 – 12	Module 5: Weak Interaction	■ Quiz two
Week 12 – 13 – 14	Module 6: Beyond Standard Model/ Cosmology	■ Assignment three ■ Quiz three

Course Materials & Resources

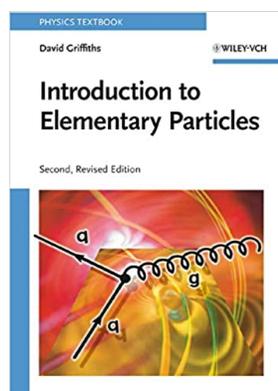
Besides in-class lectures, the course webpage (Moodle page) is the primary source of the course materials. Lecture slides, assignments, quizzes, and solutions (if any) will be uploaded to the Moodle page accordingly. To avoid any biases, I usually upload lecture slides after my in-class lectures. Any announcements, formula sheets, practice problems (if any), and other materials (if any) will also be uploaded on Moodle page. Students are strongly advised to follow the

Course webpage: <https://moodle.stfx.ca/course/view.php?id=37448>

Required Text(s)

Introduction to Elementary Particles (Second Revised Edition) by David Griffiths

Available in the StFX Bookstore



Other Books and resources

1. Nuclear and Particle Physics: An Introduction: B. Martin
2. Introduction to Nuclear and Particle Physics: A. Das and T. Ferbel
3. Techniques for Nuclear and Particle Physics Experiments: A How-to Approach: William R. Leo
4. <https://home.cern>
5. <https://www.kek.jp/en/>
6. <https://www.slac.stanford.edu/BFROOT/>
7. <http://pdg.lbl.gov>

Academic Integrity

University Policy on Academic Integrity: St. Francis Xavier values academic integrity. Therefore, all students must understand the meaning and consequences of such academic offences as plagiarism, cheating, tampering, and falsification under Section 3.8 of the [academic calendar](#). The complete university policies on academic integrity are available at <https://www.mystfx.ca/registrar-office/academic-integrity>