Theoretical Physics
Prof. Ruiz, UNC Asheville, doctorphys on YouTube

Course History

The origins of this course dates back to my graduate days in physics when I started to think of innovative ways to understand the basic physics encountered in each of my courses. As an example, one can essentially derive the Maxwell equations from Coulomb's Law and Special Relativity. You can think of this course as a collection of insights and tricks uniquely gathered into one course. Examples include the use of group theory to reveal the meaning of the square root of minus 1, integral tricks for deriving some of the common integrals in physics, a derivation of the Dirac Equation, and Feynman's derivation of the Schrödinger Equation that formed the seed to his work leading to sharing the Nobel Prize in Quantum Electrodynamics. Also included is the calculation of the shift of Mercury's perihelion from General Relativity.

Brief Course Description

Application of mathematical methods to classical, statistical, relativistic, and quantum mechanics, as well as introductory field theory. Emphasis is on revealing fundamental structure and connections. The powerful theoretical techniques learned serve as excellent preparation for graduate study in physics and related fields such as engineering.

Theoretical Physics (Math Physics)

A general *Theoretical Physics* course is sometimes called Mathematical Physics or Math Physics. Such a course focuses on the mathematical methods employed across many areas of physics, engineering, and related fields. We learn the "tools of the trade" and how to use them. This makes our course very powerful as these mathematical tools are used in so many fields, even those outside physics such as economics. A graduate with such knowledge has the power to work in diverse fields.

Richard Feynman (1918-1988). Courtesy nobelprize.org.

Finally, *theoretical physics* teaches you elegant tricks and offers you deep insight into physics. Richard Feynman, America's most colorful physicist for many years, often pointed out the importance of theoretical physics and using innovative mathematical methods to see things from different points of view. He was often described as a magician when it came to applying mathematics to physics.

This course follows in this spirit, teaching you "magical" math tricks and shortcuts. Then, we present elegant formulations of the laws of physics, giving you a better appreciation of the beauty of physics.

Topics

Part I - Emphasis on Seeing Physics in an Elegant Fashion

0. Introduction
A. Taylor Series. Rotation Matrix. Groups.
B. What is e? Euler's Formula. Integral Tricks.
C. Special Relativity.
D. "Derivation of the Maxwell Equations."
E. Differential Form for the Maxwell Equations.
F. The Wave Equation and Light.
G. Deriving The Ideal Gas Law and Thermodynamics.
H. Statistical Mechanics.
I .The Schrödinger Equation.
J. Spinors I: Pauli Matrices.
K. Spinors II: The Pauli Equation.
L. The Dirac Equation.

Part II - Emphasis on Mathematical Methods

M. Method of Frobenius and Orthogonal Functions.
N. The Dirac Delta Function.
O. Fourier Series.
P. Fourier Transforms.
Q. Laplace Transforms.
R. Convolution.
S. Complex Variables I: Cauchy Integral Formula.
T. Complex Variables II: The Residue Theorem and Poles.
U. Green's Functions .
V. Transfer functions.
W. Principle of Least Action.
X. General Relativity and Mercury.
Y. Feynman's Derivation of the Schrödinger Equation.
Z. Review

YouTube

I made YouTube videos to accompany this text. The videos can be found at

https://www.youtube.com/user/doctorphys

Find the Section entitled "Theoretical Physics 2021."