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

Group Theory (220) Fall 2020

End-of-Term Project

Deadlines: Topic choices are due before Thanksgiving.
Papers are due on Thursday, December 17, 2020.

The end of term project for Physics 220 will be a *short* paper explaining a nugget of truthy goodness about symmetry in physics.

Your goal in deciding what to say should be to try to save the rest of us from having to read the papers. 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.

I would prefer a level of detail and technical sophistication comparable to that of my lecture notes. Anything we've covered 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 Thanksgiving. Below are some topic suggestions, involving wildly varying levels of difficulty. The list is certainly not in any sense exhaustive. Creative topics are encouraged.

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:

`2020F-220-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 which 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.

1. Group integrals, matrix models, 2d Yang-Mills [claimed by Zipei Zhang]
2. Symmetry breaking (and topological defects) in liquid ^{3}He from Landau-Ginzburg theory. *e.g. Exotic properties of superfluid ^{3}He*, G. E. Volovik. [claimed by Xiang Li]
3. No all-transversal universal gate set (Knill-Eastin theorem). The proof of this theorem uses just facts about Lie groups. [Claimed by Ahmed Akhtar]
4. Continuous symmetry versus quantum error correction. [V Albert, ... Salton] here and here. These papers allege that the Knill-Eastin theorem is involved. Explain how.
5. Categorical symmetries, non-invertible defect lines. (I have in mind, *e.g.* this and this). [Claimed by Dachuan Lu]
6. Affine Lie algebras.
7. Quantum groups. For example, the Drinfeld quantum double $D(G)$ and its representations and their characters. here And its relation to Kitaev's quantum double model. [claimed by Hongrui Li]
8. Group averages, in lattice gauge theory for example. Weingarten formula. Strong coupling expansion of lattice gauge theory using characters. *e.g.* Munster and Montvay. https://arxiv.org/abs/1301.5401 [Claimed by Yuan Zhang]
9. Counting invariant operators of given dimension. [start here]
10. Moonshine.
11. Loop groups and applications to metallic states. [Suggested and claimed by Meng Zeng]

[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`.

12. Tensor category theory and anyons. Appendix E of Kitaev's honeycomb paper. [Claimed by Hung-Hwa Lin]

13. Haar-random states and their entanglement properties. [Page]

14. Quantum error correction and large N. [Milekhin, https://arxiv.org/abs/2008.12869]

15. Massless particles and representations of the Lorentz group [start here] [Claimed by Jiashu Han]

16. There are more symmetric unitaries than can be made by evolution by symmetric Hamiltonians. [here]

17. The group theory behind phonon-phonon coupling and its use in nonlinear phononics experiments. [Suggested and claimed by Kelson Kaj]

18. Group theory of quasicrystals [Suggested and claimed by Elliot Kisiel]

19. Symmetry Equivariant Neural Networks [Suggested and claimed by Raghav Kansal]

20. Group actions on multisymplectic manifolds [Suggested and claimed by Brian Tran]

21. Kondo effect for other spin symmetry groups [here]

22. Group cohomology description of classically-impossible quantum tasks, aka [contextuality]

23. $\mathsf{SL}(2,\mathbb{R})$ and strings in AdS_3 [Suggested and claimed by Zhengdi Sun]

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