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

Physics 213 Quantum information is physical, Winter 2023

End-of-Term Project

Deadlines: Topic choices are due by week 8.
Papers are due on Thursday, March 23, 2023.

The end of term project for Physics 213 will be a *short* paper explaining a nugget of truthy goodness about the physics of quantum information theory.

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 (PRL format). 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.

Please aim for a level of detail and technical sophistication comparable to that of my lecture notes. Anything we've covered in lecture 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 and sophistication. 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:

`2023W-213-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. Hiding classical data non-locally in quantum states [here, here, here]
2. Exponential decay of correlations and the area law [here, here]
3. Active error correction of zero-temperature topological quantum memory [here] (Claimed by Will Brunner)
4. Fault tolerance [here] (Claimed by Jerry Yan)
5. The quest for stable finite-temperature topological quantum memory [Start here. Some other useful references might be this and this]
6. Effects of local decoherence on topological order [here] (Suggested and claimed by Yu-Hsueh Chen)
7. Quantum cellular automata [Start here and here, but be aware of this and this] (Claimed by Xiang Li)
8. Quantum marginal problem and representation theory [here, here] (Claimed by Morgan Makhina)
9. Finding the ground state of a local Hamiltonian is (QMA) Hard [See the book by Kitaev Shen and Vyalyi or here or here] (Claimed by Lingyuan Lyu)
10. Entanglement phase transitions in monitored circuits [Start here]

---

[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. Renormalization group monotonicity from quantum information theory [here] (Claimed by Eugene Chen)

12. Quantum advantage with shallow circuits [here] (Claimed by Jubal John Peter)

13. Boson sampling [here. Note the existence of recent experimental work. You might find Scott Aaronson's blog to be a helpful resource here.] (Claimed by Zichen He.)

14. Measurement-based quantum computation (MBQC) and symmetry-protected topological phases (SPTs) [here] (Claimed by Wenrui Yang)

15. The Petz recovery map [try here or here]

16. Approximate quantum Markov chains – a strengthening of SSA [Fawzi-Renner, this thesis]

17. Quantum information theory directly in the continuum [Witten lectures] (Tentatively claimed by Tony Aportela)

18. Why and when does statistical mechanics work for isolated quantum systems? Eigenstate thermalization hypothesis [this paper] (Claimed by Xiaoyi Wu)

19. Ge-Eisert Dragons: not all area law states are groundstates of local hamiltonians [here]

20. Isometric tensor networks (toward efficiently contactable tensor networks in $d > 1$) [here and here]

21. Quantum Fano inequality [Chapter 12.4 of Chuang and Nielsen] (Suggested and claimed by Chen Li.)

22. Which many-body unitaries can be generated by symmetric gates? [this new paper and refs cited therein] (Claimed by Runqiu Xu)

23. An entanglement diagnostic for symmetry-protected topological phases [here]

24. s-sourcery, perhaps for gapless states [here, §4.2 here, here] (Suggested and claimed by Rolando Ramirez-Camasca)

25. Measuring entanglement [here and maybe here]

26. Entanglement entropy in quantum spin liquids [here and here] (Claimed by Simon Martin)

27. Pretty good quantum LDPC codes (and maybe something about their relationship to recently-constructed good codes) [here, and maybe here, here, here] (Suggested and claimed by Guru Jayasingh)

28. Shor's algorithm and quantum Fourier transform [here and here] (Claimed by Qiyu Liu)

29. Some interesting quantum algorithm that we didn't talk about

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