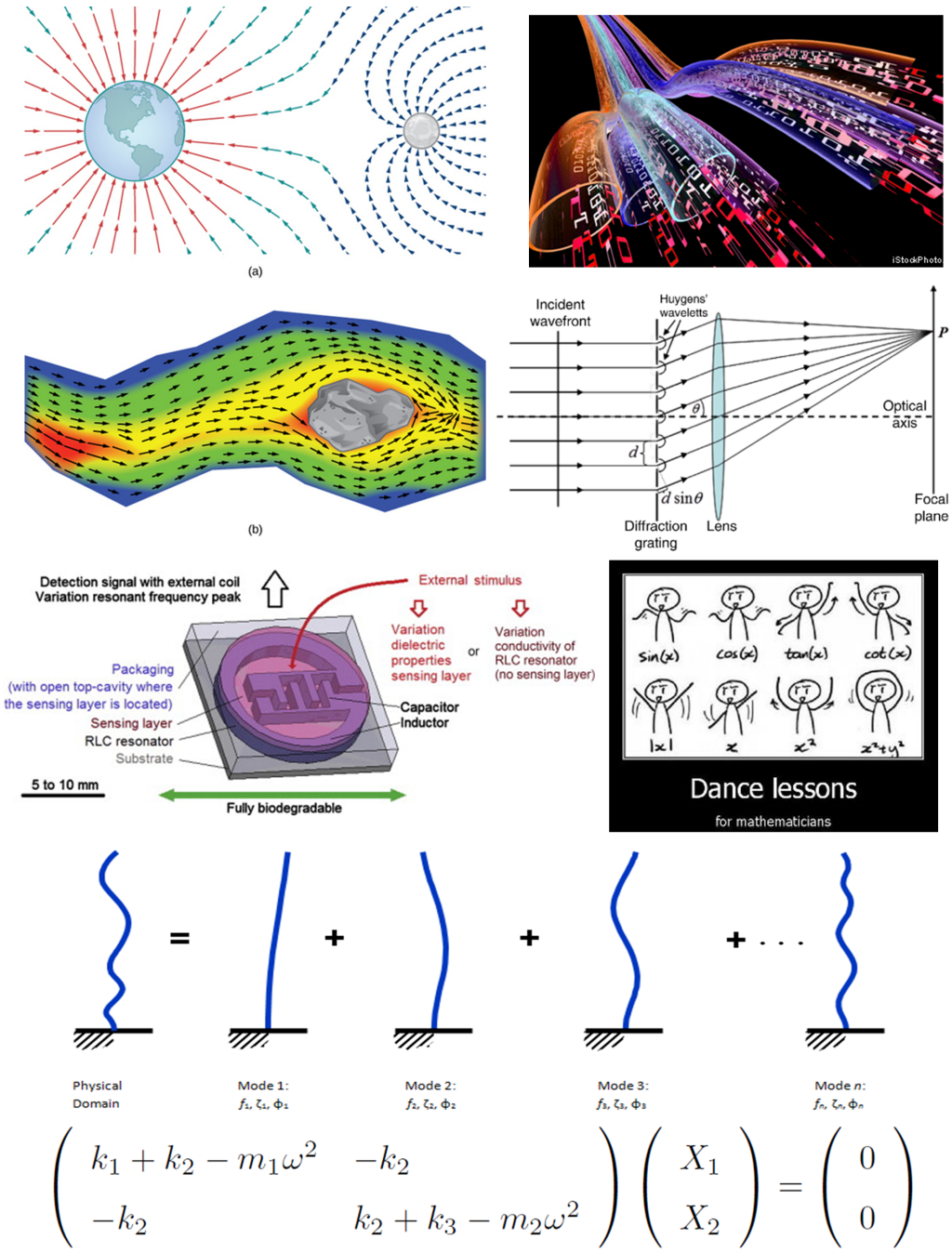
ENGN/PHYS 225: Mathematical Methods for Physics and Engineering
Winter 2021
Course Web Page: `https://erickson.academic.wlu.edu/teaching/mathmethods_w2021/`



$$\begin{pmatrix} k_1 + k_2 - m_1\omega^2 & -k_2 \\ -k_2 & k_2 + k_3 - m_2\omega^2 \end{pmatrix} \begin{pmatrix} X_1 \\ X_2 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}$$

Figure 1: Math Methods Applications aka Cool stuff We'll Learn in this Course. Clockwise from top left: Gravitational fields and fluid flows (vector calculus); digital filters (complex numbers) and data compression (Fourier and matrices); geometric optics (complex numbers); math dance lessons (woo-hoo); and vibrational modes of structures (ODEs and Matrix Math); Implantable wireless sensors (complex numbers and PDEs). Image adapted from: [1]; [2], [3], [4]; [5] and [6], [7].

Course/Instructor Info

Course Meets:	MWF 2.30 - 3.35pm, Sci Ad 102
Instructor:	Jon Erickson
Virtual classroom:	Zoom link (click here)
Virtual office:	Zoom link (click here)
Contact:	ericksonj@wlu.edu; 540.458.8293

COVID-19 Policies and Protocols

The winter 2021 term, we are still contending with the ongoing COVID-19 pandemic. Needless to say, the pandemic has upended our daily lives and continues to be a very serious health concern. ***We must do our collective best to keep everyone safe and healthy***—in this class, around W&L, and around the Lexington/Rockbridge area. We all must take individual responsibility in achieving this aim. At all times, we will strictly adhere to COVID-19 safety guidelines required by the University, the Virginia Department of Health, the CDC, and plain old common sense, including:

1. Everyone must health ***attest daily*** *before* coming to class: attest.wlu.edu. Do NOT attend in-person meetings if you are sick. Seek medical advice asap.

2. Everyone must ***wear a mask that properly covers both mouth and nose*** to protect others and yourself.

3. ***2 meter physical distancing*** is in effect at all times.

4. You will be asked to ***wipe down*** tables, chairs, desks that you use before departing the classroom.

5. Limit personal travel whenever possible. This is one of the rare instances when you are encouraged NOT to pop the W&L bubble.

We'll likely encounter some challenges as we learn how to optimally navigate this unprecedented learning environment. Anticipate this situation will remain fluid. Please continue to be your wonderful selves—***flexible, patient, and understanding***. We'll do our best to create a productive and fun learning environment while doing absolutely everything within our collective power to keep everyone healthy and safe. Please keep lines of communication open. If you have a concern, please speak up. If you have a question, please ask it. If you have a suggestion, please share it.

As of this writing (January 17, 2021) we are planning for:

1. Course meetings hopefully starting in person starting 01 Feb 2021—or as soon as it is deemed safe and sensible to do so—with accommodation for virtual. We have a big room to spread out...and still collaborate.

2. Office hours: virtual via Zoom or in-person individual meetings. Drop-ins are welcome but to avoid a potential logjam please try to set up an appointment—my office space only allows for 1 (possibly 2) students at a time. (This breaks my teaching heart—one of my favorite aspects of the job and fondest teaching memories come from the times we cram around the table in my office, snacking on chocolates while working through circuits and enjoying each others' collective company.)

3. The instructor will carefully monitor the collective health status of students in the class, at the university, and around the greater Lexington/Rockbridge area. While this class is listed by the Registrar as "in person", *the instructor reserves the right to conduct virtual lecture and/or lab sessions, when doing so is deemed to be in the best interest of our collective health and safety.* Such decisions will be broadcast with as much advance notice as possible, but please be aware any such transition may happen literally overnight.

Course Text and Topics Covered

Mathematical Methods in the Engineering and Physics, GN Felder and KM Felder, 1 ed. (2016), ISBN 978-1118449608).

- Vector calculus: gradient ∇, divergence $\nabla\cdot$, curl $\nabla\times$, Laplacian ∇^2; Gauss' Divergence Theorem and Stokes Theorem)
- Curvilinear Coordinate Systems (Cartesian, Polar, Cylindrical)
- Complex Numbers and Phasors; Euler's Identity: $z = re^{i\phi} = r\left(\cos\phi + i\sin\phi\right)$
- Linear Algebra (Basic Matrix Operations, Eigenvector/value problems: $Ax = \lambda x$)
- Fourier Series and Transforms: $f(t) = \sum_n c_n e^{i\omega_n t}$
- 1st and 2nd order Ordinary Differential Equations (ODEs): $a\ddot{x} + b\dot{x} + cx = f(t)$
- Partial Differential Equations (PDEs)—diffusion and wave equation:
  $\partial_t^2 u = c^2\nabla^2 u$ and $\partial_t u = \alpha\nabla^2 u$

What We'll Study and Course Objectives

This course is about practical math and solving a variety of real-world problems. We'll skilfully apply a collection of math techniques to a range of problems commonly encountered in various branches of physics and engineering (optics, quantum, E and M, fluids, electronics, structural engineering, etc). Translation: we'll spend some time on the fundamentals—making sure we know what's underneath the metaphorical mathematical hood—but we'll concentrate on formulating and developing and interpreting solutions to some really interesting applications. We'll also focus on using software in software (e.g. the beloved Matlab) to visualize and interpret solutions—a powerful means to intuit and communicate what all of the math symbols and equations actually mean.

To help convince you of the utility of math methods, check out the front page of this syllabus. As you can see, in Engn/Phys 225, there are heaps of interesting problems we'll learn to solve!

Course Objectives

- Learn fundamental principles underlying various useful math methods
- Learn to skilfully apply these math tools to real world problems
- Become adept at using software packages (e.g., MATLAB) to develop, visualize, interpret, intuit solutions

- Gain intuition for how and where to apply a certain math method
- Develop the dispositions of persistence and curiosity in solving challenging applied math problems

Basic Problem Sets

We will tackle one set of problems for each unit we cover. These will consist of relatively simpler problems that cover the "basics", designed to give you sufficient practice to gain full competency with core concepts. Each student will submit written solutions *individually*. You are more than welcome—in fact, strongly encouraged—to collaborate with classmates, but each student must submit their own solution set.

Problem sets will be assigned and collected approximately a weekly basis, synced to the topical coverage throughout the winter. We'll adjust our speed on various topics, as necessary. Problem sets will posted at the end of class, typically each Wednesday and will be typically due at the beginning of class one week later (e.g.,the following Wed). Due dates will be clearly posted on the course website. Late homework will not be awarded credit unless it is the result of an officially excused absence. You are still invited to turn in unexcused late homework so that I can provide you with feedback. Please write homework in an orderly, legible manner.

Solutions to all problems will be posted to the course website; you are strongly encouraged to consult them, as necessary.

Challenge Problems

Throughout the term, we will tackle approximately 3 multi-week challenge problems. These will be bigger, relatively more complex problems that require integration and application of core concepts across units (e.g. combinging concepts from matrix math and Fourier series). Students will collaborate in small teams (≈ 3 students total) to develop, present, and submit a single written solution. These problems will often be a "Choose your own adventure" variety. Each team will select one from a set of possible problem problem prompts focusing on different physics or engineering domains. The main idea is to allow students to pursue topics of particular interest to them. Each team member is expected to fully engage in all phases of developing solutions for these challenge problems. The main idea is to help show you the power of math applications. Hopefully, they are interesting, challenging, and fun problems to gnaw on that demonstrate the power of math.

Exams

There will be 2 exams spread throughout the term, roughly at weeks 6 and 12. Both will be take-home exams. They will focus on and be representative of the basic problem sets. The main idea here is to encourage you to really lock in core concepts. See the course schedule for exam dates. Exams will be closed book, closed note, no calculators permitted. I will provide you with all relevant reference material (e.g., equation sheet). No late exams will be accepted.

Grading

Letter grades will be assigned primarily on a numerical score basis, but will also be influenced by the instructor's subjective assessment of your overall competence and performance (more on this in a minute). The percentage of each component contributing to your grade is listed below.

Basic Problem Sets	40 %
Challenge Problem Sets	40 %
Exams	20% (=2 $\times$ 10%)
Total	100%

Your final state of competence is much more important than your overall numerical average. The subjective component is simply a mechanism by which—*when appropriate*—I can translate your final state into an appropriate letter grade. Throughout the term we will have many occasions to interact in the classroom. At the end of the 12 weeks together I gain a very good sense for placing students on the spectrum of "who really knows their stuff." Factors considered during this evaluation include, but are not limited to: class participation, team work, intellectual independence and growth, demonstrated overall competency in course work. Please know that this policy is in place neither to hurt or help you. If you have any questions about this grading policy, please come talk to me.

COURSE POLICIES

Inclusive Classroom[1]

In our classroom, all students are welcome regardless of race/ethnicity, gender identities or expressions, sexual orientation, socio-economic status, age, disabilities, religion, regional background, Veteran status, citizenship status, nationality and other diverse identities that we each bring to class.

Your success at W&L and beyond is enhanced by the innovation and creativity of thought that inclusive classrooms facilitate. The success of an inclusive classroom relies on the participation, support, and understanding of you and your peers. We encourage you to speak up and share your views, but also understand that you are doing so in a learning environment in which we all are expected to engage respectfully and with regard to the dignity of all others.

Any student who has difficulty affording groceries or who lacks a safe and stable place to live and believes this may affect their performance in the course is urged to contact me or Student Affairs for support.

Academic Honesty

According to the White Book[2], the Honor System is the "fundamental principle that a spirit of trust pervades all aspects of student life." The system is one of "mutual trust" which clearly establishes that "Students should do their own work, *represent themselves truthfully, and claim only that which is their own*" (emphasis added by JE). The system is not designed to "work against or frighten" students, rather it was designed to allow students "unparalleled academic freedom."

You are expected to abide by the W&L Honor System at all times. Any suspected Honor Violation will be reported to the Executive Committee. In such an event, the instructor reserves the right to assign a grade of zero on that assignment and/or a failing grade for the course. (I believe in my heart that this policy will never ever come into play, but I am, more or less, legally compelled to explicitly state it in the official course syllabus.) Specific policies regarding homework assignments, lab reports, and exams are described in detail below. If you are ever in doubt about whether an action is within bounds, please consult with me first.

Assignment Policy

You are allowed and strongly encouraged to discuss all problems sets with class mates. For "Basic Problem Sets", written solutions must be generated by you alone. Consultation with or seeking aid from solutions from previous offerings of this course is strictly forbidden.

Code Usage/Sharing Policy

This term, we will make regular use of matlab to computer and visualize. Programming is a core skill that you should develop with substantial benefit now and in the future. The best way to learn to code is by example. This is typically copying, pasting, modifying examples for official Mathworks documentation or help forums; or collaboration with a classmate. Be sure to cite sources of help. You are welcome to freely share and develop code together, but make sure you do the gut check

[1] Adapted from University of Kentucky Center for Teaching Excellence`https://cte.ku.edu/creating-inclusive-syllabus`

[2] Full text of White Book available at `http://www.wlu.edu/x48217.xml`

"Could I do this by myself if I had to?" Rest assured you will be required to do so both on exams in the class and very likely you will need to do so in your STEM career future. If you are ever in doubt whether some code sharing or collaboration is in bounds, ***ask first***.

Exam Policy

Any collaboration on, or discussion pertaining to, exams is strictly prohibited.

Special Academic Accommodations

Washington and Lee University makes reasonable academic accommodations for qualified students with disabilities. All undergraduate accommodations must be approved through the Title IX Coordinator and Director of Disability Resources, Elrod Commons 212, (540) 458-4055. Students requesting accommodations for this course should present an official accommodation letter within the first two weeks of the term and schedule a meeting outside of class time to discuss accommodations. It is the student's responsibility to present this paperwork in a timely fashion and to follow up about accommodation arrangements. Accommodations for test-taking must be arranged with the professor at least a week before the date of the test or exam, including finals

Attendance Policy

Lectures

This is a workshop-style class (aka a mostly flipped classroom). You are *strongly encouraged* to come prepared to class—which means reading and reviwing materials ahead of time. Hopefully, the time we spend together in the classroom solving problems and clarifying tricky concepts are beneficial to you and worth attending. That said, there is no formal attendance policy. *Your education is in your hands.* If you miss class for a legitimate reason (illness, family emergency, etc.) I will make every effort to help you get caught up as soon as possible. You must notify me *before class, in person or by phone,* to explain the circumstances of an excused absence. In the event of an unexcused absence (i.e., "Whoops, I slept in"; "I had paper due for another class"; "I left a day early for Winter Break", etc.), you are solely responsible for staying up to date with class notes and news (e.g., deviations from the calendar of topics covered, exam procedures, etc.).

Note on Athletics

Sanctioned athletic competitions, but not practice sessions, qualify as an excused absence. Please notify me of an athletic absence well in advance of the athletic event.

Electronic Devices and Texting

Figure 2: Electronics is a No Texting Zone.

I would like to believe I am a pretty easy-going, congenial guy, but the one thing that absolutely drives me bonkers is texting during class. So, thank you in advance for powering down your cell phone/iPhone/whichever device, and for respecting the strict no-texting policy.

If you must have your phone on for tending to, say, a medical or family emergency, please inform me before the start of class.

Regarding laptops in class: From time to time, we'll workshop coding and visualizing math in class. You'll definitely want your laptop while workshopping matlab. Otherwise, there isn't really any compelling reason why you would use one during lecture, so if you have insist on using a laptop, please ask me first—any reasonable requests will be entertained and carefully considered (but I do not promise to grant it).

Sick Day Policy

If you are feeling ill, please stay home—you must attest "in the red" and are thus required to stay home per university covid guidelines. Seek professional medical advice as needed. Get some rest, get a friend to bring you notes from class and chicken soup and get better soon! It is in everyone's best interest for you to minimize interpersonal contact when you are feeling sick, especially when you are symptomatic. I trust your judgment and do not require a doctor's note. (However, please remember to contact me regarding this absence).

Suggestions and Feedback

Suggestions for improvement, constructive criticism, and positive feedback are welcome at anytime. Please do not hesitate to approach me with any concerns you may have about this course. I take your feedback very seriously and will sincerely respond to all received comments. It is the main mechanisms by which the course will improve over time (sometimes instantaneously, when possible!).