Quantum Information is Physical (Physics 213/113)
Winter 2023

Course times and locations: For times of lectures and office hours please see the course webpage.

Use of the Web: The course web page is

http://physics.ucsd.edu/~mcgreevy/w23/ .

Problem sets, solutions, lecture notes, handouts, announcements, *etc* will be distributed via this page. You should check it regularly (*e.g.* before each lecture) for new material. It will help to look at the relevant lecture notes *before* the lecture happens.

Content: The course will include a primer on Shannon's theory on the compression and transmission of information, and its extensions to quantum systems. Applications to many-body physics incorporate the consequences of locality, which include

- the ubiquitous area law for the entanglement entropy of subsystems in low-energy states,
- constraints on the dynamics of quantum field theories, and
- the ideas about tensor networks which underlie state-of-the-art numerical methods.

The final section of the course will explore the deep connections between fault-tolerant quantum computers and highly-entangled (spin liquid) phases of matter.

The target audience includes students working on high energy physics, condensed matter physics (soft and hard) and astrophysics, both theorists and experimenters, as well as ambitious undergrads with some familiarity with quantum mechanics.

Texts: I do not plan to follow any textbook very closely. My posted lecture notes will be the main text.

I will sometimes refer you to some relevant sections of the books listed in §0.2 of the lecture notes.

Grading:

Grades will be determined by problem sets, class participation, and, for those of you enrolled in 213, a brief final paper. More details about the final paper can be found on the homework page of the course website.

Problem sets:

Problem sets are a very important part of this course. Sitting down yourself and trying to reason your way through a problem not only helps you learn the material deeply, but also develops analytical tools fundamental to a successful career in science. I recognize that students also learn a great deal from talking to and working with each other. I encourage each student to make his/her own attempt on every problem and then, having done so, to discuss the problems with one another and collaborate on understanding them more fully. Such collaboration adds most to the understanding of those participants who have done the most by themselves first. The solutions you write up after any discussion and then submit must reflect your own work. They must not be transcriptions or reproductions of other people's work.

In doing the problems, you should feel free to use whatever computational software (*e.g. Mathematica*) you find useful; please make a note in your write-up when you do so.

Problem sets will be posted on the course web page. They will generally be due at the beginning of lecture.

Homework hand-in procedure:

- Homework will be handed in electronically. Please do not hand in photographs of hand-written work. The preferred option is to typeset your homework. It is easy to do and you need to do it anyway as a practicing scientist. A LaTeX template file with some examples is provided here. If you need help getting set up or have any other questions please email me.

- To hand in your homework, please submit a pdf file through the course's canvas website (at canvas.ucsd.edu) under the appropriate assignment, hwnm (where nm are the decimal digits of the assignment number). If you don't see the assignment on canvas send me an email; it probably means I forgot to create it.

Thanks in advance for following these guidelines. Please ask me if you have any trouble.

Miscellaneous unsolicited advice about how to do well in this class:

Participate in lecture! I will post my lecture notes, but they are intended as a supplement to what is presented in lecture, not a substitute.

Keep up with the material. Review the lecture notes from previous lectures before the next one. The structure of this course is a bit of an experiment, and I am relying on all

of you to follow its twists and turns. I will post the relevant reading assignments in advance; read ahead.

Start the homework problems as early as possible. Give yourself some time to think about them, and keep them in mind when you are reading and in lecture.

Ask lots of questions (during lecture, by email, during office hours). I particularly encourage email questions, and make an effort to answer them promptly. The fact that you can ask questions is the point of having classes and not just having everyone go learn on their own.