INTEGRATED PHD PROGRAMME IN PHYSICAL SCIENCES

COURSE DESCRIPTION IN OUTLINE

The course descriptions given below is simply an attempt to give a rough outline of the material to be covered. But of course the detailing out and the point of view is one to be decided upon by the teacher. The same is true regarding the suggested textbooks. Generally one expects that attempts will be made to suggest to the students even at the level of the basic courses (in the first two semesters) the linkages with more advanced courses to come later. Also to indicate how the core material relates to more recent applications Furthermore efforts may be made to establish connectivity to other courses going on concurrently or to those that are to come subsequently, to impart the sense of organic unity of the physical sciences. Emphasis will be placed on tutorials and in having examples of the material covered in the lectures to concretise the underlying ideas and facilitate the application of basic principles to solving problems.

First Semester

PHY101 CLASSICAL DYNAMICS : 3-1-0-4

Review of Newtonian mechanics, inertial frames of reference; Galilean Principle of Relativity; non-inertial frames.
Generalised co-ordinates, the Principal of Least Action, the Lagrangian.
Motion in one dimension and turning points - relation between the potential energy and the period of motion.
The two-body central force problem, Kepler motion.
Small oscillations, normal modes, forced and damped oscillations under friction- non-linear oscillators, perturbation theory and parametric resonance, motion in a rapidly oscillating field.
Rigid body motion- Euler's angles and equation - the asymmetric top.
Collision theory - scattering, small angle scattering, Rutherford's formula.
Hamiltonian formulation, canonical transformations, Poisson brackets. Liouville's theorem Hamiltonian-Jacobi theory, Action-Angle variables.
Phase space, phase space trajectories, fixed points and their stabilities.

Goldstein : Classical Mechanics
Landau and Lifshitz : Mechanics
Percival and Richards : Classical Dynamics
Marion : Mechanics
Hand and Finch, Analytical Mechanics.

PHY102 MATHEMATICAL METHODS I 3-1-0-4

Vector analysis, Green, Gauss and Stokes theorems.
Linear vector spaces and linear operators. Matrices & eigenvalue problem.
Theory of complex variables, Cauchy-Riemann conditions, Cauchy integral theorem, Taylor-

Laurent expansion, classification of singularities, analytic continuation, theorem of residues and evaluation of definite integrals and series.
Ordinary differential equations and series solution. Sturm-Liouville problem and orthogonal functions, special functions.
Green's functions for self-adjoint differential operators and eigenfunction expansion. (Laplace, Poisson, Diffusion, Wave equation etc to be discussed).

G. Arfken, Mathematical Methods for Physicists
I.N. Sneddon, Special Functions of Mathematical Physics & Chemistry
P.K. Chattopadhyay, Mathematical Physics
E. Kreyszig, Advanced Engineering Mathematics
Mathews and Walker, Mathematical Physics
P. Dennery & A. Kryzwicki, Mathematics for Physicists
C.M. Bender & S.A. Orszag, Advanced Mathematical Methods for Scientists & Engineers
E. Butkov, Mathematical Physics
R.W. Churchill & J.W. Brown, Complex Variables & Applications

PHY103 QUANTUM MECHANICS I 3-1-0-4

Need for Quantum Mechanics. Operators and Linear Vector Spaces to describe observables and states of a system. Eigenstates and eigenvalues. Expansion into eigenstates and probabilistic interpretation. Canonical commutation relations. Uncertainty principle.
Position and momentum representations. Wavefunctions.
Schrödinger and Heisenberg equations of motion.
Probability density and probability current densities. Ehrenfest Theorem.
Stationary states; Non-stationary states: as examples Gaussian and Airy wave-packets for a free particle. Time-independent Schrödinger equation.
One dimensional problems: bound states, reflection and transmission, linear harmonic oscillator, the coherent state, tunnelling through potential barriers and examples. Illustrations from mesoscopic physics, quantum wires etc
Motion in three dimensions. Central potential problems (bound states in 3D).
Symmetry in quantum mechanics. Angular momentum and spin; Addition of angular momenta.

Merszbacher : Quantum Mechanics
Sakurai : Modern Quantum Mechanics
Cohen-Tannoudji, Diu and Lalöe, Quantum Mechanics I
Schiff : Quantum Mechanics
Landau and Lifshitz : Quantum Mechanics
Messiah : Quantum Mechanics I and II
Powell and Craseman : Quantum Mechanics
K. Gottfried, Quantum Mechanics
Bransden and Joachim, Introduction to Quantum Mechanics
Townsend, Quantum Mechanics

PHY104. ELECTROMAGNETIC THEORY I 3-1-0-4

Electrostatics & methods of solving boundary value problems, Multipole expansion of electrostatic potentials. Dielectrics.
Biot-Savart Law & Ampere's Law. Vector potential.
Faraday's Law and time-varying fields.
Maxwell's equations, energy and momentum of the electromagnetic field, Poynting Vector, Conservation Laws.

J.D. Jackson, Classical Electrodynamics
J.R. Reitz, F.J. Milford & R.W. Christy, Foundations of Electromagnetic Theory.
D.J. Griffiths, Introduction to Electrodynamics

PHY191. BASIC LABORATORY I 0-2-6-6

The aim of this course is to help develop a temperament among the students so that they may feel some confidence in setting up experimental arrangements for investigating physical problems, and go beyond the black box push-button mentality. Instead of specifying a set of pre-existing equipment and already set-up experiments, this curriculum gives emphasis to the universal principles and underpinnings of experimental techniques through a laboratory-based hands-on course and design of experiments.

As a first step towards this goal it is necessary to introduce the working principles of basic measuring instruments and sensors and how they can be used to measure and to control different physical variables. For this purpose it is essential that the students become familiar with the principles and practice of electronics. Accordingly one of the components of this course is Electronics which will be superposed on the part devoted to investigation of physical phenomena in order to avoid compartmentalisation. For convenience this component is spelt out first:

1. Measurement of Thevenin parameters (V[TH] and R[TH]) of a DC power supply (Battery).
    - Plot V[load] versus R[load] curve and mark slope and stiff regions.
    - In the slope region measure V[load] for at least two different R[load] and characterize V[TH] and R[TH].
    - In the stiff region measure I[Load] for at least two different R[Load] and characterize V[TH] and R[TH].
    - Measure V[TH] by using a multimeter and compare with the estimated value of V[TH] and comment.
2. Characterization of semiconductor diodes and designing of transformer based full wave rectifier.
    - Draw three characterization curves of two rectifier diodes (Germanium, Silicon) and one Zener diode.

- Estimate turn ratio of a transformer by measuring voltage ratio (primary and secondary).
- Construct a Full wave rectifier and measure input and output waveforms of the rectifier.

3. Characterization of a Zener Regulated DC power supply.

    - Measure V[C], V[rms], g and PIV of a full wave rectifier and compare them with their calculated values.
    - Design a R-C filter and measure p-p ripple voltage and compare with calculated value.
    - Design a Zener regulator after the above filter and measure load dependency and load regulation (voltage).

4. Characterization of an n-p-n transistor and designing of fixed biased CE transistor amplifier.

    - Draw base and collector characteristic curves of an n-p-n transistor in the CE configuration.
    - Mark saturation, cutoff and active regions and determine Q point for best transistor operation.
    - Design a simple fixed biased CE amplifier with the estimated Q point. Determine current gain and compare with the specified value.

5. Use of a transistor as electronic switch and designing a memory unit (R-S flip flop).

    - Use a transistor as a switch to operate a LED in the output with low frequency input.
    - By using high frequency square wave input measure t[on] and t[off].
    - Design a R-S flip-flop and complete its truth table with S as input. Catch a bit from a low frequency pulse train.

Price, Analog Electronics (Prentice-Hall)
Hickman, Analog Electronics (Newnes)
Bogart, Electronic Devices and Circuits (Universal Book Stall)
Streetman, Solid State Electronic Devices (P/H/I)
Horowitz and Hall, The Art of Electronics (Cambridge)

Another important component of this course is Optics. The details of this course are spelt out below:

1. Familiarization set:

    - Verification of the laws of geometrical optics
    - Lens formulae
    - Experiments with equilateral prism

- Optical lever

2. Verification of Fresnel equations of EM theory
3. Experiments in Polarization Optics
   - Characterization of state of polarization (SOP)
   - Production of polarized light
   - Poincare sphere and Stokes parameters
4. Critical angle of an equilateral prism
5. Gaussian beam characterization
6. Use of a hollow prism and n (refractive index) of liquids
7. Verification of Claussius-Mossotti relation
8. Matrix methods in Optics: simulation experiments
9. Kramers-Kronig relation: a study

PHY105. COMPUTATIONAL METHODS IN PHYSICS I 2-0-2-4

Introduction to Fortran programming and basic numerical methods will be imparted to the students through lectures and projects based on the numerical analysis of elementary physical problems illustrating such techniques.

Second Semester

PHY201. STATISTICAL MECHANICS 3-1-0-4

Review of thermodynamics. Need for statistical mechanics.
Basic ideas of probability and statistics, random walks, Gaussian and Poisson Distributions, Central Limit Theorem.
Distribution functions and phase space. Liouville equation, mixing and ergodicity.
Ensembles: Micro canonical, Canonical, Grand canonical. Partition function - connection with thermodynamic potentials
Quantum Ideal Gases - Fermi-Dirac/Bose-Einstein Statistics. Various applications of ideal fermions to specific heat and susceptibility of metals, etc.
Various applications of ideal bosons to black body radiation and Planck distribution, etc.
Imperfect gases.
Basic ideas of phase transitions.

Callan, Introduction to Thermodynamics & Thermostatistics
F. Reif, Fundamentals of Statistical & Thermal Physics
R.K. Pathria, Statistical Mechanics
L.E. Reichl, A Modern Course in Statistical Physics
Kerson Huang, Statistical Mechanics

PHY202 MATHEMATICAL METHODS II 3-1-0-4

Elements of Group Theory.
Fourier and Laplace transforms, Saddle point method and asymptotic expansions.
Integral Equations
Calculus of Variations.
Functional integration and functional differentiation.

Mathews & Walker, Mathematical Physics
C.M. Bender & S.A. Orzag, Advanced Mathematical Methods for Scientists & Engineers

PHY203. QUANTUM MECHANICS II 3-1-0-4

Scattering theory - Born approximation and partial wave analysis.
Time independent perturbation theory.
Variational method
The WKB approximation.
Time independent perturbation theory (Fermi's Golden Rule).
Adiabatic and Sudden Approximations
Geometric Phases and the Bohm-Aharanov Effect.
Rotation group, Tensor operators and the Wigner-Eckart theorem.
Illustrations from atomic, molecular and nuclear physics.
Pure and Mixed states. Density Matrix formalism

Landau & Lifshitz: Quantum Mechanics
Messiah, Quantum Mechanics I & II
Davidov, Quantum Mechanics
Sakurai : Modern Quantum Mechanics
Cohen-Tannoudji, Diu & Lalöe, Quantum Mechanics II
Ryder, Quantum Field Theory
Flugge, Practical Quantum Mechanics

PHY204 ELECTROMAGNETIC THEORY II 3-1-0-4

Lorents Invariance of Maxwell's equations; Review of Special Relativity; Maxwell's equations in covariant form; four-vector potential and the electromagentic field tensor.
Propagation of plane electromagnetic waves, reflection and refraction.
Propagation through anisotropic and chiral media.
Radiation from an accelerated charge, retarded and advanced potentials.
Radiation multipoles
Wave guides, Resonant Cavities.

J.D. Jackson, Classical Electrodynamics
J.R. Reitz, F.J. Milford & R.W. Christy, Foundations of Electromagnetic Theory.

PHY291 BASIC LABORATORY II 0-2-6-6

As an essential component of this course is to introduce the student advanced techniques in electronics the syllabus of which is given below:

1. Design a differential amplifier with collector and emitter resistances 2.2 K** and 4.7 K** respectively and measure the following:
   - Error voltage.
   - Inverting and non-inverting output gain with single ended input and output configuration.
   - Use the differential amplifiers a comparator and plot characteristic curve.
2. Make a circuit with IC 741, which would have zero output offset. Perform following experiments:
   - Design inverting, non-inverting and voltage follower amplifiers. Measure gains and compare with estimated values.
   - Design summing, subtractor and averager amplifiers with unity gain and compare results with estimated values.
3. Perform following experiments with proper truth table:
   - Use NAND gate to realize the functions of NOT, AND, OR and EX-OR gates. Indicate corresponding Boolean operation.
   - Design a digital voting machine (using NAND gates only) for three voters by following Karnaugh Map optimization technique.
4. Perform following experiments with proper truth table:
   - Design digital circuits for half adder and subtractor by using NAND gates only.
   - Show a circuit diagram of a full adder by using NAND gates only. Explain the design and operation.
5. Perform following experiments with proper truth table:
   - Make a J-K flip-flop circuit by using NAND gates only. Show toggle and self-oscillation (racing) in the output.

     Design Master-Slave J-K flip-flop and show the output performance.

The other component of this course is to develop the innovativeness of the student to put to use the knowledge, attitudes and techniques acquired through the basic electronics and optics courses in the first semester, to conceive, design, build and implement projects for the measurement of say a physically interesting quantity or the experimental verification of some physical principle or the quantitative observation of some interesting phenomena etc. Some of the experiments are listed below:

- Paramagnetism

- Frank-Hertz experiment
- Energy gap in semiconductors
- Hysterisis loop
- Two-probe and four-probe measurements

PHY205. COMPUTATIONAL METHODS IN PHYSICS II 2-0-2-4

This course will involve lectures on advanced numerical techniques and projects based on the numerical analysis of advanced physical problems illustrating such techniques.

Third Semester

PHY391. METHODS OF EXPERIMENTAL PHYSICS 3-1-3-7

1. Error analysis: Errors in observation and treatment of experimental data, estimation of error, theory of errors and distribution laws, least squares method, curve fitting, statistical assessment of goodness of fit.
2. Basic measurement techniques and the underlying physical principles
   - Low temperature
   - Low voltage
   - High vacuum
3. Spectroscopic techniques: Theory and experiments
4. Theory and experiments in Nanophysics

PHY303. QUANTUM MECHANICS III 3-1-0-4

Path Integral Formulation of Quantum Mechanics.

Relativistic quantum mechanics : Klein-Gordon and Dirac equations. Relativistic hydrogen atom.

Canonical quantization of fields : the Schrödinger field and its applications to many-body problems. (Illustration through superfluidity, superconductivity, hard-sphere bose gas etc.)

Quantization of real and complex scalar fields, and the Maxwell field (non-covariant quantisation in the radiation gauge). Spontaneous and Induced Emission of Photon from Atoms.

Covariant perturbation theory. QED at tree level and calculation of processes such a Compton scattering, Moller scattering, etc.

PHY302. CONDENSED MATTER PHYSICS 3-1-0-4

Binding and cohesion in solids. Bonds and bands.
Crystal Structure, X-ray Diffraction, Reciprocal Lattice.

Periodic potentials, Bloch's Theorem, Kroning Penney Model, Free electrons and nearly free electrons; tight binding approximation.
Elementary ideas of band structure of crystalline solids.
Concept of holes and effective mass; density of states; Fermi surface; explanation of electronic behaviour of metals, semi-conductors and insulators.

Lattice vibrations, harmonic approximation, dispersion relations and normal modes, quantization of lattice vibrations and phonons. thermal expansion and need for anharmonicity.

Transport properties of solids. Boltzmann transport equation. Wiedemann-Franz law. Hall effect.

Superconductivity: Phenomenology, penetration depth, flux quantization etc. Josephson effect.

Semiconductors: intrinsic and extrinsic, carrier mobility etc.

Thermal properties of solids.

Magnetism in solids.

Optical and Dielectric Properties.

Dekker, Solid State Physics
Kittel, Introduction to Solid State Physics
Ashcroft and Mermin, Introduction to Solid State Physics.
Ziman, Principles of the Theory of Solids.

PHY303. NUCLEAR & PARTICLE PHYSICS 3-1-0-4

This course aims at familiarizing the student with the basics of the physics of the atomic nucleus and of elementary particles.
Orders of magnitudes and units
Accelerators
Passage of Radiation through matter
Detectors
The nuclear two-body problem
The Liquid Drop Model.
The Shell Model.
The Collective Model.
Beta decay of nuclei.
Gamma decay of nuclei.

Hadrons (mesons and baryons)
Gauge theory and Electroweak interaction
Hadronic interactions.
Quarks and the basics of the Standard Model

Subatomic Physics, H. Frauenfelder and E.M. Henley, Prentice Hall 1974.
W.E. Burcham and M. Jobes, Nuclear and Particle Physics, Addison Wesley 1998
Pooh, Rith, Scholz and Zetsche, Particles and Nuclei, Springer 1995.
D.H. Perkins, Elementary Particle Physics
A. Preston & A. Bhaduri, Nuclear Physics

FOURTH SEMESTER COURSES

RELATIVISTIC QUANTUM FIELD THEORY 3-1-0-4

Relativistic notations.
SU(2) and the rotation group.
Lorentz Group and SL(2,C).
Homogeneous and Inhomogeneous Lorentz Group and their Algebras.
Spinors.
Relativistic Covariant Equations- Klein Gordon, Dirac and Maxwell equations.
Quantization of free fields: Canonical and Path Integral Approach.
Covariant quantisation of the Maxwell field.
Interacting Fields and the Gauge Principle.
Feynman-Dyson Perturbation Expansion and Feynman Diagrams.
Quantum Electro-Dynamics. Tree Level Calculations of Compton Scattering Cross-section etc.
Loops, Divergences, Regularization and Renormalization.
Anomalous magnetic moment of the electron and the Lamb-Shift.

GENERAL RELATIVITY & COSMOLOGY 3-1-0-4

Special theory of relativity. Tensor analysis. Covariant and contravariant tensors. Metric tensor. Affine connection and curvature tensor. Bianchi identities.

General theory of relativity. Equivalence principle. Principle of general covariance. Geodesics and equation of motion of particles. Gravitational field equations. Schwarzschild solution.

An introduction to the standard big-bang cosmological model. Cosmological principle. Robertson-Walker metric. Hubble's law and red-shifting of light. Energy-momentum tensor for a perfect fluid. Equation of state and solution of Einstein's equations for radiation, matter and vacuum energy. Cosmic microwave background radiation.

S. Weinberg, Gravitation and Cosmology
Misner, Thorne and Wheeler, Gravitation
R. Wald, General Relativity.
Kolb and Turner, Early Universe.

QUANTUM THEORY OF MANY BODY SYSTEMS 3-1-0-4
Review of perturbation theory for time evolution operator (propagator) - interaction picture - Dyson equation.
Time evolution in frequency (Fourier-Laplace transform domain) - resolvent expansion - Lippman-Schwinger equation - T matrix/multiple scattering theory.
Finite temperature Green's function - retarded case - application to superconductivity.
Salpeter equation.
Ward identitites and Feynman diagrams.
Ring and ladder diagrams - Bethe-Bruckner-Goldstone theory.
Coulomb interaction - Hartree-Fock theory - Random Phase Approximation (RPA).
Electron-phonon (Frohlich) interaction - superconductivity.
Superfluidity.

A. L. Fetter and J. D. Walecka, Quantum Theory of Many Particle Systems
G. D. Mahan, Many Particle Physics
Mattuck, A Guide to Feynman Diagrams in the Many Body Problem
Negele,
P. Nozieres and D. Pines, The Theory of Quantum Liquids, Vols. I & II
March, Young and Sampanthar,

CHEMICAL PHYSICS 3-1-0-4

Quantum Chemistry and the Nature of the Chemical Bond.
Chemical Kinetics and Thermodynamics. Order of the Reaction. Rate laws.
Mechanism of Chemical Reactions: (a) Collision Theory (b) Transition State Theory (c) Potential Energy Surface (d) Kramers Escape Rate.
Enzyme Reactions: Solution kinetics, characterization of enzymes, control mechanisms.
Electron Transfer: (a) Dynamical Electrochemistry (b) Electron Transfer (c) Quantum Models (d) Electron Charge Transfer in Proteins.

PLASMA PHYSICS 3-1-0-4.

Plasma State of Matter: Introduction
Motion of a charged particle in electromagnetic field.
Plasma as a fluid; elementary discussions on wave motion in plasma.
Fluid nature of plasma, waves in a "cold" plasma. Derivation of the general dispersion relation, different types of waves in plasma and their classification. Dispersion relations for different waves, Effects of finite temperature on wave propagation.
Kinetic theory of Plasma.
Elements of Magneto-hydrodynamics (MHD)
Elements of Parametric excitation and nonlinear waves in Plasma.
Experimental methods for measuring plasma parameters.
Elementary ideas of confinement of high temperature plasma.

Principles of Plasma Physics, N. A. Krall and A. W. Trivelpiece, McGraw-Hill (1973)
Introduction to Plasma Theory, D. W. Nicholson, John Wiley (1983)
Introduction to Plasma Physics (2nd Ed), F. F. Chen, Plenum Press (1989)
Plasma Physics - Basic theory with fusion application, (2nd Ed.) K. Nishikawa and M. Wakatani, Springer-Verlag (1994)
Fundamentals of Plasma Physics (2nd Ed.), J. A. Bittencourt, (Published by Bittencourt (1995))
The Physics of Fluids and Plasmas, An Introduction for Astro Physicists, Arnab Raichaudhuri, Cambridge Univ. Press, First South Asian Ed. (1999)

SOFT CONDENSED MATTER PHYSICS 3-1-0-4

Liquids
correlation functions from scattering experiments (static and dynamic)
Virial expansions

Integral equations for structure functions
Liquid Crystals:
Nematic
Broken symmetry
Onsager theory
Landau theory
Smectic
Elasticity
Phase transitions
Isotropic (liquid) → Nematic
Nematic → Smectic
Solids
Elasticity (Eulerian & Lagrangian)
Defects- vacancies, dislocations, disclinations. Domain walls.
Polymers.

Chaikin & Lubensky, Principles of Condensed Matter Physics
Hansen & Mcdonald, Theory of Simple Liquids
De Gennes, Liquid Crystals
Landau & Lifshitz, Theory of Elasticity
Doi & Edwards, Polymers
De Gennes, Scaling Concepts in Polymer Physics

SYSTEMS FAR FROM EQUILIBRIUM 3-1-0-4

Growth Processes
Diffusion limited aggregation
Eden Growth Process.
Surface Roughening.
Driven Diffusive Systems
Traffic Flow Problems.
Self Organised Criticality.
Driven Charged Lattice Gas.
Granular Flow.

Solids Far From Equilibrium, ed. C. Godriche
Baraban & Stanley, Fractal Properties of Surface Growth
Debashish Chowdhury, Physics Reports.
P. Bak, How Nature Works. A. Mehta,

MESOSCOPIC PHYSICS.3-1-0-4

History of the subject, fabrication techniques, basic differences between semi-conductors and metals.
Quantum wave guides, effective mass approximation, Landauer-Buttiker approach to conductance, Comparison with Kubo formalism, violation of Onsager reciprocity relations, conductance quantization in point contacts, conductance quantization in superlattices, conductance quantization in modulated quantum wires.
Breit-Wigner resonance and Fano resonance, delay time for resonances, Friedel sum rule,

Levinson's theorem.
Bound states in the continuum, weak and strong localization in disordered systems, Thouless energy scale, decoherence at 0 K.
Persistent currents in closed and open systems, parity effect and its violation for persistent currents, temperature dependence of persistent currents, effect of disorder and electron-electron interactions on persistent currents.
Integral and fractional Quantum Hall effect and conductance quantization.
Quantum dots, electronic states in quantum dots, Hund's rule in a quantum dot, transport across quantum dots (capacitance approach), Kondo problem in a quantum dot, level statistics in a quantum dot and Random Matrix Theory.
Luttiger liquid in 1D.
Noises in mesoscopic systems, Nyquist-Johnson noise, shot noise, 1/f noise.
Definition of mesoscopic superconductivity in terms of Ginzburg-Landau theory, Ginzburg-Landau limit and London limit, phase transitions- magnetization and heat capacity of mesoscopic superconductors, Giant vortex state and mixed vortex state, proximity effect and Andreev reflection.

OPTICAL PHYSICS

NONLINEAR and QUANTUM OPTICS: (16 lectures)
Classical linear and nonlinear optics:
Anharmonic oscillator model, nonlinear susceptibilities, absorption, dispersion, nonlinear wave mixing, coupled mode equations, phase matching condition, phase conjugation, optical bistability.

Few-level atom models: semiclassical theory
Two-level atom, optical Bloch equations, steady state response, probe amplification and resonance fluorescence, semiclassical dressed states. Population trapping. Coherent transient phenomena such as optical nutation, photon echoes, self-induced transparency.

Interaction between atoms and quantized fields:
Quantization of the electromagnetic field, Jaynes-Cummings model, dressed states, vacuum field Rabi oscillations, collapses and revivals, spontaneous emission in free space, density of states, Fermi Golden Rule and Wigner-Weiskopf theory. Inhibition of spontaneous emission. Some remarks on unconventional cavities such as dielectric microspheres and photonic band-gap structures.

Quantum theory of four-wave mixing and parametric down-conversion.

Coherent control of atom-field interactions - electromagnetically induced transparency, lasing without inversion.

LASER THEORY AND OPTICAL COHERENCE: (16 lectures)

Spontaneous and stimulated emission, modes of a cavity, population inversion, saturated gain and threshold, Doppler broadening, Lamb dip, hole burning, single mode laser master equation (Scully-Lamb theory), laser photon statistics and laser linewidth. Micromaser and microlaser.

Classical and Quantum Coherence functions:

Young's double slit experiment, mutual coherence function, complex degree of coherence, van Cittert-Zernike theorem, Hanbury-Brown- Twiss experiment, higher-order coherence functions.

Polarization properties of quasi-monochromatic light - coherency matrix, degree of polarization, Stokes parameters, Poincare sphere.

Quantum Coherence functions a la Glauber - coherent states, sub-poissonian statistics, photon antibunching and squeezed states of light.

ATOMIC MOTION IN LASER LIGHT: (16 lectures)
Atom cooling and trapping; atom interferometry; Bose-Einstein condensation of laser-cooled and trapped atoms, Atom lasers, Nonlinear atom optics, optical lattices.

QUANTUM INFORMATION THEORY 3-1-0-4

Foundations of quantum theory; states, observables, measurement, dynamics. Spin-half systems and photon polarizations, qubits versus classical bits. Pure and mixed states, density matrices. Orthogonal measurements, positive operator valued measures. Unitary evolution, extension to superoperators. Master equation and decoherence. Quantum measurement. Quantum entanglement, Bell's theorems. Classical information theory, entropy. Quantum information theory, quantification of entanglement, communication complexity. Quantum cryptography and teleportation. Turing machines, reversible computation, universal logic gates and circuits. Quantum computers and circuits. Quantum algorithms: search, FFT, prime factorisation. Quantum simulations. Quantum error correction and codes. Fault-tolerant quantum computation. Physical implementations: ion traps, quantum dots, cavity QED, NMR.
J. Preskill, http://www.theory.caltech.edu/people/preskill/ph229
A. Peres, Quantum Theory: Concepts and Methods.

MICRO-ELECTRONICS & VLSI DESIGN 3-0-6-6

SWAPAN SEN SYLLABUS COMES HERE

ASTROPHYSICS 3-1-0-4

Review of necessary background

Classical Mechanics
Kepler's laws and Newtonian gravitation, elements of spherical trigonometry, celestial mechanics, orbits in solar system, Galilean Relativity
Special Relativity and Electrodynamics
Notion of relative time and Lorentz transformations, Maxwell's equations, dynamics of a charged particle in electromagnetic field, transverse Doppler effect, acceleration of charged particles, radiation emission in different frequencies, Pulsar emissions, SNR emissions, energetics
Thermodynamics

Statistical Mechanics Black body radiation, colour temperature diagram forstars, kinetic theory of gases, concepts of distribution function, phase space and Liouville's theorem, Boltzmann equation, Saha equation, earth and planetary atmosphere and particle energy distribution, laws of thermodynamics and entropy, isothermal and adiabatic equations of state.

Hydrodynamics and Plasma Physics

Hydrostatic and hydrodynamic equilibria, equations of motion, concept of viscosity and angular momentum transfer, Four momentum and conservation laws, Orbit theory, cosmic magnetic fields, phase and group velocity, propagation of waves through plasma, interplanetary and interstellar scintillations, magnetosphere of compact objects.

Atomic and Molecular Physics

Atomic and molecular spectroscopy, Line radiation and information therein, Line profiles, radiation transfer, recombination lines and ionized hydrogen regions, stimulated and spontaneous emission, elemental abundances from stellar spectra, chemical composition of stellar atmospheres, energies and frequencies of molecular transition, line broadeningdue to Doppler, thermal and collisions

Gravitation, Astrophysics and Cosmology

Newton's gravity and action at a distance, Solar System, Sun as a Star, Nucleosynthesis and solarluminosity, Solar interior, Solar oscillations, Solar wind, Planetary orbits and perturbative effects, Perihelion precession.

Gravity on a large scale, Concept of general relativity, Mathematical introduction to manifolds, metric, connection, curvature, torsion, Geodesics and equations of motion, Einstein's equations and conservation laws, Electrodynamics, hydrodynamics and thermodynamics on curved space time, Solutions to Einstein's equations, Schwarzschild, Kerr, Reissner-Nordstrom and equations of motion of particles therein. Tests of general relativity, Gravitation as a field and gravitational waves in linearised gravitation theory, Generation and propagation of gravitational waves, Attempts at detection of G waves, 3+1 splitting of space-time, basic ideas of numerical relativity.

Stars, internal constitution, HR diagram, evolution of stars, Mass-Luminosity relations, Spectral classification, Nucleosynthesis, Supernovae, Core collapse, Introduction to white dwarfs, neutron stars and black holes, Black hole thermodynamics

Astrometry, Hubble's law and cosmic distance scales, Large scale structure, Cosmological solutions of Einstein's equations, Friedmann-R-W model, Cosmological red shift and expansion, Cosmic microwave background, anisotropies and relation to structure formation, Big bang and thermal history of the Universe, Baryogenesis and early Universe, Inflation and Cosmological constant, Brief review of alternative cosmologies (optional), Gravitational lensing, dark matter, Active galactic nuclei, Quasars, Physics of accretion.

PHYS 522 QUANTUM FIELD THEORY & STANDARD MODEL 3-1-0-4

Just as the earlier course led to QED this one should lead to the Standard Model.

LOW AND INTERMEDIATE ENERGY NUCLEAR PHYSICS

"SINP and VECC chaps to provide syllabus"

ACCELERATOR BASED PHYSICS 3-1-0-4
(Total: 42 Lectures + 8 Tutorial=50)

Introduction: 4 lectures

Motion of charged particle in electric and magnetic field, drift, DC and RF acceleration, Relativistic expressions, Brief history and review of various particle accelerators.

Introduction to accelerators:4 Lectures

Principle of CockcroftWalton, Vandegraaff, tandem, linear accelerator, Cyclotron, Synchrotron and storage rings, microtron and betatron, Induction linac.

Transverse Beam Dynamics: 7 Lectures

Accelerator magnets, Dipole, Quadrupole and Sextupole magnets, General multipole expansion, Equations of motion, field index, Betatron oscillations, Weak and strong focusing, Piecewise method of solution, Transfer matrix technique, Transfer matrices for drift space, dipole, quadrupole, Stability criterion, Closed form solution and amplitude function, Beta function, Twiss parameters, Phase space ellipse, Lioville's theorem, Beam emittance.

Longitudinal Beam Dynamics: 5 Lectures

Longitudinal phase space dynamics, Momentum compaction, Phase stability, Equation of motion, Synchrotron oscillation, separatrix parameters, Longitudinal emittance.

Cyclotron: 6 Lectures

Basic principle of cyclotron, Resonance condition, Orbit stability, Limitations of classical cyclotron, AVF cyclotron, Isochronism and shape of the magnetic field, Injection, Central region, Extraction, Beam quality time structure, energy resolution and emittance.

RF Linear Accelerator: 6 Lectures

Linear accelerating structures, Wideroe and Alveraz linac, transit time factor, Electron linac, Accelerating field and dispersion curve, Ion linac, Empty cavitywave types and modes, Loaded cavity Space harmonics, travelling wave and standing wave structures, RFQ linac (briefly).

Ion Sources: 4 Lectures

Principle of ionization, Ion sources for positive ions Duoplasmatron, PIG, ECR, Ion sources for negative ions surface, volume and charge exchange, Beam formation.

Synchrotron and storage rings: 4 Lectures

Electron synchrotron, Synchrotron radiation source, total radiated power, critical wavelength, proton synchrotron, collider principle, Beam cooling.

Application of accelerators: 2 Lectures

Research applications, Element analysis, Medicine, Industry.

PHYSICS OF MATERIALS I 3-1-0-4

The Born-Oppenheimer Approximation. Many-electron systems. Hartree and Hartree-Fock Approximations. The Density Functional Theory. Electronic Structure of solids. Advanced Electronic Structure Methods. KKR, LMTO, TB-LMTO. Total Energy and Phase stability at T=0K.

Disordered Solids. The recursion method. Configuration averaging, Spatial Ergodicity. Mean Field Approximations. Coherent Potential Approximation. Configuration Space and configuration fluctuations. Augmented Space Technique.

- *Electronic Structure of Solids and Alloys, eds. O.K. Andersen, V. Kumar, A. Mookerjee. (World Scientific)*
- *Electronic Structure of Solids, O.K. Andersen, O. Jepsen (Proceedings of the Varenna School, 1983)*
- *SERC School Lecture Notes, 2000, Calcutta : S.K. Ghosh, M. Harbola*
- *Electronic Structure of Alloys, Kudrnovský and Drchal*
- *Solids, Surfaces and Clusters, eds. D.D. Sarma, A. Mookerjee (Gordon Breach)*

PHYSICS OF MATERIALS II 3-1-0-4

Phase transformations. Ising and ANNI models. Frustration and its effect on the Phase diagram.

Entropy and internal energy. Analysis of phase transformations in alloys. The Cluster-variation technique and Entropy. The Concentration Wave analysis of Khatchaturyan. Orbital Peeling and pair energies. Construction of Phase diagrams. Study of specific cases.

Magnetic Phase transitions in solids. Itinerant picture of magnetism in metals. The LSDA. Non-collinear magnetism. Disordered magnetic systems. Spin Glasses.

- *Phase Transformations, Ducastelle and Gautier*
- *Theory of Phase Transformations, Khatchaturyan, Rev. Mat.Science*
- *Spin Glasses, D. Chowdhury and A. Mookerjee, Physics Reports*
- *Spin Glasses, D. Chowdhury (World Scientific)*

In the Fourth Semester courses at a more advanced level will be offered in different areas, as given above, grouped together under general headings such as:
Condensed Matter Physics
Statistical Physics
Nonlinear Dynamics
Field Theory & High Energy Physics
Astrophysics & Cosmology
Optics
Nuclear Physics
Electronics
Plasma Physics
Mathematical & General Physics
Chemical Physics
etc.
and these may be deemed as areas of **specialization** of the student. Each course shall run in the pattern 3-1-0-4.
Apart from the three courses chosen by each student, (s)he will be required to start a project which may be theoretical or experimental in character and this shall constitute the possible kernel of his(her) M.Phil. Dissertation or Ph.D. thesis as the case may be. Since such a project will involve considerable more time involving interaction with the project advisor(s), the credit point assignment will be 6 for this activity.

SUBSEQUENT SEMESTERS

Subsequent semesters will be essentially devoted to research activities in the chosen topics and from time to time Special Topics Courses at an advanced level will be offered to broaden and deepen the base of the research scholars.