Methods of Mathematical Physics
PHY 428

Dr. Paul V. Quinn Sr.

Fall 2018

This is your syllabus for Physics 428. It tells you what this course is about and gives you an overview of what you will learn. It contains the details of how your work will be graded throughout the course as well as information on the material, homework and exams.

Class Times: Tuesday and Thursday - 5:10 pm -6:25 pm
Location: Lewis Lab - 512

CONTACT INFORMATION

Instructor:	Paul V. Quinn Sr.
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OFFICE HOURS

By appointment on Tuesdays.

TEXT

Mathematical Methods for Physicists - A Comprehensive Guide, (7^{th} ed.), George B. Arfken, Hans J. Weber, and Frank E. Harris, 2013.

SUPPLEMENTAL TEXT (not required)

- *Mathematical Methods in the Physical Sciences*, (3^{rd} ed.), M. L. Boas, John Wiley & Sons, 2005.
- *Methods of theoretical physics*, P.M. Morse and H. Feshbach, 1953.
- *A course of modern analysis*, E.T. Whittaker and G.N. Watson, 1902.
- *Mathematics for Physics: A Guided Tour for Graduate Students*, P. Goldbart and M. Stone, 2009.
- *Schaums Mathematical Handbook of Formulas and Tables*, (3^{rd} ed.), Murray R. Speigel, Seymour Lipschutz, and John Liu, McGraw-Hill, 1999.

COURSE CONTENT

For many of you, this will probably be the last mathematics course that you take in your physics career. This builds off of many topics you learned in your undergraduate physics career. This course will review many of the mathematical techniques used to model problems in physics. It will take these topics and expand your knowledge of how to apply them to more advanced graduate level work This course will also teach you many new and advanced techniques of analysis that will help you with material in your other graduate physics courses as well as your research. These analytical mathematical techniques are essential to the solution of advanced problems in physics and engineering. Topics will include the following: calculus of variations, methods for solving ordinary and partial differential equations, Sturm-Liouville theory, complex analysis, Greens functions, Fourier series, and integral transforms. Some more advanced mathematical topics may be included if time permits

3 semester hours, 3 clock hours

RATIONALE

For many students, once the first year of physics courses is complete, they have to take a series of upper level courses without any kind of intermediate course allowing them to get used to the language and ideology of the field. This mathematical physics course will serve just that purpose. It will serve as an intermediate buffer between the introductory courses and the upper level courses that dive into the heart of material covered in the physics major. This course will also supplement some material that is never covered in some of the upper level physics courses due to the lack of time. Topics that are usually glossed over such as heat flow and point sources can be covered in a more in depth manner, while preparing the students for the material that is to come in many different upper level classes. This course is a mathematical physics course that teaches students how to apply problem-solving techniques in physics. Similar courses are offered in most physics departments at other colleges and universities. To keep our physics curriculum up to par with what is offered in other universities, the addition of this course to our physics classes is essential.

COURSE OBJECTIVES

Upon successful completion of this course, the student will be able to:

- Demonstrate how to use Lagrange's Equations to analyze mechanical systems.
- Relate Hamilton's Principles and the Hamiltonian when analyzing physical systems.
- Work with various physical systems as defined in Hilbert Space.
- Describe functions as orthonormal vectors, using eigenvectors and eigenvalues as they apply to quantum mechanics and other fields of physics.
- Identify Legendre Polynomials and how they apply to various physical systems such as electromagnetism and quantum mechanics.
- Identify Bessel Functions and how they apply to various physical systems in optics and thermodynamics.
- State various forms of the diffusion equation as it applies to thermodynamics and mechanics.
- Solve various forms of the wave equation as it applies to all fields of physics.
- Explain Fourier and Laplace transforms and use them to approach applications in thermodynamics and in quantum mechanics

METHODS

This class is a lecture course that will incorporate notes from the professor, textbook readings, mathematical exercises, and some numerical problem solving. Since discussion and demonstration of various mathematical methods plays a major role in understanding the concepts taught in this class, attendance and participation is absolutely necessary.

COURSE STRUCTURE

The course is run for two lecture periods a week with some problem solving, and has been designed to try and facilitate your understanding of the course material. The lecture will cover a lot of the main ideas discussed in the text, but not everything. I will highlight the ideas and sections that I feel are important. If I dont mention it in lecture, then you are not responsible for that material. About once a week, you will submit completed homework problems as assigned by me. We will discuss and go over some of the problems that you were assigned. Then, on certain dates you will take an exam to test your knowledge of the material. I expect and encourage student participation in class. When something is not clear, please point it out so that I can make it so. Chances are that if you dont understand a concept, others in the class dont either. For further help, you can see me after class, during office hours, or by special appointment.

ASSESSMENT

The course assessment will be a subset of homework problems, written examinations, an oral examination and classroom participation.

INTERNET ACCOUNTS

Since much of the work given throughout the course will be online through D2L, all students are required to have an internet account. Students may receive messages from the professor through e-mail as well as be expected to complete assignments given through D2L. Students will be required to check their D2L accounts everyday for messages from the professor and to keep up with the material assigned for the course. Not checking the course content on D2L IS NOT an acceptable excuse for missing the assignment or its due date. Points will be docked accordingly in such cases.

TENTATIVE COURSE OUTLINE

I. Calculus of Variations

  A. Functionals
  B. Euler Equation
  C. Brachistochrone Problem
  D. Lagrangian Multipliers
  E. Isoperimetric Problems
  F. Hamilton's Principle
  G. Lagrange's Equations
  H. Noether's Theorem

II. Coordinate Transformations: Tensor Analysis

  A. Linear and Orthogonal Transformations
  B. Eigenvalues and Eigenvectors
  C. Diagonalization of Matricies
  D. Curvilinear Coordinates
  E. Scale Factors and Basis Vectors
  F. General Curvilinear Coordinates
  G. Vector Operators
  H. Cartesian Tensors
  I. Dyadics
  J. General Coordinate Systems
  K. Tensor Notation of Vector Operations

III. Special Functions

A. Factorial Function
B. Gamma Function and the Recursion Relation
C. Gamma Function of Negative Numbers
D. Formulas Using the Gamma Function
E. Beta Functions
F. Relating Gamma and Beta Functions
G. The Error Function
H. Asymptotic Series
I. Stirlings Formula
J. Elliptical Integrals and Functions

IV. Orthogonal Functions and Sturm-Liouville Theory

A. Introduction to Hilbert Space
B. Functions Viewed as Vectors
C. Sequences of Functions
D. Complete Orthonormal Sets
E. Expansions in Terms of Orthonormal Functions
F. Sturm-Liouville Problem
G. Hermitian Operators
H. Gram-Schmidt Method

V. Series Solutions of Differential Equations

A. Legendre's Equation
B. Rodrigues Formula and Generating Functions
C. Legendre Polynomials
D. Legendre Series and the Associated Legendre Functions
E. Generalized Power Series and the Method of Frobenius
F. Bessel's Equation and Bessel Functions
G. Hermite and Laguerre Functions

VI. Partial Differential Equations

A. The Heat Flow/Diffusion Equation
B. Laplace's Equation (Steady-state temperature in a rectangular plate)
C. Heat Flow in a Bar or Slab
D. One-Dimensional Wave Equation
E. Vibrating Strings
F. Normal Modes and Characteristic Frequencies
G. Vibration of a Circular membrane
H. Steady state Temperature in a Sphere

I. Poissons Equation

VII. Functions of a Complex Variable

A. Analytic Functions
B. Contour Integrals
C. Laurent Series
D. Residue Theorem
E. Methods of Finding Residues
F. Definite Integral Evaluation with Residue Theory
G. Residues at Infinity
H. Conformal Mapping

VIII. Transform Methods

A. Laplace Transform
B. Laplace Transform Solutions of Ordinary Differential Equations
C. Fourier Transform
D. Convolution: Parsevals Theorem
E. Inverse Laplace Transform
F. Dirac-delta Function
G. Green's Functions
H. Transform Solutions to Partial Differential Equations

HOMEWORK

Read ahead in the text during the week as assigned.

- Read ahead in the text.
- Read through your classnotes.
- Work through the relevant examples in the text and the notes.
- Write up the assigned problems and have them prepared for collection.
- Ask questions if anything is unclear.

GRADING POLICY

You will have homework assignments throughout the course of the semester. Three tests will be administered, one in late early January, one in early March, and one in mid to late April. A cumulative oral final exam will be given at the end of the course. Your course grade will be broken up as follows:

Hour Test 1	25%
Hour Test 2	25%
Homework	30%
Final Exam	20%

Grading of tests and homework will be based on the process you use as well as your final result. Certainly if the process is correct, but you have a slight mathematical error, you will receive the majority of points for that particular problem.

ATTENDANCE POLICY

There is no required attendance for class as per Kutztown University policy. However, lecture is the primary avenue in which information from the course will be disseminated. Therefore, missing lecture will probably reduce your effectiveness in completing the coursework and obtaining a high grade. In all cases, it is the students responsibility to be aware of the scheduled assignments and/or exams. Material that is handed in late will be downgraded accordingly.

HOMEWORK POLICY

You should feel free to work together on your assigned homework problems. You can get help from friends, but it is important to make sure that you understand the help given to you and then write up your own work. You should not write up the group effort, nor copy someone else's work. On the due date, I will collect the homework for grading. The main purpose for homework is for you to practice solving physics problems.

MISSED ASSIGNMENTS OR EXAMS

Late homework will not be accepted without a valid excuse. If you are absent from an exam, a zero will be recorded until a valid excuse is shown. Then a make-up exam will be arranged. In order for an absence to be excused, the student must present either (1) a note signed by a doctor (not the school nurse) or (2) a statement from the dean or any other relevant academic official. When homework is missed, it will be your responsibility to make it up and hand it in. Don't miss the final. If there are extenuating circumstances, see me as soon as possible.

ACADEMIC DISHONESTY

You are expected to practice the highest possible standards of academic integrity, and in fairness to students who put in an honest effort, cheaters will be dealt with harshly. A ny deviation(s) from this expectation will result in imposed sanctions as detailed in Kutztown Policy ACA-027, which can include: receiving a zero for the assignment, a failing grade for the course, suspension from the University, or dismissal from the University. This includes improper citation of sources, using another student's work, and any other form of academic misrepresentation.

TITLE IX REPORTING

In order to comply with Title IX of the Education Amendments of 1972 and University policy, Kutztown University's faculty and staff must report incidents of sexual violence, sexual harassment, dating violence, domestic violence, and stalking, including relevant details, such as the names of those involved in the incident, to the Department of Public Safety and Police Services and to Jesus Peña, Title IX Coordinator. The only exceptions to the faculty member's reporting obligation are when previously listed offenses are communicated by a student during a classroom discussion, in a writing assignment for class or as part of a University-approved research project. Information regarding the reporting of sexual violence and resources available to victims of sexual violence is set forth at:

http://www2.kutztown.edu/about-ku/administrative-offices/social-equity/title-ix-information.htm

ADA ACCOMODATIONS

If you have already disclosed a disability to the Disability Services Office (215 Stratton Administration Building) and are seeking accommodations, please feel free to speak with me privately so that I may assist you. If you have an injury sustained during military service including PTSD or TBI, you are also eligible for accommodations under the ADA and may contact the Disability Services Office.