1 Course Outline and Philosophy

This course weaves together three topical strands: mathematics, physics, and programming. We will examine advanced mathematical techniques that are useful in understanding common situations that arise in physics. The emphasis here is on the practical usefulness of the mathematics toward the understanding of the physics. Many of the physical situations we examine will be beyond the boundaries of physics courses you have had previously – the intention is to give you the tools so that when you do encounter these situations in other physics classes, you do not need to spend time learning the math, but can focus on the physics. Here, we will be focusing on the math as a means to an end.

Mathematical Physics is in some ways two parallel and interwoven courses. One course deals with analytic mathematical theorems and techniques: problems you can solve on paper or in your head, or that require formal proofs. The other course deals with using numerical and computational techniques to solve complex problems that are difficult or impossible to solve analytically.

These courses will move forward together, each informing the other. The analytic course will cover three primary topics: Fourier series, ordinary differential equations, and partial differential equations. The computer course will cover numerical integration techniques, Fourier transforms, simple and complex oscillators, chaotic systems, and relaxation methods. The analytic course will require regular homework sets, while the computer course is structured around four major projects. (More details on these assignments below.)

Following this course, students will be able to successfully address some mathematical problems common in physics (and in other disciplines) using both the analytical and numerical tools developed in this courses. They will be able to solve many common differential equations, and will have experience identifying periodic signals embedded in long, complicated data series. They will know how to design (and more importantly, how
to test) their own computer programs to solve numerical problems.

We will be using two classrooms this semester: the Unix computer cluster in Frank room 331 and Frank 220, depending on the needs of the day’s lesson plans.

2 Required Texts

This course will be using two textbooks:


This book contains the analytic mathematical material we will cover in the course, and most of the homework problems will be drawn from it.


This book contains the numerical and programming material necessary for the course.

3 Course Assignments

Homework sets will be assigned on a regular basis dictated by the pace we set in moving through the material. They will consist of a few problems from Boas and/or Garcia, and perhaps other problems of our design. Thoroughly developed and clearly expressed solutions sets will be expected to be turned in on or before the given due date for each assignment. Further details and updates will be posted to the course web site, given above.

3.1 Projects

The numeric/computational side of this course is structured around four major projects, that will be due roughly once a month. To help you avoid the problem of leaving things to the last minute, some of these projects have been split into two parts. Usually, the first part will involve setting up and testing programs, while the second part will involve applying them to some complex and interesting situation. The first part is weighted one-third of the total grade for the project, while the final report is worth two-thirds of the grade. You may turn in one rewrite for an improved grade within one week (seven days) of the day upon which you receive your graded project. Rewrites are due at 5 pm on that day.
These projects will mirror the analytic work we will be covering from the textbook and in the homeworks, but will require programming the Unix machines in room 331 using the Matlab language. The first project will involve simple numerical integration techniques, the second will involve using Fourier transforms to identify periodic signals, the third will require the use of the Runge-Kutta algorithm to solve ordinary differential equations, and the fourth will require the application of the relaxation technique to a partial differential equation.

The details of these assignments and their due dates will be given on the course web page. A rough schedule is also given in Table 1. Each project will require you to submit a written report that presents and explains your results. The written reports should include all relevant plots, tables, and computer code, but they should not be just a collection of file printouts stapled together. The final project writeups should be essays written in clear, concise, direct, and correct English. They should answer the questions posed in the assignment as part of a narrative structure, not as simple question/answer statements. The first part of the project, which is about completing and testing the code, may be more casual, but you should think of these projects as being more like lab reports and less like homework sets. The final reports for projects 1, 2 and 4 should either be printed out, stapled together, and left in Don’s mailbox in room Frank 234, or emailed as a single PDF file to Don. Do not email many file attachments. More details will be explored in class.

For the final report of the third project, you will give an 15 minute oral report to the class instead of a written report to the instructors. It is expected that this report will follow the standard structure of a physics talk, covering introductory material, an explanation of the model being tested, a presentation of the methods used to test the model, the results obtained, the implications of those results, and how you tested the validity of the results. The talk should use Powerpoint, Keynote, or other appropriate visual aid software, for visual support, and it may also require animations or matlab demonstrations, depending on the topic.

It is critical you understand that the projects are intended to be an opportunity for you to explore. The explicit questions posed are the minimum you need to do to obtain a passing grade on the project. To truly show mastery and receive an A, you need to go beyond the explicit questions being asked and ask your own questions. Don’t just accept the graph or number you produce: challenge it! Ask why it looks the way it does. Ask what would happen if you alter the parameters. Make sure you understand the implications of what you have done. The projects are designed to require steady work over several weeks. If you try to do them all in a single day, the night before they are due, you will rob yourself of the opportunity they provide to explore the territory. This is more important than reaching a particular destination.

Collaboration outside of class on projects is not acceptable. Much, if not all, of the

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1You may use your own computer to write the programs, but make sure you keep a copy of your code on the 331 computers so we can workshop it in class time together!
computer code will be developed together in class. It is acceptable to share files of computer code, as long as you (a) credit the person who wrote it and (b) add your own comments to indicate your understanding of what the code is doing. Beyond the explicitly approved sharing of files, however, you should not work together on the projects. All of these projects have little, hidden twists or mysteries to figure out. You should figure them out yourself or with your instructor, not with other students.

3.2 Homework

Homework problems will consist of a few problems that will be assigned with particular due dates, usually the following week, depending on the complexity of the problem. Each problem will count equally toward your final homework grade. Due dates and other details will be on the course web site.

I expect all homework solutions to be written in clear handwriting (you may also submit electronic PDF files created with LaTeX, if you choose, but that is not required). Motivation, explanations, and analysis must supplement the equations in clear, correct English. If I cannot follow your analysis, or if your reasoning is not clear, you will receive a C or D on the assignment, regardless of whether the answer is correct or not.

You may work with other students in the class on these homework sets. In fact, collaboration is encouraged. However, there are limits to collaboration, and there is a boundary line between collaboration and copying. For your own protection, do not actually write up the solutions that you intend to submit while you are with your study group. Figure out how to solve the problem together, but you should actually do the problem by yourself. It is too easy to mistakenly think you have understood a problem when you copy it from someone else. MAKE SURE YOU GIVE CREDIT TO PEOPLE WHO HELP YOU!!!! Write their names on your homework submission, like “I discussed this answer with Jim Jones.”

3.3 Exams

There will be two exams for this course: one mid-semester exam and one cumulative final exam at the end of the semester. These will be take-home exams, but they are not to be collaborations with other students. Each exam will be handed out in an envelope or uploaded to Canvas, with a set duration for your work (to be specified when the exam is distributed). You choose when to start the clock by opening the envelope or printing the file from Canvas. Once you open the envelope or look at the printout, you may not discuss the exam with anyone except the instructor until after the deadline.

The exams will cover material from both aspects of the course, and they may even introduce new material that you can tackle with the tools you have learned in class. The exams will lean more heavily on the analytical material than the numeric/programming work, but I do not exclude computational problems from consideration. Acceptable tools
and resources will be specified with the exam.

The final exam will be due at 5:30 pm on Monday, May 15th. The first mid-term exam will be due Tuesday, April 4th, at 5:20 pm.

3.4 Seminar

Enrollment in Math/Physics 320 requires participation in the Physics Department Seminar. This one-hour session each Wednesday afternoon at 2:30 provides an opportunity for physics students to meet each other, to hear about interesting events (meetings, talks, or new results), share the results of their work with each other, see what other students are doing, and so forth. We try to have a speaker each week, and sometimes we bring in guests from outside the department.

It is an important part of the physics curriculum, as it gives students at all stages in the program an opportunity to interact. The beginning students can see what kinds of activities they will be doing in a year or two, and the advanced students get practice developing their public speaking skills. If you want to share something interesting you’ve learned with the seminar, just send Steve Shapiro a title and abstract to reserve a slot in the schedule.

You are required to give at least one presentation in Seminar. You may choose what you wish to present, but it could be a homework problem you found interesting, or a computational project you completed, or anything course-related that you would like to share with the other students. A natural choice would be your Project #3, since you will have to give that presentation in class, anyway, but be warned that there aren’t many slots left in the seminar after that date! Get on Steve’s schedule as soon as possible!

4 Grading Policy

Projects and homework will be graded on a ten-point scale, where two points correspond to a single letter grade. After averaging, plus and minus correspond to a half-point on either side of a boundary. I apply the following rubric to assign points:

A (8-10): Full completion of the assignment. Analysis is clear. At most one or two minor mistakes. Work is fully explained, and you have shown thought about what your work means. The validity of your answer is tested through sanity checks. Thorough understanding of the problem and its context.

B (6-8): Assignment is complete, but only competently so. The bare minimum work is done. Perhaps one serious mistake. An otherwise failed assignment can still end up with a B if you recognize that you have gone awry, and provide some indication of where you think you might have gone wrong. Modest understanding of the problem and its context.

D (2-4) - Insufficient work. No English explanations of intent or reasoning. Poor understanding of the problem, its context, and its implications. Flailing about.

F (0-2) - Little to no work. Just an answer (even if that answer is correct). No understanding. No explanation whatsoever.

Your contributions to this class will be weighted in the following manner:

1. Homework = 34%,
2. Mid-term exam = 10%,
3. Final Exam = 10%,
4. Projects = 36% (9% each),
5. Class & Seminar Participation = 10%

5 Schedule

A rough schedule of topics is given in Table 1, along with the due dates for the projects. These due dates set the pace of the class, because we want to ensure that you have the tools necessary to complete the projects in time to successfully do so. Content for individual class sessions is flexible, and will depend on your skills and needs. You may not need as much time for some topics, which will enable us to move through them more quickly, and therefore spend more time on other topics.

6 Course Policies

6.1 Credit Hours

This course is worth four credits, although we will only spend four hours in official class contact per week. For a four-credit course, it is expected that you spend on average twelve hours a week on the course. This expectation is based on the faculty approved standard that students are awarded one credit for every three hours they spend on course work. Although we will spend class time explaining analytical, numerical, and programming techniques, students will do their own problem-solving, code development, implementation, debugging, and testing between class meetings. I will expect you to spend at least an average of an hour a day on your homework assignments, and you should be prepared to spend an average of four or five hours a week on the projects. There will be approximately one chapter of assigned reading every two weeks, which will probably take about two hours a week to read. You will also want to spend at least an hour a week studying for exams, each of which will probably take ten hours to complete. That’s an average of
Table 1: Tentative Course Schedule

<table>
<thead>
<tr>
<th>Dates</th>
<th>Topics or Assignments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 30-Feb 10</td>
<td>Intro to computational programming</td>
</tr>
<tr>
<td>Feb 13 - Mar 15</td>
<td>Fourier Analysis</td>
</tr>
<tr>
<td>Feb 17</td>
<td>Project 1a due</td>
</tr>
<tr>
<td>Mar 03</td>
<td>Project 1b due</td>
</tr>
<tr>
<td>Mar 17</td>
<td>Project 2a due</td>
</tr>
<tr>
<td>Mar 27-Apr 07</td>
<td>Numerical Solutions to ODEs</td>
</tr>
<tr>
<td>Mar 31</td>
<td>Project 2b due</td>
</tr>
<tr>
<td>Apr 10-Apr 27</td>
<td>Analytic Solutions to ODEs</td>
</tr>
<tr>
<td>Apr 14</td>
<td>Project 3a due</td>
</tr>
<tr>
<td>Apr 24/26</td>
<td>In-class presentations of Project 3 reports</td>
</tr>
<tr>
<td>Apr 27-May 08</td>
<td>Partial Differential Equations</td>
</tr>
<tr>
<td>May 09</td>
<td>Project 4 due</td>
</tr>
</tbody>
</table>

18 hours a week, for a fourteen week semester, leading to a total estimate of about 270 hours of total work.

### 6.2 Attendance Policy

Attendance will not be taken as a daily policy. However, this class is heavily based in the participation in group discussions, and therefore chronic absence will interfere with your ability to learn what the class has to offer. Our attitude is that if you can do well without going to class, then the class is a waste of your time, and it’s our job to make the class time so essential that missing class will hurt your grade without having to explicitly count absences. However, it should also be said that Guilford’s policy for classes that meet three times a week is that if you miss nine or more classes, you are not really taking the course, and you may be forcibly withdrawn. If you know of an impending situation that will require your absence from class, you must contact Don in advance. Late assignments are not accepted, but we are usually very accommodating to requests for extensions, if the schedule allows.

### 6.3 Honor Code

I am a firm believer in acting with integrity and performing at least to the standard of the Guilford Honor Code. The work you submit is understood to be claimed by you to be your work. If others helped you, or if you got ideas from other sources, you must credit them appropriately. We have a zero-tolerance policy for plagiarism. If we are convinced you have violated the Guilford Honor Code, you will fail this course, and the case will be
referred to the Dean’s Office for the possibility of other consequences. According to the college catalog, the statement, “I have been honest and have not observed any dishonesty,” gives testament to the honor system and should be pledged in writing on all academic work. Compliance is assumed even if the statement does not appear on college work. The word “pledged” may substitute for the longer statement.

6.4 Accommodations

Guilford College complies with the Americans with Disabilities Act by providing a process for disclosing disabilities and arranging for reasonable accommodations. The policy may be found online at: [https://intranet.guilford.edu/?page_id=3763](https://intranet.guilford.edu/?page_id=3763).

Students who require accommodations must complete a disabilities disclosure form and submit it to the Disability Resources Coordinator, located in 217 Hege Library—right down the hall from the Learning Commons (2nd floor of the library), along with the appropriate documentation. It is the student’s choice to disclose difference/disability information to individual instructors. However, only students who provide their instructors with a 504 Accommodations Agreement may receive accommodations. All disability information is treated confidentially and is not a part of your academic record.