Physics 301: Mathematical Methods

Spring 2021

Mathematical Methods in Physics introduces you to the mathematical techniques used to model physical systems and solve problems that arise in the physical sciences. We will cover orthogonal coordinates systems, Fourier series, vector calculus in curvilinear coordinates, series solutions of differential equations and special functions, techniques for solving partial differential equations, and additional material as time allows.

Basic Information

PROFESSOR: Dr. Robert McNees (he/him). I will often sign emails as "Bob" but please address me as "Dr. McNees" or "Professor." I am asking students to address me this way to help normalize the use of academic titles. If you're wondering why this is important, have a look at this article or read Dr. Susan Harlan's poem "My First Name."

EMAIL: `rmcnees@luc.edu`. You *must* use your "@luc.edu" address when sending me an email. Emails sent from outside accounts sometimes get blocked by Loyola's mail servers.

OFFICE: My office is Room $\pi \times 10^2$ (314) in Cudahy Science Building. I will often stream lectures from there, but for other online meetings I will probably be in my living room. Regularly scheduled office hours have been replaced with email, online discussion, and zoom meetings by appointment. If we can't work something out over email or in discussion, we'll set up a video meeting to talk about it.

LECTURES: MWF from 10:50-11:40 via Zoom.

DISCUSSION: F from 8:10-9:00 via Zoom.

WEBSITES: `http://jacobi.luc.edu/p301.html`
`Phys 301 on Sakai`

Important: Video Meetings, Recordings, and Privacy

In this class software will be used to record live lectures and discussions. As a student in this class, your participation in our meetings will be recorded. These recordings will be made available only to students enrolled in the class, to assist those who cannot attend the live session, or to serve as a resource for those who would like to review content that was presented. All recordings will become unavailable to students in the class when the Sakai course is unpublished (i.e. shortly after the course ends, per the Sakai administrative schedule). Students who prefer to participate via audio may disable their video camera so only audio will be captured. Students who wish to disable both audio and video may do so, and take part using Zoom's chat functionality. The use of all video recordings will be in keeping with the University Privacy Statement.

Privacy Statement

Assuring privacy among faculty and students engaged in online and face-to-face instructional activities helps promote open and robust conversations and mitigates concerns that comments made within the context of the class

will be shared beyond the classroom. As such, recordings of instructional activities occurring in online or face-to-face classes may be used solely for internal class purposes by the faculty member and students registered for the course, and only during the period in which the course is offered. Students will be informed of such recordings by a statement in the syllabus for the course in which they will be recorded. Instructors who wish to make subsequent use of recordings that include student activity may do so only with informed written consent of the students involved or if all student activity is removed from the recording. Recordings including student activity that have been initiated by the instructor may be retained by the instructor only for individual use.

Course Information and Policies

Objectives

In your first few physics courses you surveyed mechanics, electricity and magnetism, waves and vibrations, heat, and quantum phenomena. The goal of Physics 301 is to develop the mathematics needed for more rigorous descriptions of physical systems than the treatment in your introductory courses.

This is one of the most important courses in the Physics major because it equips you with skills and techniques needed for courses like mechanics, electromagnetism, optics, and quantum mechanics. The material is also highly relevant for engineering, computer science, and related fields. Everything you do from here on out in the physics major will rely on the things we learn in this course. So you should think of this material as foundational and try to really master everything we cover. Devoting time to this course will have a significant payoff in your junior and senior years.

The prerequisites for Phys 301 are Phys 235 (Modern Physics) and Math 263 (Multivariable Calculus). We will rely heavily on concepts and skills you learned in these courses and their prerequisites, including

- Single variable calculus: Derivatives and integrals of functions of a single variable, differentials, Taylor series
- Multivariable calculus: Functions of multiple variables; partial derivatives; divergence, gradient, and curl; line, surface, and volume integrals; Green's theorem; Stokes's Theorem
- Vectors: Components, dot products, cross products, magnitude, basis vectors, unit vectors

If you feel a little rusty on any of these topics, please take the time to thoroughly review them in your multivariable book or the text for this course. Also, Differential Equations (Math 264) is a co-requisite for this course. It covers material that you will need to know later in the semester. If you have a conflict with the pre- or co-requisites for the course please contact me right away.

Most of you are taking this course alongside Phys 314 (Theoretical Mechanics), so we will spend the first few weeks developing a command of orthogonal coordinate systems. This will be helpful when you start working with coordinate systems adapted to particular physical systems (like using spherical polar coordinates to describe orbits in Newtonian gravity).

After orthogonal coordinates we will quickly review infinite polynomial series, including Taylor and MacLaurin series, and then begin our exploration of Fourier series. Fourier's technique allows us to represent functions on a finite interval as an infinite sum of sine and cosine terms. This allows us to decompose the vibrations of a string into a fundamental frequency and its harmonics, or use a sum of trig functions to approximate a square or sawtooth

wave in electronics. If time allows we will also discuss the Fourier transform.

After Fourier Series we will cover vector calculus, extending the basics of div, grad, and curl that you learned in Math 263. We will begin with a review in Cartesian coordinates, and then develop vector calculus in general orthogonal coordinate systems. Most of our examples will focus on the Cartesian, Cylindrical Polar, and Spherical Polar coordinate systems frequently encountered in the physics major. Depending on the pace of the course we may also introduce a useful notation for vectors and vector operations introduced by Einstein.

Around mid-March we will begin our study of series solutions of differential equations. By that point you will have covered the necessary prerequisites in Math 264. We will develop techniques for finding finite and infinite series solutions of wide classes of differential equations, with particular emphasis on a few equations (Legendre, Bessel) that frequently show up in models of physical systems. The solutions of these equations have several useful properties – they can be used like a set of 'basis vectors' for certain kinds of functions – which we will explore.

Finally, the last part of the course will be devoted to partial differential equations. This is a complex subject, so we will focus on techniques for solving the most common separable PDEs (Laplace, heat, wave, Poisson) encountered in your physics courses.

Throughout the semester we will sometimes use MATHEMATICA to automate or check certain kinds of calculations. Some of our time in discussion will be used to introduce the basics of MATHEMATICA and how it can be used to extend the calculations we perform in class.

By the end of this course you should be able to

- Convert between different orthogonal coordinate systems and use them to describe quantities like position, velocity, and acceleration.
- Construct the Fourier series representation of a function on a finite interval.
- Perform differential and integral vector calculus in both Cartesian coordinates and general orthogonal coordinate systems.
- Determine finite or infinite series solutions of ordinary differential equations.
- Understand the properties and uses of special functions (Legendre, Bessel) that arise in the series solutions of common ordinary differential equations.
- Employ separation of variables to solve the sorts of partial differential equations used to model physical phenomena like heat flow, wave propagation, or electrostatics.

Textbook and Materials

The textbook is *Mathematical Methods in Engineering and Physics* by Felder & Felder. The book's website can be found here. We will cover chapters 2, 8, 9, 11, and 12 in the book. Additional references, which you may find helpful, are listed on the course website.

I will frequently post lecture notes and supplementary material on both the main course website and Sakai. Our unit on orthogonal coordinate systems will be based on my notes, since the textbook doesn't cover the topic in much detail.

The university has a site license which allows you to install MATHEMATICA on your laptop. You can find information on obtaining the software here. Please install the software before the end of the first week of classes.

Let me know if you have any problems obtaining course materials and I will try to help!

Meeting Times and Locations

Lectures take place MWF from 10:50 - 11:40, via Zoom meetings that you can join from the Sakai page. The discussion section is scheduled for 8:10-9:00 on F. Discussion is an important part of the class and attendance is mandatory.

Lecture and Discussion Sections

Class will meet three times each week for lectures and once each week for a discussion section. **Attendance at weekly lectures and the discussion section is mandatory.** During the lectures we will talk about the material, work through examples, and ask each other lots of questions. Notice that I said "ask each other". You're going to get a lot of questions from me, and I expect to get a lot of questions from you. The weekly discussion section will be devoted to problem-solving strategies, the current homework assignment, and learning the basics of MATHEMATICA. Because of a quirk in the Spring 2021 schedule, we will need to use at least three of our discussion meetings for lectures.

Office Hours

Traditional office hours will be replaced with email, online discussions, and video conferencing. You can always email me to ask questions or discuss the class, and I will try to get back to you in a reasonable amount of time (see the section on Email). If we can't clear something up over email, we'll set up a Zoom appointment to talk about it.

Communications Policy

Email is the best way to reach me. I check it frequently and will try my best to respond promptly. As a rule of thumb I will always respond within 24 hours (usually sooner) during the week. Emails sent over the weekend may not receive a response until Monday. If you email me on a weekday and don't hear back within 24 hours please send a follow-up email. (Don't worry, it isn't "pestering." Working with you is a priority and I would hate to miss an important question or comment because a message was lost in a deluge of email.)

From time to time I will contact you via email and you should feel free to observe the same policy. If I send an email in the evening or late at night you should not feel obligated to respond until the next day.

Expectations

I expect you to arrive to class ready to discuss the material. That means you should read relevant sections of the book or my notes ahead of the lecture. Homework will be assigned most weeks and you should start working on it as soon as it is posted. *Do not* wait for us to go over all the material before you start. Instead, work on the homework and identify any questions you might have, so they are fresh in your mind during lecture.

Class Conduct

One important aspect of a Jesuit education is learning to respect the rights and opinions of others. Please respect

others by allowing all classmates the right to voice their opinions without fear of ridicule, and not using profanity or making objectionable (gendered, racial, or ethnic) comments, especially comments directed at a classmate.

If you have encountered any form of discrimination or harassment, I encourage you to report this to the University (https://www.luc.edu/dos/gethelp/). If you report an incident of gender-based misconduct to a faculty member, that faculty member will notify the Title IX coordinator (Jessica Landis, `jlandis@luc.edu`). The Title IX coordinator is available to assist you in understanding your options and resources on and off campus.

I try my best to be mindful of the beliefs of my students and respectful of their identities. But no one is perfect and we all make mistakes sometimes. If you think I've done or said something that doesn't live up to our shared guidelines for class conduct, please let me know.

Special Circumstances and Accommodations

Please speak to me via email or Zoom if you have any concerns about the course material or your ability to follow course policies. Rules for schedule conflicts and make up exams are outlined elsewhere in the syllabus, but you should always let me know if something happens that interferes with your ability to participate in the course. If you need special accommodations for quizzes and exams you should speak with me as soon as possible, and no later than one week in advance. Once I have the appropriate paperwork from SAC (https://www.luc.edu/sac/) we can make the necessary arrangements.

Intellectual Property

All lectures, notes, assignments, solutions, and other instructional materials in this course are the intellectual property of the professor. As a result, they may not be distributed or shared in any manner – on paper, electronically, or otherwise – without my explicit written permission. Lectures may not be recorded without my written consent; when consent is given, those recordings may be used for review only and may not be distributed. Sharing copies of homework assignments, solutions, quizzes, or exams with anyone who is not currently enrolled in the course is not allowed. **Providing these materials to students who may enroll in the course at a later date, uploading them to a website, or distributing them in any way, will be reported to department chair and the college. Likewise, obtaining copies of homework assignments or exams that were used in a previous course is not allowed and will be reported to the department chair and the college.** Recognizing that your work, too, is your intellectual property, I will not share or distribute your work in any form without your written permission.

A lot of students have Chegg accounts and use it (or similar services) to obtain help solving problems. This is not a good way to learn the material. Following along with someone else's solution doesn't actually help you learn how to solve problems yourself. Also, a lot of the solutions posted to Chegg and similar websites are wrong. In any case, posting copies of homework or exam problems on any website is a violation of my intellectual property rights and, more importantly, constitutes a violation of Loyola's academic integrity policy. Submitting solutions obtained via Chegg or similar websites on a homework assignment or exam is academic misconduct. A grade of "0" will be assigned and the incident will be reported to the Chair of the Physics Department and the Office of the Dean.

The same goes for solutions manuals: Don't use them. If I find solutions copied from a solutions manual or similar source it will receive a grade of "0."

Statement of Intent

By remaining in this course you agree to abide by the rules and policies laid out in this syllabus. Any changes to the syllabus will be announced in class, and the updated syllabus will be posted on Sakai. Missing class is not a valid reason for being unaware of changes to the syllabus.

Homework, Exams, and Grades

Homework Assignments

Homework will be assigned most weeks throughout the semester, except for exam weeks, with occasional gaps due to holidays. I expect that there will be a total of ten (10) homework assignments. Each assignment must be scanned and uploaded to your Sakai dropbox by the beginning of class on the day that it is due, or else by whatever time I specify for that assignment. If you work on a tablet you can just export your work as a pdf and upload that. Late homework will not be accepted.

Homework in this class is absolutely essential. You have to do every single problem (along with examples from the lectures and book, extra problems for things you find tricky, etc) to master the skills we're trying to develop.

You should definitely discuss the homework assignments with your classmates – you might be able to clarify a tough concept for them, or they might point out a good strategy for a confusing problem. But after working together you must go back and complete the problems on your own. If your solution looks like it was copied from someone else's work then you need to redo it from scratch. If you can't explain each step of your solution then you haven't completed the problem on your own. That is the only way to be sure that you are ready for the exams, and, more importantly, the only way to know if you understand the material.

Do not, under any circumstances, hand in homework copied from another student, a solutions manual, or some source you found on the internet. There are lots of reasons I am telling you this. First, it's cheating, and I may have to report it to the department chair. (I know, I just told you to work together. That's why taking what you learned and working out the solution on your own is so important. Don't worry; I can tell the difference between working together and copying.) Second, and more importantly, you don't learn anything that way. Obviously you don't learn anything from copying a classmate's homework. You have to be able to do this stuff on the exams, and copying won't prepare you for that. Third, you don't get much (or any) benefit when you piggyback on a solution that you find online or in a manual. Finding material that you can adapt to another problem is a useful skill, but it's not the one we're trying to develop here. Part of understanding the material in this course is figuring out how to deploy it to solve different kinds of problems or model new situations. You only develop that skill by trying different things, playing around with a problem, maybe putting it down for a while and coming back to it later.

Do the homework yourself. In every class I've ever taught, students who relied on solutions manuals, online resources, or copying from classmates ended up doing poorly on the exams. More importantly, if you don't do the homework on your own then you won't develop the command of the material needed for later classes.

☠ A Warning ☠

Never, ever hand in an assignment that you copied from a solutions manual or found online. You won't learn anything that way, and it will earn you an automatic grade of "zero" for that assignment. If it happens more than once it will be reported to the Department Chair and the Dean. Consider yourself warned.

Exams

There will be two exams and a final exam. I expect that the exams will be held during the weeks of March 1-5 and April 12-16. Exact dates will be set once we've had a chance to talk about everyone's exam schedule so we can try to minimize conflicts with other courses. The material covered on these exams will be discussed in class. A cumulative final exam will be held on Monday, May 3 from 9-11 AM.

Grades

Grades in the course are primarily determined by homework assignments and exams. Homework grades contribute 35% of your final grade in the class, the two exams count 15% each, and the final exam is worth 30%. The remaining 5% depends on your attendance and participation. To receive the full 5% you should do two things that show me you are engaging the material and thinking about what we're doing. First, you must regularly attend lectures and discussion sections. Second, you should ask questions. This can happen either in class, discussion, or via email and zoom meetings. There is no minimum number of questions you need to ask, and if you don't like to speak up in class you can ask them via zoom chat, email, or one-on-one zoom meetings. In any case, you *must* speak with me via email or a zoom meeting at least once during the semester, with a question related to something we've done in class. As long as you do these things, you get the 5%.

Once your grades have been added up and converted to a percentage, your final grade will be assigned according to the following table:

Percentage	Letter Grade
100 – 92	A
92 – 90	A−
90 – 88	B+
88 – 82	B
82 – 80	B−
80 – 78	C+
78 – 72	C
72 – 70	C−
70 – 68	D+
68 – 62	D
62 – 0	F

The lower end of each range is inclusive and the upper end is exclusive. So a grade of 90 is an "A-" and not a "B+",

while a grade of 73 is a "C" and not an "C-".

For example, suppose you finish the class with a 91% average on the homeworks, grades of 85% and 82% on the two exams, and an 89% on the final. You attended the lectures, actively participated, and asked questions over email a few times, so you get the full 5% for participating. Then your final grade would be

$$91\% \times 0.35 + 85\% \times 0.15 + 82\% \times 0.15 + 89\% \times 0.30 + 5\% = 88.6\%\,, \tag{1}$$

which earns you a B+.

Makeups and Absences

Let me know as soon as possible if you will miss a homework or exam due to illness, emergency, or a Loyola-approved activity. You will need to provide written documentation (from a doctor, for instance, or the university if you are traveling for an event) before a make up exam will be administered. The documentation must be relevant to the date you missed class. For Loyola-approved activities you should let me know as far in advance as possible, and no later than one week before the exam. Absences related to the COVID-19 pandemic are an exception to this policy; no documentation is needed in that case.

Calendar

The following is a tentative schedule for the semester.

Week	Date	Topics	Events
1	January 19-22	Intro, Orthogonal Coordinate Systems	
2	January 25-29	OCS	
3	February 1-5	OCS	
4	February 8-12	Fourier Series	1st Spring Break
5	February 15-19	FS	
6	February 22-26	FS	
7	March 1-5	Vector Calc	Exam 1
8	March 8-12	VC	2nd Spring Break
9	March 15-19	VC	
10	March 22-26	Series Solutions & Special Functions	
11	March 29 - April 2	SS, SF	Easter Holiday
12	April 5-9	SS, SF	Easter Holiday
13	April 12-16	Partial Differential Equations	Exam 2
14	April 19-23	PDEs	
15	April 26-30	PDEs	
16	May 3	-	Final Exam

Please keep in mind that these dates are subject to change. There are several reasons for this. First, this course is

usually taught on a TTh schedule and the move to MWF may change the pace a bit. Second, this is the first time I have taught this course entirely online and I'm not sure how that will affect things. Third, because of scheduling quirks the MWF classes have three fewer meetings than a regular spring term. And finally, the class may just need a bit more or less time for various topics depending on how things are going. If we fall behind I'll do my best to get us caught up. If things are going smoothly I may introduce extra material. In any case, I will always notify you about any changes I make to this schedule.

Other Things You Should Know

Important Dates

Besides the dates listed on the calendar, there are a few other important dates you should be aware of. The last day to drop this course with a grade of "W" is March 29. After this date, withdrawing from the course will result in a grade of "WF." Other important dates can be found on the CAS calendar for the Spring 2021 semester.

I am happy to help you work around important religious holidays that occur during the semester. Please contact me if you need any accommodations for activities or observances associated with any religious holidays not listed on the CAS calendar. Let me know as far in advance as possible and we will work something out.

Academic Integrity

Any incidence of academic dishonesty on a homework assignment or exam will result in a grade of "0" and will be reported to both the Chairperson of the Physics Department and the Dean of the College of Arts and Sciences. The full copy of the CAS Statement of Academic Integrity can be found at the end of this syllabus. Please note that sharing or receiving homework assignments or exam materials from previous semesters falls under the university's working definition of "plagiarism" and is a violation of the academic integrity policy.

Travel and Exams

Travel plans are not an excuse for missing a quiz or exam. This includes travel plans made by parents, without your knowledge. If you are aware of a pre-existing conflict you must let me know during the first week of class, so we can arrange a makeup. After the first week I will not accept travel conflicts as an excuse for missing a quiz or exam.

Cell Phones and Other Electronics

Try to turn off cell phones and tablets during our Zoom meetings, unless you have an important reason (like a sick family member, or a kid in daycare) to leave them on. It will be easier to stay engaged and participate without another device competing for your attention.

If an exam is held during a synchronous class meeting then you should not use any devices besides the ones needed to join the meeting and view the exam. Any other devices that can access the internet must be turned off and put away. Using other devices during an exam is a violation of the academic integrity policy and will result in a grade of zero.

How Do I Email A Professor?

Just like you were writing a letter! Use a salutation, introduce yourself, identify which class you are in, write in

complete sentences, don't use slang or abbreviations, be polite, use proper punctuation and grammar, ask questions as clearly as possible, close your message with a sign-off, and write your name at the end of the email.

Why Should I Email A Professor?

Great question. If you need to ask me something outside of class you should email me. I'm pretty good at answering questions over email! If an email explanation doesn't work then we can arrange a Zoom meeting. I'll try to respond promptly, though I may not answer until the next day if you email me late at night. Likewise, if I ever email you with a question in the evening or late at night, you should feel free to wait until the next day to respond. Emails received over the weekend may not be answered until Monday.

Student Support Resources

- ITS HelpDesk: helpdesk@luc.edu (773-508-4487)
- Library Subject Specialists: http://libraries.luc.edu/specialists
- Student Accessibility Center: https://www.luc.edu/sac/
- Writing Center: http://www.luc.edu/writing/
- Ethics Hotline: http://luc.edu/sglc/aboutus/ (855-603-6988)

College of Arts & Sciences Statement on Academic Integrity

Read the statement on the CAS website

A basic mission of a university is to search for and to communicate the truth as it is honestly perceived. A genuine learning community cannot exist unless this demanding standard is a fundamental tenet of the intellectual life of the community. Students of Loyola University Chicago are expected to know, to respect, and to practice this standard of personal honesty.

Academic dishonesty can take several forms, including, but not limited to cheating, plagiarism, copying another student's work, and submitting false documents.

Academic cheating is a serious act that violates academic integrity. Cheating includes, but is not limited to, such acts as

- Obtaining, distributing, or communicating examination materials prior to the scheduled examination without the consent of the teacher
- Providing information to another student during an examination
- Obtaining information from another student or any other person during an examination
- Using any material or equipment during an examination without consent of the instructor, or in a manner which is not authorized by the instructor
- Attempting to change answers after the examination has been submitted

- Unauthorized collaboration, or the use in whole or part of another student's work, on homework, lab reports, programming assignments, and any other course work which is completed outside of the classroom
- Falsifying medical or other documents to petition for excused absences or extensions of deadlines
- Any other action that, by omission or commission, compromises the integrity of the academic evaluation process

Plagiarism is a serious form of violation of the standards of academic dishonesty. Plagiarism is the appropriation of ideas, language, work, or intellectual property of another, either by intent or by negligence, without sufficient public acknowledgement and appropriate citation that the material is not one's own. It is true that every thought probably has been influenced to some degree by the thoughts and actions of others. Such influences can be thought of as affecting the ways we see things and express all thoughts. Plagiarism, however, involves the taking and use of specific words and ideas of others without proper acknowledgement of the sources, and includes the following

- Submitting as one's own material copied from a published source, such as print, internet, CD-ROM, audio, video, etc.
- Submitting as one's own another person's unpublished work or examination material
- Allowing another or paying another to write or research a paper for one's own benefit
- Purchasing, acquiring, and using for course credit a pre-written paper

The above list is in no way intended to be exhaustive. Students should be guided by the principle that it is of utmost importance to give proper recognition to all sources. To do so is both an act of personal, professional courtesy and of intellectual honesty. Any failure to do so,whether by intent or by neglect, whether by omission or commission, is an act of plagiarism.

In addition, a student may not submit the same paper or other work for credit in two or more classes without the expressed prior permission of all instructors. A student who submits the same work for credit in two or more classes without the expressed prior permission of all instructors will be judged guilty of academic dishonesty, and will be subject to sanctions described below. This applies even if the student is enrolled in the classes during different semesters. If a student plans to submit work with similar or overlapping content for credit in two or more classes, the student should consult with all instructors prior to submission of the work to make certain that such submission will not violate this standard.

Plagiarism or any other act of academic dishonesty will result minimally in the instructor's assigning the grade of "F" for the assignment or examination. The instructor may impose a more severe sanction, including a grade of "F" in the course. All instances of academic dishonesty must be reported by the instructor to the chairperson of the department involved, and to the Dean of the College of Arts and Sciences.

The chairperson may constitute a hearing board to consider the imposition of sanctions in addition to those imposed by the instructor, including a recommendation of expulsion, depending on the seriousness of the misconduct. In the case of multiple instances of academic dishonesty, the academic dean of the student's college may convene a hearing board. Students have the right to appeal the decision of the hearing board to the academic dean of the college in which they are registered. The decision of the dean is final in all cases except expulsion. The

sanction of expulsion for academic dishonesty may be imposed only by the Provost upon recommendation of a dean.

Students have a right to appeal any finding of academic dishonesty against them. The procedure for such an appeal can be found here.

The College of Arts and Sciences maintains a permanent record of all instances of academic dishonesty. The information in that record is confidential. However, students may be asked to sign a waiver which releases that student's record of dishonesty as a part of the student's application to a graduate or professional school, to a potential employer, to a bar association, or to similar organizations.