Algebra and Topology in Physics (Physics 239)
Winter 2021

Course times and locations: For times of lectures and office hours please see the course webpage. I will email Zoom links via Canvas.

Use of the Web: The course web page is

http://physics.ucsd.edu/~mcgreevy/w21/ .

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 first goal of this course will be to explain some essential ideas of algebraic topology through their realizations in physical systems. This course can be regarded as a continuation of the group theory course.

A very tentative outline is (notice that each item is of the form (physics thing) and (math thing)):

1. toric codes and homology groups

   higher form symmetry, p-form toric codes, quantum memory

2. supersymmetric quantum mechanics and homology groups and Morse theory

3. topological defects of ordered phases and homotopy groups

4. quantum double models and homotopy groups, knot invariants

5. topological insulators and K-theory

6. SPTs and bordisms

7. 2+1d topological order, 2-dimensional conformal field theory and category theory

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 literature listed in §0.3 of the lecture notes or to papers available on the internets.

Grading:
Grades will be determined by problem sets, class participation, and a brief final paper.

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:

- This quarter, 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).

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. The fact that you can ask questions is the point of having classes and not just having everyone go learn on their own.

Comments about on-line lectures:

An important point about Zoom lectures: there is a natural tendency to not ask questions. We must overcome this to make the lectures useful. Please ask questions! Don't worry about interrupting. Another option is to ask questions by typing them in the chat window, but I may not see such questions right away.

I will require all of your help to make sure I don't miss any such cues. Please speak up!

I am being encouraged simply to make videos of lectures (given to no one) and post them on youtube. I am resisting this because I think a crucial part of a lecture is questions and feedback from the participants.

Relatedly, it would be great if everyone can have their video on. This is a big help. For the sake of sound quality, it's best if everyone mutes their microphone except when they want to speak.

I am planning to share my computer screen and write on my iPad like the blackboard. I will display the previous "board" as I go. At your end, Zoom has an option, which I recommend, to split the window between the shared screen and the video feed (the relative size of the two is adjustable).

I will be eager to hear your feedback on (or suggestions in advance for) strategies for making on-line lectures more fruitful.