PHYSICS 4E03 — INTRODUCTION TO SUBATOMIC PHYSICS

GENERAL INFORMATION, Winter Term 2020

Matter comes to us organized into hierarchies of scale. Materials turn out to be made of molecules, and many material properties can be understood in terms of those of (and the electromagnetic interactions amongst) these molecules. But why do molecules have the properties they do? It turns out they are built from still-smaller atoms, and molecular properties can be understood in terms of the way atoms mutually interact. But why are atoms the way they are? About 100 years ago atoms also were found to be composite objects, whose properties can be understood in terms of their constituents: nuclei and electrons. Nuclei were then themselves found to consist of protons and neutrons, and we now know these in turn are built from still-smaller particles called quark and gluons.

Subatomic physics is the story of structure on scales smaller than atoms, and traditionally divides into Nuclear Physics (which studies the structure of nuclei) and Particle Physics (which studies structure on subnuclear scales). More generally Particle Physics is the on-going search for the smallest constituents of nature and the their mutual interactions, in terms of which other phenomena are explained. This course is meant to be a first introduction to Subatomic Physics, aimed at upper-year physics undergraduates. It aims to be as self-contained as possible, and so contains a rudimentary introduction to much of the required ideas that are not already part of the normal physics curriculum. It assumes a good knowledge of Quantum Mechanics and Electromagnetism. The course is not meant to be a survey course for nonspecialists, and aims to convey what is known about the substructures of Nature, while also providing an introduction to the ideas of Quantum Field Theory, which is the language in terms of which the particles and forces of nature appears to be written.

What follows is a list of the course's procedural information.

- **Instructor:** Cliff Burgess (`cburgess@physics.mcmaster.ca`); **Office:** ABB 324; **Phone:** x23175.
- **Course Web Page:** (`https://www.physics.mcmaster.ca/~cburgess/cburgess/?page_id=513`).
- **Lectures:** Lectures meet Mondays, Wednesday and Thursday from 1:30 to 2:20 pm in HH 102. Attendance to the lectures is not compulsory, but if you come I ask you to pay attention and not disrupt the class with personal conversation or distracting cellphone or laptop use. I will do what I can to ensure that you do not have to gnaw your own arm off to stay awake.
- **Tentative Course Outline:** These are main topics I intend to cover: *Electron, Proton and Neutron; Relativistic Kinematics; Conservation Laws; Decays and Scattering; Quarks and Evidence for Substructure; Inter-nucleon Interactions; Properties of Nuclei; Radioactivity and the Weak Interactions; Introduction to Quantum Field Theory* and *The Standard Model*.
- **Textbook:** The course text is *Subatomic Physics* by Henley & Garcia, which has been ordered at the bookstore. It is not compulsory to buy because I will likely only occasionally sample pieces of it and not follow it directly, since I will more closely follow my own lecture notes (available at the website for this course). Be warned that I may assign problems from this book, however, so if you

do not buy it be sure you can get the problems some other way. A possible alternative reference often used for courses like this is *Introduction to Elementary Particles* by Griffiths, though this has more of a particle physics (as opposed to nuclear) spin and although it describes Feynman rules it does so without quantum field theory and so does not really explain why they are what they are. I also sometimes draw material from my own book, *The Standard Model: A Primer*, which aims to use the Standard Model as a vehicle for introducing quantum field theory at a level appropriate to an introductory graduate class. For quantum field theory a book with a relatively light touch is *Quantum Field Theory in a Nutshell* by Tony Zee, and David Tong has a good set of lecture notes (again at a graduate level) at his Cambridge University webpage.

- **Office Hours:** I am happy to meet but usually do not just hang about the office unless I know students are coming, it is best to let me know in advance if you intend to stop in to be sure I will be there. (A simple method is either to catch me and we can talk right after class, or tell me there when you would like to meet me in my office. The time slot right after the lecture is a natural time to meet if you can, though just before the lecture is less good as I am normally preparing for the class. I will make a point of being in my office for any scheduled appointments, sometimes coming from off-campus, so if you *do* arrange one, please do show up!)

- **Marking Scheme:** The course marks are based on weekly assignments, a midterm test, a term project and the final exam. The term mark will be computed from these according to whichever of the following formulae maximizes your final mark:

Item	Option A	Option B	Option C	Option D
Assignments/Quizzes	20%	20%	20%	20%
Midterm Test	20%	0%	20%	0%
Term Project	20%	20%	10%	10%
Final Exam	40%	60%	50%	70 %

  Part of the reason for providing you this menu of alternatives is to allow you to accommodate the unexpected like sudden illnesses and the like, while making this flexibility open to *everybody* in the class. (Consequently this is my preferred way to deal with MSAF applications in this class.)

- **Assignment/Quizzes:** There will be an assignment given roughly every week, which will be due the following week. This is by far the best way to prepare for the kinds of questions you will see on the midterm or final exam and so is well worth your time. I will sometimes give assigned readings from the course lecture notes, since pre-reading material is by far the most effective way to learn the material. To be sure the material gets through (and to know what to cover if not) and because I know you are all busy there will be motivational short mini-quizzes in class on the material covered in the reading.

- **Midterm Test:** A 50-minute in-class midterm test will be held on Thursday, February 27, 2020. Those who do not write the midterm will receive a score of zero, and so avail themselves of Option B or D above. Be there or be square.

- **Term Project:** There is a written term project, due Monday April 6 (*i.e.* the last lecture), in which you will be given – on the course webpage – a list of 50 or so foundational papers in subatomic physics and asked to write a short essay describing why the authors thought it was important and why we now think so (which are not always the same). You may also choose a paper not on this list provided you first clear the paper with me. You may work in groups, provided each member submits their own independently written essay. You will be required to tell the course TA which paper you have chosen, and the names of the people in your group, by Thursday March 5.

- **Final Exam:** The Final Exam will be held during the April examination session.

- **Additional Work and Supplemental Exam:** Additional work will NOT be available for students who might wish to improve their marks. The standard McMaster rules apply regarding the availability of supplemental exams.

- **Reading you your rights:** The Centre for Student Development offers free academic skill support (see http://studentsuccess.mcmaster.ca/students/academic-skills/academic-support.html for details). Finally, although hopefully it does not need saying, be warned that the University does not tolerate cheating, plagiarism and the like. THE UNIVERSITY VALUES ACADEMIC INTEGRITY. THEREFORE ALL STUDENTS MUST UNDERSTAND THE MEANING AND CONSEQUENCES OF CHEATING, PLAGIARISM AND OTHER ACADEMIC OFFENCES UNDER THE CODE OF STUDENT CONDUCT AND DISCIPLINARY PROCEDURES (see http://www.mcmaster.ca/academicintegrity for more information).