

Undergraduate Seminar: Differential Topology and Physics: Syllabus

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Practicals

Meeting time and place: Mondays and Wednesdays at 2:40-3:55pm in Math 622.

Office hours: By appointment.

Course webpage: <https://ferojz.com/ugrad-sem-fa26.html>

Course Objectives

The goal of the course is to understand the concept of a manifold through concrete examples in physics. In the first part of the course we will meet manifolds, vector fields, differential forms, Riemannian metrics, and symplectic forms. Our approach will focus on lots of examples and solid grounding in the basic definitions, but many important, foundational theorems will be omitted for the sake of time. A more thorough treatment can be found in Modern Geometry I.

In the second part we will learn how to describe physical systems using manifolds. The primary reference will be Arnold's *Mathematical Methods of Classical Mechanics*, but we will not cover the entire book. We will end the seminar with special topics depending on student background and interest such as electrodynamics and quantization.

Since this is a seminar course there is a secondary goal to develop the skills of reading mathematical texts, presenting ideas clearly, and working together to learn a new subject. This provides flexibility for scheduling and subject matter but comes with increased responsibility: you will only learn as much as you are willing to put in.

The schedule will be updated throughout the semester on the course webpage.

Student Responsibilities

- (Talks) Every student must give two 50 minute blackboard talks. Everyone is encouraged to give a third talk, but it is not required. The grade for the third talk will replace the lowest of the first two. A topic will be assigned at least two weeks prior to the talk date. The presenter must meet with me one week before the talk to review the material and ask any questions. Two days before the talk the presenter must write and submit an abstract and immediately after the talk the presented must submit typed or handwritten notes. Notes must be written in your own words without the use of AI. Since this is a learning seminar, you are not expected to be an expert by the time you present. You are, however, expected to clearly communicate your learning progress to the rest of the class. The talk will be graded on clarity of presentation, mathematical accuracy, completeness, ability to answer questions, and timing. Each of these five categories are worth 8 points for a total of 40 per talk.
 - *Clarity*: Precise definitions and theorem statements are given. Handwriting is legible and speaking is loud enough and understandable. Board space is used effectively, i.e. don't erase what you've just written. The topics are motivated and given examples in a way that is easy to follow for the audience. For example, a talk which is aimed at the instructor instead of the other students, assumes extra background, or moves at a very fast pace is not suited for the right audience.

- *Accuracy*: The talk has minimal mathematical mistakes or mistakes are corrected quickly when pointed out. Mistated definitions, missing assumptions, or false results will result in lost points depending on how important they are to the talk.
 - *Completeness*: All topics that were assigned for the talk are covered in appropriate detail based on a discussion with me before the talk. This category is especially important since talks will build on the previous ones so missing topics will need to be covered by the following talk.
 - *Questions*: All questions should be answered without getting derailed from your talk. Points will be taken if you are unable to answer clarifying questions about your presentation. However, for more complex questions answering “I don’t know”, trying to work through an answer on the spot, or having a discussion with the class are all acceptable and will not be penalized.
 - *Timing*: Full credit will be given for having a meeting a week before, submitting an abstract in time, submitting notes after the talk, starting on time and not going over time. Each of these is worth one point. If notes are submitted late, you will lose one point each day.
- (Attendance and participation) Since the seminar is run entirely by student talks, you must attend every class and pay attention out of respect for your classmates. Laptops, phones, and all other work must be put away. If for any reason you need to miss class, please notify me at least one week before. It is your responsibility to keep up with the notes after an absence. Participation is highly encouraged, but will not be tracked for grading purposes. The talks will be “informal” meaning there should be active discussion about the material as it is being presented.
 - (Post-talk index cards) After each class every student must submit two “things” they got out of the talk written on an index card. See: <https://math.stanford.edu/~vakil/threethings.html>. Each “thing” should be a few sentences. For example, you can write down a definition or theorem you learned, a detail you were confused about, a question you want to ask, an idea for future reading, etc. Each index cards will be worth two points and be graded on effort.
 - *0 points* are given for missing index cards. I will this to track attendance.
 - *1 point* is given for very low effort “things”. For example if the talk is about vector fields, “what is a vector field?” or “a vector field is a field of vectors” would be considered very low effort.
 - *2 points* will be given for complete index cards. An example of a good “thing” for a talk about vector fields is: “why can vector fields be defined as sections of the tangent bundle and also as derivations on smooth functions? In what context is it better to use one definition over the other?” Another example is “I am confused by the definition of a vector field. Does the definition require a vector to be assigned to every point on a manifold or only to a subset? Can there be multiple vectors at each point?” Even a comment which contains a mathematical mistake such as “a vector field is a map $TM \rightarrow M$ such that...” would recieve two points since it indicates that you are at least trying to learn from the talk.

Grading Breakdown

- 40% Presentation 1
- 40% Presentation 2
- 20% Index cards