New one-year Pre-doc Course Structure at IOP

To be implemented in August 2017

1 Introduction

Institute of Physics is conducting the Pre-doc courses in the existing format for around 20 years with some modifications as and when required. It is now felt that a major restructuring of the courses is necessary in view of the current research interests and student backgrounds.

The major modifications proposed are
(i) the switch over from three trimesters to two Semesters (Aug-Dec and Jan-June/July), and
(ii) several optional courses every semester, instead of making all courses compulsory.

2   Course structure

1 Semester-I (Aug-Dec) - 2 core courses+ 3 optional courses ($5 \times 6 = 30$ credits)

101 Advanced Quantum Mechanics (Core)

102 Quantum Field theory-I (Optional)

103 Advanced Statistical Mechanics (Optional)

104 Advanced classical field theory (Optional)

105 Many body Physics (Optional)

106 Soft Condensed matter Physics (Optional)

107 Advanced Experimental Techniques (Optional)

108 Experimental Physics - Lab course (Core)

2 Semester-II (Jan-June) - 1 core, 2 optional courses, 1 project ($3 \times 6 + 12 = 30$ credits)

201 Mathematical methods, Numerical Methods and Research methodology (Core)

202 Advanced Condensed Matter Physics (Optional)

203 Advanced Nuclear Physics (Optional)

204 Quantum Field theory II (Optional)

205 High Energy Physics (Optional)

206 Quantum information and computation (Optional)

207 Nonlinear dynamics and Chaos (Optional)

208 Special topics in Condensed Matter Physics (Optional)

209 Special topics in High Energy Physics (Optional)

210 Special topics in Mathematical Methods (Optional)

211 Special topics in Quantum Mechanics (Optional)

212 Special topics in Nuclear Physics (Optional)

213 Special topics in Statistical Physics (Optional)

214 Project (Core)

Project may be submitted and defended in July, A grand viva in July.
Total: 60 credits

3   Syllabus

101 Advanced Quantum Mechanics

Review of basics through problem solving

Schrödinger equation, Heisenberg Picture, Scattering problem in one dimension, Time-independent perturbation theory, Hydrogen atom, Born Approximation. Ladder operators and coherent states.

Time-dependent perturbation theory

Interaction picture, Time ordered perturbation theory, Fermis Golden rule, Floquet.

Relativistic Quantum Mechanics

Dirac Equation, Gamma matrices and Lorentz transformation of Dirac wave function, Positive and negative energy solutions and hole theory, Coupling to electromagnetic field, magnetic moment, Klein Paradox. Dirac equation for massless particles, Helicity. Majorana representation, Dirac equation in various space-time dimensions.

Path-integral formulation

Derivation of Path-Integral representation, Time-ordered correlators in path-integral formulation, coupling to electromagnetic field, Aharonov-Bohm effect, Double well potential in path-integral formulation, Instantons, Tunneling in path-integral formulation. Path-Integral in non-simply connected configuration space.

Geometric phase

Abelian and non-Abelian Berry phase. Some examples (According to the taste of the instructor), Aharonov-Bohm effect.

Discrete Symmetries

Wigners theorem, Translation, Rotation, Lorentz Transformation (Group), Parity, charge conjugation and Time-reversal. Kramers degeneracy.

Second quantization

Indistinguishable particles, Bose and Fermi statistics, Many-body quantum mechanics in the second quantized form, Electromagnetic field in the second quantized formalism, Light Atom interaction.

Books :
1) Sakurai - Modern Quantum Mechanics
2) Landau-Lifschitz - Quantum Mechanics (Non-relativistic theory)
3) Gottfried-Yan - Quantum Mechanics : Fundamentals
4) Feynman-Hibbs - Quantum Mechanics and Path Integrals
5) Sidney Coleman - Aspects of Symmetry, (Chapter : Uses of Instantons)

102 Quantum Field Theory-I

Canonical quantization of free field theory

Canonical quantization of free (complex) scalar field. Retarded, Advanced and Feynman propagator. Causality. Normal-ordering of operators. Concept of (connected) multi-point correlation function. Wicks theorem. Canonical quantization of free Dirac field. Feynman Propagator. Wicks theorem for Dirac field. Canonical quantization of electromagnetic field. Feynman Propagator. Casimir effect.

Interacting scalar field

Interacting scalar field : Perturbative evaluation of correlation functions. Time-ordered perturbation theory. Feynman Diagrams. Calculation of some tree-level amplitudes in phi-4 theory.

Path-integral quantization of scalar field theory

Derivation of Feynman propagator and Wicks theorem. Path-integral quantization of Maxwell theory. Grassmann numbers and Path-integral quantization of Dirac field. Path integral quantization of interacting scalar field theory : Generating functional of connected correlators and derivation of time-ordered perturbation theory.

S-matrix

LSZ reduction. Sample calculations of tree-level S-matrix.

Symmetries

Noether's theorem and Ward identity.

Miscellaneous topics

Wick rotation. Relation between d-dimensional QFT and (d + 1)-dimensional statistical mechanical system. Introduction to Wilsonian-RG and the concept of effective low energy field theory description.

   Books :
1) Peskin and Schroeder - An introduction quantum field theory
2) Ramond - Field theory : A modern primer .

103 Advanced Statistical Mechanics

Review of Thermodynamics and Statistical mechanics by problem solving

a) Quick review of Basic postulates, potentials, Legendre transformation
b) Basics of Statistical Mechanics: random walk/Probability, Basics of ensembles , Quantum statistics

Dynamics

Boltzmann H theorem, its use for transport properties Master equation, Langevin Equation, Fokker Planck equation Simple discussions on Detailed balance, fluctuation-dissipation theorem, Onsager relations, Work theorem, Basics of Monte Carlo

Classical Interacting systems

Phase equilibrium, chemical equilibrium, Saha ionization; variational principle, Debye-Huckel theory; Van der Waals, Virial expansion; equilibrium curves, phase diagrams

Phase transitions and critical phenomena

First order,continuous transitions; Ising and $O(n)$ models; mean field theory; symmetry breaking, Order parameter; Landau theory (scalar and vector order parameter), Tricritical point, Alexander-McTauge theory; Gaussian model, Ginzburg criterion. Scaling near critical point.

Quantum systems

Bosons: Details of Bose condensation of an ideal gas and in a harmonic trap Fermions: Chandrasekhar limit, Pauli paramagnetism, Landau diamagnetism, de Haas-van Alphen effect

Books:
1. F. Reif - Fundamentals of Statistical and thermal physics
2. K. Huang - Statistical Mechanics 2nd ed
3. Chaikin-Lubenskly - Principles of condensed matter physics
Other books by (a) Pathria, (b) J K Bhattacharjee, (c) Riechl, (d) S.K.Ma, (e) Newman-Barkema

104 Advanced Classical Field Theory

Selected topics from the list

Review of Basics Classical Electrodynamics

Vector analysis, Electrostatics Boundary-value Problems, Magnetostatics, Electric and Magnetic Fields in matter, Maxwell's Equations, Electromagnetic waves, Retarded Potentials, Relativistic Formulation

Classical Electrodynamics

Covariant formulation, Dynamics of relativistic particles in electromagnetic fields, Field and radiation from oscillating sources, Scattering and Diffraction, Wave-guides, Radiation by moving charges, Bremsstrahlung, Cherenkov radiation, etc

General Relativity

Principles of equivalence and general covariance, curvilinear coordinates, affine connection, covariant derivatives, metric, curvature tensors, geodesic equations, Einstein equation, Schwarzschild solutions, black holes, tests of general relativity, big bang theory

Hydrodynamics

Conservation laws and hydrodynamic description; Navier-Stokes equation for simple fluids; hydrodynamic description of ferro and antiferro magnets.

Field theory, Symmetry and Symmetry breaking

Landau-Ginzburg theory, order parameter, mean field theory, fluctuations Goldstone theorem, topological defects, solitons in different theories, nonlinear equations, Abelian Higgs model

Continuum Mechanics

General stress tensor, strain tensor, continuum limit, Hooke's law, Elastic distortions, models for elastic solids, liquid crystals, phonons in continuum

Books :
1) J. D. Jackson - Classical Electrodynamics
2) L. D. Landau and E. M. Lifshitz - The Classical Field Theory
3) S. Carroll - Space-time and Geometry
4) R. Rajaraman - Solitons and Instantons
5) P. M. Chaikin and T. C. Lubensky, "Principles of condensed matter physics"

105 Many Body Physics

Preliminaries

a) First and Second Quantization: Quantum Mechanics with many particles; b) First quantization, many particle systems; Operators in first quantization; c) Second quantization, basic concepts The occupation number representation; d) The general form for second quantization operators; Basis change in second quantization; Examples -Operators for kinetic energy, spin, density, and current; The Coulomb interaction in second quantization.

Mean Field Theories

a) Non-interacting many particle system vs interacting many particle system. Examples; b) Concepts of mean field approximation. Idea of broken symmetry; c) Hartree-Fock approximation, Thomas Fermi approximation.; d) Hohenberg-Kohn Theorem: Self-consistent Kohn-Sham Hartree-like theory for exact ground state energy and density of electrons; potential for alternative path to include many-electron effects; e) Application: i) model of ferromagnets, Stoner model of metallic ferromagnets , ii) application to BCS theory of superconductivity, iii) application to nuclear physics. f)Short discussion on the limitations of meanfield theories.

Method of Green functions

a) Single-particle Greens functions of many-body systems: meaning and significance; Greens function of free electrons; The Lehmann representation; The spectral function; Broadening of the spectral function due to interactions; Measuring the single-particle spectral function – spectroscopy; Two-particle correlation functions of many-body systems. b)Linear response

theory and Kubo formalism for response function. c)Imaginary time Greens functions: Matsubara Greens functions; Connection between Matsubara and retarded and advanced Green's functions; Examples: Single-particle Matsubara Greens function; Evaluation of Matsubara sums .Equation of motion for Matsubara Greens functions; Wicks theorem and example of polarizability of free electrons. d) Feynman diagrams and Dyson series e) Application: i) Random impurities in disordered metals. ii) Anderson model for magnetic impurities iii) Random phase approximation for interacting electron system. iv) Application to interacting phonons(i.e beyond the Einstein model of lattice vibrations)

Renormalization Group method

a) Basic concepts; b) Wilsonian Renormalization Group c) Perturbative Renormalization Group d) Functional(or Exact) Renormalization Group method e) Applications.

Books:
1. Many-body quantum theory in Condensed Matter Physics - Karsten Flensberg and Henrik Bruus
2. Condensed Matter Field Theory - Alexander Altland and Ben Simons
3. Introduction to Many Body Physics - Piers Coleman
4. Green functions for solid state physicist - S. Doniach and E. H. Sondheimer
5. Quantum Theory of Many-Particle system - Alexander L fetter and J d Walecka
6. Renormalization methods - W. D. McComb
7. Electronic Structure Calculations for Solids and Molecules-Theory and Computational Methods by Jorge Kohanoff

106 Soft Condensed matter Physics

Selection of topics from the list

Basic introduction

Structure, scattering and correlation functions
    various structures and scattering: ordered systems, liquids (classical and quantum), polymers, fractals, glasses. Effective forces: van der Waals to various time-temperature dependent forces

Liquid crystals, Polymers, and glass

1) Liquid crystals and colloids: models, phases, and phase diagrams
2) Polymers: Gaussian (ideal), self-avoiding, semiflexible polymer; scaling and its use; theta point; solutions and melts; topological effects; Response functions (elastic, viscoelastic behaviour); Dynamics: single and many chain;
3) Gels, rubber, percolation.
4) Introduction to glass transition

Generalized elasticity

XY model, Liquid crystals, crystals;

Hydrodynamic description

Conserved quantities, broken symmetry variables, dynamics near phase transitions (critical dynamics, nucleation, spinodal decomposition, phase ordering)

Topological and geometrical problems

topological defects in ordered systems like liquid crystals Elementary analysis of BKT transition; Fluctuating surfaces, topological invariants

Books:
1. Chaikin-Lubensky: Principles of condensed matter physics
2. Doi-Edwards, Polymer dynamics
3. M Doi, Soft matter physics
4. Richard A. L. Jones, Soft Condensed Matter
Review Articles:
1. Gary L Hunter and Eric R Weeks: The physics of the colloidal glass transition Rep. Prog. Phys. 75 (2012) 066501
2. Daan Frenkel, Soft condensed matter, Physica A, Volume 313, Issues 12, 1 October 2002
3. A. Bray, Theory of Phase ordering kinetics, Adv.Phys. 43,357 (1994)
4.R. D. Kamien, Rev Mod Phys. 84, 497 (2012)

107 Advanced experimental Techniques

Introduction to material science from bulk to nano to thin films. A multidisciplinary approach to structure-property relation and overview of few advanced experimental techniques to explore them.This course involves theory and visits to various experimental facilities toprovide first hand experience.

Crystallography

X-ray Diffraction and scattering, X-ray reflection from interfaces and multilayers, Neutron scattering

Optical spectroscopy

Raman spectroscopy, Photoluminescence spectroscopy, Infrared spectroscopy

Electron spectroscopy

Reveling the electronic structure via. Synchrotron radiation, Angle integrated and angle resolved Photoemission spectroscopy, X-ray absorption spectroscopy (XAS)

Ion spectroscopy

Introduction to particle accelerator, Ion Implantation, Rutherford back scattering (RBS), particle induced x-ray emission (PIXE)

Nuclear spectroscopy

Basic principles of Resonance spectroscopy and its application: Nuclear magnetic resonance spectroscopy(NMR), electron spin resonance (ESR), muon spin spectroscopy (μSR)

Surface Science

Growth of thin films and characterization by Scanning tunneling spectroscopy (STM), Atomic force microscopy (AFM), Low energy electron diffraction (LEED),transmission electron microscopy (TEM) scanning electron microscopy (SEM)

Transport measurements

Understanding magnetic and electronic transport measurements throughSQUID-VSM magnetometer, 4 probe resistivity.

108 Experimental Physics: Lab course

5 experiments to be done.

1. Nuclear Radiation Detectors: Semiconductor/gas/scintillation/particle detectors. Their calibrations, identifying unknown source, Identification of spectral features, Attenuation and other experiments,Charged particle spectroscopy,

2. Vacuum Techniques: Working with vacuum pumps,Pressure and flow measurements, leak detection

3. Workshop training: using lathe machine for making holes, cutting, casting, drawings.

4. Transport measurements:Temperature dependence of resistivity,Hall effect, Band gap determination

5. Surface science experiments:Thin film deposition,Investigating surface atomic structure, Scanning tunneling spectroscopy, Scanning electron microscopy.

6. Electronic experiments,Solvingdifferential equations using Op Amps,Digital electronics using OP Amps, timer etc., Analog to digital conversion &vice versa

7. Experimental control through computers

8. X-ray investigation of crystal structure/Laue method

9. Muon life time measurements.

10. Possible innovative experiment

201 Mathematical Methods, Numerical Methods and Research Methodology

Topics to be chosen as per interest:
Part-I: Mathematical Methods

Review (Problem solving)

Contour integration, analytic continuation, asymptotic expansion, branch cuts and Riemann surfaces, ODE/Special functions/integral representation,distributions (generalized functions)

Integral equations, Partial differential equations

Classification of Integral equations: Fredholm (1st, 2nd kind), Volterra; Method of solution in special cases, including Wiener-Hopf method, Numerical methods; Ill-posed problems and regularization. Partial differential equations (beyond what is done in other physics courses): First and second order equations: Classification (hyperbolic, elliptic and parabolic), method of solutions, special equations like KdV, KPZ, Navier-Stokes and others.

Ref: M. Stone and P. Goldbart, Mathematics for Physics; Arfken;

Group theory

Introduction to Groups, representations, Lie groups; Applications in quantum mechanics, crystal symmetry, solid state physics.
Ref: Books By A. W. Joshi, M. Tinkham

Probability theory, measure theory and Lebesgue integration

Introduction to probability and statistics; Introduction to measure theory and probability as a measure; Integration - Lebesgue- Stieltjes, Lebsgue integrals; Discrete and continuous random variables; Various standard distributions; transformations of probability distributions; Characteristic functions; Law of large number, Tchebyshebv's inequality, central limit theorem, stable laws, large deviation theory; Bayesian inference;
Ref: P. Halmos: Measure theory; Feller: Probability theory and applications;
For Bayesian inference: Udo von Toussaint, Bayesian inference in physics, Rev. Mod. Phys. 83, 943 (2011).

Introduction to topology

Basic notions of topological space, fundamental and homotopic groups, homology and cohomology; Application in physics, like configuration and phase spaces, path integrals in QM, defects, textures, instantons, etc.
Ref: Nash and Sen, Topology for physicists; Nakahara: Geometry, topology and physics.

Part-II: Numerical Methods

1. Introduction to computer languages:
   (Fortran/C/C++/python etc..) Representation of numbers, Numerical precision and estimation of errors.

2. Numerical Interpolation and extrapolations

3. Sorting and searching

4. Linear Algebra, eigenvalue and eigenvectors

5. Root finding algorithms: Bisection method, Newton-Raphsons method, The Secant Method

6. Numerical Integration, Quadratures

7. Numerical solution to Ordinary and Partial differential equations

8. Random number generation, Monte Carlo Simulation

9. Data fitting, chi-square fitting, goodness of fit test, Kolmogorov-Smirnov test

Part-III : Research Methodology Article writing, communication skills, seminar presentation, review of research papers.

202 Advanced Condensed Matter Physics

Selection of topics

The Electron Gas and Liquid

a) The electron gas, Hartree-Fock, The fermi liquid and Landau Parameters, The Random phase approximations, strong interaction (Wigner crystals) b) Non fermi liquid c) interactions in the presence of lattice (Mott insulators) d) Electron-Phonon interaction.

Reduced Dimensionality

a) Quantum Dots, b) The special case of 1D, the Landauer formalism for transport, c) interactions in 1D: Luttinger liquids d) The 2D electron gas, the quantum Hall effect (integer and fractional) e) introduction to topological insulators.

Physics of Disordered System

a) Anderson localization, b) Weak localization, c) Hopping transport, d) The metal insulator transition e) interactions in the presence of disorder, f) many body localization.

Superconductivity

a) Preliminaries, conventional vs unconventional superconductivity. b) Microscopics of BCS theories, gauge symmetry breaking, Josephson effect. c) High temperature superconductivity, Cuprate and Pnictides superconductivity, introduction to simple models of High Tc superconductivity. d) distinction between s-wave, p-wave, d-wave superconductivity. e) heavy fermionic superconductivity.

Magnetism

a) Basics, b) Ferromagnetism and Anti ferromagnetism, spin waves. c) Stoner model, t-J Model d) Introduction to frustrated magnetism, e) Local moments, the Kondo effects and RKKY interactions. f) Introduction to heavy Fermionic system, the Kondo lattice.

Books:

1. Karsten Flensberg and Henrik Bruus, Many-body quantum theory in Condensed Matter Physics
2. Philip Philips, Advanced Solid State Physics
3. Majlis, The quantum theory of Magnetism
4. Michael P Murder, Condensed Matter Physics
5. G Mahan, Many Particle Physics
6. P de Gennes, Superconductivity in metal and Alloys
7. D Pines, Elementary Excitations in Solids
8. A. C Hewson, The Kondo Problem to heavy fermions

203 Nuclear Physics

Nuclear Physics General

NN interaction: symmetries, basics, low energy scattering and shape independence, meson theory and properties of NN interaction, Nuclear systematics: masses, radii, shapes, magnetic and quadrupole moments, shell structure, radioactivity, fission, halo nuclei.

Nuclear models

Liquid drop model, semi empirical mass formula, Fermi gas model, Basics of shell model, Hartree- Fock, pairing, Relativistic mean field formalism for finite and infinite nuclear many-body problem (intro.) rotational and vibrational spectra, giant resonances.

Nuclear reactions

Resonances and compound nucleus, direct reactions (inelastic, stripping, pickup etc.), extracting nuclear information from reactions.

Nuclear matter

Nuclear equation of state (Relativistic and Non-relativistic Formalisms), neutron stars, Quark models, quark equation of state, relativistic heavy ion collisions, signature of QGP,

Big bang and QCD phase transition, hadron and quark, phase transition in neutron stars.

Books :
1. W. Greiner and J. Eisenberg - Nuclear Models, Vol. I, II and III
2. A. Bohr and B. R. Mottelson - Nuclear Structure, Vol I and II
3. Blatt and Weisskopf - Theoretical Nuclear Physics
4. M. A. Preston and R.K. Bhaduri - Structure of Nucleus
5. B. Muller - Physics of Quark Gluon Plasma
6. Cheuk-Yin Wong - Introduction to High-Energy Heavy-Ion Collision

204 Quantum Field Theory - II

A selection of topics from the following list.

Loop calculations in scalar field theory

One-loop calculation of 2 and 4-point functions in interacting scalar field theory, Regularization and Renormalization, Renormalization group equation and beta function, Anomalous dimension, Renormalization of composite operators.

Renormalization group flow

Solution of Callan-Symanzik equation, Classification of fixed points, Multiple couplings and linearized RG-flow in the neighborhood of a fixed point, Various types of asymptotic behavior of QFT, Wilson-Fisher fixed point and introduction to ϵ-expansion in large-N vector model.

Non-Abelian gauge theory

Non-Abelian gauge theory, Path-Integral quantization of Non-Abelian gauge theories, BRST symmetry, One loop beta function of non-Abelian gauge theory and asymptotic freedom, Introduction to Wilson loop and confinement .

Effective action and global symmetry breaking

1PI effective action and Coleman-Weinberg potential, Spontaneous global symmetry breaking using 1PI effective potential, Goldstone Boson.

Gauge symmetry breaking

Spontaneous breaking of gauge symmetry and Higgs mechanism.

Anomalies

Introduction to anomalies in QFT.

Finite temperature field theory

Introduction to finite temperature field theory, Coleman-Weinberg effective potential at finite temperature, Symmetry restoration at high temperature.

Miscellaneous topics

Non-Perturbative techniques in field theory. Solitons and Instantons in field theory.

Books :
1) Peskin and Schroeder - An introduction quantum field theory
2) Ramond- Field theory - A modern primer
3) Matthew Schwartz - Quantum field theory and the standard model
4) Weinberg- The quantum theory of fields, Vol-1 and Vol-2.
5) Sidney Coleman - Aspects of symmetry

205 High Energy Physics

A selection of topics from the following list.

Introduction

Broad preview and overview, a bit of discussion of history and current status, basic ingredients of modern theories, colliders and detectors, LHC and main detectors

Symmetries and Lie Groups

Quantum numbers, conservation laws, discrete and continuous symmetries, Lie groups and algebras, SU(n) and SO(n) groups and representations, Young Tableau, hadron spectroscopy, eight-fold way, quark model

S-Matrix, Cross section and Decay rates

General discussion, relativistic kinematics, phase space, basic formulas for $2 \rightarrow 2$ scattering and decays into 2 or 3 particles, Feynman rules

Gauge Theories and Spontaneous symmetry breaking

Construction of gauge theories, discrete symmetry breaking, breaking of global and local continuous symmetries, Goldstone and Higgs phenomena

Electromagnetic Interactions

Quantum Electrodynamics, Simple processes like Moller Scattering, Bhabha Scattering, Compton scattering, pair annihilation

Weak Interaction

Fermi theory, V-A theory, C, P and CP violation, muon decay, pion, kaon and B/D-mesons decay, neutrino-electron, neutrino-muon, and neutrino-quark scattering, IVB theory, problems

Strong Interaction

Deep-inelastic scattering and structure of hadrons, Bjorken scaling, Quark-parton model, sum rules, scaling violation, splitting functions, DGLAP equation, $e^- e^+ \rightarrow$ hadrons, basic $2 \rightarrow 2$ processes involving quarks and gluons, glimpse of helicity methods

Standard Model

Motivation for $SU_c(3) \otimes SU_L(2) \otimes U_Y(1)$ symmetry and its breaking, construction of the action, masses of vector bosons and fermions, CKM matrix and CP violation

Basic processes in the Standard Model

W/Z boson decays, heavy quark production, neutral-current processes, basic Higgs boson production and decays

Beyond Standard Model Scenarios

Neutrino oscillations and neutrino mass, standard model shortcomings, effective field theories, anomalous interactions, GUTs, supersymmetry, large extra dimension, etc

    Books :
1) F. Halzen and A. D. Martin - Quarks and Leptons
2) T-P Cheng and L-F li - Gauge Theory of Elementary Particle Physics
3) V. D. Barger and R. J. N. Phillips - Collider Physics
4) V. Barger, D. Marfatia, and K. Whisnant - The Physics of Neutrinos

206 Introduction to Quantum Information

A selection of topics from the following list.

Quantum Mechanics Formalism

Postulates, density matrix, generalized measurements, qubits, no-cloning theorem

Composite Systems

Entangled states, partial trace, Schmidt decomposition, purification

Quantum Entanglement

Detection and quantification of entanglement in bipartite and multipartite systems, monotones, majorization

Quantum Operations

quantum channels, Kraus representation, quantum noise, master equations, tomography

Quantum Nonlocality

EPR paradox, Bell inequality, CHSH inequality, Tsirelson bound, PR box, steering, quantum games

Quantum Communication

superdense coding, teleportation, entanglement swapping, secret sharing

Quantum Cryptography

One-time pad, BB84, B92, Ekert protocols

Quantum Algorithms

Universal quantum gates, Deutsch algorithm, Deutsch-Jozsa algorithms, Quantum Fourier transform

    Books :
1) M. A. Nielsen and I. L. Chuang - Quantum Computation and Quantum Information

2) J. Preskill - Lecture notes on Quantum Information Theory, Online at Caltech Website
3) M. M. Wilde - Quantum Information Theory
4) A. Peres - Quantum Theory: Concepts and Methods

207 Non-Linear dynamics and Chaos

Introduction

One and two dimensional systems

Fixed points, bifurcation, limit cycles; phase plane analysis; Topological analysis

Interacting systems

Predator-Prey model/Lotka-Volterra system

Specific systems

(one or more of the following)
Enzyme Kinetics (Michaelis-Menten equation)
Neuron dynamics (Hodgkin-Huxley and FitzHugh-Nagumo models)
Kinematic waves (Belousov-Zabotinski reaction, traffic flow, Singular perturbation/shocks)
Travelling waves (Fisher-Kolmogorov problem, kdV equation)
noisy problems (Edwards-Wilkinson/KPZ problem of surface growth)

Chaos

Lyapunov exponent, Lorentz equation, Logistic map, fractals

Turbulrnce

Elementary introduction to Kolmogorov scaling.

Books :
1. S. Strogatz: Nonlinear dynamics and Chaos
2. J. Murray: Mathematical Biology I, II
3. J. K. Bhattacharjee -Staticial Physics

208-213: Special Topics

These are special courses as per research requirements, may even be research level topics not covered in other courses or topics of current interest.

214 Project (core)

Each student has to do a project (equivalent to 2 courses) and defend it at the end of the semester.