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

Physics 239 Topology from Physics Winter 2021

End-of-Term Project

Deadlines: Topic choices are due by week 8.
Papers are due on Thursday, March 18, 2021.

The end of term project for Physics 239 will be a *short* paper explaining a nugget of truthy goodness about topology in physics or something related.

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 week 8. Below are some topic suggestions, involving wildly varying levels of difficulty. The list is certainly not in any sense exhaustive. 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:

2021W-239-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 as I think of more possible topics.

1. New manifolds from cell complexes associated with quantum codes [start here]
2. Gapped boundaries for (non-chiral) topological phases [start here] [Claimed by Ahmed Akhtar]
3. Chiral topological phases and the chiral central charge [Appendix D of Kitaev's honeycomb paper] [Claimed by Xiang Li]
4. Behavior of the entanglement entropy in simple gapped groundstates [start here and look here for the incorporation of spaces with torsion homology in the case of abelian phases] [Claimed by Zhehao Zhang]
5. How to (in principle) measure the data determining a 2d topological order; Whitehead link and punctured S-matrix [here and here] [Claimed by Shubham Parashar]
6. Characteristic (anomaly) polynomials for spacetime symmetries [here, here, here] [Suggested and claimed by Dachuan Lu]
7. A connection between gapped boundaries, bosonic SPT phases, and fault-tolerant logical gates in the d-dimensional quantum double model [here and here] [Suggested and claimed by Tsung-Cheng Lu]
8. A physical system whose groundstates compute $\pi_{q\geq 2}$ of the space it's living on? [here, here. Also look for the discussion of Ref 31 of here]
9. Entanglement entropy of topological states from surgery [here and here] [Suggested and claimed by Hung-Hwa Lin]

[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.

10. Milnor homology sphere and the E_8 root lattice [start with Bredon, Theorem 8.10 and §VI.18]

11. Khovanov homology [start here]

12. Modular forms and CFT [start here] [Claimed by Zipei Zhang]

13. Find a physics realization of spectral sequences [§14 of Bott and Tu]

14. Find a physics realization of Cech cohomology

15. Non-linear sigma model description of topological phases [start here]

16. Supersymmetric quantum lattice models. [start here or here] [Claimed by Wei-Ting Kuo]

17. Supersymmetry-protected phases of matter? [start here]

18. Quantum cohomology rings (Gromov-Witten theory) and mirror symmetry [start here]

19. Topology change in string theory [start here]

20. Donaldson theory and supersymmetric gauge theory [start here or here] [Claimed by Meng Zeng]

21. Can topological field theories arising from twisted supersymmetric field theories be effective field theories for quantum phases of matter? [start here]

22. Mirror symmetry as T-duality [start here]

23. Topological phases from wrapped M5-branes (this paper) [Suggested and claimed by Zhengdi Sun]

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