Physics 374----Intermediate Theoretical Methods

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Office Hours

Office hours are immediately following class. I am also generally available in my office and happy to see students; just drop by—or, better yet, give me a call and then drop by.

Course Philosophy

This is not intended primarily as a mathematical methods course. You have already suffered through enough math courses! The key point is to be able to use the mathematical methods you have already seen--and a few more which will be introduced in the course--for non-trivial physics problems. The idea for PHYS 374 grew out of a concern on the part of the faculty that too many of our students went through our initial sequence of 171-272-273 and were still not adequately prepared for our advanced level courses. The idea of this course is to serve as a bridge between our introductory sequence and our advanced courses. The hope is to build a high level of intellectual sophistication so that our students will be in a good position to succeed in the advanced classes. The principal difficulties facing many students at the intermediate level is the lack of integration of mathematical techniques learned in various math classes to with physics. To build sophistication and integrate mathematics with physics this course will focus on a number of examples drawn from elementary physics. These examples generally will involve few new physical ideas beyond those introduced in the initial sequence. They will all be non-trivial and will involve using relatively highbrow mathematics.

A second goal of this course is to ensure that students attain some of the computational skills to succeed in our advanced courses and in the real world. Accordingly this course will make extensive use of Mathematica, a program which enables one to do numerical and analytical calculations and to display results graphically.

I also intend to use this course to fill a gap in our undergraduate program: Special relativity is not addressed after the first semester (when it is typically treated at a rather unsophisticated level). I hope to rectify this omission while at fulfilling the principal objective of this course by treating relativity using the rather elegant and sophisticated 4-vector formalism.

Books---or lack thereof

I know of no book which approaches material in the format of this course. A few useful reference books for the mathematical methods and some of the physical applications will be kept on reserve in the library.

While numerous introductions to Mathematica do exist, the **Mathematica Book** is available on-line in the Mathemica Help facility. If this proves adequate for your purposes you may spare yourself the expanse of purchasing a book on Mathematica.

Because we will not be using a textbook, it is absolutely essential that you attend class. I will make my lecture notes available to the class either in the form of handouts or on the web to compensate in part for the lack of a textbook.

Reserve Books

Mechanics---*Newtonian Dynamics* by R. Baierline

Electricity and Magnetism---*Introduction to Electrodynamics* by D. Griffiths

Waves---*Physics of Waves* by H. Georgi

Relativity---*Spacetime Physics* by E. F. Taylor and J. A. Wheeler

Math Methods--- Mathematical Methods in the Physical Sciences by M. Boas; *Mathematical Methods for Physicists* by G. B. Arfken and H. J. Weber

Mathematica----*The Mathematica Book* by S. Wolfram

All kinds of great stuff on mechanics, E&M, waves, relativity, optics *etc.*---*The Feynman Lectures on Physics* by R. P. Feynman

Homework

Problem sets will be assigned regularly. Often problem sets will require the use of Mathematica. I strongly encourage students to turn in printouts of Mathematica notebooks as the solutions of the problem sets or as part of the solutions. I also strongly encourage students to consult each other on problem sets. Ideally you should attempt all of the problems by yourselves and if get stuck you should then consult your peers.

Homework will count approximately 20% of the final grade.

Exams

There will be a midterm exam and a final exam in this course. The exams will count for approximately 60% of the total course grade.

The exams are currently planned as take-home. Take-home exams have two virtues: they reduce the time pressure on students and allow them to perform at their best and they allow for questions that are less trivial than can be done during a class period. They do have a potential drawback, however. They are impossible to police efficiently against cheating. Thus, we must rely on your integrity. I will ask you to pledge to do the exams alone and to stick to this pledge. I should note that the whole enterprise of science depends on the integrity of the researchers---when I read a scientific paper I must assume that the researchers didn't cook the books or I won't get anywhere.

Project

You will be assigned a non-trivial problem to analyze using many of the analytic and numerical methods of this course. The project will count for approximately 20% of the total grade. The project will be assigned during the first month of the course. Approximately one month later you will be responsible for turning in a brief progress report on the status of the project. At that stage, if you turn in a complete draft of the paper, I will make detailed suggestions for improving the paper. The final project must be turned in by November 24.

Tentative Course Outline

Methods for classical mechanics

Perturbation Expansions

General approach

Application to falling bodies

Physics of air resistance

Introduction of dimensionless parameters

Identification of useful regimes for approximate treatment

Comparison of exact and approximate results

Anharmonic Oscillators by multiple methods

Numerical

Quadratures

Direct perturbative expansion

Fourier methods

Comparisons of exact and approximate results

Large amplitude motion and the separatrix---identification of useful regimes

Four-Vector treatment of Special Relativity

Physical Assumptions

Sensible units c=1

Invariants

Lorentz transformations

4-vectors

Physically useful 4-vectors (Energy-momentum;4-acceleration)

Physical Applications

Approximation Methods In Electrostatics

Mathematical Tools separation of variables for PDE’s

Electrostatics in 2 dimensions

Physical realization

Multipole expansion and physical applications

Series Solutions of Laplace equation with cylindirical boundary conditions

Numerical solutions of Laplace equation---arbitrary bound conditions

Mathematical Tools separation of variables for PDE’s Electrostatics in 3 dimensions (with axial symmetry)

Mathematical tool---Legendre Polynomials

Multipole expansion

Series solutions with spherical boundary conditions

Numerical solutions of Laplace equations---arbitrary boundary conditions

Physics of Waves

Mathematical Tool---Fourier Transform

Dispersion relations---phase vs. group velocity

Numerical solutions

Additional Topics as Time Permits