Physics 230B: QFT II

Instructor: Flip Tanedo (flip.tanedo@ucr.edu / PHYS 3054) **Office Hours**: by appointment; usually available Wed 4-5pm

Course Information

Advanced Quantum Mechanics and Quantum Theory of Fields

4 Units, Prerequisite: Physics 230A or equivalent Tue/Thu 5:00-6:20pm PHYS 2111
sites.google.com/ucr.edu/p230b

Textbook: AQFT Notes by Hugh Osborn, Steffen Gielen, Carl Turner You may also use your favorite quantum field theory textbook.

We will cover the quantum theory of fields from a functional perspective, renormalization and effective theories, gauge theories and their quantization, and anomalies (as time permits). Material will be inspired by particle physics, but we will focus on general quantum field theories on continuum spacetime.

Course format: 80 min meeting with 10 min break

- First 35 minutes may include student presentations and brief assessments
- Remainder of course is a traditional lecture; student discussion *strongly encouraged*

Learning Objectives

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

- Use functional methods to quantize a quantum field theories of spin-0, spin-1/2, and spin-1 particles.
- Explain what renormalization is to colleagues. Calculate loop-level diagrams to determine renormalized parameters of a theory.
- Explain what a gauge theory is to colleagues. Quantize gauge theories.
- Be able to explain what an anomaly is to colleagues; including their origin, significance, when they are "bad," and their relationship to fermions and gauge theories.

Assessment

Students' course grade will be determined by:

- **5 bi-weekly homework assignments** due in class (*20 points* each)
- **Homework Presentation** (*20 points*) Each student presents a discussion of least one homework problem in front of the class.

No final exam. If you really want one, you can do the final projects at the end of each section of Peskin & Schroeder. I will not grade it, but you will have my respect.

Graduate students taking this class have different learning goals and targets. Assignments will be written accordingly, with technical problems identified as semi-optional. Grades will be assigned on a curve reflecting this.

Undergraduate students taking this class will be graded strictly.

Course Philosophy

The Two Questions You Can Always Ask

> *There are no stupid questions. Only stupid students.* --Physics Proverb

Questions and discussions *during class* are strongly encouraged. Do not wait until after class, do not ask physics questions privately. Our material will force you to think differently than you do in other classes you have taken, it will be a challenge.

You should *always* feel comfortable to ask the following questions.

1. "*Is it obvious that ... ?*" This means: I don't understand something and I don't want to sound stupid.
2. "*Why are we doing this?*" I understand the details, but I do not understand what the big picture is.

Teaching Philosophy

1. Learning is a challenge that requires work, commitment, and time. Struggling on a problem and not getting it completely right is far more valuable then doing exercises that are trivial.
2. It is dangerous to go alone. Collaborate. Theorists should collaborate with experimentalists. If you can't communicate now, then you're really fucked when your research/grants/tenure really depend on effective communication across disciplines.
3. Instructors should never do for students what students can do for themselves. If you're in this class, you already know the importance of doing your own exercises from your favorite field theory book.

Lecture time should combine some technical steps with 'big picture' insight. If your career depends on your ability to do detailed calculations, it is your responsibility to work through every detail of those calculations.

If your work does *not* depend on every detail in this class, then you can take what you want out of it. But *you get as much as you put in*: if you're not struggling with the homework, it's not necessarily the instructor's fault if you have a hard tine following what's going on two weeks later in class.

Policies

- **Equity and Inclusion policy**: *Don't be an asshole.* We are committed to creating an inclusive learning space where we respect one another regardless of race/ethnicity, gender identities,

gender expressions, sexual orientation, socioeconomic status, age, disabilities, religion, regional background, veteran status, citizenship status, nationality and other diverse identities that we each bring to class.
- **"I'm stuck on the homework" policy**: If you work with your colleagues, spend hours on a problem, and still can't figure it out... then I probably can't do it either. Present the problem to the class anyway. If we're all hopelessly stuck, we can ask Jose.

- **Academic integrity**: conduct.ucr.edu/policies/academic-integrity-policies-and-procedures
- **Factors of 2, π, i, ...** If you are concerned about any of these factors, then it is your homework to figure out what the correct factors are. Minus signs are marginal. The minus sign in the β function is really important, while others are not important at all.

Additional References

Feel free to use whatever quantum field theory references you like best. Some suggestions:

- Zee, *Quantum Field Theory in a Nutshell*. Gentle, conversational style rooted in physical intuition.
- Peskin & Schroeder, *An Introduction to Quantum Field Theory*. An excellent reference for performing calculations.
- Srednicki, *Quantum Field Theory* Uses the opposite metric as our class, but otherwise an excellent introduction to each of the topics in the course. Written in a style where one can "jump in" at different chapters.

Student Support Services

- **Disability Accommodations**: if you have a disability may affects your ability to participate in this course, please make arrangements with the Student Disability Resource Center (SDRC) within the first week of class, sdrc.ucr.edu/.
- **Counseling**: this is a challenging course in a challenging major. If you are concerned that you feel overwhelmed, depressed, or in need of someone to talk to during your time at UCR, you are encouraged to contact Counseling & Psychological Services (CAPS), counseling.ucr.edu/. CAPS is confidential and is a resource that many in academia have turned to at one point or another.
- **Concerns about the course**: You are strongly encouraged to speak directly to the instructor early in the quarter if there are concerns about the course. If you have concerns regarding severe problems with the course or instructor that you do not feel comfortable bringing to the instructors attention, you may reach out to the ombudsperson, help.ucr.edu/office-ombuds. encouraged to speak to the instructor first.

Tentative Weekly Course Plan

1. Path Integrals
2. Functional Methods: Scalar
3. Functional Methods: Fermions
4. Loops in QFT: Regularization

5. Loops in QFT: Renormalization
6. Effective Theory
7. Gauge Theories
8. Quantum Gauge Theories
9. Anomalies I
10. Anomalies II