ENGR 695 Advanced Topics in Engineering Mathematics Fall 2023

Instructor:	David Kelley (e-mail: dkelley) Breakiron 368, 577-1313	**Class**: **Lab**:	MWF 12:00–12:50, BRKI 065 TBD

Course web site: www.eg.bucknell.edu/~dkelley/engr695

Course Goals: The primary purpose of this course is to develop skills and understanding of mathematical methods applicable to problems drawn from the realm of the engineering sciences (also known as applied physics). Usually, but not always, such problems are expressed as systems of linear equations or as ordinary differential equations (ODEs) or partial differential equations (PDEs). Significant effort will be focused on understanding the forms that ODEs and PDEs can take and what can be done to obtain solutions to them. Similarly, various solution strategies for matrix equations will be explored as well as the physical significance of seemingly abstract concepts such as eigenvalues and eigenvectors. There are many mathematical details and methods that need to be brought together in order to find solutions to these types of problems. You will receive only an introduction to the topic here, but what you learn will position you to take on more complex problems.

Specific goals of this course are to:

- Review basic concepts of linear algebra
- Apply linear-algebraic methods to the solution of applied problems
- Develop the concept of an eigenvalue problem in both linear algebra and differential equations
- Work with important analytical and numerical methods useful in the solution of partial differential equations
- Develop proficiency with a structured programming language (MATLAB) to provide solutions to problems that cannot be solved using analytical methods

All but the last topic listed above are standard fare for a typical first-semester graduate engineering math course. The last item has been added to prepare you for a separate computational and/or numerical methods course or to give you a starting point for computational work in your own studies. The goal is to increase your confidence in your ability to use MATLAB as a tool for solving problems that might come your way in the course of your research. This course is not intended to delve into the theory of numerical methods.

Prerequisites: There are no explicit prerequisites; however, as a senior or graduate student in engineering, you should have the following mathematical background:

- Engineering calculus courses, including differentiation, integration, and some vector calculus
- At least one course in ordinary differential equations (MATH 212 or equivalent)
- Matrix-based solutions of systems of linear equations
- Proficiency with a computer for numerical calculations (Excel, MATLAB, …). Expert status in a language is not required but you should expect to develop proficiency as we move along.

Communication: Check your e-mail and the course web site at least once per day. Most announcements and course materials will be distributed via the web site or Moodle site. E-mail might also be used to distribute time-sensitive announcements. You are responsible for knowing and adhering to any policies or policy updates posted at the web site.

Textbook, References, and Resources: The textbook for the course is

Dennis G. Zill, *Advanced Engineering Mathematics*, 6th ed., Jones & Bartlett Learning, 2016.
ISBN: 978-1284105902

The book covers most of the course topics in an accessible way, and I hope that you find it a useful addition to your professional library. There are many other books in the library with “linear algebra” or “applied mathematics” in their titles. They can be good sources of practice problems and alternative explanations of concepts. Wikipedia is available as well, as is Wolfram Alpha and other internet math sites. Feel free to use them, but do so as an informed user. Caveat lector.

Evaluation: Your final grade for the course will be determined according to the following criteria:

Homework and lab work	30%	
Midterm Exam	30%	(near day 21; covers first half of course)
Final Exam	30%	(time designated by university; covers second half of course)
Quizzes	10%	(very short; roughly bi-weekly)

Individual homework and lab assignments will carry roughly the same weight for the purpose of determining your overall score for the semester. The primary purpose of the quizzes is to provide you with intermediate feedback as the course progresses.

An absolute scale with the following distribution will be used to determine your final course grade. The scale is not likely to be shifted, but if it is, it will only be shifted down (i.e., grades raised) and only because the average scores on several assignments are too low to be truly indicative of class progress.

93–100 A	87–89.9 B+	77–79.9 C+	60–69.9 D
90–92.9 A−	83–86.9 B	73–76.9 C	< 60 F
	80–82.9 B−	70–72.9 C−	

Topical Content: The course material will most likely be drawn from Chapters 1–3, 5, 7, 8, 10, 12–14, and 16 in the textbook. Some chapters will be covered thoroughly and some only lightly. Supplemental readings on additional topics might also be assigned. Specific reading assignments will be posted at the course web site. The schedule below is a general but tentative framework. Depending on progress and student interest, some of the material might be omitted and other material might be added.

- Linear (matrix) algebra for the solution of linear systems
  - Review of problem formulation and nomenclature
  - Vector spaces and abstractions from the concepts of vectors in physics
  - Solvability criteria and solution methods for the problem $A\mathbf{x} = \mathbf{b}$
  - The matrix eigenvalue problem – solutions to $A\mathbf{x} = \lambda\mathbf{x}$
  - Important matrix decompositions and representations (LU, QR, and SVD)
  - Important and interesting applied problems

- Review of the solutions to linear ordinary differential equations
  - Classifications: linearity, order, IVP/BVP
  - General form of the solution to linear problems
  - Specific equations of importance to mathematical physics and engineering analysis
  - Numerical solution options

- Nature and solution of boundary-value and eigenvalue problems based on ODEs
  - IVP/BVP distinctions
  - Linear differential eigenvalue problems
  - The Sturm-Liouville problem and the functions of mathematical physics

- Solution of partial differential equations via analytical and numerical methods
    - Nomenclature and definitions
    - Problem formulation – sources of PDEs
    - Separation of variables (SOV) for linear problems
    - Reduction of PDEs to sets of ODEs
    - Interpretation of solutions and significance of eigenvalues
    - Numerical methods using finite differences
    - Practical applications

Recommendations, Expectations, and Accommodations:

- This course was originally designed for Bucknell engineering graduate students. Almost immediately, undergraduates were invited to take the course as well with the understanding that the course would retain its graduate-level character, meaning that students would be expected to exhibit more independence and sophistication in their work than in a typical undergraduate course. Part of what has made this course valuable for undergraduates seriously considering graduate school is that it has allowed those students to experience to some degree what graduate school courses are like.

- The best way to develop your skills in mathematics is to practice – to apply new concepts and methods, not just passively listen to someone else (your professor, for instance) talk about them. To that end, you should participate in class discussions and offer solutions when you have them or pose questions when you don't have them.

- You are encouraged to work together to complete assignments and to help each other, regardless of your home department, learn the material. However, you will have to complete examinations on your own, so you do need to become proficient with the course material yourself. You should strive to gain a thorough understanding of the material via independent work.

- You are expected to comply fully with the University's academic responsibility policies. General discussion of solution techniques is acceptable, but copying problem solutions or full or partial text, sharing step-by-step instructions for solving a problem, sharing computer files, and other forms of plagiarism are not acceptable. All submitted problem solutions are expected to be your own work. Deliverables produced for lab or class exercises should be your own work as well. Refer to the "Academic Responsibility" page on the University web site or contact me if these policies are not clear.

- Please put away all electronic communication devices during class and lab time, including smart phones and watches, although they may be used briefly to take pictures of the whiteboard. If it is critical for you to be reachable during a particular session, let me know in advance. An exception to this policy is that tablet PCs and tablet-like devices may be used to take notes in class if they are kept flat on the table and used with a thin stylus or quiet keyboard; however, they could be disallowed as well if they become a distraction.

- Exams, homework and lab assignments, exam and homework solutions, supplemental readings, and all other documents shared with the class are my or others' intellectual property and may not be posted online or otherwise shared with people outside the course without my permission. Distributing someone else's intellectual property without their permission is a serious matter.

- Attendance is expected at all scheduled class and lab meetings. If you know that you will not be able to complete an assignment by its deadline or take an exam at its scheduled time, you must notify me at least 48 hours in advance in order to avoid an automatic 5% score reduction on the assignment unless extenuating circumstances apply. Official university commitments such as field trips, participation in performances, and participation in varsity athletics will normally be accommodated, as will job interviews, religious observances, and extraordinary personal opportunities. However, in accordance with university policy, incomplete or late work due to personal travel plans under your control (including those around the times of recesses and exams) will not be accommodated.

If you miss an exam, a major deadline, or other major activity due to illness, injury, or other misfortune, you must contact me as soon as possible, preferably before the scheduled time. If a health professional or other relevant authority confirms the seriousness of your case, then your absence and/or missed deadline will be excused. In the case of an exam, a make-up opportunity will be arranged.

Unexcused absences or missed deadlines (e.g., due to oversleeping) will be handled on a case-by-case basis, usually in consultation with the Dean's office. If you arrive late to an exam, you must complete it in the remaining allotted time. If you miss all of an exam, you must notify me of the circumstances as soon as possible.

- If you have or develop a medical condition or a documented or suspected learning disability that might affect your work in this course and for which you might require an accommodation, please contact the Office of Accessibility Resources (570-577-1188 or OAR@bucknell.edu) as soon as possible. Note that moving an exam or obtaining approval for extra completion time requires official coordination with OAR.

  Bucknell and I also support efforts to maintain mental health. If you are struggling and believe that it could affect your performance in this course, please contact Associate Dean Terri Norton (570-577-1800 or trn005@bucknell.edu) or me if you feel comfortable doing so. Working through official channels will enable me to provide resources and support. If you require immediate mental health assistance, call the Counseling & Student Development Center at 570-577-1604; after business hours, call 570-577-1604 and choose option 2.

Time Commitment: Time spent on coursework outside of class is guided by the Bucknell University expectations for academic engagement: "Courses at Bucknell that receive one unit of academic credit [like ENGR 695] have a minimum expectation of 12 hours per week of student academic engagement. Student academic engagement includes both the hours of direct faculty instruction (or its equivalent) and the hours spent outside of class on student work." Some weeks the work load could be greater than average, some weeks less, but it should average at least 7–8 hours per week beyond lecture and lab time. If some aspect of the work seems to require an excessive amount of time, please let me know either directly or anonymously.

Health and Safety Protocols: Most, if not all, class and lab meetings are currently expected to be in person. However, I reserve the right to require students to wear N-95 or KN-95 masks at all times during class. This is likely to happen only when the community viral transmission level for Union County is high according to the United States Centers for Disease Control and Prevention (CDC). I realize that university policy does not currently require masks, but I must be more restrictive to protect a family member who is at high risk of developing serious complications from infection.

Remote instruction via the Zoom online meeting platform might be used if, for example, I become ill, I must travel away from campus, or a major weather event makes travel dangerous. In such cases, I will provide as much advance notice as possible. It is also possible that the university will impose remote instruction or allow its adoption if an unforeseen crisis warrants it. Lectures, lab sessions, and other meetings conducted via Zoom will take place synchronously at their normally scheduled times.