No	Title	Credits
ID5080	Complex Networks	12
ID5840	Quantum Integer Programming	9
ID6030	An introduction to Nanoscience and Nanotechnology	9
ID6102	Principles and techniques of Transmission Electron Microscopy	9
PH5081	Nonequilibrium Statistical Mechanics	9
PH5480	Quantum Field Theory 1	9
PH5462	Magnetism in Solids	9
PH5481	Quantum Field Theory 2	9
PH5490	Advanced Statistical Physics	9
PH5500	Dynamical Systems	9
PH5510	Theory of Atomic Collisions & Spectroscopy	9
PH5590	Microwave Physics	9
PH5600	Physics At Low Temperatures	9
PH5620	Coherent and Quantum Optics	9
PH5670	Physics & Tech. of Thin Flims	9
PH5680	Superconductivity & Its Applications	9
PH5690	Applied Magnetics	9
PH5730	Methods of Computational Physics	9
PH5810	Introduction to Softmatter Physics	9
PH5811	Advanced Particle Physics	9
PH5813	Principles of Nanophotonics	9
PH5814	Laser Physics and Applications	9
PH5815	Physical Applications of Stochastic Processes	9
PH5830	Advanced Dynamical Systems	9
PH5840	Quantum Computation and Quantum Information	9
PH5842	Advanced topics in Quantum Computation and Quantum Information	9
PH5870	Introduction to General Relativity	9
PH5875	Advanced General Relativity	9
PH5890	Ultrafast lasers and Applications	9
PH6015	Advanced Materials and Nanotechnology Lab	8
PH5250	Advanced Electronics and Lab	12
PH5720	Numerical Methods and Programming	12
PH5110	Optics and Photonics	9
PH5210	Condensed Matter Physics II	9
PH5211	High Energy Physics	9

ID6102 Principles and techniques of Transmission Electron Microscopy

Description: This course is pitched to post-graduate students and research scholars belonging to both science and engineering disciplines. This the interdisciplinary course is suitable for those who will be using the TEM technique extensively as a characterization tool in their research.

course content: Fundamentals of TEM: Electrons for microscopy, properties of electrons, interactions with matter; resolution, elastic and inelastic scattering; electron beam characteristics, beam damage, electron guns; electron optics - electron lenses, apertures, aberrations, resolution of an electron lens, electron detectors. TEM instrument, specimen preparation, cutting, thinning, electropolishing, ion milling, ultramicrotomy, and chemical etching. Diffraction: Basic crystallography, introduction to point group and space group symmetry, Diffraction in TEM, reciprocal lattice, Laue and Bragg’s law,
sphere of reflection, the amplitude of diffracted beam, Bloch waves, dispersion surfaces and diffraction patterns, diffraction from crystals, structure factor, superlattice reflections, forbidden reflections, SAD techniques and indexing, CBED. Imaging: Principles of image contrast-Amplitude contrast, mass- thickness contrast, Z contrast, diffraction contrast, Thickness and bending effects, imaging line defects, planar defects, imaging strain fields, weak-beam
dark-field microscopy, STEM, phase contrast images Spectroscopy: Introduction to spectroscopic techniques in TEM, X-ray energy dispersive spectroscopy, qualitative and quantitative analysis, electron energy loss spectrometer.

TextBooks:

ReferenceBooks:1.Transmission Electron Microscopy, A textbook for Materials Science, D.B. Williams and C.B. Carter, 2009, Second Edition, Springer, USA. 2. Sample Preparation Handbook for Transmission Electron Microscopy, (Vol. I) Methodology and (Vol. II) Techniques, J. Ayache, L. Beaunier, J. Boumendil, G. Ehret, D. Laub, 2010, Springer, USA 3. Transmission Electron Microscopy of Metals, Gareth Thomas, 1962, John Wiley &
Sons, New York. 4. Practical Electron Microscopy in Materials Science, J.W. Edington, 1976, 4 volumes reprinted by Tech Books, Herndon, USA. 5. Electron Diffraction in the Transmission Electron Microscope, P.E. Champness, 2001, Garland Science, USA. 6. Physical Principles of Electron Microscopy, Ray F. Egerton, 2005 Springer Science+Business Media, Inc

PH5081 Nonequilibrium Statistical Mechanics

Description: To introduce the fundamental statistical mechanics of systems away from thermal equilibrium, including time-dependent phenomena such as Transport.

Course content: Linear Response Theory: Density operator, classical and quantum Liouville equations, response functions as correlators, generalized susceptibility. Fluctuation dissipation theorems, relaxation response relationships, Kubo-Green formulas, examples. Langevin dynamics: Markov processes, Langevin equation, Fokker-Planck equation, Ornstein-Uhlenbeck process. Dynamic mobility, dispersion relations. The fokker-Planck equation in phase space, diffusion limit. Diffusion in a potential, Smoluchowski equation, diffusion in a magnetic field. Kramers' escape rate formalism, Memory kernel, frequency- dependent friction, generalized Langevin equation. Dynamic critical phenomena: Time-dependent Ginzburg-Landau model, dynamic critical exponents.

Glauber dynamics of Ising Spins. Chemical kinetics: Reaction-diffusion systems. Turing and Hopf bifurcations, spatiotemporal patterns. Fitzhugh-Nagumo, Cahn-Hilliard and Kardar-Parisi-Zhang equations and applications. Asymmetric simple exclusion process. Thermodynamics at the molecular level: Irreversibility paradoxes, Maxwell's demon, Brownian ratchet, Brownian motors. Fluctuation Theorem, nonequilibrium partition identity, Crooks fluctuation theorem, Jarzynski equality.
TextBooks:1. R. Kubo, M. Toda, and N. Hashitsume, Statistical Physics II: Nonequilibrium Statistical Mechanics (Springer). 2. G. F. Mazenko, Nonequilibrium Statistical Mechanics (Wiley-VCH). 3. R. Zwanzig, Nonequilibrium Statistical Mechanics (Oxford).
ReferenceBooks:1. J. Keizer, Statistical Thermodynamics of Nonequilibrium Processes (Springer). 2. V. Balakrishnan, Elements of Nonequilibrium Statistical Mechanics (Ane Books). 3. B. H. Lavenda, Nonequilibrium Statistical Thermodynamics (Wiley). 4. R. M. Mazo, Brownian Motion: Fluctuations, Dynamics and Applications (Oxford). 5. P. Grindrod, Patterns and Waves: The Theory and Applications of Reaction-Diffusion Equations (Clarendon). 6. D. J. Evans and D. J. Searles, Fluctuation theorems, Adv. Phys. Vol. 51, pp. 1529-1585 (2002). 7. U. C. Tauber, Critical Dynamics (Cambridge).

PH5480 Quantum Field Theory 1

Description: This is intended to be the first course in quantum field theory aimed primarily at students who want to pursue a career in research in theoretical high energy physics, especially different aspects of high energy phenomenology (elementary particle physics, QCD matter at finite temperatures and densities, physics of the early Universe) and also string theory. To keep up with modern research, new contents such as thermal field theory (especially the real time formalism) and some fundamental aspects of many-body theory have been introduced.

CourseContent:1. The necessity of the formalism of QFT to incorporate indefinite particle numbers and the cluster decomposition principle" second quantisation of bosons and fermions with examples such as dilute Bose gas, BCS theory (Bogoliubov quasiparticles) [3 lectures] 2. Quick review of the Lorentz group (and its universal cover SL(2,C)) and transformation of one particle states under Lorentz transformations Wigner's little group for massive and massless cases [3 lectures] 3. The construction of massive free field theories from Lorentz invariance, locality and causality spin-statistics theorem spin 0, 1/2 and 1 show how the canonical quantisation of the classical Lagrangian is validated why antiparticles and CPT invariance are necessary for causality the CPT theorem [8 lectures] 4. Feynman, retarded, advanced and other propagators in free field theories both in the vacuum and at finite temperature and chemical potential the i-epsilon prescription, etc [2 lectures] 5. Propagators in interacting field theories physical significance of the retarded Green's function spectral function, sum rule and interpretation in terms of quasiparticles (also the discontinuity of occupation number at the Fermi surface) linear response theory and Kubo's formula for transport coefficients Kramers-Kronig relations thermodynamic susceptibilities from retarded Green's function fluctuation-dissipation relation general relation between the Feynman, retarded and advanced propagators at finite temperature [3 lectures] 6. The Kallen-Lehman representation of the vacuum propagator the LSZ theorem relating S-matrices to time-ordered propagators [2 lectures] 7. Wick's theorem and perturbative computations of vacuum correlation functions and S-matrices   Feynman rules illustrative computations in interacting scalar field theories and in the Yukawa theory   Feynman rules at finite temperature in real-time using the Schwinger-Dyson contour   Schwinger-Dyson equations in real time (example O(N) models) [6 lectures] 8. Symmetries and Noether currents   the construction of the Belifante-Rosenfeld energy-momentum tensor   Noether s (tensor) currents for spacetime symmetries (boosts, rotations, dilation and other conformal transformations)   Ward identities for correlation functions with examples such as how symmetries constrain correlation functions in conformal field theories[4 lectures] 9. Loop corrections and mass-shell renormalization introduction to renormalised partition function, the quantum effective (1PI) action and effective field theory [3 lectures] 10. Illustration of how thermal masses originate by resummation   1-loop computation of the self-energy for self- interacting non-relativistic fermions and justification for Fermi liquid theory [3 lectures] Luttinger-Ward functional and applications like the Luttinger theorem Schwinger-Dyson equations for the electron-hole propagator, Landau parameter and collective modes (zero sound) of Fermi liquid theory   derivation of the kinetic equation from Schwinger-Dyson equations [3Lectures]

TextBooks: Quantum Field Theory, Mark Srednicki, Cambridge University Press 2007 The Quantum Theory of Fields, Vols 1 and 2, Steven Weinberg, Cambridge University Press 2005 Quantum Field Theory: Lectures of Sidney Coleman, World Scientific 2018 An Introduction to Quantum Field Theory, Michael Peskin and Daniel Schroesder, CRC Press 1995 Quantum Field Theory in a nutshell, Anthony Zee, Princeton University Press 2010 Thermal Field Theory, Michel Le Bellac, Cambridge University Press 2010

Reference books: Many-particle physics, Gerald Mahan, Springer 2000 Lecture notes of Andre-Marie Tremblay (https://www.physique.usherbrooke.ca/tremblay/cours/phy-892/N-corps.pdf) Lecture Notes of David Tong (https://www.damtp.cam.ac.uk/user/tong/qft.html, http://www.damtp.cam.ac.uk/user/tong/gaugetheory.html) Basics of Thermal Field Theory, Aleksi Vuorinen and Mikko Laine, Springer 2016 Quantum Field Theory: From Basics to Modern Topics, Francois Gelis, Cambridge University Press, 2000

PH5462 Magnetism in Solids

Description: To provide sufficient background to the students in the area of magnetism and magnetic materials

Course content: Diamagnetism Isolated magnetic moments Magnetism in 3d and 4f atoms/ions - Hund’s rules “ crystalline electric field effects Curie, van Vleck and Pauli Paramagnetism Spontaneous magnetic order - Molecular field models “ Magnetic order in elements, alloys and non-metallic compounds - Exchange interactions “ Heisenberg direct exchange “ itinerant exchange “ Stoner parameter “ Double exchange “ Superexchange “ RKKY exchange Spin glass, cluster glass, and Kondo effect Ab-initio description of magnetism in solids-cluster models [Introduction] Statistical mechanics of magnetism in solids “ Landau-Ginzburg-Wilson theory “ Ising model - spin waves - Bloch T3/2 law Magnetocrystalline anisotropy Magnetism and magnetic interactions in sub-micron level particles “ phenomenon of superparamagnetism, magnetism in thin films Interaction of neutrons and electromagnetic radiation with magnetic moments “ Faraday effect, MOKE, FMR, SWR, Mossbauer effect Non-magnetic physical properties in magnetically ordered solids Magnetism in oxides and exchange mechanisms therein

TextBooks:1. D.H. Martin, Magnetism in Solids, ILIFFE Books Ltd, (1967) 2. A.H. Morrish, Physical Principles of Magnetism, John Wiley, New York
(1965) 3. P. Mohn, Magnetism in Solid State, an Introduction, Springer (2006) 4. Stephen Blundell, Magnetism in Condensed Matter, Oxford University
Press, USA (2001)
ReferenceBooks:1. S Foner (Ed.), Magnetism Selected Topics, Gordon and Breach, London (1976) 2. B.D. Cullity and C.D. Graham, Introduction to
Magnetic Materials, Wiley (2009) 3. D. C. Mattis, Theory of Magnetism I and II, Springer-Verlag (1981)

PH5481:Quantum Field Theory 2

Description: This is intended to be the second course in quantum field theory aimed primarily for students who want to purse a career in research in theoretical high energy physics, especially different aspects of high energy phenomenology (elementary particle physics, QCD matter, physics of the early Universe) and also string theory. This introduces students to the path integral techniques, non-Abelian gauge theories and their quantisation, spontaneous global and local symmetry breaking and some non-perturbative methods. Some basic aspects of gauge theories at finite temperature have also been introduced.

CourseContent:1. Path integral quantization of quantum mechanics with explicit example for a free particle and harmonic oscillator at zero and finite temperature Partition function as generating functional of correlation functions [2 lectures] 2. Path-integral quantisation of scalars and Dirac fermions derivation of Feynman rules at zero and finite temperature/chemical potential in real time via path integral formalism [4 lectures] 3. The construction of the quantum effective action via path integrals derivation of Ward identities Callan-Symanzik equation for evolution of correlation functions the beta function and the anomalous dimension notion of marginal, relevant, irrelevant operators and IR/UV fixed points proof of renormalisability of phi^4 field theory in four dimensions dimensional regularisation and Wilson-Fisher fixed points triviality of the scalar field in four dimensions   RG derivation of Fermi liquid theory (follow Polchinski) [6 lectures] 4. Path-integral quantisation of electromagnetic fields   Dirac brackets and the Coulomb gauge quantisation Faddeev-Popov method and arbitrary gauges   introduction to the BRST method [4 lectues] 5. Feynman rules of QED and computation of cross sections   Ward identities and one loop renormalisation of the charge   (sketch of) proof of renormalisability of QED to all orders in perturbation theory   gauge invariance of the quantum effective action   mitigating IR divergences of QED [4 lectures] 6. QED at finite temperature   introduction to hard thermal loop effective field theory and applications [2 lectures] 7. Non-Abelian gauge theories   one-loop renormalisation and the beta function   BRST cohomology and physical states   gauge invariance of the quantum effective action (Slavnov-Taylor identities)   sketch of proof of renormalisability to all orders in perturbation theory [5 lectures] 8. Spontaneous global symmetry breaking   Goldstone s theorem and its modern generalisations (counting of type B goldstone bosons)   Introduction to non-linear sigma model via the chiral Lagrangian of QCD   Ward identities and soft-theorems for cross sections [3 lectures] 9. Spontaneous breaking of gauge symmetry via the Higgs mechanism example of standard model and dynamical symmetry breaking in scalar QED [2 lectures] 10. Instantons, theta vacuua of Yang-Mills theories and effect of fermions   how nonperturbative effects are included in the effective chiral Lagrangian   Monopoles in QED   Witten effect and dyons Hooft Polyakov monopole   Abelian-Higgs model   vortices and confinement   Wilson loops and   t Hooft lines [5 lectures] 11. The triangle anomaly (axial anomaly in QCD as an example)   Path integral derivation of anomalies (anomalous Ward identities and non- invariance of the effective action)   consistency of the standard model (demonstration of absence of gauge anomalies) construction of anomaly polynomials (Wess-Zumino consistency conditions, BRST cohomology and descent equations)   anomalies and index theorems [3 lectures]

TextBooks:Quantum Field Theory, Mark Srednicki, Cambridge University Press 2007 The Quantum Theory of Fields, Vols 1 and 2, Steven Weinberg,
Cambridge University Press 2005 Quantum Field Theory: Lectures of Sidney Coleman, World Scientific 2018 An Introduction to Quantum Field Theory,
Michael Peskin and Daniel Schroesder, CRC Press 1995 Quantum Field Theory in a nutshell, Anthony Zee, Princeton University Press 2010 Thermal
Field Theory, Michel Le Bellac, Cambridge University Press 2010

ReferenceBooks:Many-particle physics, Gerald Mahan, Springer 2000 Lecture notes of Andre-Marie Tremblay (https://www.physique.usherbrooke.ca/tremblay/cours/phy-892/N-corps.pdf) Lecture Notes of David Tong (https://www.damtp.cam.ac.uk/user/tong/qft.html, http://www.damtp.cam.ac.uk/user/tong/gaugetheory.html) Basics of Thermal Field Theory, Aleksi Vuorinen and Mikko Laine, Springer 2016 Quantum Field Theory: From Basics to Modern Topics, Francois Gelis, Cambridge University Press 2019

PH5490:Advanced Statistical Physics

Description:This course gives the students an in-depth view of such topics such as phases, and phase transitions. This course also introduces the student to the models and techniques that are used to study such concepts as universality and scaling in the vicinity of phase transitions and the emergence of universality. The course also introduces the students to the realm of non-equilibrium statistical mechanics.

course content: Fluctuations and random processes. Brownian motion, - diffusion, random walks. Langevin equation, fluctuation dissipation theorem, irreversibility. Markov processes, master equation. Fokker Planck equation. Examples of first order and continuous phase transitions. Mean field (van der Waals and Weiss molecular field) theories. Fluid magnet analogy. Correlations, classical (Ornstein Zemicke) theory. Statistical mechanical models :Ising, lattice gas, Heisenberg, XY and Potts models. Transfer matrix method, illustration using the onedimensionalIsing model. Duality in the two dimensional Ising model. High and low temperature series expansions. Critical phenomena: long range order, order parameter, scaling, universality, critical exponents.
Peierls argument for phase transitions. Spontaneous breakdown of symmetry, Landau theory of phase transitions. Role of fluctuations, lower and upper critical dimensions. GinzburgLandau model. Higgs mechanism, examples. Merminwagner theorem. Topological (Berezinskii Kosterlitz Thouless)phase transition. Elements of the renormalization group approach to continuous phase transitions : flows in parameter space, fixed points,epsilon expansion,
real space renormalization. Connection withEuclidean field theories. Elementary ideas on percolation.____
TextBooks:1) Statistical Physics of Fields, Mehran Kardar, Cambridge University Press. 2) Lectures on Phase Transitions and the Renormalization
Group, Nigel Goldenfeld, Frontiers in Physics. 3) Statistical Physics, Landau and Lifshitz, Addison-Wesley, Reading Mass., 1970 4) Statistical
Mechanics, S. K. Ma, World Science, Phila., 1986
ReferenceBooks:1) Quantum Phase Transitions, Subir Sachdev, Cambridge University Press

PH5500 Dynamical Systems

Description:General introduction to linear and nonlinear evolution equations: Flows and maps, types of dynamical behaviour, conservative versus dissipative systems, sensitivity to initial conditions, deterministic chaos. Dynamical variables, phase space, phase trajectories and their properties. Linear autonomous systems. Phase plane analysis of 2D systems. Classification of singular points. Stability and asymptotic stability. Stable, unstable and centre manifolds. Hartman-Grobman theorem. Limitations of lin
CourseContent:
TextBooks:NIL

reference books: P.G. Drazin, Nonlinear Systems, Cambridge University Press (1992) M. Tabor, Chaos and Integrability in Nonlinear Dynamics. Wiley (1989). A.J. Lichtenberg and M.A. Lieberman, Regular and Chaotic Dynamics, 2nd Edition, Springer-Verlag (1994). E.Ott, Chaos in Dynamical Systems Cambridge University Press (2002). H.G. Schuster, Deterministic Chaos, 2nd Edition, Physik-Verlag (1995). S. H. Strogatz, Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry and Engineering, Addison-Wesley, 1994. T. Tel and M. Gruiz, Chaotic Dynamics, Cambridge
University Press, 2006.

PH5510 Theory of Atomic Collisions & Spectroscopy

Description:The course will cover quantum theory of collisions inclusive of second quantization methods to speed up graduate students to appreciate current literature in the field of theoretical atomic physics. Complementary domains of spectroscopy and collisions would be both covered, including study of resonances resulting from interference between discrete and continuum states. Methods of both non-relativistic and relativistic many-body theory will be introduced. Some older texts will be used which cover the theoretical formulation, but these will be supplemented from time to time by current literature from research journals and review papers.

CourseContent:Quantum Theory of collisions: optical theorem, differential scattering cross section, partial wave analysis, Scattering operator, reciprocity theorem, Levinson's and Seaton s theorems. Time-reversal symmetry in collisions. Lippman-Schwinger equation of potential scattering, Born Approximation, Coulomb Scattering, High energy and low energy approximations to collisions phenomena, Breit-Wigner Resonances. Fano parameterization, Eisenbud-Wigner-Smith formalism of time-delay in scattering and photoionization. Many-body theory, second quantization, electron gas in the Hartree-Fock approximation, Dyson's chronological operator, Rayleigh- SchrÃ¶dinger perturbation methods, Bohm-Pines approach to Random Phase Approximation. Feynman Diagrammatic Methods: I, II and higher order Feynman diagrams, Relativistic many body methods.

TextBooks:1. Quantum Collisions Theory by C.J.Joachain (Elsevier, 1979) 2. Quantum Theory of Many Particle Systems by A.L.Fetter and J.D.Walecka (Dover, 2003) 3. Many Electron Theory by Stanley Raimes (Elsevier, 1972) 4. Atomic Collisions and Spectra by U.Fano and A.R.P.Rau (Academic Press, 1986) 5. Atomic Structure Theory: Lectures on Atomic Physics by Walter R. Johnson (Springer; 2007)

ReferenceBooks:1. Hans Bethe and Salpeter, Quantum Mechanics o one- and Two electrons. Dover Publications 2. Paul Roman, Advanced Quantum Theory, Addison-Wesley Publishing company

PH5590 Microwave Physics

Description:Generation: Klystrons and Magnetrons. Solid state microwave generators. Tunnel diode and bulk semiconductor devices. Gunn and IMPATT. Equivalent circuits. Microwave propagation: in rectangular cylindrical and coaxial lines. Boundary conditions. Different modes. Field and current distributions. Wave guide components: Attenuators, phase shifter, crystal and bolometer detectors. Isolators, Slide screw tuners. Matched termination, directional coupler. Magic Tee. Ferrite and YIG components. Horns. Microwave Measurements: Impedance and standing wave ratio measurements. The von Hippe! method. Measurement of complex permittivity. Phase shift and attenuation measurement. Microwave integrated circuits: Principles. Stripline resonators. Microwave materials: Ferrites. Garnets. Ceramic titanates. Copper pad PTFE. Dielectric Resonators.

CourseContent:

TextBooks:NIL

ReferenceBooks:1. A.J. Badenfuller, Microwaves. Pergamon Press (1969). 2. G.J. Wheeler. Introduction to Microwaves. Prentice-Hall of India (1963). 3.
S. Y. Liao, Microwave Devices and Circuits, 2nd Edition, PrenticeHall of India (1987) . 4. K.C. Gupta, Microwaves, 8th Edition, Wiley Eastern (1989). 5.
M.L. Sisodia and G.S. Raghuvanshi, Microwave Circuits and Passive Devices, Wiley Eastern (1987)

PH5600 Physics At Low Temperatures

Description: This course will provide a comprehensive and up-to-date understanding of various aspects of low temperatures. This elective course is suitable for post-graduate students and research scholars belonging to both science and engineering disciplines.
Course content: Quantum fluids: Physical properties of helium. Superfluidity in 4He: experimental findings, two-fluid model, Bose-Einstein Condensation, macroscopic quantum state, vortex flow, critical velocities and second sound.Normal and superfluid 3He, quantum states of pairs of coupled quasi particles - Spin triplet pairing “ macroscopic quantum effects, mixture of 3He and 4He, phase diagram, properties of this mixture, topological defects in superfluid 4He and superfluid 3He and salient properties of quantum solids. Solids at low temperatures: Electrical transport, thermal, mechanical and magnetic properties, Kondo effect, superconductivity and heavy fermion materials.Production of low and ultra low temperatures, Liquid helium cryostats, Closed Circuit refrigerators: Gifford-McMahon refrigeration cycle, Pulse tube refrigerator, Physics of adiabatic and nuclear demagnetization, Pomeranchuk cooling, dilution refrigerators. Advanced materials for magnetic refrigeration, Special problems of thermal insulation, thermal contact and heat transfer at ultra low temperature and Kapitza resistance. Experimental techniques in Laser cooling.International temperature scales “ Temperature fixed points, Measurement of temperatures and different kinds of thermometers: (Primary and secondary) - Gas thermometer, vapour pressure thermometry, resistance thermometer: metal resistances like platinum, doped semiconductors like germanium, carbon and carbon glass, Ruthenium oxide, Cernox thermometers “ thermoelectric thermometer, Capacitance thermometers, magnetic thermometers, measurement of temperature in the presence of high magnetic field.
TextBooks:1) Guy K White and Phillips J Meeson, Experimental Techniques in Low-Temperature Physics, 4th Edition, Clarendon Press “ Oxford (2002).2) H.M. Rosenberg, Low Temperature Solid State Physics, Oxford University Press (1963).3) D.R. Tilley and J. Tilley, Superfluidity and Superconductivity, IoP Publishing, Bristol, 3rd Edition (1990).
4) James F Annett, Superconductivity, Superfluids and Condensates, Oxford Master Series in Physics, Oxford University Press, 1st Edition (2004).5) A.C. Rose-Innes and E.H.Rhoderick, Low Temperature Laboratory Techniques, English University Press (1973).
ReferenceBooks:1. Frank Pobell, Matter and Methods at Low Temperatures, 3rd revised and expanded Edition, Springer (2007).2. V.E. Mclintock, D.H. Meredith and J.K.

Wigmore, Matter at Low Temperatures, Blackie, Glassglow (1984).3. Christian Enns and Siegfried Hunklinger, Low Temperature Physics, Springer Verlag (2005).4. Anthony Kent, Experimental Low Temperature Physics (Macmillan Physical Science Series), AIP (1993).5. D.S. Betts, Introduction to Millikelvin Technology, Cambridge University Press (1989).6. O.V. Lounasmaa, Experimental Principles and Methods below 1 K, Academic Press (1974).7. Robert Coleman Richardson and Eric N. Smith, Experimental Techniques in Condensed Matter Physics at Low Temperatures, Advanced Books Classics (1998)8. J. W. Ekin, Experimental Techniques in Low Temperature Measurements, Oxford University Press (2006)9. P. M. Chaikin and T. C. Lubensky, Principles of Condensed Matter Physics, Cambridge University Press (2000

PH5670 Physics & Tech. of Thin Flims

Description:Preparation methods: electrolytic deposition, cathodic and anodic films, thermal evaporation, cathodic sputtering, chemical vapour deposition. Molecular beam epitaxy and laser ablation methods. Thickness measurement and monitoring: electrical, mechanical, optical interference, microbalane, quartz crystal methods. Analytical techniques of characterization: X-ray diffraction, electron microscopy, high and low energy electron diffraction, Auger emission spectroscopy. Growth and structure of films. General features. Nucleation theories Effect of electron bombardment on film structure. Post - nucleation growth Epitaxial films and growth. Structural defects. Mechanical properties of films: elastic and plastic behaviour. Optical properties. Reflectance and transmittance spectra. Absorbing films. Optical constants of film material. Multilayer films. Anisotropic and isotropic films. Electric properties to films: Conductivity in metal, semiconductor and insulating films. Discontinuous films. Superconducting films. Dielectric properties. Magnetism of films: Molecular field theory. Spin wave theory. Anisotropy in magnetic films. Domains in films. Applications of magnetic films. Thin film devices: fabrication and applications.
CourseContent:
TextBooks:NIL
ReferenceBooks:1. K.L. Chopra, Thin Film Phenomena, McGrawHill (1983), 2. K.L. Chopra and I.J. Kaur, Thin Film Soalr Cells, Plenum Press (1983).
3. L.I. Maissel and Giang (Eds.), Handbook of Thin film Technology, McGrawHill (1970). 4. J.C. Anderson, The Use of Thin Films in Physical Investigation, Academic Press (1966). 5. J.J. Coutts, Active and Passive Thin Film Devices, Academic Press (1978). 6. R.W. Berry, P.M. Hall and M.T. Harris, Thin Film Technology, Vn Nostrand (1968). 7. George Hass. Physics of Thin Films: Volumes 1':12. Academic Press (1963).

PH5680 Superconductivity & Its Applications

Description:This course aims to introduce the basic theory of superconductivity and their potential applications. This elective course is suitable for post-graduate students and research scholars belonging to both science and engineering disciplines.

course content: Properties of superconductor in normal state, Fundamental phenomena: Perfect conductivity and Meissner effect, thermodynamic critical field, other physical properties of superconductors. Electrodynamics of superconductors: London equations and penetration depth, superconductor as a macroscopic quantum state, flux quantization, Pippard's non-local electrodynamics and coherence length. Thermodynamics of the superconducting phase transition, Ginzburg -Landau theory, order parameter, Type I and Type II superconductors. Transport current, critical current density and critical magnetic fields. Surface nucleation and critical magnetic field, Hc2. Nature of mixed state " Structure of a vortex, flux flow, vortex pinning and critical current density. Microscopic (BCS) theory. Cooper pairs and the attractive interaction. BCS ground state and excitations from the ground state. Energy gap and its temperature dependence. Tunneling experiments. Josephson effect, Superconducting QUantum Interference Device (SQUID). Classical superconductors: A15 compounds, Lave phases and Chevrel phases - Other superconductors: High temperature oxide superconductors, Fullerenes, Magnesium diboride, Borocarbides and Boronitrides, novel layer iron pnictide superconductors, heavy fermion superconductivity. Applications of superconductivity: Low current applications: SQUID magnetometers, Magnetoencephalography using SQUID, High current applications: Superconducting magnet design, Magnetic Resonance Imaging, Maglev trains, Superconducting Super Colliders, Power generators, transmission lines and motors
.
TextBooks:1. Michael Tinkham, Introduction to Superconductivity, 2nd edition, Dover books on Physics Vol. I (2004). 2. J.B. Ketterson and S.N. Song, Superconductivity, Cambridge University Press (1999) 3. D.R. Tilley and J. Tilley, Superfluidity and Superconductivity, 3rd Edition, IoP Publishing, Bristol and Philadelphia (2003). 4. James F Annett, Superconductivity, Superfluids and Condensates, Oxford Master Series in Physics, Oxford University Press, 1st Edition (2004). 5. Charles Poole Jr., Horacio A Farach and Richard J Creswick, Superconductivity, Academic Press (1995).

ReferenceBooks:1. R.D. Parks (Ed.), Superconductivity, Vols. 1 and 2, Marcel - Dekker Inc. (1969). 2. A.C. Rose-Innes and E.H. Rhoderick,
Introduction to Superconductivity, Pergamon (1977). 3. J. Schrieffer and J. R. Shrieffer, Theory of Superconductivity, Advanced Books Classics (1999) 4.
J.Schrieffer and James Brooks, Hand Book of High Temperature Superconductivity Theory and Experiment, Springer (2006) 5. P.G. De Gennes,
Superconductivity of Metals and Alloys (Advanced Books Classics, (1999)

PH5690 Applied Magnetics

Description:Types of magnetic materials and their characterization. Hysteresis: Spontaneous and saturation magnetization. Permeability, susceptibility and coercive force. Demangnetization effects. Magnetic anisotropy. Domains : size, shape and motion. Bloch wall. Magnetization processes. Exchange interactions. Magnetism in elements, alloys and compounds. Measurement of magnetic moment, permeability and Curie temperature. Faraday balance. Vibrating sample magnetomerter.

Rotating sample magnetomerter. Torque magnetometer. Soft and hard magnetic materials. Materials for application in transformers, permanent magnets and motors: composition and preparation techniques. Eddy currents and loss mechanisms. Ferrites and their application. Magnetostriction : principles and materials for transducer application. Propagation of electromagnetic waves in a magnetic medium.
Magnetic storage techniques. Magneto-optics. Bubble memories and curie point writing. Amorphous magnetic materials. Production of ultrahigh magnetic fields.

CourseContent:

TextBooks:NIL

ReferenceBooks:1. David Jiles. Introduction to Magentism and Magnetic Materials, Chapman and Hall (1991). 2. D.H. Martin, Magnetism in Solids,
Illife, London (1967). 3. S. Chikazumi, Physics of Magnetism, Wley, New York (1964). 4. B.D. Cullity, Introduction to Magnetic Materials, AddisonWesley
(1972), 5. A.H. Morrish, Physical Principles of Magnetism, John VViley, New York (1965). 6. K. Moorjani and J.M.D. Coey (Eds.) Magnetic Glasses,
Elsevier (1984). 7. T. Kaneyoshi (Ed.), Introduction to Amorphous Magnets, World Scientific (1992). 8. G.M. Kalvius and R.S. Teffie (Eds.) Experimental
Magnetism, Vol.1, Wiley (1979). 9, A.H. Eschenfelder. Magnetic Bubble Technology, SpringerVerlag (1980). 10. E.P. Wolfharth (Ed.) Ferromagnetic
Materials, Vol.1, North Holland (1980)

PH5730 Methods of Computational Physics

Description:Nature, meaning and methods of computer simulation, choice and usage of programming languages and use of graphical techniques. Computability and algorithmic complexity, P, NP and N-Pcomplete problems. The traveling salesman problem. Numerical methods of solving ordinary differential equations. Simple. Multi-step and Implicit Methods, Runge-Kutta methods. Harmonic Oscillations. Damped and Driven Oscillator. Methods of numerical integration across discontinuities. Anharmonic, Free and Forced oscillators. Coupled oscillators. Electrical Circuit oscillations. Chaotic behaviour in dynamical systems. Simple one dimensional maps. Period doubling. Stability, Order and Chaos in 2dimensional motion. Mathematical idealizations and computer models (cellular automata) of physical systems. Wave Phenomenon. Fourier analysis. Interference, Diffraction and Polarization. Simulation of Young's double slit experiment. Boundary value and eigenvalue problems. Numerov algorithm. Green function solutions.
Stationary solutions of the Schrodinger equation. Some examples. The quantum mechanical harmonic oscillator. Graphical display of classical and wave
mechanical probability densities. Special functions and Gaussian quadratures. Some applications. Matrix inversions. Numerical diagonalization. Reduction to tridiagonal form. Some applications. Monte Carlo methods. Generation of random variables having specified distribution. Metropolis algorithm. Applications to some physical problems

PH5810 Introduction to Softmatter Physics

Description:This is a foundational elective course introducing soft matter physics to interested students. The course touches upon all facets of soft matter physics
CourseContent:This course will replace the existing PH5810 Simple and Complex FluidsThis is an elective course, introducing soft matter physics to interested students, The course touches upon all facets of soft matter physics, with the following three major modules.(i) basic concepts and theoretical frameworks, (ii) computational aspects(iii) experimental techniques used in soft condensed matter. Basic concepts and theoretical frameworks,Length, time and energy scales in condensed matter systems. Basic phenomenology of soft condensed matter systems: Liquid crystals, polymers, membranes, colloidal systems, phase behaviour, diffusion and flow, viscoelasticity (4 lectures.)Order Parameter, Phases and Phase transitions: Mean-field theory and phase diagrams, defining order parameters, elasticity, stability, metastability, interfacesBasic liquid crystal physics as examples, Frank free energy, Landau-de Gennes model of isotropic-nematic transition,Onsager's mean field theory, nematic-smectic transition (8 lectures)Colloidal systems: Poisson-Boltzmann theory, DLVO theory, sheared colloids, stability of colloidal systems, measurement of interaction (6 lectures)Polymers: Model systems, chain statistics, polymers in solutions and in melts,flexibility and semi-flexibility, distribution functions, self-avoidance, rubber elasticity, viscoelasticity, reptation ideas (8 lectures)Membranes: Fluid vs. solid membranes, energy and elasticity, surface tension, curvature, de Gennes-Taupin length, brief introduction to shape transitions. (6 lectures)Computational aspects - (7 lectures)Dynamics and Numerical Methodologies:
Stokes limit, Rouse and Zimm Model for polymers, membranes, relaxation, computational studies, multiscale modelingExperimental techniques in soft matter (7 lectures):Structures, correlations and dynamics of soft matter measured by light, neutron and x-ray scattering, ellipsometry, microscopy of soft matter (polarized light optical microscopy, video microscopy, confocal microscopy), rheology.

TextBooks:1. Soft Matter Physics, M. Kleman and O.D. Lavrentovich, Springer-Verlag (2003)2. Statistical Mechanics of Surfaces, Interfaces and Membranes, S.A.Safran, Addison-Wesley, Reading, MA (1994)3. Colloidal Dispersions, W.B. Russel, D.A. Saville and W.R. Showalter, Cambridge University Press, New York, (1989).4. Polymer Physics, M. Rubinstein and R. H. Colby, Oxford University Presss (2003) .5. Neutron, X-rays and Light scattering Methods Applied to Soft Condensed Matter,Edited by Th. Zemb, P. Linde, North holland, (2002).6. Experimental and computational techniques in soft condensed matter Physics, Edited by, Jeffrey Olafsen, CambridgeUniversity press (2010).

ReferenceBooks:Module I: C. W. Gardiner, Handbook of Stochastic Methods (Springer, New York, 1996). B. J. Berne and R. Pecora, Dynamic Light Scattering: With Applications to Chemistry, Biology and Physics (Dover,New York 2000). P. M. Chaikin and T. C. Lubensky, Principles of Condensed Matter Physics (Cambridge University Press, South Asian Edition, 1998). D. Forster, Hydrodynamic Fluctuations, Broken Symmetry, and Correlation Functions (Perseus Books Group, 2000). Module II: J. P. Hansen and I. R. McDonald, Theory of Simple Liquids (Academic Press, New York, 1990). Module III: P. G. de

Gennes, Scaling Concepts in Polymer Physics (Cornell University Press, Ithaca, 1979). M. Doi and S. F. Edwards, The Theory of Polymer Dynamics (Clarendon Press, Oxford, 1988). P. G. de Gennes and J.Prost, The Physics of Liquid Crystals (Clarendon Press, Oxford, 1993). Module IV: S. A. Safran, Statistical Thermodynamics of Surfaces, Interfaces and Membranes (Addison-Wesley, Reading, 1994).

PH5811 Advanced Particle Physics

Description:To present the Standard Model of Particle Physics which unifies electromagnetic, weak and strong interactions

CourseContent:Continuous symmetries and conservation laws; flavor and color symmetry revisited; Discrete symmetries: Parity, Charge conjugation; Time reversal and CPT theorem. Electromagnetic processes: helicity conservation, Compton and Bhabha scattering, higher order corrections. Weak processes: pion decay, parity violation, CP violation, neutral-meson oscillations, CKM matrix. The neutrino sector, neutrino oscillations, neutrino experiments. Strong processes: Deep inelastic scattering and the parton model, quarks and the Drell-Yan process, elementary ideas of QCD, perturbative QCD. Electroweak interactions, charged and neutral currents. Electroweak symmetry breaking and Higgs mechanism. W and Z bosons. The Glashow-Salam-Weinberg model, the standard model of particle physics. Discovery of the top quark and Higgs boson. Physics beyond the standard model. Relationship of particle physics with cosmology.

TextBooks:[1] Introduction to Elementary Particles, 2nd Edition, David Griffiths, Wiley-VCH.[2] Introduction to High Energy Physics, Donald H. Perkins,
Cambridge.[3] Quarks & Leptons, Francis Halzen and Alan D. Martin, Wiley India Edition.
ReferenceBooks:Review of Particle Physics, Particle Data Group (latest version available at http://pdg.lbl.gov)

PH5813 Principles of Nanophotonics

Description:Analysis of light-matter interaction in periodic as well as random nanoscale media and assessment of its significance in basic physics and technological applications.
CourseContent:PH Principles of Nanophotonics 1. Review of light-matter interaction: Maxwell s equations and electromagnetic wave propagation in metallic and dielectric media, concepts of refractive index and dispersion. 2. Light propagation through nanostructures: Propagation through periodic structures, analogy with band theory of solids and the idea of phonic band gap, Photonic crystals, photonic crystal fibers; Propagation through random media, bio imaging, coherent backscattering random lasing and Localization of light. 3. Optics beyond diffraction limit: Plasmonics, surface plasmon resonance, near filed optics, propagation through sub wavelength waveguides, evanescent waves, structures with negative refractive index. Optical metamaterials, negative refraction and cloaking. 4. Quantum confinement effects: Optical properties of low dimensional

semiconductors, tunable absorption and emission, light emission from confined structures, nonlinear optical effects, quantum dot lasers. 5. Overview of emerging frontiers and applications: slowing of light, nanoscale opto electronics, graphene photonics, optical magnetism, light localization and emission control, imaging and sensing.

TextBooks:Text books: 1. Principles of Nanophotonics (Series in Optics and Optoelectronics) M Ohtsu, K Kobayashi , T Kawazoe, T Yatsui and M Naruse , Taylor & Francis; (2008) 2. Introduction to Nanophotonics Sergey V. Gaponenko , Cambridge University Press (2010) 3. Plasmonics: Fundamentals and Applications Stefan Alexander Maier, Springer (2007) 4. Optical Properties of Nanostructures Ying Fu and Min Qiu, Pan Stanford Publishing (2011)

ReferenceBooks:Reference books: 1. Photonic Crystals: Molding the Flow of Light John D. Joannop0oulos, Steven G. Johnson, Joshua N. Winn and Robert D. Meade, Princeton University Press; (2008) (Also available as free-downloadable ebook) 2. Nanophotonics Paras N. Prasad, Wiley- Interscience (2004) 3. Principles of Nano-Optics Lukas Novotny and Bert Hecht , Cambridge University Press (2012) 4. Nano-Optics for Enhancing Light-Matter Interactions on a Molecular Scale: Plasmonics, Photonic Materials and Sub-Wavelength Resolution Luciano Silvestri , Baldassare Di Bartolo
and John Collins (Ed), Springer (2013).

PH5814 Laser Physics and Applications

Description:Characteristics of laser radiation: Coherence and brightness, Einstein s coefficients, rate equations, Gain coefficient, 3, 4- level lasers, Threshold gain, Creation and annihilation operators.

CourseContent:Characteristics of laser radiation: Coherence and brightness, Einstein s coefficients, rate equations, Gain coefficient, 3, 4- level lasers, Threshold gain, Creation and annihilation operators. Modes of oscillation: transverse and longitudinal, spectral line shapes and line broadening mechanisms, applications in frequency stabilization Gaussian Beams: Stability conditions, Rayleigh Range, confocal parameter Typical laser systems: Gas (He-Ne, He-Cd, Argon, CO2, Excimer), Solid (Ruby, Nd:YAG, Ti:Saphire), Fibe lasers, semiconductor, free-electron lasers; Uniqueness and their applications. Q-switching and modelocking: applications in spectroscopy, two-photon spectroscopy and nonlinear optics, laser frequency comb, optical clock. General Applications: Laser holography: holographic storage, non-destructive testing, optical disk storage, Laser metrology: laser gyro, LIDAR and atmospheric applications, laser trapping and manipulations (tweezers). Lasers in material science, pulsed laser deposition, plasma generation, micromachining and bio-applications.

TextBooks:Laser fundamentals, W. T. Silfvast, Cambridge University Press, (1998). Quantum Electronics, A. Yariv, John Wiley (1975). Lasers: Principle and Applications; J Wilson and J.F.B. Hawkes; Prentice Hall (1987)

ReferenceBooks:Lasers, A. E. Siegman, University Science Books (1986)Fundamentals of photonics, B. E. A. Saleh, M. C. Teich, John Wiley (2007).Laser Physics, P. W. Milonni, J. H. Eberly, John Wiley (2010).Few cycle laser pulse generation and its applications, Franz Kartner (Ed), Springer (2004)

PH5815 Physical Applications of Stochastic Processes

Description:To introduce students to physical applications of stochastic processes CourseContent:Probability: Joint and conditional probabilities and densities. Moments, cumulants, generating functions, characteristic function. Binomial,Poisson, Gaussian distributions. Stable distributions, limit theorems, diffusion limit of random flights. Infinitely divisible distributions. Markov processes:Chapman-Kolmogorov equation, transition rate, Kramers-Moyal expansion. Fokker-Planck equation, backward Kolmogorov equation, first passage time problems. Master equation, birth-and-death processes, chemical reaction dynamics.Stochastic differential equations, Langevin equation, Feynman-Kac formula, diffusion processes, Brownian motion, role of dimensionality, fractal properties. Reaction-diffusion equations. Random walks: Markovian random walks. Random walks and electrical networks, random walks in biology. Levy flights. Self-avoiding walks and polymer dynamics. Non- Markov continuous time random walks, transport in amorphous media. Percolation. Noise: Jump processes, power spectra, Campbell's Theorem,
Carson's Theorem. Thermal, shot,Barkhausen and 1/f noise.Random processes in deterministic dynamics: Coarse-grained dynamics, Markov and generating partitions, symbolic dynamics, recurrence statistics.

TextBooks:C. W. Gardiner, Handbook of Stochastic Processes (Springer).N. G. Van Kampen, Stochastic Processes in Physics and Chemistry(North-Holland). H. Risken, The Fokker-Planck Equation: Methods of Solution and Applications (Springer).

ReferenceBooks:N. Wax, Selected Papers in Noise and Stochastic Processes (Dover).R. L. Stratonovich, Topics in the Theory of Random Noise
(Gordon & Breach).G. H. Weiss, Aspects and Applications of the Random Walk (North-Holland).M. Kac, Probability and Related Topics in Physical
Sciences (Wiley-Interscience). H. C. Berg, Random Walks in Biology (Princeton University Press).C. Beck and F. Schlogl, Thermodynamics of Chaotic
Systems (Cambridge University Press)

PH5830 Advanced Dynamical Systems

Description: Nonlinear time series analysis: Power spectra, embedding techniques, reconstruction of attractors, calculation of dimensions. Prediction techniques, surrogate analysis. Control of chaos, synchronization. Stability, Lyapunov functions. Center manifolds, normal forms for flows and maps. Local and global bifurcations. Melnikov's method. Hyperbolic systems and strong chaos. Symbolic dynamics, Markov and generating partitions. Elements of the thermodynamic formalism. Hamiltonian dynamics: canonical transformations, symplectic group, action-angle variables, Hamilton-Jacobi equation. Liouville-Arnold integrability and dynamical symmetry. Non-integrable systems, canonical perturbation theory, small-divisor problem. KAM theorem. Area-preserving maps, fixed points, Poincare-Birkhoff theorem. Homoclinic and heteroclinic cycles. Local and global chaos. Quantum Chaos: WKB and beyond. Semiclassical quantization. Periodic orbit theory. Elements of random matrix theory. Simple models of quantum chaos. Dynamical localization and experimental realizations in atomic, mesoscopic and optical systems. Integrability in dynamical systems: Different kinds of integrability: Liouville-Arnold, algebraic, analytic, C-integrability. Painleve analysis, extension to the PDEs encountered in physical applications: KdV, modified KdV, sine- Gordon, nonlinear Schrodinger and Burgers equations. Nonlinear waves, solitary waves and solitons. Infinite number of conservation laws. Elementary ideas on quantum integrability: Bethe ansatz. Dynamics of networks. Regular, small-world, growing, scale-free and random networks. Comparison with percolation. Evolution on networks. Physical applications. Stochastic dynamical systems: Discrete and continuous random variables. Shot noise, Poisson noise, white noise. Gaussian processes. Markov chains, Markov processes, birth-and-death processes. Brownian motion, Langevin equation, master equation, Fokker-Planck equation. Correlation functions, power spectra, Wiener-Khinchin theorem. Diffusion processes, stochastic differential equations.

Reaction-diffusion equations with noise. Turbulence: Navier-Stokes equation, Boussinesq approximation, symmetries, conservation laws. Phenomenology of fully-developed turbulence. Kolmogorov's 1941 theory. Intermittency. Multiscaling and RG methods. 2D turbulence.

CourseContent:

TextBooks:NIL
ReferenceBooks:H.D.I. Abarbanel, Analysis of Observed Chaotic Data, Springer-Verlag, 1996. E. Ott, T. Sauer and J. A. Yorke, Coping with Chaos,
Wiley, 1994. L. Perko, Differential Equations and Dynamical Systems, 3rd Edition, Springer (INdia), 2004. S. Wiggins, Introduction to Applied Nonlinear
Dynamical Systems and Chaos, Springer-Verlag, 1990. J. Guckenheimer and P. Holmes, Nonlinear Oscillations, Dynamical Systems and Bifurcations of Vector Fields, Springer-

Verlag, 1983. E. A. Jackson, Perspectives in Nonlinear Dynamics, Vols. 1 & 2, Cambridge University Press, 1990. A. J. Lichtenberg and M. A. Lieberman, Regular and Chaotic Motion, 2nd Edition, Springer-Verlag, 1994. H-J. Stockmann, Quantum Chaos -- An Introduction, Cambridge University Press, 1999. F. Haake, Quantum Signatures of Chaos, Springer-Verlag, 1991. P. G. Drazin and R. S. Johnson, Solitons: An Introduction, Cambridge University Press, 1990. D.J. Watts, Small Worlds: The Dynamics of Networks Between Order and Randomness, Princeton University Press, 1999. R. Albert and A.-L. Barabasi, Statistical Mechanics of Complex Networks, Rev. Mod. Phys. Vol. 74, p. 47 ff. (2002). N. G. van Kampen, Stochastic Processes in Physics and Chemistry, North-Holland, 1985. C. W. Gardiner, Handbook of Stochastic Methods, Springer-Verlag, 1997. U. Frisch, Turbulence, Cambridge University Press, South Asian Edition, 1999.

PH5840 Quantum Computation and Quantum Information

Description:This course is intended as a follow-up to the basic course in Quantum Computation and Quantum Information (PH5840). It is structured to be an advanced topics course that will address the need of research scholars and final year students aiming to pursue research in this area. The contents of the course are broad enough that it will give the students an overview of the current research topics in the field and equip them with the techniques and methods required to tackle research problems.

CourseContent:(1) Quantum Correlations: Bipartite entanglement measures such as concurrence, entanglement entropy, entanglement witness, PPT criterion.Multipartite entanglement: tangle; mutual information; monogamy of correlations.Quantum Discord: definition and properties(2) Random States and Operators: Haar measure, how to generate quantum states uniformly at random, random unitary operators; Some properties and applications.(3) Quantum Error Correction: CPTP maps, conditions for QEC, Stabilizer codes, Fault-tolerance, Topological QEC\(4) Quantum Information processing with Continuous Variable States: Gaussian States: Mathematical description, properties; Covariance matrix, Uncertainty relation, Coherent states, Cat statesWigner function; Other phase-space representations like q-function, p-function, Husimi ¦Squeezed light: properties and applications; Two-mode squeezing and EPR statesLinear-optics-based QC: Beam-splitter, phase-shifters, MZI.(5) Quantum Shannon Theory: Von Neumann entropy and its properties (Subadditivity, Concavity) Relative entropy, conditional entropy, Mutual Information, Strong SubadditivityQuantum Data Processing inequality, Schumacher compression, Classical and quantum capacity of quantum channels(6) Open Quantum Systems: Lindblad formalism, Markovian and non- Markovian dynamics(7) Quantum Metrology(8) Optional topics: Quantum Cryptography, Adiabatic Quantum Computing, Experimental realizations of
Qubits.

TextBooks:Geometry of Quantum States, Bengtsson and Zyczkowski, Cambridge Univ Press, (2017). Quantum Error Correction, T. A. Brun and D.Lidar, Cambridge Univ Press (2013). Quantum Information Theory, Mark M. Wilde, Cambridge Univ Press (2013). Quantum Information with Continuous Variables, S. L. Braunstein and A. Pati, Springer (2012).
ReferenceBooks:Quantum Correlations beyond Entanglement, A. Streltsov, Springer (2015). Open Quantum Systems, Brauer and Peturccione, Oxford Univ Press (2003)

PH5842 Advanced topics in Quantum Computation and Quantum Information

Description:This course is intended as a follow-up to the basic course in Quantum Computation and Quantum Information (PH5840). It is structured to be an advanced topics course that will address the need of research scholars and final year students aiming to pursue research in this area. The contents of the course are broad enough that it will give the students an overview of the current research topics in the field and equip them with the techniques and methods required to tackle research problems.
CourseContent:(1) Quantum Correlations: Bipartite entanglement measures such as concurrence, entanglement entropy, entanglement witness, PPT criterion.Multipartite entanglement: tangle; mutual information; monogamy of correlations.Quantum Discord: definition and properties(2) Random States and Operators: Haar measure, how to generate quantum states uniformly at random, random unitary operators; Some properties and applications.(3) Quantum Error Correction: CPTP maps, conditions for QEC, Stabilizer codes, Fault-tolerance, Topological QEC\(4) Quantum Information processing
with Continuous Variable States: Gaussian States: Mathematical description, properties; Covariance matrix, Uncertainty relation, Coherent states, Cat statesWigner function; Other phase-space representations like q-function, p-function, Husimi ¦Squeezed light: properties and applications; Two-mode squeezing and EPR statesLinear-optics-based QC: Beam-splitter, phase-shifters, MZI.(5) Quantum Shannon Theory: Von Neumann entropy and its
properties (Subadditivity, Concavity) Relative entropy, conditional entropy, Mutual Information, Strong SubadditivityQuantum Data Processing inequality, Schumacher compression, Classical and quantum capacity of quantum channels(6) Open Quantum Systems: Lindblad formalism, Markovian and non- Markovian dynamics(7) Quantum Metrology(8) Optional topics: Quantum Cryptography, Adiabatic Quantum Computing, Experimental realizations of
Qubits.

TextBooks:Geometry of Quantum States, Bengtsson and Zyczkowski, Cambridge Univ Press, (2017). Quantum Error Correction, T. A. Brun and D. Lidar, Cambridge Univ Press (2013). Quantum Information Theory, Mark M. Wilde, Cambridge Univ Press (2013). Quantum Information with Continuous Variables, S. L. Braunstein and A. Pati, Springer (2012).
ReferenceBooks:Quantum Correlations beyond Entanglement, A. Streltsov, Springer (2015). Open Quantum Systems, Brauer and Peturccione, Oxford
Univ Press (2003).

PH5870 Introduction to General Relativity

Description:To introduce students to the general theory of relativity and prepare them for eventually learning advanced topics such as cosmology and the physics of black holes as well as gravitational waves.

CourseContent: Objectives: To introduce students to the general theory of relativity and prepare them for eventually learning advanced topics such as cosmology and the physics of black holes as well as gravitational waves. Course Contents: Essential special relativity Lorentz transformations - Length contraction and time dilation - Metric tensor - The light cone - Contravariant and covariant vectors - Tensors and transformations - Infinitesimal generators of translations, rotations and boosts - Algebra of the generators - The Lorentz and the Poincare groups Learning outcome: Understand essential aspects of special relativity and evaluate its observable consequences. Classical fields in special relativity Action formulation for coupled oscillators - Action describing a real, canonical, scalar field in Minkwoski spacetime - The Euler-Lagrange field equation - Conservation of angular momentum - Action governing the complex scalar field - Equations of motion - Global gauge invariance - Local gauge invariance and the need for the electromagnetic field Noether s theorem - External symmetries - Conserved quantities - Dilatations - The conformal stress-energy tensor - Internal symmetries and gauge transformations.The electromagnetic field tensor - The first pair of Maxwell s equations - The four current vector - The continuity equation - Action governing the free electromagnetic field - Interaction of the electromagnetic field with charges and currents - The second pair of Maxwell s equations Equations governing the free field - Electromagnetic waves - The stress-energy tensor of the electromagnetic field - The retarded Green s function - The Lienard-Wiechart potentials - Radiation from moving charges Learning outcome: Understand the behavior of classical fields in flat spacetime and recognize the close connection between symmetries and conservation laws. Spacetime, geometry and gravitation The scope of the general theory of relativity - Geometry and physics - Space, time and gravity in Newtonian physics - The equivalence principle - The principle of general covariance Learning outcome: Appreciate that gravitation is geometry. Calculus on Riemannian manifolds Manifolds and coordinates - Curves and surfaces - Transformation of coordinates - Contravariant, covariant and mixed tensors - Elementary operations with tensors - The partial derivative of a tensor - Covariant differentiation and the affine connection - The metric - Geodesics - Symmetries and Killing vectors - Conserved quantities - The Riemann tensor - The equation of geodesic deviation - The curvature and the Weyl tensors Learning outcome: Understand the nature of curved spacetimes and learn to carry out calculus on curved manifolds.

Field equations of general relativity The principle of minimal gravitational coupling - The vacuum Einstein equations - Derivation of vacuum Einstein equations from the action - The Bianchi identities - The stress-energy tensor - The cases of perfect fluid, scalar and electromagnetic fields - The structure of the Einstein equations Learning outcome: Appreciate the structure of the equations of motion governing the gravitational field.

TextBooks:1. L. D. Landau and E. M. Lifshitz, The Classical Theory of Fields (Course of Theoretical Physics, Volume 2), Fourth Revised English Edition (Pergamon Press, New York, 1975). 2. F. Scheck, Classical Field Theory (Springer, Heidelberg, 2012). 3. S. Coleman, Aspects of Symmetry (Cambridge University Press, Cambridge, England, 1988). 4. L. H. Ryder, Quantum Field Theory, Second Edition (Cambridge University Press, Cambridge, England, 1996). 5. B. F. Schutz, A First Course in General Relativity (Cambridge University Press, Cambridge, 1990). 6. R. d Inverno, Introducing Einstein s Relativity (Oxford University Press, Oxford, 1992). 7. J. B. Hartle, Gravity: An Introduction to Einstein s General Relativity (Pearson Education, Delhi, 2003).

ReferenceBooks:1. A. O. Barut, Electrodynamics and Classical Theory of Fields and Particles (Dover, New York, 1980). 2. M. Carmeli, Classical Fields (Wiley, New York, 1982). 3. B. Felsager, Geometry, Particles and Fields (Springer, Heidelberg, 1998). 4. S. Carroll, Spacetime and Geometry (Addison Wesley, New York, 2004). Advanced texts 1. C. Itzykson and J. B. Zuber, Quantum Field Theory (McGraw-Hill, New York, 1986). 2. S. Carroll, Spacetime and Geometry (Addison Wesley, New York, 2004).

PH5875 Advanced General Relativity

Description:To introduce students to advanced aspects of general relativity, involving the physics of black holes, cosmology and gravitational waves

CourseContent: Objectives: To introduce students to advanced aspects of general relativity, involving the physics of black holes, cosmology and gravitational waves. Course Contents: Schwarzschild geometry and experimental tests of general relativity The general static isotropic metric - The Schwarzschild solution - Symmetries and conserved quantities - Motion of particles in the Schwarzschild metric - Precession of the perihelion of Mercury - Bending of light - Gravitational redshift Learning outcome: Appreciate the consistency of predictions of general relativity with experimental and observational data. Static and stationary black holes Schwarzschild black hole - Event horizon, its properties and significance - Singularities - The Kruskal extension - Penrose diagrams The Reissner-Nordstrom and the Kerr solutions - Frame dragging - Ergosphere - Penrose process Black hole thermodynamics - Hawking radiation Learning outcome: Understand the structure of black holes and examine interesting processes that can occur near them. Cosmology Homogeneity and isotropy - The Friedmann-Lemaitre-Robertson-Walker line-element - Geodesics - Friedmann equations - Solutions with different types of matter - Cosmological red-shift - Luminosity and angular diameter distances - Cosmological parameters - Age of the universe - Supernovae and late time acceleration Cosmic microwave background radiation - Thermal history - Big bang nucleosynthesis The horizon problem - The inflationary scenario - Generation of perturbations in the early universe - Evolution of perturbations - Anisotropies in the cosmic microwave background - Recent constraints Learning outcome: Appreciate the theoretical and observational foundations leading to the standard model of cosmology. Gravitational waves The linearized Einstein equations - The transverse-traceless gauge - Solutions to the wave equation Generation of gravitational waves - The quadrupole formula for the energy loss - Sources of gravitational waves - The case of the Hulse-Taylor binary pulsar Gravitational waves from binary systems - Interferometric detectors - Detection of gravitational waves - Observed events - Gravitational wave astronomy - Implications for astrophysics of compact sources and theories of gravity The stochastic gravitational wave background - Current constraints - Implications for the physics of the early universe Learning outcome: Understand the nature of gravitational waves, their origin, methods devised to detect them and appreciate the prospects of astronomy with gravitational waves.

TextBooks:1. L. D. Landau and E. M. Lifshitz, The Classical Theory of Fields (Course of Theoretical Physics, Volume 2), Fourth Edition (Pergamon Press, New York, 1975). 2. B. F. Schutz, A First Course in General Relativity (Cambridge University Press, Cambridge, 1990). 3. E. W. Kolb and M. S. Turner, The Early Universe(Addison-Wesley, Redwood City, California, 1990). 4. R. d Inverno, Introducing Einstein s Relativity (Oxford University Press, Oxford, 1992). 5. J. B. Hartle, Gravity: An Introduction to Einstein s General Relativity (Pearson Education, Delhi, 2003). 6. S. Carroll, Spacetime and Geometry (Addison Wesley, New York, 2004). 7. M. P. Hobson, G. P. Efstathiou and A. N. Lasenby, General Relativity: An Introduction for Physicists (Cambridge University Press, Cambridge, 2006). 8. S. Weinberg, Cosmology (Oxford University Press, Oxford, England,2008).

ReferenceBooks:1. S. Weinberg, Gravitation and Cosmology (John Wiley, New York, 1972). 2. A. P. Lightman, W. H. Press, R. H. Price and S. A. Teukolsky, Problem Book in Relativity and Gravitation (Princeton University Press, New Jersey, 1975). 3. S. Dodelson, Modern Cosmology (Academic ity Press, Princeton, New Jersey, 2013). Advanced textbooks 1. S. W. Hawking and G. F. R. Ellis, The Large Scale Structure of Spacetime (Cambridge University Press, Cambridge, 1973). 2. C. W. Misner, K. S. Thorne and J. W. Wheeler, Gravitation (W. H. Freeman and Company, San Francisco, 1973). 3. R. M. Wald, General Relativity (The University of Chicago Press, Chicago, 1984). 4. E. Poisson, A Relativist s Toolkit (Cambridge University Press, Cambridge, 2004).

PH5890 Ultrafast lasers and Applications

Description:To introduce Ultrashort laser pulses and some of their applications CourseContent:Unit 1: Ultrafast Light Sources:Q-switching and mode-locking, Nanosecond, Picosecond and Femtosecond Lasers, Synchrotron source.Unit 2: Applications in Time-Domain Spectroscopy:Need of lifetime measurements in semiconductors / organic materials. Various methods of lifetime measurements: Oscilloscope methods, Time-correlated single photon counting, Fluorescence upconversion, pump-probe spectroscopy.Unit 3: Applications in Nonlinear Optics:Self-focusing and self-defocusing, Optical rectification, Z-scan and four wave mixing technique, measurement of second and third order optical nonlinear susceptibility, Idea of optical gates.Unit 4: Applications in Fibre optic communication:Basics of optical fibre, photodetectors, fibre lasers, semiconductor lasers and optical communication, Group velocity dispersion and dispersion compensation.Unit 5:Applications in tunable Lasers and High Harmonic Generation:White light continuum generation, Transient absorption, Optical parametric oscillators, Petta Watt lasers and other applications.

TextBooks:Text books and References: ¢ Few-Cycle Laser Pulse Generation and its Applications, Franz X. Kartner, SPRINGER (2004) ¢ Pulse fluorometry using simultaneous acquisition of fluorescence and excitation, D J S Birch, R E Imhof, and A. Dutch, Rev. Sci. Instrum. 55, 1255 (1984) ¢ The Principles of Nonlinear Optics, Y R Shen, Wiley-Interscience (2003) ¢ Nonlinear Fibre Optics, G P Agrawal, Academic Press (2001)
ReferenceBooks:Text books and References: ¢ Few-Cycle Laser Pulse Generation and its Applications, Franz X. Kartner, SPRINGER (2004) ¢ Pulse fluorometry using simultaneous acquisition of fluorescence and excitation, D J S Birch, R E Imhof, and A. Dutch, Rev. Sci. Instrum. 55, 1255 (1984) ¢ The Principles of Nonlinear Optics, Y R Shen, Wiley-Interscience (2003) ¢ Nonlinear Fibre Optics, G P Agrawal, Academic Press (2001)

PH6015 Advanced Materials and Nanotechnology Lab

Description:To introduce laboratory techniques for the synthesis and characterization of advanced materials, and techniques in nanotechnology.

CourseContent:Growth of thin-films using PVD, synthesis of materials such as carbon nanomaterials, magnetic nanoparticles and 2D systems. Characterization of the above materials using techniques such as SEM, TEM, Raman spectroscopy, XRD, magnetization studies, XPS, AFM and electrical transport. Hardness test and electrical transport studies on nanocrystalline diamond. Photo I-V characterization of solar cells.
TextBooks:Handout notes will be provided
ReferenceBooks:Handout notes will be provided