

ELEMENTARY PARTICLE PHYSICS 1

COURSE SYLLABUS

PHZ 6355, 3 CREDIT HOURS

FALL 2022

M,W,F: PERIOD 7, 1:55PM-2:45PM, [NPB 1200](#)

INSTRUCTOR: Prof. Guenakh Mitselmakher

Office: NPB 2021

Email: mitselmakher@phys.ufl.edu

Phone: 352-392-5703

OFFICE HOURS: After the lectures or by appointment.

COURSE WEBSITE: <http://elearning.ufl.edu>

COURSE COMMUNICATIONS: Orally or by email.

CLASS NOTES AND RECOMMENDED TEXTBOOK:

Class Notes:

https://ufl.instructure.com/courses/460773/files/folder/Class_Notes_PHZ6355

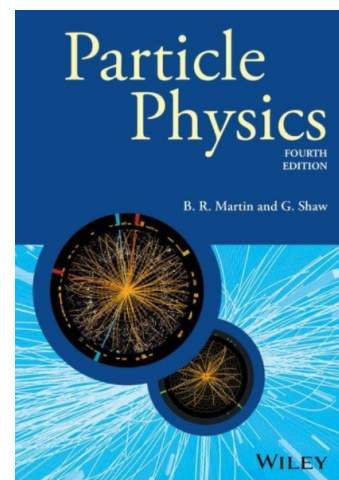
Textbook: **Particle Physics**,

B.R. Martin and G. Shaw 4th edition, John Wiley&Sons

COURSE DESCRIPTION FROM COURSE CATALOG: Dirac and Klein-Gordon equations, Feynman diagrams, scattering amplitudes; the standard model of weak, electromagnetic, and strong interactions; phenomenology of high energy physics.

PREREQUISITE KNOWLEDGE AND SKILLS: Consent of instructor. **PHY 3101** or **PHY 3063**; Some knowledge of quantum mechanics and special relativity is assumed.

COURSE GOALS AND/OR OBJECTIVES: This is Part 1 of the graduate course on elementary particle physics. It is designed



to give motivations and history of experimental discoveries and of theoretical concepts that emerged from the quest for understanding the most fundamental constituents of matter and the primary forces of nature.

This course is not intended as a systematic study of the subject. If you chose to pursue further specialized graduate studies in particle physics, you will get advanced courses as part of your graduate curriculum. After this course I want to leave you with a preliminary understanding of a broad spectrum of interesting questions and topics in high-energy particle physics.

The course requires a practical knowledge of some aspects of special relativity, basic concepts of quantum mechanics, and practical knowledge of calculus.

By the end of this course, students will know at an introductory level the main concepts of elementary particle physics and will be able to solve some related problems. See the Modules section in Canvas for details.

INSTRUCTIONAL METHODS: This course meets three times a week for lectures and discussion in person. Class notes and other pertinent content will be made available primarily through the Canvas e-Learning system, which can be accessed through <http://elearning.ufl.edu/> Students are expected to read the corresponding class notes and the assigned sections in the textbook ahead of the scheduled lecture on the topic. As an alternative option used in rare cases, a lecture may be held online in a Zoom conference during regular class time. In such a case, a link to the Zoom online conference room will be announced at least 3 hours ahead of class and provided by the instructor in the Canvas calendar. Guest lecturers are possible.

The midterm exam and final student presentations will be held online in Zoom in the evenings, at a time agreed upon to avoid scheduling conflicts.

Homework problems are assigned approximately every three weeks to assess your understanding of the concepts and your ability to calculate the solutions. To help you stay on track, quick quizzes (typically one question) will be given occasionally, administered online through Canvas at the end of some lectures and due by midnight of the same day. A mid-term written test will be given. At the end of the course students will give presentations on original experimental papers on particle physics. See the Assignment Policy section below for details regarding assignment submissions.

COURSE TOPICS:

- **Introduction:**
 - Overview of elements of the "Standard Model" of particle physics.
 - Fermions: Quarks and Leptons.
 - Gauge Bosons and Forces. Higgs boson.
 - Brief history of Particle physics, discovery of fundamental particles.

 - **Basic theoretical and experimental tools used in particle physics:**
 - Reminder about the concepts used in the course and equations related to special relativity and quantum mechanics. Production of new particles, different frames of reference. Particle-wave duality and uncertainty principle.
 - Symmetries: discrete and continuous. Conservation laws and quantum numbers in particle physics.
 - Energy-momentum conservation as a basis of kinematics of decays and scattering and as a tool for experimental studies in particle physics.
 - Notions of phase space, matrix element, scattering cross-section, probabilities of particle decays. Resonances in particle physics.
 - Accelerators.
 - Interactions of particles with matter.
 - Particle detectors.
 - Statistics as applied to particle experiments.

 - **Physics to be studied in the Particle Physics course and history of related ideas and discoveries.**
 - Generations in the Standard Model.
 - Current understanding of generational structure. Weak, electromagnetic and strong interactions. Concept of generations and Universality of interactions. Particles masses in the Standard model and role of Higgs boson.
 - Electromagnetic interactions and photon as carrier. Feynman diagrams, radiative corrections (high orders of interactions).
 - Strong interactions, nuclear forces and discovery of hadrons.
 - Mesons and Baryons and their systematics. Experimental probes of Structure of particles.
 - Discoveries of quarks, gluons and color. Strongly interacting particles in the Standard Model. Modern theory of strong interactions at quark-gluon level (QCD).
 - Low energy weak interactions. Fermi theory of weak interactions.
 - W and Z boson as carriers of weak interactions, their discovery.
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- Electroweak Unification. Symmetry breaking and the Higgs mechanism. Higgs particle discovery and studies.
- **P and CP Violation. Studies of physics beyond the Standard Model (Topics Optional).**
 - Discoveries of P and CP Violation.
 - Asymmetry between matter and antimatter in the Universe.
 - CP Violation and the Early Universe.
 - Neutrino mass and oscillations, CP violation in neutrinos (overview).
 - Supersymmetry.
 - Dark matter.

WEEKLY SCHEDULE (TENTATIVE)

Approximate weekly course schedule is given below. It lists the recommended class notes and textbook.

Note, that students are expected to read the listed material before a lecture.

Week 1, August 24 - 26, 2022

Introduction to course. Overview of the Standard Model.

Natural units.

Read Class Note A01 which you can find here:

https://ufl.instructure.com/courses/460773/files/folder/Class_Notes_PHZ6355

- Use this link (above) for reading all the Class Notes referenced further in the weekly schedule.
- Some recommended book chapters (Martin&Shaw 4th edition) are referenced below in the weekly schedule.

Week 2, August 29 - September 2

Kinematics as a tool, examples.

Class Notes A02, A03.

Week 3, September 5 – 9

NO CLASS MONDAY, Sep 5 (Labor Day)

Kinematics examples discussion (end)

QM observables. Experimental Observables. Cross section (experiment).

Class Notes A03, A04, A05.

Week 4, September 12 – 16

Perturbation theory. Phase space, Matrix element, calculation of scattering and decay. Forces via exchange of particles, related potential. Feynman diagrams, virtual particles. Perturbation theory and radiative corrections.

Class Notes A06, A07, A08.

ASSIGNMENT: HW1

Week 5, September 19 - 23

Accelerators. Interaction of particles with matter(beginning).

Class Notes A09, A10.

Week 6, September 26 - 30

Interaction with matter (end). Detectors. Examples of large detectors such as CMS, Auger.

Class Notes A10, A11, A12.

Week 7, October 3 - 7

NO CLASS FRIDAY, Oct 7 (Homecoming)

Statistics as applied to particle experiments.

Class Notes A13.

Week 8, October 10 - 14

Discovery of electron, proton, photon, neutron.

Class Notes A14.

ASSIGNMENT: HW2

Week 9, October 17 - 21

Relativistic QM, Klein-Gordon and Dirac equations. Discovery of Antimatter.

Yukawa particle and discovery of pions and muons.

Class Notes A15, A16.

Week 10, October 24 - 28

Neutrino hypothesis and discovery, neutrinos of 2nd and 3rd generations.

Universality.

(Concepts of neutrino masses. Mixing and oscillations to be discussed later.)

Class Notes A17, A18.

ASSIGNMENT: HW3

Week 11, October 31 – November 4

Discovery of strange particles and resonances.

Class Notes A19.

Week 12, November 7 - 11

NO CLASS FRIDAY, November 11 (Veterans Day)

First three Quarks and systematics.

Class Notes A20.

ASSIGNMENT: Mid-term Test

Week 13, November 14 - 18

Charm, bottom and top quarks discoveries.

Class Notes A21.

Week 14, November 21 – 25

NO CLASSES on Wed, Nov 23 and Fri, Nov 25 (Thanksgiving)

Three forces in particle physics in more details. Neutral currents discovery. W and Z bosons discovery. Electroweak unification and Higgs discovery (beginning).

Class Notes A22. Textbook Ch 10 (Beginning).

ASSIGNMENT: HW4

Week 15, November 28 - December 2

Higgs discovery.

Class Notes A23 (Beginning to slide 29). Textbook Ch 10 (Higgs discovery, end)

Week 16, December 5 - 7

Post Higgs physics. (Beyond the Standard Model physics.)

Class Notes A23 (End).

ASSIGNMENT: Student Presentations

CLASSES END ON December 7

Disclaimer: The weekly schedule may be modified to enhance understanding and following the interest of students. HWs, mid-term test, quizzes and student presentations schedule will be announced as appropriate.

Optional Material (If time allows)

Parity and CP violation, matter-antimatter asymmetry in the universe.

Textbook Ch 11.1 and Ch 11.2.1,11.2.2.

Beyond the Standard Model physics (continuation).

Textbook Ch 12.1,12.2

METHODS BY WHICH STUDENTS WILL BE EVALUATED AND THEIR GRADE

DETERMINED:

Contributions to the grades are:

- 1) homework assignments (approximately every three weeks). Max contribution of all homeworks combined is 40%.
 - 2) a mid-term test (by approximately the middle of the semester, outside of normal lecture hours). Max contribution of midterm to the total grade is 20%.
 - 3) quick quizzes (typically one question). Max contribution of all quizzes combined is 10%. The quizzes are administered as assignments in Canvas.
 - 4) a student presentation of a published journal paper on particle physics. Max contribution of the presentation to the total course grade is 30%.
- HWs and mid-term test will typically have bonus points.
 - Student presentations will be in lieu of the final exam. They will take place outside of the normal lecture hours before the end of the semester at the time agreed to in class. Papers for the presentations will be selected by the students but must be approved by the lecturer. The detailed rules of the presentations will be discussed in class.
 - A late homework contribution is reduced by half if overdue by less than 7 days. A homework that is overdue by more than one week will not be graded and no makeups are allowed. A valid excuse must be consistent with related UF policies.

Your final letter grade will be based on the total percentage obtained by adding four contributions from HWs, mid-term test, quick quizzes and the student presentation:

A	85% of the max or above
A-	80% of the max
B+	75% of the max
B	70% of the max
B-	65% of the max
C+	60% of the max
C	55% of the max
C-	50% of the max
D+	45% of the max
D	40% of the max
D-	35% of the max

COURSE POLICIES:

ATTENDANCE AND MAKE UP POLICY: You are expected to attend lectures regularly. You are also expected to interact with the instructor and with your fellow students through

in-class activities. Requirements for class attendance and make-up exams, assignments, and other work in this course are consistent with university policies that can be found at: <https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx>

ASSIGNMENT POLICY: Homework due dates, mid-term test date, quizzes and student presentation date(s) will be set on the course calendar, which may be accessed via Canvas. A laptop or personal computer is required to access the course content in Canvas. Quizzes, Homeworks and the Mid-term test are administered as electronic Assignments within Canvas with problems attached as a PDF file. Solutions to these assignments are to be submitted as a PDF file within Canvas assignment blocks by the shown deadline(s). In order to create the solutions PDF file, handwritten work can be scanned with a personal computer or a smartphone app such as Adobe Scan or the entire document created electronically.

HOMEWORK AND QUIZ POLICY: Every homework set will be made available through Canvas at least a week before the posted deadline for its completion. The HW assignment should be completed as a PDF file and turned in Canvas by the due deadline. Homework may be collaborative with all work done individually. Each student must turn in their own assignment with sufficient detail on the solutions to judge that the student understood the solution. Quick quizzes may be assigned in Canvas during any week, they are not collaborative. Solutions to the quizzes must be submitted as a PDF file and turned in Canvas by the due deadline.

ONLINE COURSE EVALUATION: Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at <https://gatorevals.aa.ufl.edu/students/> Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals or via <https://ufl.bluera.com/ufl/> . Summaries of course evaluation results are available to students at <https://gatorevals.aa.ufl.edu/public-results/>

UF POLICIES:

UNIVERSITY POLICY ON ACCOMMODATING STUDENTS WITH DISABILITIES: Students with disabilities requesting accommodations should first register with the Disability Resource Center (352-392-8565, <https://disability.ufl.edu/students/get-started/>) by

providing appropriate documentation. Once registered, students will receive an accommodation letter which must be presented to the instructor when requesting accommodation. Students with disabilities should follow this procedure as early as possible in the semester.

UNIVERSITY POLICY ON ACADEMIC CONDUCT: UF students are bound by The Honor Pledge which states, “We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honesty and integrity by abiding by the Honor Code.” On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Conduct Code (<https://sccr.dso.ufl.edu/process/student-conduct-code/>) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor.

CLASS DEMEANOR OR NETIQUETTE: All members of the class are expected to follow rules of common courtesy in all communications, including email messages, threaded discussions and chats. Students are expected to arrive to the lectures and scheduled class events on time and keep cell phones and other personal electronics on mute through the lecture and class event periods.

COVID-19 STATEMENT: In response to COVID-19, the following recommendations are in place to maintain your learning environment, to enhance the safety of our in-classroom interactions, and to further the health and safety of ourselves, our neighbors, and our loved ones.

- If you are sick, stay home. Please call your primary care provider if you are ill and need immediate care or the UF Student Health Care Center at 352-392-1161 to be evaluated.
- As with any excused absence, you will be given a reasonable amount of time to make up missed work. Find more information in the university attendance policies at: <https://catalog.ufl.edu/UGRD/academic-regulations/attendance-policies/>

PRIVACY AND IN-CLASS RECORDING POLICY: Our class sessions may be audio visually recorded for students in the class to refer back. Students who participate with their camera engaged or utilize a profile image are agreeing to have their video or image recorded. If you are unwilling to consent to have your profile or video image recorded,

be sure to keep your camera off and do not use a profile image. Likewise, students who un-mute during class and participate orally are agreeing to have their voices recorded. If you are not willing to consent to have your voice recorded during class, you will need to keep your mute button activated and communicate exclusively using the "chat" feature, which allows students to type questions and comments live. The chat will not be recorded or shared. As in all courses, unauthorized recording and unauthorized sharing of recorded materials is prohibited.

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A "class lecture" is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To "publish" means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

GRADING POLICY: A General information on the UF grading policies can be found here: <https://catalog.ufl.edu/UGRD/academic-regulations/grades-grading-policies/>

GETTING HELP:

If you have a problem with the technology used for class or e-learning, contact UF helpdesk: <http://helpdesk.ufl.edu>, tel. (352) 392-HELP or via e-mail at helpdesk@ufl.edu

Other resources are available at <http://www.distance.ufl.edu/getting-help> for:

- Counseling and Wellness resources
- Disability resources
- Resources for handling student concerns and complaints
- Library Help Desk support.

Should you have any complaints with your experience in this course please visit <http://www.distance.ufl.edu/student-complaints> to submit a complaint.

CAMPUS RESOURCES:

U Matter, We Care: If you or someone you know is in distress, please contact umatter@ufl.edu 352-392-1575, or visit “U Matter, We Care” website at: <https://umatter.ufl.edu/> to refer or report a concern and a team member will reach out to the student in distress.

Counseling and Wellness Center: Visit the Counseling and Wellness Center website at: <https://counseling.ufl.edu/> or call 352-392-1575 for information on crisis services as well as non-crisis services.

Student Health Care Center: Call 352-392-1161 for 24/7 information to help you find the care you need, or visit the Student Health Care Center website: <https://shcc.ufl.edu/>

University Police Department: Visit UF Police Department website at: <https://police.ufl.edu/> or call 352-392-1111 (or 9-1-1 for emergencies).

UF Health Shands Emergency Room / Trauma Center: For immediate medical care call 352-733-0111 or go to the emergency room at 1515 SW Archer Road Visit the UF Health Emergency Room and Trauma Center website at: <https://ufhealth.org/emergency-room-trauma-center>

GatorWell Health Promotion Services: For prevention services focused on optimal wellbeing, including Wellness Coaching for Academic Success, website: <https://qatorwell.ufsa.ufl.edu/> or call 352-273-4450.

Career Connections Center: Website: <https://career.ufl.edu/> Reitz Union Suite 1300, 352-392-1601. Career assistance and counseling services.

Library Support: Website: <https://cms.uflib.ufl.edu/ask> Various ways to receive assistance with respect to using the libraries or finding resources.

Teaching Center: Website: <https://teachingcenter.ufl.edu/> Broward Hall, 352-392-2010 or to make an appointment 352- 392-6420. General study skills and tutoring.

Writing Studio: Website: <https://writing.ufl.edu/writing-studio/> 2215 Turlington Hall, 352-846-1138. Help brainstorming, formatting, and writing papers.

Student Complaints: Visit the Student Honor Code and Student Conduct Code webpage at: <https://sccr.dso.ufl.edu/policies/student-honor-%20code-student-conduct-code/> for more information.

On-Line Students Complaints: View the Distance Learning Student Complaint Process at: <https://distance.ufl.edu/getting-help/student-complaint-process/>

Disclaimer: This syllabus is subject to change as the need arises.

Last update: 8/14/22