M.Sc. Physics Syllabus 2014 Synopsis (Credits: 90)

Semester I (Credits: 20 = 5 × 4)

Paper	Module	Group	Subject	No. of Classes	Marks
MPHC4101	MM I	A	Differential Equations	24	50
	MM II	B	Complex analysis & tensors	24	
MPHC4102	CM I	A	Classical Mechanics I	24	50
	QM I	B	Quantum Mechanics I	24	
MPHC4103	EL I	A	Electronics I	24	50
	EL II	B	Electronics II	24	
MPHC4104	SP I	A	Statistical Physics I	24	50
	ED	B	Electrodynamics	24	
MPHC4151	CL I	A	Core Experiments I(Non Electronics)	24	50
	CMP I	B	Computer Tools & Interfacing	24	

Semester II (Credits: 20 = 5 × 4)

Paper	Module	Group	Subject	No. of Classes	Marks
MPHC4205	GRP	A	Group Theory	24	50
	RLED	B	Relativity & Relativistic Electrodynamics	24	
MPHC4206	CM II	A	Classical Mechanics II	24	50
	FM	B	Fluid Mechanics	24	
MPHC4207	QM II	A	Quantum Mechanics II	24	50
	QM III	B	Quantum Mechanics III	24	
MPHC4208	SS I	A	Solid State I	24	50
	SP II	B	Statistical Physics II	24	
MPHC4252	CL II	A	Core Experiments II (Electronics)	24	50
	CMP II	B	Numerical Computing	24	

Semester III (Credits: 25 = 5 × 5)

Paper	Module	Group	Subject	No. of classes	Marks
MPHC4309	ATM	A	Atomic & Molecular Physics	24	50
	SSII	B	Solid State II	24	
MPHC4310	NUC	A	Nuclear Physics	24	50
	PAR	B	Particle Physics	24	
MPHE4301/ MPHE4302	EL-GR/MPI	A	General Relativity/ Material Physics I	24	50
	EL-PLM/MP2	B	Plasma Physics/ Material Physics II	24	
MPHS4301/ MPHS4302	SPL-API/SSEI	A	Introductory Astrophysics/ Foundations of Solid State Electronics	24	50
	SPL-APII/SSEII	B	Physical Cosmology/ Semiconductor devices	24	
MPHC4353	AL I	A	Advanced Experiments I (Comm.)	24	50
	PRJ I	B	Project Level 1	24	

Semester IV (Credits: 25 = 5 × 5)

Paper	Module	Group	Subject	No. of Classes	Marks
MPHS4403/ MPHS4404	SPL-APIII/SSEIII	A	Stellar Structure & Evolution/ Communication Theory	24	50
	SPL-APIV/SSEIV	B	Stellar atmosphere, Interstellar medium & galaxies/ Digital Signal Processing	24	
MPHS4405/ MPHS4406	SPL-APV/SSEV	A	Standard Model of Particle Interactions in Astrophysics/ VLSI	24	50
	SPL-APVI/SSEVI	B	Astroparticle Physics/ Microprocessors & Microcontrollers	24	
MPHS4407/ MPHS4408	SPL-APVII/SSEVII		Computational Astrophysics/ Optoelectronics, Photonics &Nanomaterials, Nanodevices	48	50
MPHS4451/ MPHS4452	SPL-APVIII/SSEVIII		Special Lab – Astrophysics/ Solid State Electronics	48	50
MPHS4453	ALII	A	Advanced Experiments II	24	50
		B	Project Level 2		

Approved M.Sc. Syllabus 2014

SEMESTER 1

MPHC4101 [24 Lectures]

Group AMM1:

Differential equations

Differential equations: Theory of general second order linear homogeneous differential equation, Singular points, Fuchs' theorem, Wronskian, second solution, Self adjoint equations: Sturm Liouville theory.

Special Functions: Basic properties (recurrence &orthogonality relations, series expansion) of Bessel equations.

Inhomogeneous differential equations: Green functions.

Integral Transforms: Fourier and Laplace transforms and their inverse transforms. Transforms of derivative and integral of a function. Solution of differential equations using integral transforms.

Group BMMII:

Complex analysis and tensor

Recapitulation: Complex numbers, triangular inequalities, Schwarz inequality, Function of a complex variable – single and multivalued function. Limit and continuity. Differentiation – Cauchy-Riemann equations and their applications. Analytic and Harmonic Functions.Complex integrals. Cauchy's theorem (elementary proof only), converse of Cauchy's theorem, Cauchy integral formula and its corollaries, Series - Taylor and Laurent expansion, classification of singularities, branch point and branch cut, residue theorem and evaluation of some typical integrals using this theorem.

Tensors: Tensors as transformational invariants, mathematical operation with tensors (addition, subtraction & multiplication), metric tensors, raising and lowering of indices, unit tensor, Levi Civita symbol, invariant volume elements, covariant differentiation, Christoffel symbol.

MPHC4102

Group ACM1: [24 Lectures]

Classical Mechanics I

An overview of the Lagrangian formulation: Some specific applications of Lagrange's equation, small oscillations, normal mode frequencies.

Hamiltonian's principle: Calculus of variations, Hamilton's principle, Lagrange's equations from Hamilton's principle, Legendre transformations and Hamilton's canonical equations, canonical equations from a variational principle, Principle of least action.

Rigid Bodies: Independent coordinates, orthogonal transformations and rotations (finite and infinitesimal), Euler's theorem, Euler angles , Inertia tensor and principal axis system, Euler's equations, heavy symmetrical top with precession and nutation.

Group BQM I : [24 Lectures]

Quantum Mechanics I

Recapitulation of basic concepts:

Vector space: Axiomatic definition, linear independence, bases, dimensionality, inner product, Gram-Schmidt orthogonalization.

Operator method in quantum mechanics: Formulation of quantum mechanics, uncertainty principle for two arbitrary operators, one dimensional harmonic oscillators by operator method. Three dimensional harmonic oscillator.

Schrodinger, Heisenberg and interaction pictures.

Angular momentum: Angular momentum algebra, raising and lowering operators, matrix representation of $j = ½$ and $j = 1$ spin, addition of two angular momenta: Clebsch-Gordan coefficients, examples.

MPHC4103

Group A ELI [24 Lectures]

Electronics I

Semiconductor Physics: Intrinsic and extrinsic semiconductor, energy band diagram, carrier concentration in both cases, p-n junction band diagram Junction current, I-V and C-V characteristics, Metal semiconductor junction (Schottky barriers) [12 Lectures]

Devices: Reverse biased p n junction as a Si-detector for detection of high energy particles, Bipolar Junction transistor, Ebers-Moll model, voltage divider bias, amplifier frequency response. [(1+1+1+1+2)=5 Lectures]

Tunnel diode: I-V characteristics, negative voltage region. [1 Lecture]

Unijunctiontransistor(UJT), application as a relaxation oscillator. [2 Lectures]

MOSFET, Shockley's equation, biasing of MOSFET: voltage divider bias. [3 Lectures]

Silicon Controlled rectifier (SCR, Thyristor) characteristics and application. [1 Lecture]

List of Books:

(1) Semiconductor physics and devices by Donald a. Neamen (Tata Mac Graw Hill)
(2) Electronic Devices and Circuit Theory, R.L. Boyletad and L. Nashelsky (PHI)
(3) Microelectronic circuits by Sedra and Smith (Oxford University Press)

<u>Group BELII</u> [24 Lectures]

<u>Electronics II</u>

*Analog circuits:*OPAMP basic concepts (Voltage difference amplifier, basic internal circuit diagram), inverting and non-inverting amplifier (recapitulation) [1 Lecture]

Comparators [2 Lectures], multivibrators [3 Lectures], Square wave, triangle wave and pulse generators. [3 Lectures]

Digital Circuits: Introduction (basic gates: diode-diode logic, transistor-transistor logic, binary to decimal, decimal to binary conversion, hexadecimal numbers, Boolean algebra). [2 Lectures]

Some of Products (SOP) and Product of sum (POS) rule, Karnaugh map [2 Lectures]

A/D, D/A converter [2 Lectures], Flip-Flops (SR, JK) [2 Lectures]

Counters, Multiplexer. [2 Lectures]

Communications: Transmission lines, active filter (Butterworth -1st order): High and low pass [1 Lecture], Modulation: FM, PM, PCM [3 Lectures]

List of Books:

(1) Electronic Devices and Circuit Theory by R.L. Boylestad and L. Nashelsky (PHI)
(2) Digital Principles and Applications by Donald P. Leach, Albert Paul Malvino, GoutamSaha (Tata McGraw-Hill)
(3) Digital computer electronics by Malvino and Brown.
(4) Networks, Lines and Fields by J.D. Ryder (PHI)
(5) Electronic Communication Systems by Kennedy and Davis (McGraw-Hill)

<u>MPHC4104</u>

<u>Group ASPI</u> [24 Lectures]

<u>Statistical Physics I</u>

Introduction: Objective of statistical mechanics, specification of the state of a many particle system, phase space, counting the number of microstates in phase space, statistical ensemble, postulate of equal a priori probability,Liouville's theorem, ergodic hypothesis, H-theorem, probability calculation, thermal, mechanical, general interaction.

Microcanonical ensemble: Thermal interaction between systems in equilibrium, temperature, heat reservoirs, sharpness of the probability distribution, applications.

Canonical ensemble: System in contact with a heat reservoir, Boltzmann distribution, canonical partition function, calculation of mean values in canonical ensemble, connection with thermodynamics, entropy of an ideal gas, Gibbs' paradox, applications.

Grand canonical ensemble: System in contact with a particle reservoir, chemical potential, grand canonical partition function and grand potential, fluctuation of particle number, chemical potential of an ideal gas, applications.

<u>Group BED</u> [24 Lectures]

<u>Electrodynamics</u>

Vector and scalar potentials, Gauge transformations: Lorentz and Coulomb gauge, Green functions for the wave equation.

Simple radiating systems: Fields and radiation of a localized oscillating source, electric dipole fields and radiation.

Radiation by moving charges: Lienard-Wiechert potentials and fields for a point charge, charges moving with uniform velocity, accelerated charges, radiation from accelerated charges moving (i) with low velocities and (ii) with relativistic velocities, brehmstrahlung, synchrotron radiation. Total power radiated by an accelerated charge – Larmor's formula, angular distribution of radiation, radiation reaction – Abraham Lorentz formula.

<u>MPHC4151</u>

<u>Group ACL1</u>

<u>Core experiments (Non-electronics)</u>

1. Determination of Planck's constant
2. Study of Michelson's Interferometer
3. Frank Hertz experiment
4. Study of Iodine Spectra
5. ESR

Group B

Computer Tools & Interfacing

Introduction to Open Source Computing: Brief inventory, The Linux Command Line Computing Environment Data Visualization and Curve fitting using Gnuplot

Scientific computing using Python/ Numeric/Scipy/Matplotlib: Language essentials and Library functions.

Interfacing: Elements of Interfacing theory, Sensors, Actuators, Data width and time sensitivity, Handling the Expeyes box: Digital I/O, Data acquisition and analysis of acquired data. Design of experiments using the Expeyes box and python programming

SEMESTER 2

MPHC4205

Group AGRP [24 Lectures]

Group Theory

Sets, maps, equivalent relations and classes, definition of monoids and groups, generators and cyclic groups, permutation groups, alternating groups, isomorphisms, Cayley'sthorem, cosets and Lagrange's theorem, conjugate subgroups, normal subgroups, factor group, homomorphisms.

Group representations, faithful and unfaithful representations, equivalent representations and characters, construction of representations, invariance of functions and operators, classification of eigenfunctions, reducible and irreducible representations, Schur's lemmas, orthogonality theorems, statements and illustrative interpretations.

Lie groups and Lie algebras, SU(2) and SU(3)

Group BRLED [24 Lectures]

Relativity and Relativistic Electrodynamics

Special Relativity: Lorentz transformations, four-vectors, tensors, transformation properties, metric tensor, raising and lowering of indices, contraction, symmetric and antisymmetric tensors, four dimensional velocity and acceleration, four-momentum and four-force, covariant equations of motion, relativistic kinetimatics (decay and elastic scattering), Lagrangian and Hamiltonian of relativistic particles.

Relativistic electrodynamics: Equation of motion in an electromagnetic field, Electromagnetic field tensor, covariance of Maxwell's equations, Maxwell's equations as equations of motion, Lorentz transformation law for the electromagnetic fields and the fields due to a point charge in uniform motion.

MPHC4206

Group A CMII [24 Lectures]

Classical Mechanics II

Canonical transformations: Generating functions, examples of canonical transformations, group property, integral invariants of Poincare, Lagrange and Poisson brackets, infinitesimal canonical transformations, conservation theorem in Poisson bracket formalism, Jacobi's identity, angular momentum Poisson bracket relations.

Hamilton-Jacobi theory: The Hamilton-Jacobi equation for Hamilton's principle function, the harmonic oscillator problem, Hamilton's characteristic function, Action-angle variables.

Lagrangian and Hamiltonianformulationsforcontinuoussystems:Transitionsfroma discrete to a continuous system, Lagrangian for continuous systems:acoustic fields in gases, the Hamiltonian formulation for continuous systems, canonical equationsfrom a variational principle, Poisson brackets and canonical field variables.

Group BFM [24 Lectures]

Fluid Mechanics

Ideal Fluids: Equation of continuity, Euler's equation, Hydrostatics, the conditions that convection be absent, Bernoulli's equation, the energy flux, the momentum flux, the conservation of circulation, potential flow, incompressible fluids, the drag force in potential flow past a body.

Viscous fluids: The equations of motion of a viscous fluid, Energy dissipation in an incompressible fluid, flow in a pipe, flow between rotating cylinders, the law of similarity, flow with small Reynolds' number, exact solutions of equations of motion for viscous fluid.

MPHC4207

Group AQMII [24 Lectures]

Quantum Mechanics II

Approximation methods: Time-independent perturbation theory, first and second order corrections to the energy eigenvalues, first order correction to the eigenvectors, degenerate perturbation theory, application to the one-electron system – relativistic mass correction, spinorbit coupling (LS and jj), Zeeman effect and Stark effect, variational method: He atom as an example, first order perturbation, exchange degeneracy, Ritz principle for excited states for He atoms.

Time-dependent perturbation theory: Interaction picture, constant and harmonic perturbation – Fermi's Golden rule, sudden and adiabatic approximation.

Symmetries in quantum mechanics: Conservation laws and degeneracy associated with symmetries, continuous symmetries – space and time translations, rotations, rotation group, homomorrphisms between SO(3) and SU(2), explicit matrix representation of generators for j = ½ and j = 1, rotation matrices, discrete symmetries – parity and time reversal.

Identical Particles: Meaning of identity and consequences, symmetric and antisymmetricwavefunctions, Slater determinant, symmetric and antisymmetric spin wavefunctions of two identical particles, collisions of identical particles.

<u>Group BQMIII</u> [24 Lectures]

<u>Quantum Mechanics III</u>

Relativistic Quantum Mechanics: Klein-Gordon equation, Feynman-Stuckelberg interpretation of negative energy states and concept of antiparticles, Dirac equation, covariant form, adjoint equation, plane wave solution and momentum space spinors, spin and magnetic moment of the electron, non-relativistic reduction, helicity and chirality, properties of gamma matrices, charge conjugation, normalization and completeness of spinors, Lorentz transformation of the Dirac equation, bilinear covariants and their transformations under parity and infinitesimal Lorentz transformation, Weyl representation and chirality projection operators.

Field quantization: Basic ideas, construction of conjugate momentum from Lagrange density, commutation relations for bosonic and anti-commutation relations for fermionic fields in terms of field and momentum or creation and annihilation operators, quantization of scalar and complex scalar fields.

<u>MPHC4208</u>

<u>Group ASS I</u>

<u>Solid State I</u>

Lattice dynamics: Classical theory of lattice vibrations under harmonic approximation, vibrations of linear monatomic and diatomic lattices, acoustical and optical modes, long wavelength limit, optical properties of ionic crystal in the infrared region, adiabatic approximation (qualitative discussion), normal modes and phonon lattice heat capacity, models of Debye and Einstein, comparison with electronic heat capacity [6 Lectures]

Band theory of solids: Bloch equation, empty band, nearly free electron theory (NFE), band gap, number of states in a band, tight binding approximation, effective mass of an electron in a band, concept of holes, classification of metal, semiconductor and insulator, topology of Fermi surface, cyclotron resonance – de Haas-Van Alphen effect [6 Lectures]

Dielectric properties of solids: Complex dielectric constant and dielectric losses, relaxation time, classical theory of electronic polarization and optical absorption, ferroelectricity – case of $BaTiO_3$ [4 Lectures]

Magnetic properties of solids: Quantum theory of paramagnetism, Spin paramagnetism, Pauli theory, Ferromagnetism: Curie-Weiss law, temperature dependence of saturation magnetization, Hesienberg's exchange interaction, ferromagnetic domains, Magnetic anisotropy, ferromagnetism and antiferromagnetism [8 Lectures]

Group BSP II [24 Lectures]

Statistical Physics II

Quantum statistical mechanics: Quantum-mechanical ensemble theory: the density matrix, Quantum Liouville's theorem, density matrices for microcanonical, canonical, grand canonical ensemble, simple examples of density matrices – one electron in a magnetic field, particle in a box.

Systems of indistinguishable particles – BE and FD distributions, Ideal Bose and Fermi gas, statistics of occupation number, equation of state, BE condensation, Thermodynamic behavior of ideal Bose gas, blackbody radiation, thermodynamic behavior of ideal Fermi gas, the electron gas in metals, statistical equilibrium of white dwarf stars.

MPHC4252

Group ACLII

Core experiments II(electronics)

1. Determination of band gap and reverse saturation current of a pn junction diode
2. Contruction of astablemultivibrator and VCO
3. To study UJT characteristics
4. To study Active Filters (High pass, Low pass, Band pass, Notch)
5. To study T filters (High and Low pass filter)
6. To study Pi Filters (High and Low pass filter)

Group B CMPII [24 Lectures]

Numerical Computing

Array Computing in Python, Implementing Numerical tools in Python: Solution of linear systems, root finding, interpolation and least square polynomial approximation, Numerical integration, ODES: Euler, Modified Euler and RK45: Studying linear and nonlinear oscillators, Bouncing balls and Chaos, Uses of the random number module.

SEMESTER 3

MPHC4309

Group AATM [24 Lectures]

Atomic and Molecular Physics

Review of one electron atom: Discussion of hydrogeniceigenfunctions, parity, probability density, angular and radial distribution functions, expectation values. Interaction with electromagnetic radiation: time dependent perturbation, induced absorption and emission, transition rates, selection rules. Fine structure splitting and energy corrections of hydrogenic atoms. Zeeman effect, Paschen-Back effect, Stark effect.

Many electron atoms: Central field approximation, Slater determinant, electronic configurations-shells, subshells, degeneracies, L-S coupling, j-j coupling, Hund's rule, Lande interval rule. Approximation methods: Hartree self-consistent field approximation.

Molecular structure: Molecular Hamiltonian, Born-Oppenheimer approximation, electron shells of diatomic molecules, hydrogen molecular ion by LCAO method, calculation of bond length and dissociation energy, shapes of molecular orbitals, pi and sigma bonds.

Molecular rotation and vibration: Solution of nuclear equation, molecular rotation: rigid and non-rigid rotator, centrifugal distortion, symmetric top molecules, molecular vibration: harmonic oscillator approximation, anharmonicity, Morse potential.

Molecular spectra: Electronic, vibrational and rotational transitions in diatomic molecules, vibration-rotation spectra, Franck-Condon Principle, Fortrat diagram, Flourescence and phosphorescence. Raman spectra.

Group BSSII [24 Lectures]

Solid State II

Crystallography: Review of fundamental ideas, crystal class, point group and space group, common crystal structures, reciprocal lattice and Brillouinzone, Bragg-Laue formulation of X-ray diffraction by a crystal, atomic and crystal structure factors, electron and neutron diffraction by crystals (qualitative discussion) [6 Lectures]

Magnetic resonances: Nuclear magnetic resonances, Bloch equation, longitudinal and transverse relaxation time, hyperfine field, electron spin resonance. [6 Lectures]

Imperfections in solids: Frenkel and Schottky defects, defects in growth of crystals, colourcentres and photoconductivity, luminescence and phosphors, alloys – order-disorder phenomena, Bragg-Willaims theory, Hume-Rothery compounds, Extra-specific heat. [6 Lectures]

Superconductivity: Phenomenological description of superconductivity, heat capacity, energy gap and isotope effect, Meissner effect, type-I and type-II superconductors, BCS theory-expression for energy gap, Josephson effect (qualitative), High-T_c superconductors (qualitative)

[6 Lectures]

<u>MPHC4310</u>

<u>Group ANUC</u> [24 Lectures]

<u>Nuclear Physics</u>

Basic nuclear properties: Size, shape,charge distribution, spin and parity, isospin, Binding energy, magnetic dipole moment and electric quadrupole moment.

Nucleon-nucleon interaction: Properties of deuteron, determination of ground state properties of deuteron by solving Schrodinger equation, excited states of deuteron. Nucleon-nucleon scattering: Experimental low-energy n-p scattering data, partial wave analysis and phase shifts, scattering length, effective range theory, determination of cross section for S-wave n-p scattering, singlet and triplet interaction of nucleons, spin dependence of nuclear forces, tensor (non-central) potential expressions, the exchange force model, Meson theory.

β-decay: Energetics of β decay, Fermi's theory of β decay, comparative half- life, allowed and forbidden transitions, selection rules for Fermi and Gamow-Teller transitions, parity non-conservation and Wu's experiment.

Nuclear models: Liquid drop model, Bethe-Weizsacker semi-empirical mass formula, Bohr-Wheeler's theory of fission, Single particle shell model: validity and limitations.

Nuclear reactions: Quantum mechanical calculations of scattering and reaction cross sections, total cross section, shadow scattering, Bohr's compound nucleus hypothesis, Principle of detailed balance and reciprocity theorem, Breit-Wigner one-level formula for resonance scattering, barrier penetration, direct reactions: stripping and pick up reactions, optical model.

Group B

Particle PhysicsPAR [24 Lectures]

Symmetries and conservation laws, hadron classification by isospin and hypercharge, SU(2) and SU(3): groups, algebras and generators, Young tableaux rules for SU(2) and SU(3), quarks, color, charm, B mesons, the discovery of the top quark, the states of the neutral K system, strangeness oscillations, CP violation, elementary ideas about the electroweak interactions and QCD.

MPHE4301

Group AEL-GR [24 Lectures]

General Relativity

General Relativity: The equivalence principle, non-inertial frames and non-Euclidean geometry, general co-ordinate transformations and the general covariance of physical laws, curvature tensor, Bianchi identity, Geodesic equation and equation for geodesic deviation, energy-momentum tensor and conservation laws, Einstein equations, Hilbert's variational principle, gravitational energy-momentumpseudotensor, Newtonian approximation, linearized field equations, static spherically symmetric spacetime, Schwarzchild's exterior solution, FRW metric, motion of perihelion of mercury, bending of light, gravitational redshift, radar echo delay.

Or

MPHE4301

Group AMP1

Material Physics I

Materials Physics: Classification of materials according to bonding – Pauling and Philips theories.

[4 Lectures]

Growth of synthesis of materials: single crystal growth, zone refining, doping of semiconductors, growth of films, Epitaxy: Theoretical growth models FM, VW and SK, molecular beam epitaxy (MBE). [8 Lectures]

Characterization of materials: Optical microscopy, X ray diffraction, structure determination from XRD data, Thermal methods DTA/DSC, microscopy: TEM & SEM, AFM: principles only.

UV and IR, Nuclear techniques:: NMR, ESR, Mossbauer and positron annihilation (principles only), Inelastic scattering: applications to materials [12 Lectures]

Group BPLM [24Lectures]

Plasma Physics

Introduction: Definition of plasma, sources in nature, basic plasma phenomena – quasineutrality, Debye shielding, plasma frequency (mention processes).

Single particle motions: Motion of particle in constant and slowly time-varying electromagnetic fields and non-uniform magnetic fields. Magnetic bottle, loss cone, magnetic heating of plasma.Magnetohydrodynamics: Fundamental MHD equations, Generalized Ohm's law, magneticReynold's number, magnetic confinement of plasma. Non-linear effects: Plasma sheath, plasma probe. Waves in plasma: Electron plasma waves, Langmuir waves, ion waves. Ion-acoustic waves, electrostatic electron oscillations and ion waves normal to magnetic field, ordinary and extraordinary waves, right and left circularly polarized waves, hydromagnetic or Alfven waves.

Or MPII

Material Physics II

Phase transition in materials: thermodynamics and phase diagrams, statistical theories of phase transitions, critical phenomenon, calculation of critical exponents, van der Waals and ferromagnets),

Diffusion in solids, variation of diffusion constant with temperature.

[6 Lectures]

Mechanical properties: Hardness: Classification, deformation and fracture. [4 Lectures]

Electrical properties of metals, alloys, resistivity variation of materials at low and high temperatures.Effect of pressure on resistivity. [4 Lectures]

Magnetic materials: Application and related principles, Spintronics – Introduction.

[4 Lectures]

Glass transition – Theories, tunneling states, Ceramics – Introduction.

[6 Lectures]

MPHS4301

SPL-API

Group A: Introductory Astrophysics [24 Lectures]

Interpretation of the difference and nature in which modern astronomy and astrophysics are related; how astrophysics and cosmology are essentially interlinked and yet different in their approaches; different scales and orders of magnitude in astrophysics and cosmology: mass, length and time.

The Celestial sphere: Celestial co-ordinates celestial times, Stellar Parallax, Photometry and magnitude scales, Blackbody radiation, The color index, characteristic temperature in astrophysics, extinction of light.

Binary Systems and Stellar Parameters: Classification of Binary stars, Mass determination using visual binaries, Eclipsing, Spectroscopic Binaries, Search for Extrasolar planets.

Radiative Transfer: Description of radiation field, Transfer equation.

SPL-APII

Group B: Physical Cosmology :

Cosmology: Homogeneity and isotropy of the universe: explanation and examples to illustrate the concept, expansion and Hubble's law: mathematical derivation of Hubble's law using homogeneity and isotropy, comparison of scales to illustrate the effects of expansion on celestial objects, particles in the universe, Newtonian dynamics of the universe: scale factor, physical distance and co-moving distance, Friedmann equation and fluid equation, acceleration equation, solutions of the Friedmann equation: evolution of the universe, Observational parameters: Hubble constant, density parameter, deceleration parameter, Cosmological constant and evolution of the universe.

MPHS4302

SPL-SSEI

Group A: Foundations of Solid State Electronics

Free electron theory, Fermi-Dirac statistics, density of states, intrinsic and extrinsic carrier concentrations, mobility and diffusion constant, Einstein relation, temperature dependence of mobility, negative differential mobility, Boltzmann transport equation, magneto-transport – Hall effect and magneto-resistance, thermoelectric power. 2D density of states, Quantum Hall effect, high-field effects – hot electrons, velocity saturation, ballistic and quantum transport, tunneling, impact ionization and avalanche breakdown, space charge in semiconductors, relaxation effects, ambipolar effects, experimental determination of mobility, diffusion constant and lifetime of minority carriers, Haynes-Shockley experiment. Optical properties – reflection, absorption, transmission, direct & indirect bandgaps, electron-hole pair recombination, Auger effect, kinetics of traps and recombination centres, Shockley-Hall-Read statistics. Surface states, surface recombination velocity, pinning of Fermi level, noise, basic device equations.

SPL-SSEII

Group B: Semiconductor Devices (MOS and CCD) [24 Lectures]

MOSFET and CCD: Surface charge and C-V characteristics of MIS, device characteristics, Non-equilibrium conditions, linear and saturation regions, sub-threshold region, mobility, temperature dependence, threshold shift, short channel effects, FAMOS, VMOS, types of MOSFET. Fabrication of MOS – implantation, oxidation, metallization, etching, lithography, contacts.

Charge coupled devices (CCD): interface trapped charge, charge storage, basic CCD structure, surface and buried channel CCD; charge storage and frequency response, IRCCD.

MPHC4353

Group A

Core Experiments III (Communication)

CLIII

1. Pulse Width Modulation and Demodulation
2. Study of frequency modulation and its demodulation using IC
3. Pulse Position Modulation and Demodulation
4. Study of Amplitude shift Keying and Demodulation
5. Study of Freequency Shift Keying and Demodulation [XR2206 Function generator]
6. Study of Amplitude Modulation and Demodulation [IC version 1496]

Microprocessor (8085)

- Succinct understanding of architecture
- Instruction set
- Introduction to SIM8085
- Programs related to
    1. Data block copy in forward, reverse, partial reverse
    2. Arithmetic operations – 8 bit, 16 bits, multibyte
    3. Code generation
    4. String operation
- Input-Output data through port
- Interfacing with 8255 PPI
    1. LED
    2. 7-segment display

- Delay routine
    1. Calculation of execution time
    2. Application of delay to data input-output

Group B

Project – Level 1

Students to take up a project under the guidance of a supervisor.

SEMESTER 4

MPHS4403

SPL-APIII

Group A: Stellar Structure & Evolution [24 Lectures]

Stellar structure: Structure of Main Sequence stars, virial theorem and stellar energy sources.

Nuclear burning in stars: H burning, He burning, core collapse.

Isotropic stellar model and a comparison with real main sequence stars, Chandrasekhar mass.

Convection in stars and their stability

Theory of Main Sequence (MS) stars: homologous model, Eddington luminosity: radiativestability, evolution of low and high mass MS stars, late stages of evolution, end stages of stars as a function of mass.

SPL-APIV

Group B: Stellar atmosphere, Instellar Medium &Galaxies[24 Lectures]

Stellar spectral classification: Observed Hertzsprung-Russel diagram, Physical basis of the classification.

Stellar atmospheres: applications of radiation transfer, plane parallel atmosphere, grey atmosphere, Eddington approximation and formation of spectral lines.

Interstellar medium and star formation: Interstellar dust and gas, formation of proto-stars, pre-main sequence evolution, stars, brown dwarfs and planets, initial mass function.

Galaxies: Normal galaxies: morphological classification, physical characteristics and kinematics, Intergalactic medium.

MPHS4404

SPL-SSEIII

Group A: Communication Theory [24 Lectures]

Random signals and noise: Probability, random variables, probability density function, autocorrelation, power spectral density. Analogue communication systems: amplitude and angle modulation and demodulation systems, spectral analysis of these operations, super heterodyne receivers, elements of hardware, realizations of analogue communication systems, signal-to-noise ratio (SNR) calculations for amplitude (AM) and frequency modulation (FM) for low noise conditions. Fundamentals of information and channel capacity theorem.

Synchronous digital Hierarchy (SDH): Data over SDH, Electromagnetic waves, Multipath Radio Wave Propagation Models. Spectrum Issues.Concepts of 2^{nd}& 3^{rd} Generation of cellular Mobile systems.

Microwave Science & Technology Sources: Klystrons, magnetrons TWT, Solid State Microwave Devices. Cavities, Q Factor, waveguides, strip line, micro strip, attenuators, isolators, directional couplers. Microwave Monolathic Integrated circuits (MMIC).

SSEIV

Group B: Digital Signal Processing [24 Lectures]

Fundamentals of discrete time system: Basic definitions, important sequence, Linear and time invariant systems, impulse response, shifting, convolution, Linear constant coefficients difference equations, HR, IIR systems.

Frequency domain analysis: Fourier transform of sequencies, properties, Inverse F.T., sampling of continuous time signal, Sample and Hold amplifiers, Nyquist rate and aliasing problem, interpolation formula, frequency response of rectangular window, recovery of analog signal.

Discrete Fourier Transform: DFT and its computation, circular and linear convolution, FFT, Time and frequency decimination, IDFT, Interpretation of DFT results, DFT-FT relationship.

Z-transform, properties, calculation of IZT, Application to the solution of difference equations, System function of a digital filter.

MPHS4405

SPL-APV

Group A: Standard Model of Particle Interactions in Astrophysics[24 Lectures]

The very early universe: Local gauge invariance, Non-Abelian gauge theories.

Quark-Gluon Plasma: Running coupling constant and asymptotic freedom, Cosmological quark-gluon phase transition.

Electroweak theory: Fermion content, "spontaneous breaking of U(1) symmetry, Gauge bosons, Fermion interactions, Fermion masses, CP violation.

"Symmetry restoration" and phase transitions: Effective potential, U(1) model, Symmetry restoration at high temperature, Phase transitions, Electroweak phase transition.

SPL-APVI

GroupB: Astroparticle Physics [24 Lectures]

Astroparticle physics in perspective: Relationship to High Energy Physics, Astrophysics and Cosmology.

Elementary particle processes in galactic, intergalactic and atmospheric production and transmissions, Physics of particle and radiation detection, Acceleration mechanisms in sunspots, supernovae shocks and accreting binaries. Primary cosmic rays: Charged and uncharged components: neutrino, gamma, x-ray and gravitational wave astronomy. Secondary cosmic rays: Atmospheric propagation, cosmic rays at the sea level and underground, Extensive air showers.

MPHS4406

SPL-SSEV

Group A: VLSI [24 Lectures]

VLSI designflow: Switch level RC delay models. CMOS technologies.

Layout design rules: Circuit characterization and performance estimation: Delay estimation. Logical effort and transistor sizing.Power dissipation, Interconnect design margin. Reliability: Scaling, Circuit simulation: CMOS Design and layout: Analog MOS circuits: Sub-circuits – switch, diode, current sinks and sources, current mirrors. Amplifiers – inverters, differential amplifiers. Digital MOS circuits: CMOS combinational logic gates, multiplexers, latches and flip-flops. Device and circuit characterization. Interconnect simulation. Modelling and Synthesis with the Verilog HDL, Digital System Design, electronic Design Automation Tools.Ultrafast GaAs digital and linear ICs.

SPL-SSEVI

Group B: Microprocessors and microcontrollers [24 Lectures]

Microprocessors: Introduction to microcomputers – memory-I/O interfacing devices. 8085 CPU, Architecture BUS timings, Demultiplexing the address bus generating control signals, instruction set, addressing modes, illustrative programs, writing assembly language programs: looping, counting and indexing-counters and timing delays, stack and subroutine, extension to 8086 CPU.

Intefacing chips – special purpose and general purpose interfacing chips, Microprocessor applications.

Microcontrollers: Introduction to microcontrollers – 8051, Assembly language programming with microcontrollers.

MPHS4407

SPL-APVII

Computational Astrophysics [48 Lectures]

Introduction to Matlab as a tool for numerical and symbolic computation: Basic matlab tools, matrix manipulation, writing functions, random numbers. Numerical computing using matlab interpolation, root finding of nonlinear eqautions, curve-fitting tools, numerical differentiation and integration, ode solvers (with examples).

Astrophysical and Cosmological modeling

Stellar models: Solving the Lane-Emden equations numerically with polytropic equation of state (with different polytropic indices) with special case being of white dwarfs.

Studying the evolution of the universe: Solving the Friedmann equations numerically and finding the scale of distances and age of the universe for different models with current cosmological parameters.

Application of Image analysis techniques and FFT in Astrophysics.

MPHS4408

SPL-SSEVII

Optoelectronics & Photonics [24 Lectures]

Optical properties of semiconductors: Fresnel equations, determination of optical constants, excitons, free carrier absorption, Franz-Keldysh& Stark effects, Kramers-Kronig relation. Types of luminescence, van Roosbroeck – Shockley relation, heterojunctions, strained layers.

Optoelectronic devices: Photodetectors – photoconductors, photodiodes, PIN diodes, CCD, QWIP. Solar Cells – bulk & thin film: p-n junction, Schottky& MIS, c-Si, a-Si, CdTe, CIGS, tandem and concentrator systems. LEDs: materials & structures, edge vs. surface emitters, high efficiency and white LEDs. OLEDs and PLEDs. Lasers: inversion condition and optical confinement, threshold current, DHJ, QW, QWR & QD lasers, Quantum Cascade lasers (QCL).

Modulators: Franz-Keldysh& Quantum-Confined Stark effect (QCSE) modulators, electro-optic & SEED devices.

Photonics – Photonic crystals and bandgaps, photonic integrated circuits. Fiber-optic communication systems, erbium-doped fiber amplifiers, fiber gratings and lasers.Night vision devices.

Nanomaterials&Nanodevices [24 Lectures]

Physics of nanomaterials, types of nanostructures – quantum size effect – quantum wells, wires and dots, variation of density of states, preparation of nanomaterials – top down, bottom up methods, self-assembled monolayers. Determination of particle size from TEM, XRD and light scattering, Fullerene, Carbon Nanotubes (CNTs) – Physics& Technology, Nanodevices in electronics & interdisciplinary areas.

MPHS4451

SPL-APVIII

Astrophysics Laboratory

1. To estimate the temperatures of an artificial star by photometry.
2. To study the solar limb-darkening effect.
3. To study effective temperature of stars by B-V photometry.
4. To determine the solar constant using the principle of calorimetry.
5. To study the Fraunhofer absorption lines from the solar photosphere.
6. To study the Hubble's law and to determine Hubble's constant using SN1a data and galaxy spectra (from CLEA).
7. Analysing SN1a data to determine the deceleration parameter and the Hubble parameter of the universe.

MPHS4452

SPL-SSEVIII

Solid State Electronics Experiments

1. Microcontroller 8051
2. Experiments based on Digital Signal Processing: MATLAB
3. Experiments with standard PCM Kits: Sampling, Quantization & Coding & Multiplexing of multiple PCM signals.
4. Using MATLAB (Student Version) for the simulations of Digital Transmissions via Modulations – PAM, QAM, FSK& Synchronization in Digital Communications.
5. Digital & Analog communication
6. To study A/D & D/A conversion

7. SPICE simulation of Analog MOS circuits.
8. Study of comparator
9. Fiber Optics Experiment
10. Magneto-resistance and Hall coefficient
11. Mobility of semiconductor

MPHS4453

ALII

Advanced Experiments II

Counters, Decoder, Multiplexer

Project Level 2

Students to continue the project started in Sem III