Physics Orientation

PHYS 1000

Physics: Purpose and Practice

- Observation
- Measurement
- Synthesis
- Verification
- Generalization

Experiment and Theory

- Experimental Method
- Development of Theory
- Experimental-Theory Interaction

Areas of Classical Physics

- Mechanics
- Electromagnetism
- Statistical Mechanics
- Optics

Areas of Modern Physics

- Special Relativity – General Relativity
- Quantum Mechanics – Field Theory
- Atomic Physics
- Condensed Matter Physics
- Quantum Optics – Laser Physics
- Nuclear Physics – Elementary Particle Physics
- Nonlinear Dynamics and Chaos
- Astrophysics – Cosmology

Physics and Society

- Research – Development – Implementation
- Transportation
- Energy
- Environment

Evolution of Physics

PHYS 2001

Development of Mechanics

Relativity of Position. Aristotle, Crescas, Bruno
Relativity of Motion. Galileo, Newton
Action Principle. Leibniz
Mechanical Doctrine. Newton, Laplace

Development of Field Physics

Locality. Newton, Faraday
Gravitational Field. Newton, Laplace
Electromagnetic Field. Maxwell
Field Doctrine. Einstein

Development of Spacetime Physics

Relativity of Space and Time. Einstein
Relativity of Acceleration. Mach, Einstein
Gravitational Field. Einstein
Black Holes and Singularities. Penrose
Search for a Unified Field. Mie, Einstein, Weyl

Development of Quantum Physics

Light Quanta. Einstein
Non-Objective Physics. Heisenberg
Vacuum Structure. Nambu, More
Standard Model. Gell-Mann, Glashow, Salam, Weinberg
Quantum Doctrine. Bohr

Further Developments

Conflict Between Quantum Theory and General Relativity
String Physics. Nambu
Cellular Physics. Yukawa, Penrose
Beyond the Quantum Doctrine

The Solar System

PHYS 2021

Earlier Astronomy
- Ancient Greek Astronomy
- Renaissance Astronomy
- Galileo and Newton

Observational Astronomy
- Gravity
- Celestial Clockwork
- The Sky
- Telescopes and Observatories

Familiar Objects
- Earth
- Moon
- Sun

Terrestrial Planets
- Mercury
- Mars
- Venus

Jovian Planets and Moons
- Jupiter
- Jupiters Moons
- Saturn
- Other Worlds

Vagabonds
- Asteroids
- Comets
- Meteors

Stars, Galaxies, and the Universe

PHYS 2022

Optics

- Properties of Light
- Optical Telescopes
- Radio and IR Telescopes

Stellar Astronomy

- Solar Characteristics
- Stellar Characteristics
- Analyzing Starlight
- Celestial Census
- Double Stars

Stellar Evolution

- Birth of Stars
- Stellar Evolution
- Star Clusters
- Variable Stars
- Death of Stars

Supernova and Remnants

- Supernova
- Neutron Stars
- General and Special Relativity
- Black Holes

Galactic Astronomy

- Milky Way Galaxy

Extra-Galactic Astronomy

- Galaxies
- Quasars
- Cosmology
- Big Bang

Physics of Music

PHYS 2030

Fundamentals of vibrating Systems
- Mechanical Principles
- Simple Harmonic Motion

Wave Motion
- Production and Propagation
- Reflection, Refraction, Diffraction, and Interference

Resonance

Hearing the Sound

Pith and Timbre

Combination Tones and Harmony

Musical Scale and Temperament

Application to Classes of Musical Instruments
- Strings, Brass, Woodwind, and Percussion
- Human Voice

Detection and Processing of Sound

Auditorium Acoustics

Introductory Physics

PHYS 2211

Motion in One Dimension

Motion in Two Dimension

Newton's Laws

Work and Energy

Conservation of Energy

Systems of Particles

Momentum and Collisions

Rotational Motion

Torque and Angular Momentum

Static Equilibrium

Gravitational Fields

Introductory Physics II

PHYS 2212

Electric Charge

Coulomb' Law

Electric Field

Gauss' Law

Electric Current

DC Circuits

Magnetic Field

Faraday's Law

AC Circuits

Electromagnetic Waves

Maxwell's Equations

Honors Physics

PHYS 2231

Motion in One Dimension

Motion in Two Dimension

Newton's Laws

Work and Energy

Conservation of Energy

Systems of Particles

Momentum and Collisions

Rotational Motion

Torque and Angular Momentum

Static Equilibrium

Gravitational Fields

Honors Physics II

PHYS 2232

Electric Charge

Coulomb' Law

Electric Field

Gauss' Law

Electric Current

DC Circuits

Magnetic Field

Faraday's Law

AC Circuits

Electromagnetic Waves

Maxwell's Equations

Introduction to Modern Physics

PHYS 2213

The Classical Period

Physics at the turn of the Century
Successes and Failures of Classical Physics

Einstein, Planck, Bolzmann, and Rutherford

New Views of Space, Time, Light, and Atoms

The Development of Quantum Theory

Bohr Sommerfield Rules
Schrödinger's Equation
Heisenberg's Principle
Pauli's Principle
Dirac's Equation

Quantum Structure of Ordinary Matter

Atoms, Molecules, Solids
Electronic Bonding of One and Many Electron Atoms
Molecular Bonding
Crystal Structure and the Electronic Structure of Crystals

Statistical Physics

Bose-Einstein and Fermi-Dirac Statistics
The Classical Gas and Quantum Gas

Nuclear Structure and Elementary Particles

Radioactive Decay, Fission, and Fusion
Symmetries and Conservation Rules
Particle Classifications and Fundamental Interactions
The Search for New Particles
Ultimate Theories and Cosmologies

Condensed Matter Physics

Metals, Semiconductors, and Insulators
Semiconductor Devices
Lasers
Superconductors, Old and New
Quantum Hall Effect
Mesoscopic Physics

Classical Mechanics I

PHYS 3201

Newton's Laws

- First Law – Inertial Frames
- Second Law – Particle Motion
- Third Law – Two Particles
- Work – Kinetic Energy – Potential Energy
- Angular Momentum

Systems of Particles

- Center of Mass
- Conservation of Momentum
- Conservation of Energy
- Conservation of Angular Momentum

Central Force Motion

- Conservation of Energy and Momentum
- Effective Potential – Radial Motion – Apsides
- Universal Law of Gravitation
- Gravitational Orbits – Time Dependence
- Reduction of the Two Body System
- Scattering

Oscillations

- Simple Harmonic Oscillator – Phase Space
- Damped Oscillations
- Harmonically Driven Oscillations – Resonance
- Impulsive Driving Forces – Green's Function Solution
- Coupled Oscillations – Normal Modes
- Non-Linear Oscillations – Finite Pendulum – Chaos

Stellar Astrophysics

PHYS 3021

Background
- Light and Energy
- Light and Matter

Stellar Characteristics
- Spectral Lines
- HR Diagram

Stellar Interiors
- Interior Structure
- Nucleosynthesis

The Sun
- Solar Interior

Post-Main-Sequence Stellar Evolution
- Massive-Star Evolution
- Pulsations
- Supernovae

Degenerate Stars
- White Dwarfs
- Neutron Stars and Pulsars
- General Relativity
- Black Holes

Wave Mechanics

PHYS 3043

Schrödinger Equation
Probability Interpretation of the Wave Function
Average Values, Operators, Eigenfunctions & Eigenvalues, Stationary States,
General Probability Interpretation of the Wave Function, Uncertainty Relations

Free Particles
Motion and Spreading of Wave Packets

Particles in a Box and a Ring

Potential Barriers, Tunnel Effect

Delta-Function Potentials
Parity, Exchange Forces, Chemical Bonds

Harmonic Oscillator

Phonons

Two-Level Systems, Pauli Matrices

Angular Momentum

Electrostatics and Magnetostatics

PHYS 3122

Review of Vector Calculus

Electrostatics
- Coulomb's Law
- The Electric Field
- Gauss' Law

Electric Potential
- Poisson's and Laplace's Equations
- Boundary Conditions

Work and Energy of Static Electric Fields

Methods for Calculating Potentials
- Laplace's Equation
- Images
- Separation of Variables
- Multipole Expansions

Electrostatic Fields in Matter
- Polarization
- Fields of Polarized Objects
- Electric Displacement
- Linear Dialectrics

Magnetostatics
- Lorenz Force Law
- Biot-Savart Law
- Ampere's Law
- Magnetic Vector Potential

Magnetostatic Fields in Matter
- Magnetization
- H Field
- Linear and Nonlinear Media

Electrodynamics

PHYS 3123

Electromotive Force

- Ohm's Law
- Faraday's Law
- Inductance

Maxwell's Equations

- Maxwell's Equations in Vacuum and Matter
- Boundary Conditions for Maxwell's Equations
- Energy and Momentum in Electrodynamics
- Gauss' Law

Electromagnetic Waves

- Electromagnetic Waves in One Dimension
- Polarization
- Boundary Conditions – Reflection and Transmission
- Electromagnetic Waves in Conducting and Nonconducting Media
- Dispersion
- Guided Waves

Electromagnetic Radiation

- Dipole Radiation
- Fields of a Moving Point Charge
- Radiation from a Moving Point Charge
- Power Radiated from a Moving Point Charge
- Radiation Reaction

Thermodynamics

PHYS 3141

Introduction

Thermodynamic Systems, System State, Thermal Equilibrium, Zeroth Law
Equations of State, Ideal and Van der Waals Gases, Extensive and Intensive Variables
Mathematical Preliminaries, Perfect and Imperfect Differentials
Thermodynamic Identities, Susceptibilities

First and Second Laws of Thermodynamics

Internal Energy, Heat, and Work
The First Law, Conservation of Energy in Thermodynamics
Work on an Ideal Gas in Isothermal and Adiabatic Processes
Carnot's Cycle, Reversibility
The Second Law, Equivalent Formations, Entropy
Applications, Ideal and Van der Waals Gas, Joule-Thomson Experiment

Thermodynamic Potentials

Free Energies, Enthalpy, Helmholtz, Gibbs
Maxwell Relations
Phase Equilibrium and Phase Transitions, Gibbs Phase Rule, Phase Diagrams
Clausius-Clapeyron Equation
Chemical Potentials
Applications, Surface Tension, Blackbody Radiation, Magnetism

Kinetic Theory

Basic Assumptions, Ideal Gas
Principle of Equipartition of Energy
Specific Heat
Inclusion of Intermolecular Forces, Van der Waals Gas
Applications, Transport Phenomena

Quantum Mechanics I

PHYS 3143

Fundamental Concepts

Observables

Bra and Ket State Vectors

Probability Amplitudes

Position and Momentum Eigenstates

Heisenberg and Schrödinger Pictures

Uncertainty Relations

Free Particle

Particle-in-a-Box

Harmonic Oscillator

Coherent States

Mathematical Physics

PHYS 3151

Vector Analysis

Matrices and Determinants

Vector Spaces

Complex Variables

Fourier Expansions

Ordinary Differential Equations

Partial Differential Equations

Boundary Value Problems

Classical Mechanics II

PHYS 3202

Lagrangian Dynamics

D'alemberts' Principle – Constraints
Lagrange's Equation with Generalized Forces
Lagrange's Equation with Potential – Applications
Hamilton's Equations – Applications
Calculus of Variations – Hamilton's Principles

Non-Inertial Reference Frames

Centrifugal Force
Coriolis Force
Motion Relative to the Earth

Rigid Body Dynamics

Relations between Velocity and Angular Velocity
Newton's Law for a Rigid Body – Inertia Tensor – Principle Axes
Eulerian Angles – Euler's Equations fro a Rigid Body
Stability of Rigid Body Rotations
Rigid Body Langrangian – Symmetric Top

Waves

Waves on a String – Sound Waves
Wave Equation – General Solution
Traveling Waves
Harmonic Waves – Standing Waves
Fourier Analysis – Fourier Integral
Wave Packets – Group Velocity

Electronics I

PHYS 3211

AC and DC circuit theory

Rectifiers, power supplies, and filters

Active devices

Amplifiers, feedback, and oscillation

Multistage amplifiers a

Integrated circuits

Digital circuits

Geometrical Optics

PHYS 3223

A Review of Elementary Optics

Thin Lens Ray Tracing

Radiometry

Mirrors and Prisms

Paraxial Ray Tracing

Exact Ray Tracing

Introduction to Lens Design Software

Lens Design

Various Lens Designs

Geometrical Optics Laboratory

PHYS 3224

Spherometer

Measurement of Radius of Curvature of Various Lens Surfaces; Computation of Refractive Index Using the Lensmakers' Equation; Practice in Error Analysis

Prism Spectrometer

Measurement of the Dispersion Curve for a glass Prism by Using the Angle of Minimum Deviation; Practice in the Alignment of Optical Instruments.

Refractometer

Measurement of the Refractive Index of a number of Liquids and Solids with Abbe Refractometer

Zygo Interferometer

Measurement of the Surface and Bulk Errors of Optical Surfaces Using a Fizeau Interferometer, Practice in Setup and Alignment of Optical Components for Test

Cardinal Points of a Less

Measurement of the Effective Focal Length, Principle Planes, and Hiatus of a series of Lenses Using Moire Techniques

Aberrations Using Hartmann Disk

Measurements of the Optical Errors of a Lens Using Ray Generation Techniques

Schmidt Telescope

Measurement of Aberrations for a Corrected or Uncorrected Schmidt Telescope Using a Laser Ray Tracing Method

Resolution of Lenses

Use of a standard Resolution Targets to Measure the Resolution of Lenses; Effects of Aperture Stops on Lens Resolution

Modulation Transfer Analyzer

Evaluation of an Optical System by Generating its Modulation Transfer Function from the Fourier Transform of its Line Spread Function

Reduction Camera/Image Analysis

Use of a Precision Camera to Reduce High Resolution Objects; Evaluation of the Resulting Images Using Image Analysis Software

Modern Optics

PHYS 3225

Introduction

- Reflection and Refraction of Electromagnetic Waves
- Fermat's Principle and Huygens' Principle
- Phase and Group Velocities
- Wave Superposition
- Fourier Series and Integrals
- Coherence

Polarization

- Dichroism, Birefringence, and Optical Activity

Interference

- Wavefront Splitting Interferometers
- Amplitude Splitting Interferometers
- Multiple Beam Interference

Diffraction

- Frauhofer Diffraction
- Diffraction Gratings
- Fresnel Diffraction
- Fourier Optics and Imaging

Laser Principles

- Spontaneous and Stimulated Emission
- Population Inversion and Pumping
- Line Broadening & Gain Saturation
- Laser Resonators and Modes

Laser Behavior

- Rate Equations
- Continuous Lasers
- Transient Laser Behavior
- Q-Switching
- Mode-Locking

Types of Lasers

- Gas Lasers
- Solid-State Lasers
- Semiconductor Lasers
- Tunable Lasers

Modern Optics Laboratory

PHYS 3226

Photomultiplier

Characteristics of a Photomultiplier Tube Including Cathode Sensitivity and Photon Counting; Threshold Techniques for Dark Count Reduction

Fabry-Perot Interferometer

Measurement of the Finesse; Free Spectral Range Determination; Measurement of the Mode Separation in a Helium-Neon Laser

Acousto-Optic Modulator

Alignment of an Acousto-Optic Modulator; Bragg Angle Selectivity; Measurement of the Sound Wave Velocity in the Bragg Cell

Holography

Construction of Michelson Interferometer; Measurement of the Stability of the System; Fabrication of a Holographic Diffusion Grating and a Transmission Hologram

Diode Laser

Determination of the (Output) Power vs. (Injection) Current Relationship as a Function of Temperature; Investigation of the Spatial Characteristics of its Gaussian Beam

Fiber Optics

Measurement of the Attenuation Coefficient of Optical Fibers; Construct a Fiber Optic Sensor

Nd:YAG Laser

Operation of a Neodymium-YAG (Nd-YAG) Laser and its Q-Switching and Frequency Doubling Accessories

Single Mode Laser

Operation of a Stable Single Mode Helium-Neon Laser; Measurement of the Axial Mode Frequencies and Control of the Axial Modes to Provide the Frequency Stabilization

Acoustics

PHYS 3265

The Wave Equation

Progressive and Standing Plane Waves

Spherical Waves

Radiator Equations of Motion

Transducer Parameter Measurements

Design Considerations

Compression drivers and horns

Room acoustics

Design Programs

Room Impulse Response

Computational Physics

PHYS 3266

Growth and Decay Patterns

- Numerical solution of First Order Differential Equations
- Population Dynamics
- Nuclear Decay

Newtonian Dynamics

- Numerical Solution of Second Order Ordinary Differential Equations
- Projectiles with Drag and Lift
- Oscillations – Harmonic and Anharmonic
- Chaos

Gravitation

- Planetary Orbits – Varied Power Laws
- Relativistic Effects
- Three Body Problem
- Many Body Problem

Electromagnetism

- Electrostatics – Relaxation Methods
- Magnetic Fields – Numerical Quadrature
- Helmholtz Coils and Solenoids

Waves

- Coupled Oscillators and Fourier Analysis

Statistical Methods

- Monte Carlo Methods – Random Numbers
- Drift and Diffusion
- Cluster Growth – Fractal Dimension

Cell Models

- Molecular Dynamics – Thermal Properties of Matter
- Ising Model

Quantum Mechanics

- Bound State Wave Functions and Energies
- Tunneling

Statistical Mechanics

PHYS 4142

Thermal Concepts

Statistical Methods
- Random Events
- Probability Distributions
- Limit of Large Numbers

Entropy and the Second Law of Thermodynamics
- Direction of Natural Processes
- Macrostates and Microstates
- Statistical Weight
- The Equilibrium State
- The Partition Function and Free Energy
- Statistical Calculation of Thermodynamic Quantities

Simple Thermal Systems
- Ideal Classical Gas
- Entropy of Mixing
- Magnetic Systems
- Heat Capacity of Solids

Quantum Statistics
- Fermions and Bosons
- The Partition Function
- Blackbody Radiation
- Gibbs Distribution and the Grand Partition Function
- Fermi-Dirac and Bose-Einstein Distributions
- Electrons in Metals
- Bose-Einstein Condensation

Quantum Mechanics II

PHYS 4143

Angular Momentum

Multidimensional Systems

Hydrogen Atom

Symmetry

Variational Methods

Perturbation Theory

Matter-Radiation Interactions

Identical Particles

Atoms, Molecules, and Nuclei

Special Relativity

PHYS 4146

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Classical Mechanics and Electromagnetism: Conflict and Resolutions
- Invariants of the Old Mechanics
- Invariants of Electromagnetism

Spacetime Symmetries
- Lorentz Transformations
- Time Dilation; Length Contraction
- Apparent Rotation
- Doppler Shift

Paradoxes of Special Relativity
- Twin Paradox
- Pole-and-Barn Paradox

Particle Kinematics and Dynamics
- Energy-Momentum
- Power-Force

Tensors
- Angular Momentum
- Electromagnetic Field
- Stress

Field Kinematics and Dynamics
- Maxwell's Equations

Spin
- Spinors

Applications

Electronics II

PHYS 4206

Transfer analysis

Transducers

Analog and digital filters

Fundamentals of Microprocessors

Analog to digital and digital to analog conversion

Measurement control by microprocessors

Computer interfacing

Optical Design

PHYS 4220

Optical Performance

Gaussian Beams

Modulation and Scanning

Spectrometers

Detectors

Optomechanical Design

The Design Process

Final Design Project

Solid State Devices

PHYS 4222

Crystal Structures
- Periodic Arrays of Atoms
- Reciprocal Lattice
- Brillouin Zones

Energy Band Structure
- Single and Periodic Potential Well
- Energy Bands by Tight Binding Method

Semiconductor Statistics
- Fermi Statistics
- Occupation of Impurity Levels
- Intrinsic, N- and P-type Semiconductors

Charge Transport in Solids
- Electrical Conductivity
- Hall Effect

Carrier Diffusion Process
- Injection and Recombination
- Diffusion and the Einstein Relation

Bipolar Devices
- The p-n Junction
- The Bipolar Transistor

Unipolar Devices
- Metal-Semiconductor Contacts
- MIS Diode and CCD
- MOSFETS

Photonic Devices
- LED and Semiconductor Lasers
- Photoconductors and Photodiodes
- Photovoltaic Effect (Solar Cells)
- Integrated Optics

Biophysics

PHYS 4251

Thermodynamics

2^{nd} law and change from $\Delta S \geq 0$ to $\Delta G \geq 0$.

Energy Metabolism Pathways

Glycolysis & Acetyl-CoA
Citric Acid Cycle & e^- - Transport Chains

Chemiosmosis

Proton Potential
ATP Synthesis

Dehydration Condensations and Activation

Coenzymes & Proteins
Polysaccharides & Polynucleotides

ATP Activations

β and γ Processes

DNA Directed Protein Synthesis

Genetic Code

Self-Assembly

Entropy of H_2O
Brownian Motion and Diffusion

Molecular Motors

Ubiquinone Diffusion
Rotary Enzymes & E. Coli Flagella

Muscle

Actin, Myosin, and Tropomyosin
Chemo-Mechanical Conversion

Ion Transport

Rectified Brownian Motion

Nerve

Action Potentials
Hodgkin-Huxley Equations

Atomic Physics

PHYS 4261

Introduction
- The Periodic Table
- Isotopes

Hydrogen and One-Electron Atoms
- Gross Structure
- Fine and Hyperfine Structure
- Electron Spin
- The Vector Model
- Lamb Shift

Helium and Two-Electron Atoms
- Pauli Principle and Electron Spin Functions
- Electrostatic Interaction and Exchange Degeneracy

Many Electron Atoms
- The Central Field Approximation
- Shells, Configurations, Terms, Multiplets, and the Periodic Table
- LS Coupling and Description Ground States
- Atomic Spectra, X-ray spectra and Inner Shells

Atomic Interactions
- Electric Dipole Interaction
- Static Field Interactions
- Interaction with Incoherent Radiation, Coherent Energy

Selected Topics
- Resonance Fluorescence and Dressed States
- Multiphoton Atomic Processes
- Laser Cooling and Trappings of Neural Atomic Beams
- Atom Interferometry
- The Unbound Electron in a Central Field
- Rydberg States and Nonlinear Dynamics

Solid State Physics

PHYS 4262

Crystal Structure

Lattices and Bases; Unit and Conventional Cells; Lattice Vectors and Crystal Planes; Bragg Diffraction; Diffraction Methods; the Reciprocal Lattice; Structure Factors; and the Scattered-Wave Amplitude

Cohesion and Vibrations

Classification of Solids According to Chemical Bonding; Equilibrium Structure and Cohesive Energy from Pair-Potentials; Surface Energy; Elastic Constants; Crystal Vibrations, Classical and Quantized; Anharmonic Effects and Solid-Liquid Transitions

Band Theory of Solids

Electrons in a Periodic Potential (Bloch States); Tight-Binding Picture (States of Atoms and Molecules); Plane-Wave Picture (Free-Electron States); the Metal-Insulator Distinction (Band-Filling); Calculation of the Cohesive Energy; Breakdown (Correlations)

Theory of Metals

The Free-Electron Gas in 2D and 3D; the Homogeneous Electron Gas; the Fermi Surface; Resistive and Ballistic Transport in Electric and Magnetic Fields; the Fermi-Liquid Picture

Theory of Semiconductors

The Band-Gap and Effective-Mass Approximation; Excitons (Solid-State Lasers); Intrinsic (Thermal) Conductivity; Doped Semiconductors

Magnetism

Phenomenology of Ferromagnetism and Superparamagnetism; Elementary Microscopic Picture of (Nonitinerant) Ferro- and Antiferro-Magnetic States

Di- and Ferro-Electrics and Optical Properties

The Dielectric Function; Low-Frequency Limit (Dielectric Constant, Ferroelectrics); Linear and Nonlinear Optical Properties of Dielectric Solids

Superconductivity

Phenomenology of Superconductors (Meissner Effect and T-H Phase-Diagram, Superconduction Gap); Microscopic Picture of Superconductivity; The HTCs; Highly Correlated Conductors and Other Broken-Symmetry Ground-States

Interfacial and Mesoscopic Physics

Surface Structures and Nanostructures; Surface States; Quantum Size Effects

Nuclei, Particles and Fields

PHYS 4263

Properties of Nuclei
- Masses and Binding Energies
- Radii and Shapes

Subnuclear Physics
- Quarks, Hadrons, Baryons and Mesons
- Leptons
- Antiparticles

Fields
- QED & QCD
- Weak and Electroweak Interactions
- Gauge Theories and Unified Field Theory

Nuclear Stability and Transformation
- Bethe-Weizsacker Mass Formula
- Coulomb Barrier
- Alpha, Beta, and Gamma Decay
- Nuclear Reactions & Fission

Nuclear Reactors

Accelerators

Nuclear Structure
- The Nucleon-Nucleon Interaction
- Spin, Parity, and Isospin
- The Shell Model and Collective Model
- Nuclear Spectroscopy

Nucleosynthesis and Cosmology
- Stellar Fusion
- Supernova
- The Big Bang

Application of Nuclear Physics
- Nuclear Medicine
- Archaeological Dating
- Energy (Fission and Fusion Sources)
- Materials Characterization
- Social Issues (Nuclear Waste, Nuclear Weapons)

Nonlinear Dynamics and Chaos

PHYS 4267

Geometrical View of Dynamics
- Phase Space
- Phase Portraits

Numerical Integration of Differential Equations

Driven Oscillator Phenomena
- Resonance
- Jump Phenomena
- Entrainment
- Parametric Amplification
- Spontaneous Symmetry Breaking

Stability Analysis
- Fixed Points
- Periodic Orbits (Floquet Theory)
- Classification of Bifurcations

Routes to Chaos and Universality
- Period Doubling Cascade
- Intermittency
- Quasiperiodicity

Chaotic Geometry
- Strange Attractions
- Self-Similarity

Chaotic Dynamics
- Butterfly Effect
- Lyapunov Exponents

Control of Chaos

Advanced Laboratory I

PHYS 4321

Classical Physics

- Deterministic Chaos
- Fiber Optics
- Microwaves

General Quantum Theory

- Photoelectric Effect
- Nuclear Magnetic Resonance

Solid State Physics

- Hall Effect and Magneto Resistance
- Temperature Dependence of Resistance
- Properties of Diodes
- Wave-Particle Duality
- Pockels Effect

Atomic Physics

- Atomic Structure
- Zeeman Effect
- Rutherford Scanning

Nuclear and Particles Physics

- Radioactivity and Muon Lifetime

Advanced Laboratory II

PHYS 4322

Classical Physics
- Deterministic Chaos
- Fiber Optics
- Microwaves

General Quantum Theory
- Photoelectric Effect
- Nuclear Magnetic Resonance

Solid State Physics
- Hall Effect and Magneto Resistance
- Temperature Dependence of Resistance
- Properties of Diodes
- Wave-Particle Duality
- Pockels Effect

Atomic Physics
- Atomic Structure
- Zeeman Effect
- Rutherford Scanning

Nuclear and Particles Physics
- Radioactivity and Muon Lifetime

Introduction to Continuum Physics

PHYS 4421

Stress, Strain & Elastic Deformations

Hertzian Mechanics and Beyond

Dynamics and Stability of Elastic Media

Elements of Dislocations

Elastic Waves

Ideal Fluids

Euler's Equation & Hydrostatics

Incompressible Fluids

Navier-Stokes Equation

Newtonian and non-Newtonian Fluids

Laminar Flow & Pipe Flow

Stokes Formula

Surface Phenomena & Capillary Waves

Contact Angles and Wetting Instabilities in Fluids

Jets and Droplet Formation

Rayleigh-Taylor and Rayleigh-Bernard Instabilities

Onset of turbulence.

Introductory Diffractions Studies

PHYS 4655

Crystal Diffraction, Reciprocal Space, and Crystal Phases

- Diffraction Conditions: Both Geometric and Reciprocal Space
- Relation Between Crystal Lattice and Reciprocal Lattice
- Reciprocal Space for Polycrystalline Materials
- Sampling of Reciprocal Space by HDS Camera and Θ-2 Θ Diffractometer
- Bragsg's Law, Miller Indices, Bragg' Planes
- Diffraction Intensities
- Phase Identification Procedures

Symmetry

- Crystal Systems
- Pont Groups
- Space Groups
- Systematic Absences
- Stereographic Projections
- Maue Pattern Symmetry in Crystal Alignment

Formation and Pathology of Powder Diffraction Patterns

Application Techniques

- Indexing and Lattice Parameters
- Texture Analysis
- Crystalline Size and Strain Analysis
- Thermal Vibrations

Nuclear and Particle Physics

PHYS 6011

The Nuclear Shell Model
- Independent Particle Motion in Nuclei
- Residual Interactions in Nuclei

The Nuclear Pairing Model
- Pairing Forces in Nuclei
- BCS Theory of the Nuclei

The Collective Model
- Phenomenological Models of Rotations and Vibrations
- The Elliot SU(3) Model
- The Interacting Boson Model

Exotic Atoms
- Mounic Atoms
- Pionic, Kaonic, Hyperionic, and Antiprotonic Atoms

Mesons and Baryons
- Charmonium and Quarkonia
- The Nucleon
- SU(3)

Quantum Chromadynamics (QCD)
- Gauge Theory of QCD
- Quark-Quark Potentials
- The Nucleon-Nucleon Interaction

Weak Interactions
- Flavor and Flavor Mixing
- The Cabibbo-Kovayashi-Maskawa Matrix
- Neutrons, Masses and Oscillations
- Electroweak Unification

The Neutral Kaon System
- K˚ - K˚ Oscillations
- Violation of CP and Time-Reversal Symmetry
- The Matter-Antimatter Asymmetry of the Universe

Group Theoretical and Dynamical Algebra Techniques
- Cartan Theory of Lie Algebra
- SU(3) Description of Nuclei

Classical Mechanics I

PHYS 6101

Newton's Laws

Systems of Particles

Central Forces

Langrangian Dynamics

Rigid Body Dynamics

Oscillations

Classical Mechanics II

PHYS 6102

Canonical Transformations

Hamilton – Jacobi Theory

Canonical Perturbation Theory

Langragian Dynamics of Continuous Systems

Electromagnetism I

PHYS 6103

Electrostatics

Conductors and Dielectrics

Potential Theory

Steady Current

Magnetostatics

Magnetic Matter

Quasistatic Fields

Maxwell's Equations

Electromagnetism II

PHYS 6104

Conservation Laws

Electromagnetic Waves

Waveguides and Cavities

Radiation

Scattering and Diffraction

Covariant Electromagnetism

Lagrangian and Hamiltonian Formulations

Quantum Mechanics I

PHYS 6105

Elementary Quantum Systems

Linear Spaces and Linear Operators

The Harmonic Oscillator

Matrix Representation of Quantum Mechanics

Observables and Measurements

Position, Momentum, and Function Space Representations

Quantum Dynamics

Rotations and Continuous Transformation Groups

Statistical Mechanics I

PHYS 6107

Statistical Basis of Thermodynamics

Microcanonical Ensemble Theory

Caononical Ensemble Theory

Grand Canonical Ensemble Theory

Quantum Statistics

The Theory of Simple Gases with Internal Degrees of Freedom

Interacting Systems, Cluster Expansion

Phase Equilibrium and Phase Transitions

Quantum Mechanics II

PHYS 6106

Systems with Spin and Angular Momentum

Central Force Problems

Time-Independent Perturbation Theory

Other Methods of Approximation

Time – Dependent Phenomena

Scattering Theory

Electromagnetic Fields in Quantum Mechanics

Many – Body Quantum Mechanics

Survey of Physics

PHYS 6110

Problems in Classical Mechanics

Newtonian Mechanics and Conservation Laws
Non – Inertial Frames of Reference
Langrangian and Hamiltonian Techniques
Normal Modes and Small Oscillations
Orbit Equations

Problems in Electricity and Magnetism

Maxwell's Equations
Electrostatice, Magnetostatics
Electromagnetic Radiation

Problems in Thermodynamics

Thermodynamic Laws and their Applications to Physical Processes
Thermodynamics Functions
Phase Changes

Problems with Statistical Mechanics

Kinetic Theory of Gases
Classical and Quantum Statistics

Problems in Quantum Mechanics

Schrodinger's and Heinsenberger's Approaches
Formalism
Angular Momentum
Bound State Problems
Time – Independent and Tome – Dependent Perturbation Theory
Scattering Theory

Mathematical Methods of Physics I

PHYS 6124

Complex Analysis
- Analytic Functions
- Cauchy's Theorem
- Contour Integration

Vectors and Matrices
- Linear Spaces and Transformations
- Matrices and Determinants
- Eigenvalue Problems
- Diagonalization

Sturm – Liouville Theory
- Self – Adjointness and Boundary Conditions
- Eigenfunctions Expansions
- Green Functions
- Special Functions

Mathematical Methods of Physics II

PHYS 6125

Partial Differential Equations
- General Classification
- Separation of Variable
- Integral Transformations

Random Processes
- Laws of Probability
- Distributions
- Stochastic Equations

Group Theory
- Basic Definitions
- Representation Theory
- SU(2), SU(3), and 0(3)

Applied Quantum Mechanics

PHYS 6201

Basic postulates of quantum mechanics

The harmonic oscillator

Identical Particles

Angular momentum & the hydrogen atom

Perturbation Theory

Fermi's Golden Rule

Quantum statistics

Applications

Applied Electromagnetism

PHYS 6202

Maxwell's Equations and the Poynting Theorem

Wave Propagation in a Conducting Medium, Wave Impedance

Skin Effect in Coaxial Systems

Telegraph Equations and Transmission Lines

Guided Waves, Wave Guides & Resonant Cavities

Radiation and Antennas

Refraction, Reflection & Transmission

Modulation and Demodulation

Solid State Physics

PHYS 6203

Crystal Structure

Cohesion and Vibrations

Band Theory

Theory of Metals

Theory of Semiconductors

Magnetism

Optical Properties

Superconductivity

Surface Physics

Mesoscopic Physics

Electronics I

PHYS 6204

AC and DC circuit theory

Rectifiers, power supplies, and filters

Active devices

Amplifiers, feedback, and oscillation

Multistage amplifiers a

Integrated circuits

Digital circuits

Electronics II

PHYS 6206

Transfer analysis

Transducers

Analog and digital filters

Fundamentals of Microprocessors

Analog to digital and digital to analog conversion

Measurement control by microprocessors

Computer interfacing

Condensed Matter Physics I

PHYS 6210

Structure and scattering

- Crystal Structure
- Reciprocal Space
- Diffraction
- Liquid Crystals
- Quasicrystals

Electronic Structure

- Bloch's Theorem
- Energy Bands
- Nearly Free Electron Model
- Tight-Binding Method
- Density Functional Theory
- Modern Electronic Structure Calculations
- Fermi Surface Effects

Transport Properties

- Semiclassical Model of Electron Dynamics
- Conduction in Metals

Lattice Dynamics

- Harmonic Crystals
- Phonons
- Dispersion Relations
- Anharmonic Effects
- Electron-Phonon Interaction

Response Functions

- Linear Response Theory
- Dielectric Function
- Plasmons, Polarons, Polaritons
- Optical Properties
- Energy Loss of Fast Particles in Solids

Condensed Matter Physics II

PHYS 6211

Second Quantization

Magnetism

- Classical Theory
- Quantum Theory of Free Atoms and Ions
- Crystal Field Effects
- Exchange Interactions
- Heisenberg Model
- Spin Waves
- Pauli Paramagnetism
- Landau Diamagnetism
- Ferromagnetism in Metals

Phase Transitions

- Mean Field Theory
- Critical Exponents, Universality, and Scaling
- Ising Model
- Renormalization Group Approach
- Magnetic Ordering

Superconductivity

- Summary of Superconducting Properties
- BCS Theory
- Ginzburg-Landau Theory
- Josephson Effect
- Type-II Superconductors and Vortices
- High Tmpurature Superconductors

Atomic Physics I

PHYS 6265

Review of Quantum Mechanics

Symmrtries, Bound States, and Resonances
Method of Approximations
Angular Momentum

Atoms and Ions

One Electron System
Many Electron System
Atomic Spectra

Interactions With Light

Photon Emission and Absorption
Photon-Ionization
Multiphoton Processes

Contemporary Topics in Atomic & Molecular Physics

Cooling and Trapping of Atoms
BEC
Atom Optics

Atomic Physics II

PHYS 6267

Kinematics of Collision Processes

Potential Scattering

The Integral Form for Potential Scattering

Semi-Classical Approximations

Variational Methods

Analytical Properties of Scattering Amplitudes

Identical Particle

Electron-Atom and Heavy Particle Collisions

Tim-Dependant Scattering

Graduate Laboratory

PHYS 6300

Classical Physics
- Deterministic Chaos
- Fiber Optics
- Microwaves

General Quantum Theory
- Photoelectric Effect
- Nuclear Magnetic Resonance

Solid State Physics
- Hall Effect and Magneto Resistance
- Temperature Dependence of Resistance
- Properties of Diodes
- Wave-Particle Duality
- Pockels Effect

Atomic Physics
- Atomic Structure
- Zeeman Effect
- Rutherford Scanning

Nuclear and Particle Physics
- Radioactivity and Muon Lifetime

Statistical Mechanics II

PHYS 7123

Brownian Motion and Diffusion

Onsager's Theory of Irreversible Processes

Boltzmann Equation

Hydrodynamic Fluctuations

Green-Kubo Formula

Quantum Relaxation

Applications

Gravity

PHYS 7125

General Covariance
- Tensor Algebra
- Tensor Calculus
- Affine Connections
- Curvature

Gravitational Dynamics
- Action Principle
- Stress Tensor

Weak Fields
- Gravitational Waves
- Gravitational Radiation

Strong Fields
- Black Holes
- Singularities
- Black Hole Thermodynamics
- Black Hole Radiation

Cosmology
- Isotropic Universes
- Big Bang

Spinor Methods
- Algebraic Classification

Many – Particle – Quantum Mechanics

PHYS 7141

Second Quantization
- Determinants and Permanents
- Operators

Exactly Solved Problems
- Non-Interactive Particles
- Coupled Harmonic Oscillators
- Delta Function Interactions

Hartree-Fock Theory
- Homogeneous Electron Gas
- Lipkin Model

Density Functional Theory
- Exact Results
- Local Density Approximation

Pairing Phenomena
- Seniority Model
- BCS Theory

Green Function Perturbation Theory
- Dyson Expansion
- Wick's Theorem
- Feynman Diagrams
- Linked-Cluster Theorem

Fermions
- Dyson and Bethe-Salpeter Equations
- Random Phase Approximation

Bosons
- Feynman-Bilj Theory
- Gross-Pitaevskii Equation

Path Integrals
- Coherent States
- Perturbation Theory
- Monte-Carlo Methods

Group Theory and Quantum Mechanics

PHYS 7143

Definition of a Group
- Finite and Infinite Groups
- Abelian and Non-Abelian Groups
- Subgroups, Cosets, and Conjugacy
- Group of Permutations

Representations by Matrices
- Schur's Lemmas and the Orthogonality Theorem
- Regular Representation
- Characters and Character Table Construction
- Irreducible Representations
- Applications to Quantum Numbers

Crystallographic Point Groups
- Crystal Field Splitting
- Selection Rules

Transformation Groups
- Time Translations and Time Reversal
- Space Translation and Parity
- Rotations and Clebsch-Gordon Coefficients
- Tensor Operators

Atomic Physics Applications
- Angular Momentum
- L-S Coupling
- Fine Structure and Hyperfine Structure

Molecular Physics Applications
- Molecular Orbitals
- Electronic Transition Selection Rules
- Vibrations and Normal Modes

Nuclear Physics Applications
- The Shell Model

Lorentz Group
- Rotations , Boosts and Spinor Representations: SU(2)

SU(n)
- Young Tableaux
- SU(3) and Quarks

Quantum Field Theory

PHYS 7147

Canonical Quantization

Dirac Equation

Feynman's Path Integral

Fermions and Bosons

Examples from Quantum Electrodynamics

Schwinger's Formulation

Quantum Logics

PHYS 7150

Classical Logics
Boolean Operations: OR, XOR, POR

Hilbert Space
Basic concepts: Spectral Resolutions

Quantum Logics
Grassman Algebras
Clifford Algebras
Interpretations as Logics

Classical Set Theory
Application to Classical Field Theory

Quantum Set Theory
Applications to Quantum Field Theory, Quantum Spacetime
Vacuum Structure

Quantum Dynamics
Action Principles

Quantum Computation

Quantum Optics I

PHYS 7222

Interaction of light with atoms
- Rabi oscillations
- Momentum transfer and light force

Quantization of the electromagnetic field
- Novel quantum states

Density Operators
- Master equations
- Optical Bloch equations.

Optical coherence

Continuous mode quantum optics

Resonance fluorescence

Amplification and attenuation of light

Nonlinear optics

Quantum Optics II

PHYS 7223

Quantization of interacting charges and field
Coulomb and multipolar gauges

Quantum Theory of Open Systems
Conditional quantum dynamics.

Interactions of light with matter

Nonclassical states of light and matter

Laser Cooling

Matter Wave phenomena and interferometry

Statistical Optics

PHYS 7221

Random Variables

Random Processes

First-Order Properties of Light

Partial Coherence

Light Scattering

Photoelectrical Detection and Photon Statistics

Nonlinear Dynamics

PHYS 7224

Preliminaries
- Phase Space
- Phase Portraits
- Existence and Uniqueness Theorems
- Numerical Integrations

Attractors and Instabilities
- Poincare-Bendixon Theorem
- Basins of Attraction

Bifurcation Theory
- Linear Stability Analysis
- Center Manifold Reduction
- Unfolding and Nonlinear Analysis
- Classification Scheme
- Codimension-Two Bifurcations

Attractor Reconstruction
- Time Series Analysis
- Power Spectra
- Delay Coordinate Embedding
- Dimension Calculations

Chaos and Universality
- Period Doubling Cascade
- Renormalization Group Analysis
- Symbolic Dynamics

Pattern Formation
- Ginzburg-Landau Equation
- Applications to Fluid Convection
- Applications to Laser Instabilities