University of California at San Diego – Department of Physics – Prof. John McGreevy

Physics 215C Quantum field theory, Spring 2025

End-of-Term Project

Deadlines: Topic choices are due by week 8.
Papers are due on Thursday, June 12, 2025.

The end of term project for Physics 215C will be a *short* paper explaining a nugget of truthy goodness somehow related to quantum field theory.

Your goal in deciding what to say should be to try to save the rest of us from having to read the relevant papers if we don't want to. Give some context, say what the crucial point is, say what the implications are.

I plan to post all the papers on the course webpage, so we can all read them. Reading the other papers is part of the assignment.

The paper should be approximately 2 pages in a TeX format for which I'll provide a template. You may include arbitrarily many figures, which need not count toward the page limit. The page limit is not sharp, but keep in mind that I will post all the papers to the course webpage and everyone should read everyone else's paper: you don't want to torture your classmates. You may add appendices which do not count toward the page limit if this would be useful to you.

I would prefer a level of detail and technical sophistication comparable to that of my lecture notes. Anything we've covered in lecture or homework in 215ABC may be assumed known (though a reference to a specific section of the notes might be helpful). Your paper may contain as much detail as you like, but complicated technical details must be put in a box and labelled, so that the reader may read only the label on the box without losing the narrative thread. Examples of boxes into which you may put details are footnotes, appendices and actual boxes. There is no page limit on appendices.

Please tell me (by email) what topic you plan to study as soon as possible, but not later than week 8. Below are some topic suggestions, involving wildly varying levels of difficulty. The list is certainly not in any sense exhaustive, and I will keep adding to it as I think of more topics. Creative topics are encouraged. As topics are claimed, I will mark them on this document.

Submission instructions:

I will post an assignment on Canvas by which you can submit your paper. It would help me if you name the file in the following format:

`2022S-215C-YourLastName-YourFirstName.pdf`

Some topic suggestions:

Anything in blue below is a link to the literature.

Lists of and links to references below are intended as entry points to the literature, and not as complete citations of all good work on the subject. For each paper you should of course always also read all papers that cite it[1][2], as well as all of the papers to which it refers. The order below is not meaningful, though I've tried to group related topics together. I will keep adding to this file as I think of more possible topics.

1. Constraints of unitarity and causality on the chiral Lagrangian at large N [Albert-Rastelli, 2022]
2. Rigorous QFT [Here might be a good place to start]
3. On which complexified spacetimes does QFT make sense? [Witten 2021]
4. Entanglement in QFT as a property of the algebra of observables [start here] [Claimed by Aiden Sheckler]
5. Field theory of deep learning [start (and probably end) here]
6. WZW models of 2d current algebra CFT, non-abelian bosonization [Witten, 1983]
7. Monopole catalysis of baryon decay (Callan-Rubakov effect) [see also this paper]
8. The Witten SU(2) anomaly [Witten, 1982] and recent generalizations
9. Fermion zeromodes on solitons. This is really several topic suggestions: [codimension 2: Jackiw-Rossi, codimension 3: Jackiw-Rebbi, recent related developments: Fu-Kane, Teo-Kane, McGreevy-Swingle]

   [Claimed by Rolando Ramirez-Camasca]
10. As we've seen, perturbation theory is only asymptotic [Dyson]; attempts to improve upon it by Borel resummation [Zinn-Justin's textbook]; renormalons [1204.1661]

[1] Am I exaggerating?

[2] For some of the papers listed below, a relatively complete citation list can be found using Spires: `http://inspirehep.net`.

11. Large-order perturbation theory and non-perturbative effects: Resurgence and Trans-series [start here]

12. Luttinger-Ward or 2PI resummations [start here]

13. The c-theorem in 2d QFT [Zamolodchikov] and its connection with the spectral density [Friedan-Cappelli-Latorre] and with the entanglement entropy of subregions [Casini-Huerta]

14. RG Monotonicity of entanglement in 3d relativistic QFT [Casini-Huerta]

15. RG Monotonicity and constraints on emergence of gauge theory [Grover]

16. The Kondo model (one of the first applications of the RG) [Affleck and Affleck]

17. Fermi edge singularity in X-ray absorption, from 2d CFT [Affleck, Ludwig]

18. Skyrme model of baryons. [Here or here are places to start.]

19. Realization of anomalies in the sigma model (Wess-Zumino terms) [Witten, 1983]

20. 3d Parity anomaly [Redlich, 1984] and its avoidance at the edge of topological insulators.

21. Mossbauer effect: recoil-free scattering from a solid is made possible by the quantum nature of phonons [here].

22. Spinor-helicity formalism for amplitudes [Zee, Part N]

23. BCFW recursion relations for tree amplitudes [0801.2385]

24. Conformal bootstrap

    [Claimed by Simon Martin.]

25. Derivation of ϵ-expansion from conformal field theory [this beautiful paper]

26. Theta vacua of Yang-Mills theory [see the section of Coleman's book called *Uses of Instantons*.]

27. Magnetic bions are responsible for confinement in some gauge theories on $\mathbb{R}^3 \times S^1$ [Unsal – this fascinating 'scientific memoir' has a bibliography]

28. In our discussion of effective field theory, I made a long list of physics problems to which this methodology has been applied, along with references to entry points into the literature. Any of these topics would be suitable.

29. Anything else we don't get to in lecture that's on the syllabus, or any other related topic.