

# INTRODUCTION TO PARTICLE PHYSICS

## COURSE SYLLABUS

**PHZ 5354**, 3 CREDIT HOURS

SPRING 2021, ON-LINE LECTURES

M,W,F: PERIOD 5, 11:45AM-12:35PM

**INSTRUCTOR:** Prof. Guenakh Mitselmakher

Office: NPB 2021

Email: [mitselmakher@phys.ufl.edu](mailto: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.

**REFERENCE NOTES AND RECOMMENDED TEXTBOOK:**

*Reference Notes:*

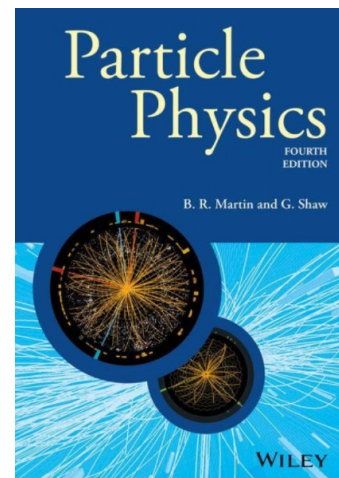
<https://ufl.instructure.com/courses/417785/files/folder/PHZ5354> Reference Notes

Textbook: **Particle Physics**,

B.R. Martin and G. Shaw 4<sup>th</sup> edition, John Wiley&Sons

**COURSE DESCRIPTION FROM COURSE CATALOG:** Descriptive survey of particle and nuclear phenomena and states: conserved quantities and quantum numbers, invariance principles.

**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 one-semester introductory graduate course on elementary particle physics. It is designed to give an introduction to 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 an overview, and not intended as a systematic study of the subject. If you chose to pursue specialized graduate studies in particle physics, you will also get advanced courses as part of your graduate curriculum. Rather, 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 on Zoom three times a week for lectures and discussion. A link to the Zoom online conference room will be provided by the instructor. Reference 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 reference notes and the assigned sections in the textbook ahead of the scheduled lecture on the topic. Homework problems are assigned every two to three weeks to assess your understanding of the concepts and your ability to calculate the solutions. To help you stay on track, in-class quick quizzes (typically one question) will be given in class occasionally. 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.

**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.
  
- **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.
  - Electroweak Unification. Symmetry breaking and the Higgs mechanism. Higgs particle discovery and studies.
  
- **P and CP Violation. Studies of physics beyond the Standard Model.**
  - 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, details optional).
- Summary on post-Higgs physics.
- Supersymmetry.
- Dark matter.
- Microscopic black holes. (optional)

### **WEEKLY SCHEDULE (TENTATIVE)**

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

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

#### **Week 1, January 11 - 15, 2021**

Introduction to course. Overview of the Standard Model.

Natural units.

Read Reference Note A01 which you can find here:

[https://ufl.instructure.com/courses/417785/files/folder/PHZ5354 Reference Notes](https://ufl.instructure.com/courses/417785/files/folder/PHZ5354%20Reference%20Notes)

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

#### **Week 2, January 18 - 22**

NO CLASS MONDAY, Jan 18 (Martin Luther King Day)

Kinematics as a tool, examples.

Reference Notes A02, A03

#### **Week 3, January 25 - 30**

Kinematics examples discussion (end)

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

Reference Notes A03, A04, A05

ASSIGNMENT: HW1

#### **Week 4, February 1 - 5**

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.

Reference Notes A06, A07, A08

**Week 5, February 8 - 12**

Accelerators. Interaction of particles with matter(beginning).

Reference Notes A09, A10

**Week 6: February 15 - 19**

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

Reference Notes A10, A11, A12

ASSIGNMENT: HW2

**Week 7: February 22 - 26**

NO ACTIVITIES THURSDAY, Feb 25 (UF Recharge Day)

Statistics as applied to particle experiments.

Discovery of electron, proton, photon, neutron.

Reference Notes A13, A14

**Week 8. March 1 - 5**

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

Yukawa particle and discovery of pions and muons.

Reference Notes A15, A16

**Week 9. March 8 - 12**

Neutrino hypothesis and discovery, neutrinos of 2<sup>nd</sup> and 3<sup>rd</sup> generations.

Universality.

Concepts of neutrino masses, mixing and oscillations.

Reference Notes A17, A18. Optional neutrino masses, mixing and oscillations discussed in Ch 2 of the Textbook.

ASSIGNMENT: HW3

**Week 10. March 15 - 19**

Discovery of strange particles and resonances. First three Quarks and systematics.

Reference Notes A19, A20

ASSIGNMENT: Mid-term Test

**Week 11. March 22 - 26**

NO CLASS WEDNESDAY, March 24 (UF Recharge Day)

Charm, bottom and top quarks discoveries.

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

Reference Note A21. Textbook Ch 11.1 and Ch 11.2.1,11.2.2.

**Week 12. March 29 – April 2**

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

Reference Note A22. Textbook Ch 10.

ASSIGNMENT: HW4

**Week 13. April 5 - 9**

Higgs discovery.

Reference Note A23 (beginning). Textbook Ch 10 (Higgs discovery, end)

**Week 14. April 12 - 16**

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

Textbook, Ch 11.1 and related to CP-violation material in Universe, material in Ch 12

**Week 15. April 19 - 21**

Summary on post-Higgs physics, including supersymmetry, dark matter and microscopic black holes.

Reference Note A23. Textbook Ch 12.1,12.2

ASSIGNMENT: Student Presentations

**CLASSES END ON April 21**

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.

**METHODS BY WHICH STUDENTS WILL BE EVALUATED AND THEIR GRADE****DETERMINED:**

Contributions to the grades are:

- 1) homework assignments (every two-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 pop up quizzes (typically one question). Max contribution of all quizzes combined is 10%. The quizzes are infrequent but may be asked at any time in class during lectures.
- 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 April 22 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:

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

## COURSE POLICIES:

**ATTENDANCE AND MAKE UP POLICY:** You are expected to attend on-line 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 POP-UP 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. Pop-up quizzes may be assigned during any lecture, they are not collaborative. Solutions of the quizzes must be submitted electronically.

**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://qatorevals.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. Summaries of course evaluation results are available to students at <https://qatorevals.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 Honor Code (<http://www.dso.ufl.edu/sccr/process/student-conduct-honor-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 email messages, threaded discussions and chats.

**COVID-19 STATEMENT:** If you are experiencing COVID-19 symptoms, click here for guidance from the CDC on symptoms of coronavirus:

<https://www.cdc.gov/coronavirus/2019-ncov/symptoms-testing/symptoms.html>

Please use the UF Health screening system and follow the instructions on whether you are able to attend class. Click here for UF Health guidance on what to do if you have been exposed to or are experiencing Covid-19 symptoms:

<https://coronavirus.ufhealth.org/screen-test-protect/covid-19-exposure-and-symptoms-who-do-i-call-if/>

Course materials will be provided to you with an excused absence, and you will be given a reasonable amount of time to make up work. Find more information in the university attendance policies at: <https://catalog.ufl.edu/UGRD/academic-regulations/attendance-policies/>

**PRIVACY 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.

**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](mailto: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](mailto: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>

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/>

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

Last update: 1/6/21