ENGR 695   Advanced Topics in Engineering Mathematics   Fall 2024

Instructor: David Kelley (e-mail: dkelley)   **Class**: MWF 12:00–12:50 pm, BRKI 065
Breakiron 368, 577-1313   **Lab**: M 4:00–4:50 pm, Dana 221

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). Such problems are often expressed as systems of linear equations or as ordinary differential equations (ODEs) or partial differential equations (PDEs). Significant effort will focus on understanding the forms that ODEs and PDEs can take and methods 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. Many mathematical details and methods must be brought together to find solutions to these types of problems. This course provides only an introduction to the topic, but what you learn will prepare 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.
- Introduce important analytical and numerical methods for the solution of PDEs.
- 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 that you might take 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, 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.

Textbook and Other Resources: The course textbook 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 course grade will be computed as shown below, although your weighted exam average must be greater than 50 out of 100 points for you to pass the course. Significant extra credit opportunities are not likely to be provided.

Homework and lab work	30%	
Midterm Exam	35%	(near day 21; covers first half of course)
Final Exam	35%	(time designated by university; covers second half of course)

Individual homework and lab assignments will carry roughly the same weight for the purpose of determining your overall score for the semester. While the exam weightings might seem high, they are typical of courses at other graduate-level programs. They implicitly assume that students will be highly engaged and therefore adequately prepared for high-stakes exams. (See "Expectations" section below.)

The weightings above might be adjusted and/or alternative assessment methods might be introduced if necessary to account for unusual circumstances, such as a major error on my part in the preparation of an exam or other assignment, a health-related change in instructional mode, or a long-term university closure. Changes will be announced with as much advance notice as possible.

Scores on major assignments will not be discussed until a 24-hour "cooling off" period has passed unless points have been added incorrectly to obtain an overall score. An absolute scale with the following distribution will be used to determine your final course grade.

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−	

Expectations: 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. Moreover, students are assumed to be more highly motivated to engage with the material and to develop at least a partial ability to assess their progress themselves. Part of what has made this course valuable for undergraduates seriously considering graduate school is that it has allowed them to experience to some degree what graduate school courses are like.

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.

Academic Responsibility: 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 items must consist of your own work. Refer to the "Academic Responsibility" page at the University web site or contact me if these policies are not clear.

Electronic Devices: 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. 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. Please notify me if you need to monitor a device for an important reason such as an ongoing family crisis.

Intellectual Property: 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 and Conflict Policy: Attendance is expected at all scheduled class and lab meetings. You are likely to struggle in this course if you do not attend class. 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. 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, probably in consultation with the Dean's office. If you begin an exam after the start time, you must complete it in the remaining allotted time. However, you may not take the exam if you arrive after the first student has completed it and left the room; this policy includes the final exam. Such a situation is equivalent to missing the exam. If you miss all of an exam due to an unexcused absence, you must notify me as soon as possible. Depending on the reason for the absence, a make-up opportunity of some kind *might* be offered for the first unexcused absence. Further unexcused absences will likely result in a significant score reduction or a score of zero for the exam or assignment.

Accommodations and Support: 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.

Advice for Success: The best way to develop your skills in mathematics is to practice via active studying. That is, you should strive to apply new concepts and methods, work through example problems, and perhaps work through derivations yourself, 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.

I encourage you to work together to complete assignments and to help each other learn the material, even if you come from different engineering departments. However, you will have to complete examinations on your own, so at some point you must become proficient with the course material yourself. You should strive to gain a thorough understanding of the material via independent work.

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: 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 if the community viral transmission level for Union County were to become high according to the United States Centers for Disease Control and Prevention (CDC). This policy applies to COVID-19 or to any other communicable disease that rises to the level of critical concern. 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.

Amendments: Additional policies or changes to the policies outlined above might be posted at the course web site. If so, they will be announced via e-mail and on the main web page. You are responsible for knowing and adhering to any posted additions and changes. Posted policies, if any, will be considered extensions or amendments to this document.

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. Shown below is a general but tentative framework.

- Linear (matrix) algebra for the solution of linear systems
  Review of problem formulation and nomenclature
  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, initial value problems (IVP) and boundary value problems (BVP)
  General form of the solution to linear problems
  Specific equations of importance to mathematical physics and engineering analysis
  Numerical solution options
  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