PHYSICS 5013

Mathematical Methods

Fall 2019

1 General Information:

Instructor: Kieran Mullen
Office: 239 Lin Hall
Office Phone: 325-5177
Office Hours: Monday/Friday 2:30-3:30pm or by appointment. (May change!)
Email: kieran@ou.edu.
Prerequisites: Calculus, Differential Equations (Ordinary and Partial), Linear Algebra, Complex Numbers
Class: Monday, Wednesday, and Friday, 10:30-11:20 in NH302.
Texts: *Mathematics of Classical and Quantum Mechanics* by Byron and Fulller (Dover edition), and *Schaum's Guide to Mathematica*

2 Course Description and Goals:

This course is for those who might have wondered:

- *What is a "tensor?"*
- *What is this "covariant" and "contravariant" nonsense?*
- *What is the connection between the Schrodinger and Heisenberg view of quantum mechanics?*
- *Green functions: do they have to be so scary?*
- *What is a contour integral?*
- *Does anyone care about Gegenbauer polynomials? Why?*
- *How do I start on a problem I've never tackled before?*
- *I need a solution somehow - how can I get some form of an idea for what it looks like?*

The goal of this course is to give the student competence in some of the fundamental mathematical tools of physicists (*i.e.* perturbation theory, extremization techniques, eigensystems), and a level of familiarity with some common ones (*i.e.* Green's functions, group theory and asymptotic analysis). At a minimum I hope to cover the first seven chapters of the text. The number of additional topics covered and the depth to which they are addressed will be determined in part by student interest.

3 Course Components:

3.1 Textbook:

The course will be based on *Mathematics of Classical and Quantum Physics* by Byron and Fuller. It is a pedogical and even mildly entertaining book that covers vector spaces, Hilbert spaces, and the connections between them. It also covers the calculus of variations, Green functions, integral equations and group theory. I will presume that you have read the chapter before we cover the material class. To this end, reading quizzes will be posted on Canvas (`canvas.ou.edu`), on the class webpage. The quizzes will be simple, if you have read the chapter first. While I don't care if you consult your textbook during the quiz, the quizzes are timed. Don't expect to thumb through the chapter to find the answers if you haven't read it at least once already. They are due the night before lectures on new chapters, so that you can let me know what you would like me to discuss in class.

A number of useful texts are listed at the end of this syllabus. I will try to make sure that some are placed on reserve at Bizzel.

3.2 Lecture

The primary pedagogical part of this course will be lecture. I will assume that you have read the material at least once before coming to lecture. You are strongly encouraged to take notes. I do not hand out copies of my lecture notes. The action of taking notes is an aid in itself to learning, since you must put the concepts into your own words. I also strongly encourage you to copy over your notes, creating a clearer, cleaner version of them for your own use on exams. This will not only help you solidify concepts in your mind, it will force you to clear up any confusion you have, or at least list questions so that you can get matters cleared up online or in lecture.

While this is a course on mathematics, it will be taught with a physicist's bias. The approach will to be use as much rigor as required, but no more so than needed. The emphasis will be on giving students mathematical tools they will need in their courses and research.

3.3 Workshops

When possible and time permits, we will have in-class exercises or "workshops." Too often students encounter their first real difficulties when they are struggling alone, on the homework. These workshops will allow you to try to solve problems in small groups with someone nearby who can help you if you get stuck. Ideally workshops are graded simply on active engagement. If you are working thoughtfully and persistently, you will get full credit for the workshop.

3.4 Mathematica

While this is not a course on numerics, a modern scientist must be able to handle problems that go beyond pencil and paper. Moreover, the connection between matrices, differential equations, and operators will be a central theme of the course. Therefore it will be necessary to be able to solve problems numerically. To this end, we will use MATHEMATICA in this course. This symbolic

mathematical package is available free to all OU students; however, if you are more familiar with a different system (e.g. MatLab) and have access to it, you may use it instead.

I will schedule a special introductory session or two on MATHEMATICA. If you've never used MATHEMATICA, I've assigned the Schaum's guide to MATHEMATICA, which will get you started. It will show you the basics of how to handle functions, matrices, and plotting.

3.5 Homework:

The primary goals of this course is to give you skills, and homework is the place to develop and prove those skills. Homework assignments will be handed out roughly once a week, with about 10 assignments over the semester. It will also be posted to Canvas as well. Homework will often cover key concepts not discussed in lecture, and so is an integral part of the course. *Passing the exams but skipping the homework will not allow you to pass this class.*

While students may wish to collaborate on homework, it should be stressed that simply copying the solutions of others will not prepare them for the exam. It is also cheating! Students are expected to turn in their own work. See the student handbook under academic misconduct for a complete description of infractions and policies.

Late homework will not be accepted after the solutions are placed online.

3.6 Exams:

Exams will be **closed book**, but open notes. You will be allowed use anything in your own handwriting. Currently I expect to have two midterms and one final exam. It is my preference to schedule these exams in the evening so that you have enough time to demonstrate your abilities. Students who cannot take exams on scheduled dates should let me know at the earliest oppurtunity.

4 Evaluation:

The tentative plan for grading is based on the following:

10%	Reading Quizzes and Workshops
30%	Midterm exams (2 at 15% each)
20%	Final Exam
40%	Homework

There are too few students to contemplate curving the grades. The scale will be on a slightly enlarged straight scale and grades will be given as follows:

A	87.5-100%
B	75-87.5%
C	62.5-75%
D	50-62.5%
F	0-50%

5 Additional Resources

While our textbook is a good resource, any text serves only as a starting point. There are a number of resources you might wish to consult:

- *Mathematical Methods of Physics* by G. Arfken*

  A very standard math methods book and an excellent reference. It spends a lot of time on special functions. Also handy for bludgeoning small animals, since it is heavy. It is a standard and even useful reference. However, it's a bit dry as a textbook.

- *Mathematics for Physics: A Guided Tour for Graduate Students* by Stone and Goldbart*

  A more modern take on Math Methods, aimed specifically at the graduate level in physics. It is clear and readable, with lots of unusual examples. While it has lots of concrete applications, it covers more abstract topics than Arfken and our textbook. It was my second choice for the main textbook in this course.

- *Methods of Theoretical Physics (parts 1 & 2)* by Morse and Feshbach*

  The old standard for math methods courses. Some of my colleagues still use it, others despise it for its dry presentation and out-of-date topics (dyadics, anyone?). Still, a very valuable resource for Green functions.

- *Advanced Mathematical Methods for Scientists and Engineers* by Bender and Orszag†

  In the first two chapters, B&O show you nearly everything that you can do to solve linear ordinary differential equations. The rest of the book is magic. This is **the** reference on asymptotic expansions. It shows you how to tackle nonlinear equations, equations with singular behavior and boundary layers. It shows you how to beat an approximate solution out of nearly any differential equation. Highly recommended to anyone going into theory.

- *Handbook of Mathematical Functions* by Abramowitz and Stegun

  A very standard math reference. While it has tables of the values of functions that you will never use, it has pages and pages of special relations for functions that can break an intractable problem into a tamer one. It is very cheap (another Dover book) so its worth picking up.

- *Table of Integrals, Series and Products* by Gradshteyn and Ryzhik

  Another very standard math reference, but perhaps not as necessary as the one above, since MATHEMATICA can do a lot of very awkward integrals. Worth picking up used if you are planning to be a theorist.

- *Handbook of Differential Equations* by Zwillinger

*On reserve in Bizzel Library.
†On reserve in Bizzel Library.

What your integral table does for complicated integrals, Zwillinger does for differential equations. First, there is a list of all standard ODE's and PDE's with references telling you how they are solved. The rest of the book briefly explains techniques for attacking differential equations, along with references on how to learn more. Terse and brilliant.

- *Accuracy and Stability of Numerical Algorithms* by Nicholas Higham†

  Exactly what it says on the label. It is useful for choosing the correct numerical approach to a problem and learning how to estimate numerical error. Just because a computer told you the answer doesn't mean that it's right.

- *Geometric Vectors* by G. Weinreich†

  Gabby Weinreich was one of the most talented and intuitive professors I have known. This slim volume tries to help you sort out the many species of vectors. (For example, contravariant axial vectors vs. covariant polar vectors). It has non-standard vocabulary, but much more concrete visualization.

- *Mathematica Help Browser*

  I have found it often useful to look up special functions in the MATHEMATICA help browser. It will often tell you the original differential equation that generates the function, and various interesting properties. If all else fails, you can even look at plots of the function to learn about its properties.

6 OU Policies and Procedures:

6.1 Covid related policies:

While covid vaccination can not be legally required, it is available at no cost and is strongly encouraged. Seriously, we're scientists and should believe in the best protection it can provide.

Similarly masking cannot be be mandated, but it is strongly encouraged. Masking is of direct benefit to the individual by reducing the chance of infection, and of indirect benefit by preventing transmission to others. While I have been vaccinated it is still possible for me to have a sub-clinical case and I would not want to inadvertently transmit the virus if that happens. If you feel ill, please get tested at the OU Goddard Health Facility.

6.2 Reasonable Accommodation:

Any student in this course who has a disability that may prevent him or her from fully demonstrating his or her abilities should contact me personally as soon as possible so that we can discuss accommodations necessary to ensure full participation in this class and facilitate educational opportunities. You can also receive guidance from the Disability Resource Center, (Goddard Health Center, Room 166, 325-3852).

For more information please visit `http://www.ou.edu/drc/home.html`

6.3 Adjustments for Pregnancy/Childbirth Related Issues:

Should you need modifications or adjustments to your course requirements because of documented pregnancy-related or childbirth-related issues, please contact your professor or the Disability Resource Center at 405/325-3852 as soon as possible. Also, see `http://www.ou.edu/eoo/faqs/pregnancy-faqs.html` for answers to commonly asked questions.

6.4 Final Exam Preparation Period

Pre-finals week will be defined as the seven calendar days before the first day of finals. Faculty may cover new course material throughout this week. For specific provisions of the policy please refer to OUs Final Exam Preparation Period policy (`https://apps.hr.ou.edu/FacultyHandbook#4.10`).

6.5 Title IX Resources and Reporting Requirement:

For any concerns regarding gender-based discrimination, sexual harassment, sexual assault, dating/domestic violence, or stalking, the University offers a variety of resources. To learn more or to report an incident, please contact the Sexual Misconduct Office at 405/325-2215 (8 to 5, M-F) or smo@ou.edu. Incidents can also be reported confidentially to OU Advocates at 405/615-0013 (phones are answered 24 hours a day, 7 days a week). Also, please be advised that a professor/GA/TA is required to report instances of sexual harassment, sexual assault, or discrimination to the Sexual Misconduct Office. Inquiries regarding non-discrimination policies can be directed to University Equal Opportunity Officer and Title IX Coordinator at 405/325-3546 or smo@ou.edu.

For more information, visit `http://www.ou.edu/eoo.html`

6.6 Weather Emergency Protocol:

During an emergency, there are official university procedures that will maximize your safety. Severe Weather: If you receive an OU Alert to seek refuge or hear a tornado siren that signals severe weather

1. LOOK for severe weather refuge location maps located inside most OU buildings near the entrances
2. SEEK refuge inside a building. Do not leave one building to seek shelter in another building that you deem safer. If outside, get into the nearest building.
3. GO to the buildings severe weather refuge location. If you do not know where that is, go to the lowest level possible and seek refuge in an innermost room. Avoid outside doors and windows.
4. GET IN, get down, and cover up.
5. WAIT for official notice to resume normal activities.

6.7 Fire Alarm/General Emergency:

If you receive an OU Alert that there is danger inside or near the building, or the fire alarm inside the building activates:

1. LEAVE the building. Do not use the elevators.
2. KNOW at least two building exits

3. ASSIST those that may need help
4. PROCEED to the emergency assembly area
5. Once safely outside, NOTIFY first responders of anyone that may still be inside building due to mobility issues.
6. WAIT for official notice before attempting to re-enter the building.

6.8 Armed Subject/Campus Intruder:

If you receive an OU Alert to shelter-in-place due to an active shooter or armed intruder situation or you hear what you perceive to be gunshots:

1. GET OUT: If you believe you can get out of the area **without** encountering the armed individual, move quickly towards the nearest building exit, move away from the building, and call 911.
2. HIDE OUT: If you cannot flee, move to an area that can be locked or barricaded, turn off lights, silence devices, spread out, and make a plan of attack if the shooter enters the room.
3. TAKE OUT: As a last resort fight to defend yourself.

For more information, visit `http://www.ou.edu/emergencypreparedness.html`

6.9 Mental Health Support Services

If you are experiencing any mental health issues that are impacting your academic performance, counseling is available at the University Counseling Center (UCC). The Center is located on the second floor of the Goddard Health Center, at 620 Elm Rm. 201, Norman, OK 73019. To schedule an appointment call (405) 325-2911.

For more information please visit `http://www.ou.edu/ucc`