P231: **Methods of Theoretical Physics** (Fall 2020)

INSTRUCTOR: Flip Tanedo (flip.tanedo@ucr.edu)
TEACHING ASST: Ian Chaffey (ichaf001@ucr.edu)

FORMAT: Remote/Online
STYLE: Asynchronous

Critical Information

WEB PAGE: https://sites.google.com/ucr.edu/p231/

Lecture notes, homework and our course calendar will be linked from the course web page. Internal material may be posted to `iLearn`. We will use Slack for communicating with each other and `iLearn`'s emailing platform for high-priority announcements.

This course is offered remotely. Expect 3–5 short (10 min) recorded min-lectures each week to supplement a set of course notes and assigned readings. The focus of this course is solving the problems, *not* the lectures.

Course Description

This is a crash course in mathematical methods for physics and the technical communication skills that will be necessary for your scientific career. The topics are selected to ensure students are prepared for the first-year graduate curriculum at UCR. Our main goal is to solve differential equations using Green's functions. To do this, we will develop and use techniques from linear algebra and complex analysis. If time permits, we may explore other topics toward the end of the course such as statistical methods for physics and astronomy. This is not a mathematics course, it is *boot camp* for physicists.

Evaluation

- **Explainer Videos** (30%): Each week you will prepare and upload one video explaining how to do one of the homework problems.
- **Peer Review** (30%): Each week you will review five videos by your peers. You will grade them based on a rubric and you will provide constructive feedback.
- **Interviews** (10%): Each week you will have a 10 minute interview with either Flip or Ian to discuss your homework and the course. These interviews will help validate the peer review grades and give us feedback on what topics to review in class.
- **Surveys** (10%): Each week you will complete a short survey with review questions and requests for metacognitive feedback.
- **Essay** (10%): In the second half of the course, you will have a one-time written assignment to prepare a 'how to' guide on solving the harmonic oscillator using the techniques in the course.
- **Slack Engagement** (10%): You are expected to contribute to the discussion on Slack by either asking questions, answering your peer's questions, sharing useful resources, and otherwise contribution to the class culture.
- No exams.

I expect you to *work together* and to abide by the UCR academic integrity policies. I strongly encourage you to use the Slack workspace to communicate. You are free to use whatever resources you have available; please cite sources appropriately. When in doubt, cite.

Course Objectives

The contents of this course build a mathematical foundation that is at the core of graduate-level physics and astronomy. The topics are chosen to provide a foundational understanding of the mathematical methods needed in the first year graduate curriculum.

The course methodology is designed to build soft skills necessary to succeed in academia. Being able to effectively communicate one's technical work (or even one's technical confusion) is a key skill for the rest of your scientific careers, academic or otherwise. This is an unusual time to be starting graduate school. Our remote learning goals are to (1) use this as an opportunity to engage with ideas in a way that is *more* aligned with the way you will learn as a Ph.D student, and (2) build community within your graduate cohort.

Textbook

There is no required textbook. Course notes and a list of suggested references are posted online, including low-cost Dover edition books and no-cost digital books through the UCR library. You are strongly encouraged to have *some* mathematical physics reference available.

Technology requirements

For this course, you will need to be able to record 5–10 minute videos of yourself explaining the solutions to homework problems. There are many ways to do this, check out the UCR Keep Learning website[1] for suggestions. Your videos do not need to be polished: you need to be effective, not flashy. You are encouraged to arrange for your recording to show your face while talking if possible; this will help us build familiarity with one another. At the very minimum, your videos must be narrated in your own voice.

In the second half of the course you will prepare a short written document explaining how to solve for the Green's function of a harmonic oscillator. You are strongly encouraged to use LaTeX. We will use Zoom to hold one-on-one interviews and Slack for broader communication. Registered students will receive email invitations.

Topics

The main theme of the course will be understanding how to solve the partial differential equations that pop up in physics using Green's functions. The rough number of weeks is an estimate.

1. **Dimensional analysis**. [1 week] How do you tell a physicist from a mathematician?
2. **Differential equations**. [2 weeks] Are differential equations just linear algebra?
3. **Complex Analysis**. [2 week] How do I integrate around poles?
4. **Green's functions**. [3 weeks] How do I solve differential equations?
5. **Variational principles**. [1 weeks] Where did these equations come from?

[1] https://keeplearning.ucr.edu/recording-video-presentationsperformances

6. **Special Topics**. [1 weeks] Special topics to be decided. Possibilities include: probability and statistics (how do you know when you've discovered something?), statistical learning (what is machine learning?), differential geometry (what is a magnetic monopole?).

Teaching Team

INSTRUCTOR: Prof. Flip Tanedo is a particle physicist who specializes in theories of dark matter. He enjoys science fiction on screen (*Star Trek*) and as short stories (recent favorites: N.K. Jemisen and Ted Chiang). As graduate students you are invited to address your faculty by their first names—you are a young colleague, no longer just a 'student.'

TEACHING ASSISTANT: Ian Chaffey is a 5th year graduate student working with Flip. In normal times, you may see him wearing a Grateful Dead t-shirt appropriate for his UC Santa Cruz background. His recent work focuses on theories of self-interacting dark matter. He took this course in 2016.

General Advice

I strongly encourage you to ask questions and engage with one another, for example through our Slack workspace. There are two questions that you can *always* ask:

1. "*Is it obvious that...?*" This means: I don't know if I fully understand something. Maybe I'm looking at it the wrong way, what is the best way to see that this is true?
2. "*Why are we doing this?*" You may understand the details, but have lost track of the big picture. What is the main point of this section?

These are good ways to clarify what we're doing without worrying about "appearing dumb" for asking them.

Inclusive Accommodation, Support

Students who need any accommodations that require my attention should contact me in the first week of class. Students with permanent or temporary disabilities should be sure to make accommodations with the Student Disability Resource Center[2].

We are committed to an inclusive classroom where our views may be challenged, but where we will always respect each other's dignity and humanity. We each have a responsibility to hold ourselves and one another (including faculty) accountable for maintaining this standard. In the case of any incidents in the classroom, we will (1) find a respectful resolution together, or if this is not possible (2) discuss with the necessary parties outside of the class, or if neither is feasible, (3) reach out to either Help at UCR[3] and/or the Office of the Ombuds[4]. Please know that all University of California staff and faculty are designated Title IX responsible employees which means we are required to report any instances of sexual violence or sexual harassment to our Title IX office; if you are looking for a confidential source of support, please reach out to the UCR CARE office[5].

[2] https://sdrc.ucr.edu/
[3] https://help.ucr.edu
[4] https://ombuds.ucr.edu
[5] https://care.ucr.edu/

UCR maintains a Keep Learning website[6] with resources to assist in remote learning including technology advice. At any time in this course or in your time at UCR you should feel comfortable reaching out to Counseling & Psychological Services[7] if you are feeling distress or anxiety. This is a commonly used resource for graduate students.

Our Values & Learning Philosophy

This is an unusual year to be a first-year graduate student. Our goal with this course is to adapt in a meaningful way to make this experience valuable. Our guiding principles are:

- **Your time and attention are precious.** Remote learning can quickly cause Zoom fatigue. We want to allow as much flexibility in your lives.
- **Your words are more important than mine.** Rather than traditional lecture, it's better for us to find more meaningful ways to engage with the material and each other. This will be a flipped classroom where we focus on you solving problems rather than hearing me tell you about solving problems.
- **Your cohort is valuable.** Your grad school colleagues are your most valuable allies. Even though we may not be in the same place, let's learn to find effective ways to collaborate with one another. *Respect one another*, both as human beings and as allies on a shared academic journey[8].
- **This is a support class.** There is no comprehensive exam test for this course. The main purpose of this course is to make sure you have the mathematical tools to succeed in your grad classes this year. This class is not trying to "weed out" any students or place undue burden on your attention.
- **Communication is key.** As young scientists, you will be judged as much on your ability to communicate your science verbally as your ability to 'do' your science[9]. You will present your homework as videos because this trains your for every oral exam, conference talk, and interview that you have ahead of you.
- **You get what you put in.** You must work through problems to get anything out of this course. You don't have to do many and it doesn't have to take much time, but you will get nothing from just 'watching' this course.

Policies

- **Course Load**. By UCR Senate Regulation 760, one unit of course credit corresponds to 3 hours of course work per week (including time in class). This is a 4 unit course and so you are expected to spend up to 12 hours a week. Most of this time will be spent working on problems, preparing your videos, and interacting with others. I anticipate that one can meet

[6] https://keeplearning.ucr.edu/

[7] https://counseling.ucr.edu/

[8] Nobody will better understand the challenges of being a graduate student in this place and at this time than your classmates. When you graduate and launch your scientific careers, it will be you competing for positions against similar graduates from other departments across the world. Your classmates now are your best allies to push yourself to be better and to support one another through the challenges ahead.

[9] I firmly believe that being able to communicate is part of the definition of 'doing' science.

the learning objectives without using the full 12 hours, but let me know if you are spending significantly more than 12 hours on this course.

- **Equity and Inclusion**. We are committed to creating an inclusive learning space where we respect one another regardless of race/ethnicity, gender identity or expression, sexual orientation, socioeconomic status, age, disabilities, religion, regional/national background, veteran status, citizenship status, and other diverse identities that we each bring to class.
- **No bullying**. This course (and grad school in general) requires students to share work with one another. We will treat each other with respect in our constructive criticism and we will not share each others' materials outside our course without their explicit and written permission. Do not be a troll or bully anyone in this course; we are each offering some vulnerability to support this learning environment. *Seriously, don't be an asshole.*
- **Communication**. Please use Slack as the primary way of communicating for physics questions and administrative questions. If there are administrative issues that are specific to you that you do not want to share, you can email the professor. Please use `[P231]` in the subject of the email and anticipate a 2-day turnaround time. Major course announcements will be sent through `iLearn`, which should forward to your email.
- **What to do if you're stuck on a problem**. The suggested course of action is:
  1. Ask in the appropriate Slack channel.
  2. If there isn't an adequate response, you can reach out to the TA by email, please use `[P231]` in the subject of the email.
  3. If there is still confusion (i.e. there's likely an error on the homework—sorry) you can reach out to the professor by email, please use `[P231]` in the subject of the email.
- **Attendance**. Most of this course is asynchronous. However, your participation in the Slack workspace is important; please make it a habit to review the workspace regularly. Individual one-on-one interviews will be arranged at a time that is as mutually convenient as possible.
- **Late homework**. Due to the peer review aspect of this course, late homework will not be accepted. This is stricter than my past policies, but in exchange we are reducing the amount of work required for submission.
- **Academic Integrity**. All students are expected to abide by the highest standards of academic integrity[10]. Academic misconduct (cheating) will be reported to the UCR Student Conduct & Academic Integrity Programs and will be penalized to the fullest amount. A brief summary:
  - You are encouraged to collaborate with others on homework and presentations.
  - You are expected to write your solutions based on your own understanding.
  - You are allowed you use *any* references outside of the assigned course materials. You are expected to cite these sources in your submitted work or presentations.
  - Always cite. When in doubt, ask ahead of time.

[10] https://conduct.ucr.edu/policies/academic-integrity-policies-and-procedures