PHYS 7147 - Fall 2018
TT 1:30pm - 2:45pm, Howey S104

quantum field theory - course schedule

Homework - grading
Homeworks, a take-home mid-term, and a final exam; the grades will be based on these (60%/20%/20%). Exams and homeworks include optional problems ("bonus" = extra credit). Homework assignments will be posted on the web every Thursday, due Tuesday, and by graded by your fellow students by the next Tuesday.

August 21

1. Lattice Field Theory

Diffusion as a sum over Paths

Reading: Chapter 1 - Lattice Field Theory
Cvitanović lecture notes

Reading: A. Zee Chapter I.1 - Who Needs It?
From A. Zee "Quantum Field Theory in a Nutshell"

Reading: C. Itzykson and J.-M. Drouffe - Statistical field theory, vol 1 (Cambridge U. Press, 1991)
Chapter 1: From Brownian motion to Euclidean fields (A nice discussion of free propagation as Brownian walks)

August 23

2. Discrete Fourier transforms

Fourier modes as eigenmodes of translation

Reading: Chapter 1 - Lattice Field Theory
Cvitanović lecture notes

Homework #1 - problems
- due Tue Aug 28, in class

August 28

3. Green's function in Quantum Mechanics

Reading: Chapter 2 - Path integral formulation of Quantum Mechanics
Cvitanović lecture notes

Reading: L.P. Kadanoff - Statistical Physics; Statics, Dynamics and Renormalization
Chapter 3: Gaussian Distributions (available online)

Reading: Physics Today - review

August 30

4. Path integral - Quantum Mechanics

Reading: A. Zee Chapter 2 - Path integral formulation of Quantum Mechanics
Homework #2 - problems
- due Tue Sep 4, in class

September 3

Labor Day

September 4

5. Dirac-Feynman's Formulation of Quantum Mechanics

QM amplitudes as a sum over paths

Reading: Chapter 3 - Path integral formulation of Quantum Mechanics
Cvitanović lecture notes

Reading: Chapter 6 - Path Integrals in Quantum Mechnics
M. Srednicki book

September 6

6. Collective excitations

Elastodynamic equilibria of 1- and 2-dimensional solids. Phonons.

Reading: A. Zee Chapter I.3 - From Mattress to Field
Reading: Section 1.6 - Collective excitations: from particles to fields
Cvitanović lecture notes

Homework #0 - template
If you like to write up your solutions in LaTeX, here is a template

Homework #3 - problems
- due Tue Sep 11, in class

September 11

7. Quefithe

Reading: Fable - Quefithe
Reading: Chapter 2 - Generating functionals
What the mole saw

September 13

8. Quefithe

Dyson-Schwinger equations

Reading: Chapter 2 - Connected, 1PI Green's functions
Tying the Nudo del Diablo

Homework #4 - problems
- due Tue Sep 18, in class

September 18

9. Quefithe

Reading: Chapter 3 - Path Integrals
What the crow saw

September 20

10. Quefithe

What the fox saw: it's just a Fourier transform. Tree expansions: Saddle point evaluation of path integrals, one loop (leading h-bar) corrections. Ward identities: symmetries relate and constrain different Green's functions.

Reading: Review - by Feynman
Reading: Chapter 5 - Field theory path integrals
Cvitanović lecture notes

Homework #5 - problems
- due Tue Sep 25, in class

September 25

11. Perturbation expansions are asymptotic

Formally, perturbation series is always asymptotic, but can be very accurate.

Reading: Section 5.6 - Saddle-point expansions are asymptotic
Cvitanović lecture notes

Reading: QED - is it finite, not asymptotic?

September 27

12. Scalar field theory

The first physical result: Yukawa interaction by scalar fields (mesons) is attractive.

Reading: A. Zee Chapter I.3 - From Mattress to Field
Reading: A. Zee Chapter I.4 - From Field to Particle to Force
Homework #6 - problems
- due Thu Oct 11, in class

October 2

13. Scalar field theory

Reading: A. Zee Chapter I.5 - Coulomb and Newton: Repulsion and Attraction
Reading: A. Zee Chapter I.11 - Field Theory Redux

October 4

14. Effective action

While the full partition function for bare particle interactions is the easiest to derive, the physical content of a theory is given by the `effective action', the interctions between dressed particles (this is a continuation of lecture 9, a deeper dive).

Reading: Sections 2.H and 2.I - 1PI Green's functions, vacuum bubbles

The 1pI generating functional is the Lagendre transform of the connected diagrams generating functional.

Reading: Sections 3.E and 3.H - Legendre transforms

The 1pI generating functional can be interpreted as the `effective' (or `quantum') action functional.

Homework #7 - problems

- due Thu Oct 18, in class

October 8-9

fall recess

October 11

15. The Dirac Equation

Reading: A. Zee Chapter II.1 - The Dirac Equation

Reading: W. Greiner and J. Reinhardt - Dirac equation

The excerpt in ChaosBook.org/library (click on Field Theory link) covers Dirac's original derivation of his equation.

October 16

16. Midterm

All material covered in the 1. part of the course, up to fall recess: generating functions, path integrals, their perturbative expansions, scalar fields propagators.

Homework - midterm

- usual time, in class

midterm grades distribution [all solutions are in the book]

October 18

17. SU(2) and SO(3)

Spin 1/2 is hiding in our Euclidean 3D space in plain sight, and nature has chosen to us it. Its representation theory will carry over also to the Minkowsky spacetime SO(1,3).

Reading: Notes 11.1 - SU(2) and SO(3)

SU(2) - SO(3) correspondence

Reading: W.G. Harter - Hamilton's turns

(for fun only) How Hamilton (who would have guessed...) used quaternions to to extend the discrete Fourier transform from a circle to a sphere.

Homework #8 - problems

- due Thu Oct 25, in class

October 23

18. SO(1,3) and SU(2) x SU(2)

Reading: Roger Penrose - Dirac's electron and antiparticles

From "The Road to Reality". Skim through Chapt 24, read at least starting with section 24.7 The Dirac equation.

Reading: Roger Penrose - The standard model of particle physics

From "The Road to Reality". Skim through Chapt 25 at your pleasure, none of this will be on the final exam :)

Reading: Jakob Schwichtenberg - SO(1,3) and SU(2) x SU(2)

Refresh your QM, sect. 3.6 SU(2). Then work through the commutators of sect. 3.7 The Lorentz Group SO(1,3). Make sure you know the distinction between Weyl, Majorana and Dirac spinors. Can skip sects. 3.7.11 Infinite-Dimensional Representations and 3.8 The Poincare Group, but do read sect. 3.9 Elementary Particles in preparation for learning about the Standard Model.

October 25 lecturer: B.F.L. Ward

19. Celebrating 50 years of the Standard Model

The role of Quantum Field Theory loop corrections in establishing the validity of the Standard Model (which David Gross now wants us to call the Standard Theory, in view of its experimental validation).

Reading: Sabine Hossenfelder - String theory

So you want to be a string theorist? Here are pros and cons.

Homework #9 - problems

- due Tue Nov 6, in class

October 30

20. gamma mu nu gymnastics

Reading: V. K. - Dirac Matrices and Lorentz Spinors
The signature of the Minkowsky metric makes Lorentz transformations not unitary, and thus (complex conjugate transpose spinor) x (complex spinor) is not a scalar under Lorentz transformations

Reading: V. K. - Propagator for the Dirac Spinor Field
is perhaps what you would expect it to be

Reading: Chapter 3 - Dirac equation
From Peskin and Schroeder, "An Introduction to Quantum Field Theory"; study pp. 35-44, 49-52, 62-63, rest we'll skip.

November 1

21. Feynman rules

Reading: A. Zee Appendices C and D - Feynman rules
Homework #10 - problems
- due Thu Nov 8

November 6 lecturer: Brian Swingle

22. How to calculate a signature of chaos in field theory using diagrams

This material ties into Swingle's 11:15am Theoretical Physics Seminar. Go hear it :)

Reading: Debanjan Chowdhury and Brian Swingle - Onset of many-body chaos in the O(N) model
The growth of commutators of initially commuting local operators diagnoses the onset of chaos in quantum many-body systems.

November 8

23. Feynman rules

Reading: P. Cvitanovic - Feynman rules part I
Apologies for bad audio - thsi was the first test of recording online lectures. Mouse over video's top edge to change the resolution.

Reading: P. Cvitanovic - Feynman rules part II
Big day: our first QED Feynman integral. Click on video's gearwheel, lower right edge, to change the resolution.

Homework #11 - problems
- due Thu Nov 13, in class

November 13

24. Electron magnetic moment

Reading: A. Zee Chapter VIII.3 - The treshold of ignorance
Reading: A. Zee Chapter III.4-6 - Electron magnetic moment
Skim through Chapt III.4-5, work through Chapt III.6 Sect "Dirac's triumph".

Reading: P. Cvitanovic - Electron magnetic moment (Dirac triumph) (part 1)
Big day: our first QED Feynman integral. Click on video's gearwheel, lower right edge, to change the resolution.

Reading: P. Cvitanovic - Electron magnetic moment (Dirac triumph) (part 2)
Dirac explains a factor of 2 in observed electron magnetic moment.

Reading: P. Cvitanovic - Electron magnetic moment (Dirac triumph) (part 3)
Schwinger's vertex.

November 15

25. Feynman Diagrams

Reading: D. Kaiser - Physics and Feynman's Diagrams
American Scientist 93, 156 (2005)

Reading: Kelly Devine Thomas - Feynman Diagrams and the Evolution of Particle Physics
The Institute Letter, I.A.S. (Spring 2009)

Reading: P. Cvitanovic - a very brief history of diagrammatics
(worth a glance) A lighting fast way to compute commutators, but you have to learn how to draw first. See page 38.

Reading: L. Dixon - Look ma - no Feynman's diagrams!
How we calculate amplitudes these days (October 3, 2013)

Homework #12 - problems
- due Tue Nov 20, in class

November 15; recorded July 25, 2013 lecturer: Edward Witten

25 extra Feynman Diagrams in String Theory

Reading: video - What any physicist should know
even if she does not want to do mess with strings.

Reading: Freeman J. Dyson - The World on a String
To balance the pied piper song - a delightful sceptic's view.

November 20 lecturer: Ignacio Taboada

26. Standard Model

Reading: Apostolos Vasileiadis - Symmetry
(for fun only) Gauge invariance is not preserved!

Homework - no problem
- none due this week

November 21-23

Thanksgiving

November 27

27. Electron magnetic moment

Reading: A. Zee Chapter III.6 - Electron magnetic moment
Work through Chapt III.6 Sect "Schwinger's triumph".

Reading: Matthew Schwartz Chapter III-3: - The anomalous magnetic moment
Complementary, even more compact than Zee's derivation.

Reading: Appendices C and D - Feynman rules
Referred to in calculations of Chapt III.6.

Reading: P. Cvitanovic - Anomalous electron magnetic moment (Schwinger's triumph)
Schwinger's \alpha/2\pi calculation sketched out. (You'll have to screw up the volume, sorry.)

Reading: Dan Styer - Calculation of the anomalous magnetic moment of the electron
The accuracy available as of 21 June 2012 "is the equivalent of measuring the distance from Los Angeles to New York to within the width of a bacterium, or of measuring the distance from the Earth to the Moon to within the width of a single human hair."

Reading: Toichiro Kinoshita - Fine Structure Constant, Electron Anomalous Magnetic Moment, and Quantum Electrodynamics
The heroic calculation of Toichiro Kinoshita: status as of 2010.

[Schwinger's headstone]

November 29

28. Gauge invariance

Ward identities: symmetries relate and constrain different Green's functions.

Reading: Sections 3.G and 3.H - Point transformations
Reading: A. Zee Chapter III.4 - Gauge invariance: A photon can find no rest
Reading: Sections 3.A and 3.B - Ghoulies and ghosties
Reading: A. Shapere and F. Wilczek - Geometry of self-propulsion at low Reynolds number
(Not covered in this lecture, but might interest you:) From swimming to gauge potentials. But what is a photon, really?

Reading: The base space (space of unlocated shapes) - for cats
A fibration and a base space :)

Homework #13 - problems
- due Tue Dec 4, in class

December 4

29. Renormalization

Reading: Chapter * - Parametric representation
Unpublished notes: momentum space Feynman integrals, parametric representation.

Reading: Chapter * - Renormalization
Unpublished notes: Power counting, UV divergences, subtractions, counterterms.

Reading: Chapter * - Gauge-invariant sets
Unpublished notes: high-orders diseases; gauge set counting; finitness conjecture.

December 4

GT classes end

Homework Final exam - syllabus

An overview of material covered by the final exam.

[midterm grades]

December 6 - freebie

30. Gribov copies

Reading: Higgs Boson - blues
Reading: Nick Cave - and The Bad Seeds

The full length version

December 10

final exam 2:40pm - 5:30pm

closed book, closed lecture notes.

Course grades distribution [alert me if I am missing some homework grades]

until December ?

course opinion survey

CETL web link

October 29 - December 14

spring registration

Reading: PHYS-7143 - Group Theory

The Spring 2019 group theory course can be described this way: Suppose someone came to you and asked, "On planet Z, mesons consist of quarks and antiquarks, but baryons contain three quarks in a symmetric color combination. What is the symmetry group?" The answer requires some thought, and leads to magic that beguiles field theorists. We might get to the answer by the end of the course - but our focus will be on basic tools of group theory: finite groups, subgroups, cosets, and conjugacy, group of permutations, matrix representations, tensors, Schur's Lemma, characters and character table construction, irreducible representations, Lie groups, rotations and why you need no Clebsch-Gordon coefficients. Hope you will join me. Tell your friends to join us too.

December 17

GT grades due at noon

December 24

the future looks bright

Future's So Bright, I Gotta Wear Shades [click right, open in new tab]

svn: $Author: predrag $ - $Date: 2018-12-01 20:44:03 -0500 (Sat, 01 Dec 2018) $