DEPARTMENT OF PHYSICS
UNIVERSITY OF THE PUNJAB
COURSES FOR M.Phil/PhD Programme

Phys 501 ADVANCED MATHEMATICAL PHYSICS (CR3)

Nonlinear ordinary differential equations, Bernoulli's equation, Riccati equation, Lane-Emden equation, Nonlinear Pendulum, Duffing's equation, Pinney's equation, Perturbation theory, Bogoliubov- Krilov method.
Linear partial differential equations, classification, initial and boundary values problems, Fourier analysis, Heat equation, Wave equation, Laplace equation etc.
Integral equations, classification, integral transform separable kernels, singular integral equations, Wiener-Hopf equations, Fredholm theory, series solutions.
Variational methods, The Euler-Lagrange equations, Solutions to some famous problems, Sturm-Liouville Problem and variational principles, Rayleigh-Ritz Methods for partial differential equations.
Matrix algebra, method of Faddeev, Caley-Hamilton' theorem, functions of matrices. Functions of matrices, Kronecker and Tensor products, special matrices.

Recommended Books :

1. *Advanced Mathematical Methods for Engineering and Science Students by G. Stephenson and P. M. Radmore, Cambridge University Press, 1990.*
2. *Mathematical Methods for Physics and Engineering by K.F. Riley, P.M. Hobson, S.J.Bence, CUP, 2006.*
3. *Mathematical Methods for Engineers and Scientists Volume 1.2.3., by K.T. Tang, Springer, 2007.*
4. *Mathematics for Physics by M.Stone, P.Goldbart, CUP, 2009.*
5. *Mathematical method for Physicists by G.B. Arfken, H.J. Weber, Academic Press, 2005.*

Phys 502 EXPERIMENTAL TECHNIQUES IN PHYSICS (CR3)

Introduction – Characterization of Solid Materials:
Bulk characterization, Surface Characterization, Interface Characterization
Requirements of Characterization
Ambient Requirements, Kinetic Theory Concepts, Vacuum Concepts, Sample Preparation
Vacuum Technology:
Production of Vacuum (pumps), Measurement of Vacuum (gauges)
Information Carriers:
Electrons and Ions as Information Carriers, Production of Electrons & Ions
Electron Emission:
Theory of Secondary Electron Emission, Energy Distribution of the Secondaries, Secondary Electron Yield, Yield Measurement Methods – Manual Method, Automatic Method
Electron Energy Analyzers:
Ideal Analyzer, Magnetic Analyzers, Retarding Field Analyzer, Sector Analyzer, Cylindrical Mirror Analyzer
Electron & X-Ray Sources:
Auger Electron Spectroscopy:
Auger Electron Emission, Notation, Depth Profiling & Interface Analysis
Applications of Aes:
Fundamental Interface Studies, Materials Science, Catalysts, Electronics
XPS & UPS:
Introduction, Shapes & Shifts, Ahemical Analysis
LEED & RHEED:
Optical and Electron Microscopy:

Optical Microscopy, Scanning Electron Microscopy, Transmission Electron Microscopy, Scanning Transmission Electron Microscopy

Scanning Probe Microscopy:

Atomic Force Microscopy, Scanning Tunnelling Microscopy, Magnetic Force Microscopy

DLTS:

X-Ray Diffraction:

Production & Properties of X-rays, Diffraction of X-rays, Experimental Methods, Determination of Crystal Structure.

Books Recommended:

1. *Vacuum Deposition, byL. Holland, Chapman & Hall Ltd., London, 1970*
2. *Handbook of Thin Film Technology, by L. Maissel & R. Glang, Higher Education, 1970*
3. *Handbook of Vacuum Physics Vol. 2, by A.H. Beck, Pergamon Press, 1966*
4. *Characterization of Solid Surfaces, by P.F. Kane and G.B. Larrabee, Plenum Press, N.Y. 1974*
5. *Methods of Surface Analysis, by J.M. Walls, Cambridge University Press, Cambridge, 1988*
6. *Auger Microprobe Analysis, by I. Ferguson, Adam Hilger, Bristol, 1989*
7. *Practical Surface Analysis, by Auger and X-ray Photoelectron Spectroscopy, by D. Briggs and M.P. Seah, John Wiley & Sons, 1983*
8. *Elements of X-ray Diffraction, B.D. Cullity & S.R. Stock, Prentice Hall, 2003*
9. *Interpretation of X-ray Powder Diffraction Patterns, by H. Lipson and H. Steeple, Macmillan, 1970*
10. *Essentials of Crystallography, by D. Mckie and C. Mckie, Blackwell Scientific Publications, 1986*

Phys 503 NONLINEAR PHYSICS (CR3)

NonLinearity and Non Linear Effects,Superposition principle, Harmonic and anharmonic oscillators, Pendulum, Phase Portrait, Harmonic balance method, Frequency shifts, Background modification, Driven damped Duffing oscillator, Non Linear Resonance, Determinstic Chaos, Logistic Map, Fixed Points and Stability of 1-D maps, Transients and Attractors, Period Doubling, Butterfly Effect(SIC), Bifurcation Diagram, Universality, Feigenbaum numbers, Self Similarity, Lyapunov Exponent, Maps and Flows, Phase Space , Rayleigh Bernard convection and Lorenz model, Dynamical flows, Fixed points and stability, Dissipative and Conservative systems, Autonomous and non autonomous systems, Strange attractor, Fractal character, Fractals, Hausdorff dimension, Bifurcation diagram, Periodic and Chaotic behavior, Wave Equation and Dispersion Relation, Dispersive Waves, Types of Linear waves, Superposition principle, Carrier wave and wave modulation,Amplitude dependent phase velocity and NonLinear effects, Solitary waves, Dispersion and NonLinearity, Experimental observation, KdV equation, solitary wave solution, FPU recurrence, Soliton collisional property, Evolution of arbitrary pulse Soliton amplitude, speed and width,Reductive Perturbation method, Envelope and carrier wave Nonlinear Schrodinger equation, Solitary wave solution, Communications, Optical Fibres and Optical Solitons, Attenuation, Dispersion and NonLinearity parameters.

Books Recommended:

1. *Chaos and Non Linear Dynamics, Hilborn, Oxford University Press (1994)*
2. *Deterministic Chaos, Schuster, Physik Verlag (1984)*
3. *Fundamental of Optoelectronics, Pollock Irwin (1995)*
4. *Nonlinear dynamics and chaos, Thompson & Stewart, Wiley (1986)*
5. *Nonlinear science: the Challenge of complex systems, by Z.Yashida, springer (2010).*

Phys 504 MICROELECTRONICS AND SEMICONDUCTOR DEVICES(CR3)

Semiconductor Material and Device Fabrication:
Silicon and other semiconductors as device materials; Effect on carrier lifetime and mobility; bulk crystal growth; effect of segration coefficient, GaAs crystal growth techniques, crystal characterization, epitaxial growth, with molecular beam epitaxy and multiplayer structures, defects in epitaxial layers. Active regions; Dopants and their limits of solubility; diffusion doping, thermal oxidation, dielectric and polysilicon deposition, metallization, wet and dry etching, optical and next-generation lithographic methods, Schottky and ohmic contacts; Process modeling: SUPREM and MicroTec; SIA 'roadmap'.
Devices and Circuits:
FET devices and theory; MOSFET; MOS capacitor, accumulation, depletion and inversion modes, enhancement and depletion modes of operation; n-and p-channel devices; I-V operating relations in active and saturation regions, threshold voltage, NMOS and CMOS inverters, gates and flip-flops, implication for performance of scaling down device size, GaAs FET; principle of operation, linear and saturation characteristics, GaAs FET physical and impirical modeling.
Non-ideal effects in Devices:
Deep level effects; Electronic transitions probabilities, deep states, principal of conventional DLTS, determination of deep traps parameters, Noise performance; sources of noise, low frequency g-r noise, output conductance and transconductance dispersion in devices.
Alternative Device Structures:
Heterostructures HEMTs and HBTs, thyristor and related power devices, Devices and applications, nanostructures devices.

Books Recommended:

1. *MOSFET Theory and Design, Warner RM and Grung B L (OUP 1999).*
2. *Physics of Semiconductor Devices by S. M. Sze, Pub. John Wiley & Sons 1981.*
3. *Fundamentals of Modern VLSI Devices, Taur Y and Ning T H (CUP 1998).*
4. *Physics of Semiconductor Devices by S. M. Sze, Pub. John Wiley & Sons, 2nd Edition, 1981.*
5. *Semiconductor Devices, Physics and Technology, by S. M. Sze, Pub. John Wiley & Sons*
   2nd Edition, 2002.

Phys 505 SELECTED TOPICS IN THEORETICAL PHYSICS (CR3)

Conformal Field Theory

Conformal transformations, finite conformal transformations, intinitesimal confromal transformations, conformal group, conformal transformation of quantum fields, theory in dimensions greater than two.

Two dimensional conformal field theory, Lie algebra of conformal group, energy-momentum tensor in two dimensions, Virasoro algebra and representations, free scalar field theory, free spinor field theory, Kac-Moody algebra and representations.

Books Recommended:

1. *Conformal Field Theory* by P.Di Francesco, P. Mathieu and D.Senechal Springer-Verlag, Heidelberg, 1997
2. *Conformal Field Theory* by S. Ketov World Scientific, Singapore, 1997.

Phys 506 THEORY OF CONDENSED MATTER (CR3)

Electronic Structure of Solids, Independent particles in periodic potential, Bolch's theorem, nearly free electron and tight binding methods, Pseudopotentials, density functional theory, Metals, Density of states, Fermi surfaces, exchange and correlation in the electron gas, screening, Insulators and Semiconductors, Ionic and covalent bonding, real and momentum space description, electronic structure of simple semiconductors.
Solids in External magnetic field, Pauli-paramagnetism of conduction electrons, Landau-diamagnetism of conduction electrons, De Haas-van Alphen effect, the quantum Hall effect. Optical Processes and Excitons:, ptical Reflectance, Kramer-Kronig relation, excitons, Frenkel excitons, Mott-Wannier excitons, Raman effect in crystals.
Collective Quantum Phenomena in Condensed Matter, Collective modes, Correlation functions and response functions, response of independent electron gas, electron-phonon interaction, Ginzburg-Landau theory of phase transition, polarons, metal-insulator transitions, Wigner crystal, superconductivity, pairing and elementary BCS theory, Josephson effect.

Books Recommended:

1. *Solid State Physics, by Ashcroft and Mermin, Brooks Cole, (1976).*
2. *Introduction to Solid State Physics, by C. Kittel, Wiley,87th Edition, (1996).*
3. *Principles of the Theory of Solids, by J. M. Ziman,CUP (1972).*
4. *Solid State Physics Grasso, G. Parravicini, Gp, (AP 2000)*
5. *The Physics and Chemistry of Solids, by Elliott, SR, Wiley, (1998).*
6. *Advanced condensed Matter physics, by L.M. Sander, CUP (2009).*
7. *Order within Chaos, Berge, Pomeau & Vidal, Wiley(1994)*
8. *Solitons and Non Linear Wave Equations, Dodd et al, Academic Press (1982)*
9. *Solving Equations with physical understanding Acton & Squire Adam Hilger (1985)*
10. *Waves called Solitons, Remoisssenet, Springer Verlag (1994)*

Phys 507 RELATIVISTIC QUANTUM MECHANICS (CR3)

Review of quantum mechanics and special relativity; Lorentz transformations; relativistic wave equations: Spinless particles: The Klein-Gordon equation. Spin-1/2 particles: The Dirac equation; its covariant form. Conserved current. Dirac and Feynman interpretations of the negative energy solutions; gamma matrices and their properties; spin and magnetic moment of a Dirac particle; plane-wave solutions of the Dirac equation; orthonormalization conditions for the Dirac solutions; energy and spin projection operators for the Dirac spinors; Dirac equation for a particle of zero rest mass; two component theory; behaviour of the Dirac equation under Lorentz transformations with special reference to parity; Dirac's bilinear covariants; Dirac and Majorana particles.

Books Recommended:

1. *Classical Theory of Fields, Ellis Horwood, 1992.*
2. *F. Halzen and A. D. Martin, Quarks and Leptons, John Wiley and Sons, 1984.*
3. *Greiner, Relativistic Quantum Mechanics, Springer, 1995.*
4. *H. Muirhead, The Physics of Elementary Particles, Pergamen Press, 1965.*
5. *H.M.Pilkuhn, Relativistic Quantum Mechanics, Springer, 2005.*
6. *J. R. Aitchison and A. J. G. Hey, Gauge Theories in Particle Physics, Adam Hilger, 1989.*
7. *J. D. Bjorken and S. D. Drell, Relativistic Quantum Mechanics, McGraw Hill, 1964.*

Phys 508 GROUP THEORY (CR3)

Elementary concepts, Symmetric and alternating groups of finite degree, Order of a permutation. Orbits of the sysmmetirc and alternating groups, Stabilizer subgroups and transitive groups. Free products of groups. Group amalgams and their embeddability in groups, Generalized free product of groups, Permutational product of groups, Cartesian product of groups, Wreath product of groups, Multiplicative group of a finite field, Projective line over finite fields, projective and linear groups through action.

Books Recommended:

1. *Kochendorffer. R. Group Theory (MeGraw Hill London, 1970).*
2. *.Coxeter, H.S.M. and Moser. W.O. Generators and Relations for Discrete Groups (Springer Verlag, New York, 1984).*
3. *Rose, I.S. Course in Group Theory (Cambridge Univ. Press. 1978).*
4. *Magnus, W.Karrass. A. and Solitar. D.: Combinatorial Group Theory (Interscience, New York, 1969)*
5. *Johnson, D.I.: Topics in the Theory of Group Presentations (Cambridge Univ. Press, 1980).*

Phys 509 ADVANCED COMPUTATIONAL PHYSICS (CR3)

Mathematica /MATLAB Introduction, *Mathematica* /MATLAB Basics, Getting Help, Basic calculations, *Mathematica* /MATLAB Programming Introduction, Factorial Example, Functional Programming, Pattern Matching & Replacement Rules, Association, Simple Programming, Blocks and Modules, Computational Tasks
Introduction to data analysis, Data distribution, Different techniques for data representation and plotting.
Introduction to problem solving techniques in Physics, Visualization of problems by graphical presentations. Problem solving methods e.g., Schrodinger Equation, Shooting Method, Energy Eigenvalues and Eigenfunctions, Perturbation Theory
Variational Method, Matrix Methods, Quantum Well applications, Deterministic Simulations, Diffusion
Monte Carlo Simulations, Percolation Theory, Disease Propagation, Evolutionary Methods, Genetic Algorithms, Molecular Dynamics.

Books Recommended:

1. *Introduction to MATLAB 7 for Engineers by W.J. Palm III, Mc Graw Hill.*
2. *A guide to MATLAB for Beginners and Experienced Users by B.R. Hunt, R.L. Lipsman, J.M. Bosenberg, Cambrigde University Press.*
3. *MATLAB an introduction with Applications by Amos Gilat, Wiley.*
4. *Applied Numerical Methods Using MATLAB by W.Y. Yang, W. Cao, T. S. Chung, J. Morris, Wiley.*
5. *Applied Mathematica by W.T. Shaw & J. Tigg, Addison Wesley (1994)*
6. *Computational Methods in Physics by Paul Harrison, Pub by WileyBlackwell (27 Sep 2001)*
7. *Computational Physics, S.E. Koonin, Longman Higher Education; Har/Dis edition (31 Dec 1986).*
8. *Numerical Recipes, W.H. Press et al, Cambridge University Press (1986)*
9. *Numerical Recipes, W.H. Press et al, Cambridge University Press (1986)*
10. *Quantum wells, wires and dots: Theoretical and Computational Physics by P. Harrison*
    Pub by John Wiley & Sons (29 Nov 1999).
11. *The Mathematica Book, S. Wolfram, Cambridge University Press (1996)*

Phys 510 PLASMA PHYSICS (CR3)

Introduction to plasma physics, occurrence of plasmas in nature, concept of temperature, Debye shielding, criteria for plasmas, applications of plasma physics.
Single particle motion, motion of charged particles in uniform E and B fields, motion of charged particles in non-uniform E and B fields, motion of charged particles in time varying E and B fields, adiabatic invariants.
Plasmas as fluids, relation of plasma physics to ordinary electromagnetic, the fluid equation of motion, equation of continuity, the complete set of fluid equations, plasma approximations.
Waves in plasmas, representation of waves, group velocity, plasma oscillations, electron plasma waves, sound waves, ion waves, validity of plasma approximation, comparison of ion wave and electron wave, electrostatic electron oscillations perpendicular to B, electrostatic ion waves perpendicular to B, the lower hybrid frequency, EM waves with Bo=0, EM waves perpendicular to Bo, cutoffs and resonances, EM waves parallel to Bo, hydromagnetic waves, magnetosonic waves.

Books Recommended:

1. *Fundamentals of Plasma Physics (third edition) by J. A. Bittoncourt, Springer-Verlag, 2004.*
2. *Fundamentals of Plasma Physics, P.M.Bellan, CUP, 2008.*
3. *Introduction to Plasma Physics and controlled fusion (second edition) by Francis F. Chen, Plenum Press, 1984.*
4. *Plasma Physics by Peter A. Sturrock, Cambridge University Press, 1994.*
5. *Plasma Dynamics by R. O. Dendy, Clarendon Press - Oxford, 1990.*

Phys 511 APPLICATIONS OF X-RAY DIFFRACTION METHODS (CR3)

The powder and single crystal methods; single crystal cameras; powder cameras; single crystal diffractometer; powder diffractometer; qualitative and quantitative phase analysis; the powder method of crystal structure determination; residual stress measurements.

Books Recommended:

1. *Basics of X-ray Diffraction and its applications, by K.R. Hebbar, I.K. International Pub. House, 2007.*
2. *Elements of X-Ray Diffraction by B. D. Cullity; Addision-Weseley Publ. Co. Inc., Reading Ma (Usa), 1978.*
3. *X-Ray Diffrcation Procedures by H. P. Klug And L. E. Alexander; John Wiley And Sons, New York Ny USA, 1976.*
4. *X-Ray Crystallography by M. J.Buerger Krieger Publishing Company; Reprint edition, June 1980.*

Phys 512 QUANTUM FIELD THEORY (CR3)

Classical field theory, lagrangian mechanics, variational principle, vibrating stings, classical field theory, Lorentz transformations, Lorentz group, representations of Lorentz group, classical scalar fields, Klein-Gordon equation, complex scalar fields, energy-momentum tensor, electromagnetic field, Maxwell's equations, spinor field, Dirac equation, symmetries and conservation laws, Noether's theorem, translation invariance.Quantization of fields, canonical quantization of fields, quantization of scalar fields, particle interpretation of quantum field theory, normal ordering, non-Hermitian fields.
Interacting Quantum Fields, interacting fields, perturbation theory, time ordering, S-matrix, cross-section, decay rate of an unstable particle, higher order perturbation theory, Wick's theorem, second order perturbation theory, Feynman rules and diagrams, renormalization, mass enormalization, coupling constant renormalization, field renormalization.

Books Recommended:

1. *Introduction to the Theory of Quantized Fields by N. N. Bogoliubov and D.V. Shirkov, Wiley, 1959.*
2. *Quantum Field Theory by C. Itzykson and J- B. Zuber McGraw-Hill, 1980.*
3. *Quantum Field Theory by L. H. Ryder Cambridge University Press, 1999.*
4. *Quantum Field Theory by M. Kaku, Oxford University Press, 1993.*
5. *Quantum Field Theory by F. Mandl and G. Shaw, Wiley, 1984.*
6. *Relativistic Quantum Fields by J. D. Bjorken and S. D. Drell, McGraw-Hill, 1965.*
7. *The Quantum Theory of Fields Vol. I, II byS. Weinberg, Cambridge University Press, 1995.*
8. *Quantum Field theory by M.A.Srednicki, CUP (2007).*

Phys 513 SPECTROSCOPY (CR3)

Spectroscopic techniques:
Nature of excitation measured, measurement process,
Absorption, fluorescence, X-ray, flame, UV/VIS, FTIR, laser, NMR, mass, AA, ATR and Raman spectroscopy.
Sample preparation techniques:
Solid, liquid and film type sample preparation techniques. In addition to the established KBr pellet technique, systematic experimental comparison of different techniques, mutual advantages and applications, Nondestructive method determination of molecular conformation, determination of molecular orientation.

Recommended Books :

1. *Analytical Absorption Spectroscopy by M.G. Mellon, John Wiley & sons (1950).*
2. *Combining Imaging and Spectroscopy: Solving Problems with Near-Infrared Chemical Imaging. Microscopy Today by E. N. Lewis, E. Lee and L. H. Kidder, publisher John Wiley & Sons, Inc., Vol. 12 (2004).*
3. *Handbook of High-Resolution Spectroscopy, by Martin Quack (Editor), Frederic Merkt, publisher John Wiley & Sons, Inc., September 2009.*
4. *Laser Spectroscopy by W. Demtröder, 3rd Ed. (Springer, 2003).*
5. *Spectroscopy1 by S.Walker and H.Straw Academic Press (1961).*
6. *Spectroscopy2 by S.Walker and H.Straw Academic Press (1962).*
7. *Spectrometric Techniques by G.A. Vanasse Academic Press (1981).*

Phys 514 ADVANCED QUANTUM FIELD THEORY (CR3)

Path Integral Quantization, Quantum field theory and functional integration, path integral quantization, scalar field theory, Green function, S-matrix, Lehmann-Symanzik-Zimmereman reduction, perturbation theory, Wick's theorem, Feynman rules for phi^4 theory, spectral representation.
Renormalization, regularization, BPH renormalization, renormalization group, Callan-Symanzik equation, asymptotic freedom.
Gauge theories, abelian and non-abelian theories, quantization of gauge theories, gauge fixing and Faddeev-Popov quantization, integration over Grassman variables, Berezin rules, Feynman rules for Quantum Chromodynamics (QCD), renormalization of QCD.

Books Recommended:

1. *An Introduction to Quantum Field Theory, by M. Peskin and D. Schroeder Perseus Books, Reading, (1995).*
2. *Field Theory:A Modern Primer by P. Ramond Addison-Wesley, Reading (1990).*

3. *Quantum Field Theory by C. Itzykson and J- B. Zuber, McGraw-Hill, (1980).*
4. *Quantum Field Theory by L. H. Ryder Cambridge University Press, (1999).*
5. *Quantum Field Theory by M. Kaku, Oxford University Press, (1993).*
6. *Quantum Field theory by M.A.Srednicki, CUP (2007).*
7. *The Quantum Theory of Fields Vol. I, II, by S. Weinberg Cambridge University Press, (1995).*

Phys 515 SUPERCONDUCTIVITY (CR3)

Discovery, zero resistance and critical temperature, magnetization, perfect diamagnetism, Meissner effect, trapped flux, type I and II behaviour, superconducting elements and compounds, cuprate superconductors, structures and preparation, doing phase diagram.
Qualitative Description of the Superconducting State, The pair state, effective wave function. Y (**r**), time-and space-dependence of the phase, Aharonov-Bohm effect, London equations, penetration depth, flux quatisation, gauage invariance.
Thermodynamics of Superconductors, Free energy, critical field, heat capacity, second-order phase transition, demagnetizing effects.
Josephson Effects, Discovery (including single particle tunneling), principles, quantum interference, DC and r.f. SQUIDS, applications of SQUIDS, AC effects, voltage standard.
Ginzburg-Landau Theory and Type II behaviour, Landau theory of phase transitions, Ginzburg-landau free energy and equations, type II behaviour and flux lines, flux pinning, current carrying capacity, beam model, practical magnet materials, superconducting magnets and their uses.

Books Recommended:

1. *Superconductivity of Metals and Cuprates by Waldram J. R. (IoP Publ. 1996).*
2. *Introduction to Superconductivity by Tinkham M, 2nd Edition, McGraw-Hill, (1996).*
3. *Physical Propterties of High-Temperature Superconductors by Ginsberg D. M. (ed), World Scientific.*
4. *Concise Encyclopaedia of Magnetic & Superconducting Materials by Evetts J. e. (ed), Pergamon, (1992).*

Phys 516 STANDARD MODEL OF PARTICLE PHYSICS (CR3)

Relativistic Quantum Mechanics, Electromagnetic waves and interaction, Dirac and Klein-Gordon density and current, electromagnetic scattering, charge conjugation and parity invariance, gamma matrix algebra, Compton scattering, massless Dirac particles, charged and neutral weak currents, weak scattering.
Gauge Theory of Electroweak Interaction, Gauge symmetry, non-Abelian gauge symmetry, weak interactions, electroweak interactions, spontaneous symmetry breaking, discrete and continuous symmetries, global symmetries and Goldstone's theorem, local symmetries and Higg's mechanism, properties of the Higgs boson, ultraviolet divergences, renormalizability, dimensions of fields and couplings.
Quantum Chromodynamics Colour and properties of SU(3), (SU(3) gauge symmetry, strong interactions, effective charge and asymptotic freedom, grand unification.

Books Recommended:

1. *An Introduction to Quantum Field Theory by Peskin M E and Schroeder D V, Addison-Wesley, (1995).*
2. *Gauge Theories in Particle Physics by Aitchison I J R and Hey A J G, 2nd Edition, Adam Hilger, (1989)*
3. *Quantum Field Theory by Ryder L H, 2nd Edition, CUP, (1996).*
4. *Quantum Field Theory byMandl F and Shaw G, Revised Edition, Wiley, (1993).*
5. *Gauge Theories in Particle Physics by Aitchison I J R and Hey A J G, 2nd Edition, Adam Hilger, (1989).*

Phys 517 QUANTUM OPTICS, SIGNALS AND SYSTEMS (CR3)

Review of quantum fields; quantization of the electro-magnetic field; energy- and number states, coherent states, mixed states and density operator. Quantum optical coherence and squeezed states. Absorption, emission and photoelectric effect. Noise in lasers and detectors. Quantum optical experiments; photodetection theory; direct, homodyne and heterodyne detection; squeezed and photon-number state generation; application to optical communication and interferometers. Introduction to quantum cryptography and quantum computation.
System analysis techniques and their application to circuit and filter design, robotic control, computer simulation, communication, and speech and image processing. Topics include: Laplace- and Z-transform techniques; system transfer functions; filtering; Convolution and deconvolution; feedback stability analysis; Fourier transforms; modulation system analysis; and sampling theorems.

Books Recommended:

1. *Computer Explorations in Signals and Systems Using MATLAB by J. R. Buck, M. M. Daniel, and A. C. Singer, Printice-Hall, (1997).*
2. *Methods in Theoretical Quantum Optics by Paul M. Radmore, (Oxford Series in Optical and Imaging Sciences, 15) et al*
3. *Optical Coherence and Quantum Optics by Leonard Mandel, Emil Wolf Cambridge University Press, (1995).*
4. *Quantum Optics by Marlan O. Scully, M. Suhail Zubairy (Contributor) (1995).*
5. *Signals and Systems by A.V. Oppenheim and A. S. Willsky, with S. H. Nawab, Printice-Hall, Second Edition, (1997).*
6. *Superconductivity, by C.P. Poole. H.A. Farach, R.J.Creswick, R.Prozorov, Academic Press, 2007.*

Phys 518 GROUP THEORETICAL METHODS IN PARTICLE PHYSICS (CR3)

Elements of group theory; Normal subgroups; Quotient groups; Law of transformations; Homeomorphism and isomorphism; group representations; reducible and irreducible representations; Lie groups; Lie Algebra and its standard form; introduction to the group integration over the parameters of a Lie group; Casimir operators; matrix representations of generators of SU(2) and SU(3); roots of SU(2) and SU(3); weights of various representations of SU(2) and SU(3); Young's tableaux and irreducible representations of the permutation group, SU(2) and SU(3); decomposition of the product of irreducible representations; Clebsh-Gordan coefficients; eightfold way; quark model; flavour, spin and colour wave functions of quark antiquark and three quark systems.

Books Recommended:

1. *D.B. Lichtenberg, Unitary Symmetry and Elementary Particles, Academic Press, 1970.*
2. *F. Halzen and A. D. Martin, Quarks and Leptons, John Wiley and Sons, 1984.*
3. *Fl. Stancu, Group Theory in Subnuclear Physics, Clarendon Press, Oxford, 1996.*
4. *J. P. Elliot and P. G. Dawber, Symmetry in Physics, Vol. 1 and 2, The Macmillan Press Ltd, 1979.*
5. *J. F. Cornwell, Group Theory in Physics, Academic Press London, 1997.*
6. *M. Creutz, Quarks, gluons and lattices, Cambridge University Press, 1983.*
7. *W. U. Ki Tung, Group Theory in Physics, World Scientific, 2003.*
   P. Ramond, Group theory: A Physicist's Survery, CUP, 2010

Phys 519 OPTOELECTRONICS (CR3)

*Photonic devices***:**
Radiative transitions and optical absorption, semiconductors materials for opto electronics, visible LEDs, infrared LEDs, organic LEDs, Semiconductor Laser; Laser materials, Laser operating characteristics, carrier and optical confinement, optical cavity and feedback, distributed feedback Lasers and quantum-well Lasers,
Photodectors:
potoconductor and phtodiodes, mtal-smiconductor, hterojunction, photodiode and phototransistors; photoconductor, quantum efficiency and response speed, Avalanche photodiode.
Solar Cells:
Semiconductor and polymer solar cells, solar radiations and ideal conversion efficiency, p-n junction solar cell, amorphous and compound-semiconductor solar cells, interface and then film solar cells, optical concentration to reduce cost, optical fiber sensor, CCD, optical information and processing, optical computing.

Books Recommended:

1. *Fundamental of Photonics by B. E. A. Saleh and M. C. Teich, John Wiley, New York, 1991.*
2. *Fiber Optic Communication Systems by G. P. Agarwal, John Wiley & Sons, New York, 1992*
3. *Fiber Optics and Optoelectronics Fiber Optics and Optoelectronics, 2nd Edition, Ed.P.K.Cheo, Prentice Hall, 1990.*
4. *Lasers and Optical Engineering by P. Das, Springer-Verlag, New York, 1991.*
5. *Laser and Electro-Optics, C.C. Davis, Cambridge University Press, 1996.*
6. *Optoelectronics by J. Wilson and F. B. Hawkes, Prentice Hall, New York, 1989.*
7. *Optoelectronic Technology and Light wave Communication Systems by Chinlon Lin, Van Nostrand Reinhold, New York, 1989.*
8. *Optical Computing by M. A. Karim and A. A. Awwal, John Wiley & Sons, 1992.*
9. *Optical Fiber Communications by Gerd Keiser, McGraw Hill International Ed. , New York, 1991.*
10. *Optical Fiber Communication, Gerd Keiser, 3rd Edition, McGraw Hill, 2000.*
11. *Optoelectronic Devices by X. Li, CUP, 2009.*
12. *Physics of Semiconductor Devices by S. M. Sze, Pub. John Wiley & Sons, 2nd Edition, 1981.*
13. *Principles of Optical Engineering by F.T.S.YU and I. C. Khoo, John Wiley & Sons, New York, 1990.*
14. *Semiconductor Devices, Physics and Technology, by S. M. Sze, Pub. John Wiley & Sons, 2nd Edition, 2002.*

Phys 520 OPTICAL PROPERTIES OF SOLIDS (CR3)

Classification of optical processes, optical coefficients, optical materials, microscopic models, classical propagation of light in optical medium, atomic oscillators, vibrational oscillators, the Lorentz oscillators, Multiple resonances, the Kramer- Kronig relationships, Dispersion relations, optical anisotropy, birefringence, interband transitions, The transition rate for direct absorption, Band edge absorption in direct gap seminconductors, interband obsorption above the band edge, measurement of absorption spectra,
Excitions, free excitions, excitions in external fields, Frenkel excitions,
Luminescence, interband luminescence, photoluminescence, electroluminescence,Semiconductor quantum wells, the quantum stark effect, Quantum dots,Plasma reflectivity, Free carrier conductivity, the Drude model, impurity absorption plasmons, phonons, infrared active phonons, infrared reflectivity and absorption, the classical

oscillator model, The Lyddance-Sachs-Teller relationship, polaritons, polarons, inelastic light scattering. Phonon life time
Nonlinear optics, the nonlinear susceptibility tensor, the physical origin of optical nonlinearities, second order nonlinearities, third order nonlinear effects.

Books Recommended:

1. *An Introduction to Solid State Physics & its applications, Elliot & Gibbson, MacMillan 1976.*
2. *Introduction to Solid State Physics (7th edition) Wiley, 1996.*
3. *Optical Properties of Solids, Mark Fox, Oxford University Press, 2001*
4. *Optical Characterization of Solids, Daniela Drogman, Springer, 2002*
5. *Optical Properties of Solids, F. Wooten, Academic Press, 1972.*

Phys 521 QUANTUM ELECTRODYNAMICS (CR3)

The electromagnetic field in free space: classical and quantized. The electromagnetic interaction and gauge invariance. The geometry of gauge invariance. The Dyson expansion of the S-matrix and the Wick's theorem. Feynman diagrams in position and momentum space. The Feynman rules of QED and their uses for all possible physical processes in the second order. Scattering of two particles; unpolarized cross-section for the electron-positron to muon-antimuon and the electron-muon scattering. Scattering by a static electric field; elastic electron-nucleon scattering and the nuclear form factor. Bremsstrahlung and the infra-red divergence. An introduction to the charge renormalization in QED, and the running QED coupling.

Books Recommended:

1. *F. Mandl and G. Shaw, Quantum Field Theory, John Wiley, 1988.*
2. *F. Helzen and A. D. Martin, Quraks and Leptons, John Wiley, 1984.*
3. *Griffiths, Introduction to Elementary Particle Physics, John Wiley, 1987.*
4. *Greiner, Quantum Electrodynamics, Springer, 1994.*
5. *J. R. Aitchison and A. J. G. Hey, Gauge Theories in Particle Physics, Adam Hilger, 1989.*
6. *McMahon, D, Quantum Field theory Demystified, McGraw- Hill, 2008.*
7. *Peskin and Schroeder, An introduction to Quatnum Field Theory, Addison-Wesley Publishing Co., 1995.*
8. *R. P. Feynman, Quantum Electrodynamics: a lecture note and reprint volume, Benjamen Press.*

Phys 522 Introduction to Magnetism and Magnetic Materials (CR3)

Introduction: magnetism and various magnetic materials with their applications, Review of basic magnetostatics, orbital and spin magnetic moments of electron, atomic origins of magnetism. **Paramagnetism:** classical and quantum phenomenology of paramagnetism, the Curie-Weiss law, free electron model, Pauli paramagnetism. **Diamagnetism:** diamagnetic susceptibility, the Meissner effect in superconductivity. **Ferromagnetism:** spontaneous magnetization, Weiss molecular field theory of ferromagnetism, origin of the Weiss molecular field, collective-electron theory of ferromagnetism, origin of ferromagnetic domains, types of domain wall, Barkhausen effect, ferromagnetic magnons. **Antiferromagnetism:** neutron diffraction, Weiss theory of antiferromagnetism, temperature dependence of magnetic susceptibility, origin of negative molecular field, antiferromagnetic magnons. **Ferrimagnetism:** Weiss theory of ferrimagnetism, ferrites, the garnets. **Magnetic Anisotropy:** magnetocrystalline anisotropy, origin of magnetocrystalline anisotropy, shape anisotropy, induced anisotropy, stress anisotropy (magnetostriction), magnetic surface

anisotropy, magnetic interface anisotropy. **Magnetic resonance:** Nuclear magnetic resonance, Bloch equations of motion, ferro- and antiferro- magnetic resonance.
Special Topics: magnetism in thin films and nanoparticles, exchange bias effect, magneto-optics, magnetic semiconductors and insulators, magnetoresistivity, magnetic liquids, magnetic memory and magnetic sensor, spin Hall effect and inverse spin Hall effect, Kondo effect, Andreev reflection, multiferroics.
Selected Experimental techniques: techniques involved in growth and characterization of the magnetic materials.
Reference books:
1. Introduction to Magnetic Materials, by B.D. Cullity and C.D. Graham, 2008.
2. Magnetism and magnetic materials, J. M. D. Coey, 2009.
3. Fundamentals of Magnetism, by Mathias Getzlaff, 2007.
4. Magnetic Materials: Fundamentals and Device Applications, by N.A. Spaldin, 2011.
5. Magnetism: Fundamentals, by L. Etienne et al, 2004.
6. Physics of Magnetism and Magnetic Materials, by K.H.J. Buschow and F.R. de Boer, 2003.
7. Magnetism in Condensed Matter, by S. Blundell, 2001.
8. Modern Magnetic Materials: Principles and Applications, by Robert C. O' Handley, 1999.

Phys 523 LATTICE DYNAMICS (CR3)

Born Oppenheimer approximation, Adiabatic approximation, Harmonic approximation, Normal modes.
Bose Einstein distribution function, Experimental methods - Neutron diffraction, Phonon dispersion curves, Linear monatomic lattice, Linear diatomic lattice, Nearest neighbour force constants, Acoustical and Optical phonons, 2-D square lattice, Dynamical matrix, Transverse and Longitudinal phonon modes, Simple cubic lattice, Dynamical matrix , bcc and fcc lattice, Density of states, Debye and Einstein model, Specific heat at high and low temperature, Optical absorption due to phonons, Phonon-phonon interactions, Electron-phonon interactions, Mathematica Computer Demonstrations, Dispersion relations & Density of States, Normal modes - pattern of vibrations, Linear monatomic lattice, Linear diatomic lattice, Monatomic square lattice, BCC monatomic lattice, Einstein & Debye Model, Bose-Einstein distribution function, Specific Heat, InfraRed Photon Absorption - Restrahlen region, Dielectric Constant, Refractive Index, Reflectivity, Absorption Coefficient, Polariton.

Books Recommended:

1. *R.F. Wallis, Phonons and Polaritons, Interaction of radiation with condensed matter IAEA, 1977*
2. *G.J. Keeler, Simulation of Phonon Dispersion curves and density of states Physics Programs, Solid State Physics, A.D. Boardman (Ed.), Wiley(1980)*
3. *S. Datta, Quantum Phenomena Modular Series on Solid State Devices, Addison Wesley (1989)*
4. *C. Kittel, Introduction to Solid State Physics, Various Editions, J. Wiley, 2004.*

Phys 524 ADVANCED COURSE IN PLASMA PHYSICS (CR3)

Diffusion and mobility in weakly ionized gases, decay of plasma by diffusion, steady state solutions, recombination, diffusion across a magnetic field, collisions in fully ionized plasmas, the single-fluid MHD equations, diffusion in fully ionized plasmas, solutions of the diffusion equation, Bohm diffusion and neoclassical diffusion.
Equilibrium and stability - introduction, hydromagnetic equilibrium, the concept of β, diffusion of magnetic filed into a plasma, classification of instabilities, two-stream instability, the "Gravitational" instability, resistive drift waves, the Weibel instability.

Kinetic theory, the meaning of $f(\boldsymbol{v})$, equations of kinetic theory, derivations of fluid equations, plasma oscillations and Landau damping, a physical derivation of Landau damping, ion Landau damping, kinetic effects in a magnetic field.
Nonlinear effects – introduction, sheaths, ion acoustic shock waves, the pondermotive force, parametric instabilities, plasmas echoes, nonlinear Landau damping, equations of nonlinear plasma physics.

Books Recommended:

1. *Fundamentals of Plasma Physics (third edition) by J. A. Bittoncourt, Springer-Verlag, 2004.*
2. *Fundamentals of Plasma Physics, P.M.Bellan, CUP, 2008.*
3. *Introduction to Plasma Physics and controlled fusion (second edition) by Francis F. Chen, Plenum Press, 1984.*
4. *Introduction to Plasma Physics by R. J. Goldston and P. H. Rutherford, IOP Publishing Limited, 1995.*
5. *Introduction to Plasma Physics with space and laboratory applications, by Donald A. Gurnett and Amitava Bhattacharjee, Cambridge University Press, 2005.*
6. *Plasma Dynamics by R. O. Dendy, Clarendon Press - Oxford, 1990.*

Phys 525 SURFACE ANALYSIS TECHNIQUES BY ELECTRON EMISSION (CR3)

Introduction to surface and its importance in materials performance, various processes taking place at the surfaces, surface cleanliness and contamination under different vacuum condition Interaction of Electrons with Solids, Secondary Electron Emission, Energy distribution of Secondary Electrons. Electron Scattering (Elastic and Inelastic), characteristic energy losses in Solids, Plasma losses (Surface and bulk) Range of Electrons in Solids, Ionization losses. Secondary Electron Yield, Secondary Emission Coefficient, Back Scattering coefficient, Angular Variation of yield. High yield secondary Emitters, Low Yield Materials, Surface effects (Contamination, roughness) on Yield, Application of secondary electron yield Auger Electron Emission, Emission Mechanism of Auger electron, Electron energy Analysers (Ideal analyzer, retarding field analyzer, cylindrical mirror analyzer, Magnetic analyzer), auger electron data acquisition and analysis, Chemical shifts in Auger spectra, Contamination effects on Auger emission, Application of Auger Electron Spectroscopy. X-ray photoelectron spectroscopy: Basic principals and theory, Photo-ionisation cross-section, line-shapes and fine structure, chemical shifts inelastic scattering and sampling depth, Instrumentation , X-ray sources, electron energy analysers, data recording and processing, applications of XPS.

Books Recommended:

1. *Auger Microprobe Analysis, Ian Ferguson, Adam Hilger, Bristol, 1989.*
2. *Characterization of Solid Surface by P.F. Kane and G.B. Larrabee, Plenum press, N.Y. 1974.*
3. *Handbook of Vacuum Physics Vol 2, by A.H. Beck, Pergamon Press, 1966.*
4. *Methods of Surface Analysis, edited by J.M. Walls, Cambridge University Press, Cambridge, 1988.*

Phys 526 NONLINEAR WAVES AND SOLITONS (CR3)

Basics of linear and non-linear (ordinary and partial) differential equations, superposition principle, Some non-linear equations e.g. non-linear wave equation, non-linear Schrodinger's (NLS) equation, sine-Gordon equation, Liouville's equation, Korteweg-de-vries (KdV) equation, modified KdV equation, Burger equation, Boussinesq equatio etc.
Conservation laws, basic idea, conserved quantities for the KdV equation, Gardner transformation, conservation laws for the sine-Gordon equation.

Solutions of non-linear equations, travelling-wave solutions, solitary waves and solitons, Hirota's method (the bilinear form), bilinearization of non-linear differential equations, solutions, of bilinear equations, Backlund transformation, Theorem of Permutability, Backlund transformations for the KdV equation, sine-Gordon equation etc., Riccati equation, Inverse methods, the AKNS scheme, eigen value problem, Lax pairs, Darboux transformation and multi-soliton solutions.

Recommend Books:

1. *C. Rogers and W. K. Schief, "Backlund and Darboux Transformations: Geometry and Modern Applications in Soliton Theory", Cambridge: Cambridge University Press (2003).*
2. *C. H. Gu, H. Hu and Z. Zhou, "Darboux Transformations in Integrable Systems, Theory and their Applications to Geometry", Berlin: Springer (2005).*
3. *G. L. Lamb Jr, "Elements of soliton theory", John Wiley & Sons New York (1980).*
4. *L. Debnath, "Nonlinear Partial Differential equations for Scientists and Engineers", Birkhauser Boston (1997).*
5. *P. G. Drazin and R. S. Johnson, "Solitons: An Introduction", Cambridge, UK: Univ. Pr. (1989) 226 P.*
6. *R. Hirota, "The Direct Methods In Soliton Theory", Cambridge, UK: Univ. Pr. (2004) 200 P.*
7. *V. B. Matveev and M. A. Salle, "Darboux Transformations and Soliton," Springer-Verlag (1991) (120pp).*

Phys 527 SOLID STATE ELECTRONIC DEVICES (CR3)

Introduction:
Semiconductor Materials, Bulk Crystal Growth, Epitaxial Growth Introduction to Physical Models, Experimental Observations (The Photoelectric Effect), The Bohr Model, Quantum Mechanics, Atomic Structure (The hydrogen atom)Excess Carriers in Semiconductors (Optical Absorption, Luminescence, and Diffusion of carriers)*Junctions:*Fabrication of p-n Junctions (Diffusion, Rapid Thermal Processing, Ion Implantation, Chemical Vapour Deposition, Photolithography, Etching, Metallization), Forward and Reverse-Biased Junctions, Metal Semiconductor Junctions, Heterojunctions,*Field effect transistors:*
Transistor Operation, The Junction FET, The Metal-Semiconductor FET, The Metal-Insulator-Semiconductor FET, The MOS Field-Effect Transistor, *Bipolar junction transistors:*Fundamentals of BJT Operation, Amplification with BJTs, BJT Fabrication, Switching, Frequency Limitations, Heterojunction Bipolar Transistors *Optoelectronic devices:*Photodiodes, Light-Emitting Diodes, Lasers, Semiconductor Lasers*Power devices:*The p-n-p-n Diode (Basic Structure, The Two-Transistor Analogy), The Semiconductor Controlled Rectifier, Insulated Gate Bipolar Transistor*Integrated circuits:*Types of Integrated Circuits - micro- and nanometer scale devices, Monolithic and Hybrid Circuits, Monolithic Device Elements (CMOS Process Integration, SOI), Charge Transfer Devices (The Basic CCD, Applications of CCDs), ULSI (Logic Devices, Semiconductor Memories)

Books Recommended:

1. *"Integrated Circuits: Theory and Applications" -by- C. Wojslaw, Reston Publishing Co. Inc., 1978.*
2. *"Physics of Semiconductor Devices" -by- M. Shur, Prentice Hall, 1990.*
3. *"Solid State Electronic Devices" -by- B.G. Streetman and S. Banerjee, Prentice Hall, 2000.*
4. *"ULSI Devices" -by- C.Y. Chang and S.M. Sze, John Wiley and Sons Inc., 2000.*
5. *"VLSI Electronics - Microstructure Science, Vol. 1" -by- N.G. Einspruch, Academic Press, 1981.*
6. *"VLSI Electronics - Microstructure Science, Vol. 2" -by- N.G. Einspruch, Academic Press, 1981.*

Phys 528 INTEGRABLE SYSTEMS IN MATHEMATICAL PHYSICS (CR3)

Hamiltonian formalism, Poisson structure, Hamiltonian systems, Integrability of a Hamiltonian system (Liouville integrability), Dynamical systems of classical mechanics, Harmonic oscillator, Action-angle variables, examples of integrable models solved by Liouville theorem, Kepler two-body problem, rigid body, systems with closed trajectories.
Korteweg-de Vries (KdV) equation, KdV equation as a Hamiltonian systems, properties of the KdV solutions, conserved quantities, Miura transformation, Integrability of the KdV equation, higher order equations of hierarchy, involution of conserved quantities, Initial value problem for the KdV equation, Inverse scattering theory in one-dimension, action-angle variables for the kdV equation.
Lax representation, Lax representation with a spectral parameter, Zakharov-Shabat formulation, zero-curvature method.

Recommend Books:

1. *A. Das, "Integrable Models" , World Scientific Lecture Notes in Physics Volume 30, World Scientific Singapore (1989).3*
2. *I. Cherednik, "Basic methods of soliton theory", Adv. Ser. Math. Phys. 25 (1996) 1-250.*
3. *L. D. Faddeev and L. A. Takhtajan, "Hamiltonian Methods in the Theory of Solitons", Springer Verlag (1987).*
4. *O.Babelon, D.Bernard, M.Talon, "Introduction to Classical Integrable Systems" CUP, 2008.*
5. *S. Novikov, S. V. Manakov, L. P. Pitaevsky and V. E. Zakharov, "Theory of Solitons: The Inverse Scattering Method" (Contemporary Soviet Mathematics) (New York: Consultants Bureau) (1984).*

Phys 529 SUPERSYMMETRY (CR3)

Supersymmetry, symmetries, No-go theorem, Clifford Algebra and spinors, Dirac and Majorana spinors, supersymmetry algebra, superfields, vector superfields, 4D SUSY Lagrangians, Wess-Zummiw Lagrangian, 2D supersymmetry, 2D supersymmetic models, SUSY transformations on fields 2D examples, BPS solitions in d=2, central charges and BPS solutions, Extended supersymmetry.

Recommend Books:

1. *Supersymmetry Demstified by P.Labelle McGraw Hill (2009).*
2. *Supersymmetry by P.M.R.Binetruy, OUP, (2007).*
3. *Supersymmetry and Supergravity by J.Wess and J.Bagger Princeton (1992).*
4. *Modern Supersymmetry: Dynamics and Duality by J.Terning, OUP (2009).*
5. *Introduction to Supersymmetry by J.W. Muller-Kirster and A.Wiedemann World Scientific (2010).*

Phys 530 NANOMATERIALS: SCIENCE, GROWTH AND CHARACTERIZATION (CR3)

Nanomaterial science:
Historic Development. Classification of Nano materials, knowledge to analyze the assumptions and predictions of these classic works, Size depending Quantum Mechanical aspects,
Growth and Characterization:
Nano particle synthesis, materials alloying, XRD, SEM, TEM (Morphology), thermal and electrical properties of nano growth, optical characterizations, device fabrication and testing, strong hand in electrical and mechanical tools.- Nanodefects.- Nanolayers.
Nanomechanical testing:
Nanoindentation, nanoscale wear and scratch tests, nano-bending and fracture tests). Force measurements on inorganic and biological matter. Materials made of nanophases, the microstructure of materials with nanoscale grains and internal particles, including the special properties associated with "nano-scaling" of particle size.

Nanoparticles and Quantum Dots:
Semiconducting and oxides, metallic fullerenes, quantum dots, 1-D Nanomaterials Nanotubes (carbon and non-carbon and composites), nanowires (metallic and semiconducting) and nanotips, including probes. Nanopatterned surfaces.
Nanoscale porous materials and nanocomposites:
Silica, Alumina, Zeolithes and others.
Biological nanostructures:
Subcellular matter; biomimetic nanomaterials, DNA controlled assembly of structures.

Recommended Books:

1. *Basics of Nanotechnology, 3rd Edition by Horst-Günter Rubahn, publisher Wiley VCH, September 2008.*
2. *Biomimetic and Bioinspired Nanomaterials by Challa S. Publisher Wiley VCH, August 2010.*
3. *Carbon Materials and Nanotechnology by Anke Krüge, Publisher Wiley VCH, March 2010.*
4. *Diffusion-controlled Solid State Reactions: in Alloys, Thin-Films, and Nanosystems by Andriy M. Gusak, T.V. Zaporozhets, Yu. O. Lyashenko, S.V. Kornienko, M.O. Pasichnyy, A.S. Shirinyan, publisher Wiley VCH, August 2010.*
5. *Foundations of Nanomechanics by Andrew N. Cbland Springer (2003).*
6. *Introductory Quantum Mechanics for Semiconductor Nanotechnology, by Dae Mann Kim, publisher Wiley VCH, March 2010.*
7. *Nanomaterials Hand book by Yury Gogost, by Taylor and Francis (2006).*
8. *Nanostructures Theory and Modelling by Christophe Jean Delerue, Michel Lannoo, publisher Springer, Feb 2004.*
9. *Nano-Age: How Nanotechnology Changes our Future by Mario Pagliaro, publisher Wiley VCH, July 2010.*
10. *Nano Mechanics and Materials: Theory, Multiscale Methods and Applications by Wing Kam Liu, Eduard G. Karpov, Harold S. Park, publisher Wiley Blackwell, December 2005.*

Phys 531 LIE GROUPS AND LIE ALGEBRAS (CR3)

Matrix Lie groups, exponential map, examples SO(3) and SU(2), Lorentz group and Poincare' group, Lie algebras, reducible and irreducible representations, Direct sums and tensor product, ideals, Killing form Classification of finite-dimensional. Algebras, Cartan subalgebra, Cartan-Weyl basis, Dynkin Ddiagrams, Weights and roots, comples semi-simple Lie algebras. applications in Physics.

Books Recommended:

1. *Introduction to Lie algebras and Representation theory, Springer (1972).*
2. *Representation theory by W.Fulton and J.Harris, Springer (1991).*
3. *Lie Groups, Lie Algebras and some of their applications by R.Gilmore, Wiley (1974).*
4. *Lie Algebras and applications by F.Iachello, Springer (2006).*
5. *Group Theory: A Physicist's survey, CUP (2010).*

Phys 532 NANOTECHNOLOGY AND NANOELECTRONICS (CR3)

Nano-semiconductor physics:
Nanowires, nanobelts, nanoribbons, nanorods.
Devices, Circuits and Systems:
The Ballistic Nanotransistors, scattering theory of the MOSFET.- Nanowire Field-Effect Transistors.-Transistors at the Molecular Scale. Focus is on the device physics and operation principles.

Device and material options for advanced silicon:
FETs at the nanoscale. Nano-circuits built using semiconductor nanowires. Non-silicon-based devices such as carbon nanotubes, semiconductor nanowires.
Non-FET based devices:
Molecular devices, Single electron transistors (SET), resonant tunneling diodes (RTD), and quantum dots, logic and memory devices.

Recommended Books :

1. *Carbon Nanotube Devices: Properties, Modeling, Integration and Applications by Christofer Hierold (Volume Editor), Oliver Brand (Series Editor), Gary K. Fedder (Series Editor), Jan G. Korvink (Series Editor), Osamu Tabata (Series Editor),, Publisher Wiley VCH, March 2008.*
2. *ESD: Failure Mechanisms and Models by Dr. Steven H. Voldman, Wiley Blackwell July 2009.*
3. *Introduction to Nanoelec tronics by Vladimir V. Mitin, V.A. Kocheleap and M.A. Strucio by Combridge University press (2008)*
4. *Introduction to Nanotechnology by Charles .P. Poole and Frank. Publisher John Wiley & Sons Inc., June 2003.*
5. *Nanoelectronics and Nanosystems by K. Goser, Springer (2003).*
6. *Nanotechnology: A Gentle Introduction to the Next Big Idea by Mark A. Ratner and Daniel Ratner, Prentice Hall (2002).*

Phys 533 THE CLASSICAL THEORY OF FIELDS (CR3)

Review of continuum mechanics, Constitutive equations and conservation equations. The concept of a field, The four dimensional formulation of fields and the stress-energy momentum tensor, the Scalar Field. Linear fields and the Klein-Gordon equation, variational method and field equations, Symmetries and conservation laws. Linear massless scalar fields and the Maxwell field equations, the electromagnetic energy-momentum tensor. Electromagnetic waves, Diffraction of waves, Advanced and retarded potentials, Multipole expansion of the radiation field, The massive vector (Proca) Field, the tensor field, the massless tensor field and the Einstein feild equations, Gravitational waves, The massive tensor field, Coupled equations.

Books Recommended:

1. *Principles of Continua with Applications by Scipio, L.A., John Wiley & Sons, 1969.*
2. *The Classical of Theory of Fields by Laudau, L.D. and Lifshitz, M, Pergamon Press 1980.*
3. *Classical Electrodynmamics by Jackson, J.D., John Wiley & Sons, 1999.*

4. *Gravitation by Misner, C.W., Thorne, K.S. and Wheeler, J.A., W.H. Freeman and Co., 1973.*
5. *An Introduction to General Relativity: Spacetime and Geometry by Carrol, S.M., Addison Wesley, 2004.*

Phys 534 COMPUTER MODELING & SIMULATION (CR3)

Development of Systems Simulation:
Basic simulation methodology

Techniques for the steady state simulation*:*

techniques for sensitivity estimation, simulation-based optimization techniques, stochastic approximation techniques, meta-modeling and the goal seeking problems, "What-if" analysis techniques, likelihood ratio (LR) Method, exponential tangential in expectation method, interpolation techniques.
Building a simulation model:
The machine interference model, the generation of pseudo- random numbers,
the generation of stochastic.
Simulation designs:
The OR approach, estimation techniques for analyzing endogenously created data, transient state vs. steady-state simulation, validation of a simulation model, variance reduction techniques, simulation projects.

Building a simulation model:

Basic simulation methodology, The machine interference model, The generation of pseudo-random numbers, The generation of stochastic variates, Computer assignments, Simulation designs project.

Recommended Books :

1. *Computer Simulation and Modeling by Francis Neelamkavil, publisher John Wiley & Sons, Inc., (January 1,1987)*
2. *Modeling and Simulation Fundamentals by John A.Sokolowski, Catherine M.Banks, publisher Wiley Blackwell, April 2010.*
3. *Theory of Modeling and simulation by Bernard Phillip Zeigler, Krieger Publishing Company (1984).*

Phys 535 APPLIED NUCLEAR PHYSICS (CR3)

Neutron Physic: The interaction of neutrons with matter in bulk, thermal neutrons, cross-section (measurement of total cross-section), diffusion theory, Fermi age equation.
Nuclear Energy Sources: Nuclear fission as a source of energy, four factor formula, the chain reacting system, the neutron cycle, critical dimensions of a thermal nuclear reactor, the calculation of the multiplication constant for a homogeneous thermal reactor, the heterogeneous thermal reactor, energy production in stars, thermonuclear reactions, CNO and P-P cycle in detailed, controlled thermonuclear reactions and fusion reactor, age of galaxy.
Radioactive Measurement and Tracer Techniques: Energy measurement, coincidence measurements, time resolution, measurement of nuclear life times, trace element analysis, mass spectrometry with accelerators.

Books Recommended:

1. *Introductory Nuclear Physics by Kenneth S. Krane, John Wiley, 1988.*
2. *Nuclear Physics in a nutshell, by C.A. Bertulani, Princeton, 2007.*
3. *Nuclear Physics by Burcham Longman Higher Education Division (a Pearson Education company).*
4. *Nuclear Physics by Kaplan, Addison-Wesley Pub Co; 2nd edition, December 1962.*
5. *Nuclear Physics by Smith Pergamon Press, 1966.*
6. *Source Book on Atomic Energy by Glasston Krieger Pub.Co., 1967.*
7. *Theoretical Nuclear Physics by Blatt and Weisskopt Dover, 1991.*

Phys 536 SPINTRONICS AND QUANTUM SPIN ELECTRONICS (CR3)

Introduction to Spin Electronics:
Histrorical Development: Two spin cahnnel model, Spin Asymmetry, Spin Accumulation, Spin Diffusion Length, Two Terminal Spinelectonics, Spin Tunneling Process, Three Terminal Spinelectronics, Meso Megnetism, Dominwall in Spin Electronics, Hybrid electonics, Spin Transport in semi conductors, Direct Spin Injection, Spin Blockade.
Coupling of Electron Spins to Nuclear Spins:
Nuclear spin in a strong magnetic field, magnetic interactions and magnetic couplings, coupling mechanisms.
conservation of spin angular momentum, photochemical reaction mechanisms, spin polarization of the triplet state, spinomers, the dynamic radical pair, magnetic effects on chemical reactions, the magnetic isotope effect on radical pair reactions, electron spin, electron intrinsic angular momentum, electron spin magnetic moment, nano magnetic arrays.

Recommended Books :

1. *Concepts in spin Electronics (series on semiconductor science & technology) by Sadamichi Maekawa, Oxford University Press, 2006.*
2. *Introduction to Spintronics, by Supriyo Bandyo, Padhlay, IEEE, 2006.*
3. *Spin Physics in semiconductor by Mikhail I. Dyakonov, Springer, 2008.*
4. *Spintronics Vol.82 by Thomaz Dietl, publisher John Wiley & Sons, Inc.,2010.*
5. *Spintronics Materials, Applications and Device, by Giulia C, Lombardi and Ginerva, Nova Science Publishers (2009).*
6. *Spin Valves in Spintronics Applications, Materials, Devices Applications and Electrical by Seogatae Bae and Jackh, publisher John Wiley & Sons, Inc., 2007.*
7. *Semiconductor Spintronics and Quantum Computation, by D.D Awschalom, D.Loss and Samarth, pub. Springer 2009.*
8. *Spintronic Material and Technology (Material Science & Engineering) by Young Xu and Sarah Thompson, publisher John Wiley & Sons, Inc., 2009.*