

# SHA 501: Mathematical Physics

<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>3</b>	<b>1</b>	<b>0</b>	<b>3</b>

## **Module 1: Vector analysis (10 hours)**

Dirac delta function, infinite series, convergence, Taylor expansion, polar coordinates – cylindrical and spherical coordinates, Scalar and vector fields, Vector analysis – gradient, divergence and curl, Gauss theorem, Stokes theorem, Green's theorem, Tensors.

## **Module 2: Linear Algebra (10 hours)**

Vector spaces, linear independence, bases, operators, matrix representations, types of matrices, systems of linear equations, determinants, eigenvalue problem for a matrix, basis transformation, applications to quantum mechanics

## **Module 3: Differential Equations and special functions (12 hours)**

Differential equations, linear equations, series solution, Special functions – Bessel equation, Bessel functions, Legendre's equation and Legendre polynomials, Spherical harmonics. Fourier series, Fourier integrals, partial differential equations, examples from physics, separation of variables, integral transforms – Fourier and Laplace transforms, Green's function method, non-linear equations and chaos

## **Module 4: Complex functions (10 hours)**

Complex plane, Complex functions, analytic functions, Cauchy-Riemann condition, power series – Taylor series and Laurent series, zeros and singularities, line integrals, Cauchy's integral theorem, Indefinite integrals, Cauchy's integral formula, Residue theorem and application to evaluation of integrals

### **Text Books:**

1. Mathematical methods for physicists, George B Arfken, 4th ed. Academic Press
2. Advanced Engineering Mathematics, Erwin Kreyszig, 7<sup>th</sup> ed., John Wiley
3. Mathematics for Physicists, P. Dennery and A. Krzywicki, Dover Publications (1996)

### **Reference Books:**

1. Theory and Problems of Vector Analysis, McGraw Hill (1959), Spiegl. M. R
2. Differential equations with applications, G.F.Simmons, Tata-McGraw Hill, 1972.
3. Finite Dimensional Vector spaces, P Halmos, 2nd Ed., Van Nostrand.

## SHA 502: Classical Mechanics

<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

### **Module 1: Equations of motion and integration (10 hours)**

Newtonian formulation, Constraints, Generalized coordinates, Introduction to calculus of variations, Principle of least action, Lagrange's equations, Applications of Lagrangian formulation – free particle, charge in electromagnetic field, motion in central field, Kepler's problem

### **Module 2: Oscillations and rigid body motion (12 hours)**

Free oscillations, system of oscillators, eigenvalue problem and normal modes, damping, forced oscillations and resonance, molecular vibrations, anharmonic oscillations, rotations, rigid body motion, the inertia tensor, Euler angles and equations of motion, motion in non-inertial reference frames, collisions and scattering

### **Module 3: Canonical Equations of motion (12 hours)**

Legendre transformations, Hamilton's equations and examples, cyclic coordinates, Symmetry, Conservation principles and Noether's theorem, Canonical transformations, Poisson bracket formulation, Hamilton-Jacobi equation, applications to classical optics and wave mechanics, action-angle variables and examples

### **Module 4: Special Relativity (8 hours)**

Galilean transformation, Propagation of electromagnetic waves, Michelson-Morley experiment, Special theory of relativity, Lorentz transformations, four-vectors, relativistic kinematics

#### **Text Books:**

1. Classical Mechanics by Herbert Goldstein, II Edition, Narosa Publishers
2. Introduction to Classical Mechanics, R. G. Takwale and P.S. Puranik, Tata McGraw Hill (1979)

#### **Reference Books:**

1. Mechanics, Landau and Lifshitz, (III Ed.) Pergamon press (1976)
2. Mechanics by K. R. Symon, 3rd edition Addison-Wesley (1971)
3. Theoretical mechanics, Spiegel M. R. (Schaum Series), McGraw Hill (1982)
4. Lecture notes on Classical Physics, Blandford and Thorne, Caltech. URL: <http://www.pma.caltech.edu/Courses/ph136/yr2004/>

## SHA 503: Electromagnetic Theory

<b>L</b>	<b>T</b>	<b>P</b>	<b>Cr</b>
<b>3</b>	<b>1</b>	<b>0</b>	<b>3</b>

### **Module 1: Electrostatics and Magnetostatics (11 hrs)**

Divergence and Curl of Electrostatic field, Laplace and Poisson equations, Boundary conditions and uniqueness theorem, Method of images. Separation of variables- Cartesian and spherical coordinates. Multipole expansion- approximate potentials at large distance, the monopole and dipole terms, origin of coordinates in multipole expansions, electric field of a dipole. Magnetostatics- Lorentz force law. Biot-Savart law. Divergence and Curl of magnetic field. Magnetic vector potential, gauge invariance and transformation

### **Module 2: Electrodynamics (10 hrs)**

Electromotive force. Motional emf Electromagnetic induction. Maxwell's equations in differential form. Maxwell's equations in matter. Boundary conditions. Conservation laws, continuity equation, Poynting theorem, Newton's third law in electrodynamics. Maxwell's stress tensor. Conservation of momentum, angular momentum. Electromagnetic Waves in vacuum. Energy and momentum in electromagnetic waves

### **Module 3: Electromagnetic waves in matter (10 hrs)**

Propagation in linear media. Reflection and transmission. Absorption and dispersion- electromagnetic waves in conductors, reflection at conducting surface, frequency dependence of permeability. Cylindrical cavities and Waveguides. Rectangular Waveguide modes. Resonance cavities-power loss in a cavity

### **Module 4: Classical Radiation theory (11 hrs)**

Potentials and fields- Scalar and vector potential, Coulomb gauge and Lorentz gauge. Retarded potentials, Jefimenko's equations. Lienard-Wiechert potentials, field of a moving point charge. Radiation- Electric dipole radiation, magnetic dipole radiation, radiation from an arbitrary source. Power radiated from a point charge, radiation reaction, physical basis of radiation reaction.

### **Text Books**

1. David J Griffiths Introduction to Electrodynamics (3<sup>rd</sup> Edition) Prentice Hall (1999)
2. J.D Jackson Classical Electrodynamics (3<sup>rd</sup> Edition). Wiley India (1999)

### **Reference Books:**

1. Electromagnetic Waves and Radiating Systems, Jordan E.C. and Balmain K. G., Prentice Hall (1968)
2. Feynman Lectures in Physics Volume 2, R. P. Feynman, R. B. Leighton and M. Sands.

## 504 SHA: Electronics I (Microelectronics)

L	T	P	C
3	0	0	3

### Module 1 : Review of General Amplifier concepts and Specialized Op-amps (10 hours)

Op-Amp internals; data sheet and interpretation; basic Op-amp application: comparators, amplifier circuits and mathematical operations; four types of feedback amplifiers: VCVS, VCCS, CCVS and CCCS. Introduction; instrumentation amplifier and characteristics; programmable op-amps; op-amps for current, voltage and power applications; high speed op-amps; operational transconductance amplifier (OTA) and Norton amplifier.

### Module 2 : Non Linear Amplifier Circuits and Active Filters (10 hours)

Introduction; log and antilog amplifiers; the linear multiplier; IC comparator; Schmidt trigger circuit; active limiters and clampers; precision rectifiers and peak detectors; Introduction; filter types; the use and advantages of active filters, filter order and poles; filter class or alignment; Butterworth, Bessel, Elliptic and Chebyshev types; First and higher-orders low-pass and high-pass filters, band-pass, band-rejection, all pass and state variable switched capacitor filters; filter characteristics and applications.

### Module 3: Specialized Single Chip Oscillators, frequency Generators and Voltage Regulators (10 hours)

(i) IC 566 -voltage controlled oscillator (VCO) operating principles and applications; (ii) IC 565- phase locked loop (PLL) operating principles and applications; (iii) IC 555 timer as an astable multivibrator and Monostable multivibrator and (iv) IC 8038 waveform generator (function generator) operating principles and applications. Introduction; linear regulators; series and shunt regulators; current boosting and current limiting circuits; IC three terminal voltage regulator principles and applications; adjustable voltage Regulators; switching regulators: types and their applications.

### Module 4: VLSI Design and Advanced digital design using VHDL (12 hours)

Introduction to MOS transistor's functioning and current models; Introduction MOS and CMOS fabrication and masking steps; Basic NMOS and CMOS design rules; Preparation of different material wafers in MOS VLSI; Design and characterization of NMOS and CMOS inverters; Design of basic logic gates, latches and flip flops in CMOS technology; Structural VLSI design; Gate arrays, standard cell, programmable logic arrays; Design of adders, counters and ALU in NMOS and CMOS technology; Introduction to SRAM and DRAM cells and memory arrays

Abstraction levels in VLSI design: Behavioral, RTL, Logic, physical conventional logic design, sequential logic design; Finite state machines; Moore Type; Mealy type constructs of VHDL languages; Need for VHDL, concurrent statements; sequential statements; behavioral description Using VHDL; structural description in VHDL; RTL-description in VHDL, mixed description.

#### Text Books:

1. T. L Floyd and Buchla, Basic operational Amplifiers and Linear Integrated Circuits, III Edition; Pearson Education Asia (2003)
2. R. A Gayakwad, Op- Amps and Linear Integrated Circuits, VI Ed., Prentice Hall of India, (2003)
3. R. F.Coughlin and F. Fdriscoll, Op- Amps and Linear Integrated Circuits, IV Ed., Prentice Hall of India.
4. A. P Malvino, Electronic Principles, Tata- Mc-Graw Hill, VI Ed, (2002)
5. W. D Stanley, Operational amplifiers with linear integrated circuits, IV Edition, Pearson cation, (2003).

## SHA 591: Electronics Lab I

L	T	P	C
0	0	6	2

1. Experiments involving operational amplifiers.
2. Experiments involving Digital Logic circuits.
3. Experiments using 8085 microprocessor trainer kits.

### **Text Books:**

1. Zbar, Albert P.Malvino and Michael A.Miller , Basic Electronics A Text Lab Manual Part B, Tana Mc-Graw-Hill Publishing Company Ltd., New Delhi, 1994.
2. Albert Paul Malvino, Electronic Principles, 5<sup>th</sup> Edition, Tana Mc-Graw-Hill Publishing Company Ltd., New Delhi, 1993.
3. Albert Paul Malvino and Donald P.Lcach , Digital Principles and Applications, 5<sup>th</sup> Edition, Tana Mc-Graw-Hill Publishing Company Ltd., New Delhi, 1994.
4. Ramesh S.Gaonkar , Microprocessor Architecture: Programming and its Applications with the 8-85/8080A latest edition (5<sup>th</sup> edition),Wiley Eastern Ltd., New Delhi, Bangalore, Madras, 2002.
5. Thomas L.Floyd,Digital Fundamentals, 9<sup>th</sup> edition,Prentice Hall, 2005.
6. M.Morris Mano, Digital Design, 3<sup>rd</sup> edition,Prentice Hall, 2001.
7. M.Morris Mano, Digital Design, 4<sup>th</sup> edition, Prentice Hall, 2006.

## SHA 592: General Physics Lab

L	T	P	C
0	0	6	2

1. Energy band gap and diffusion potential of a semiconductor
2. Photoelectric effect & Determination of Planck's constant expt – using LED
3. Hall effect experiments including temperature dependence of resistance.
4. Solar cell characteristics
5. Speed of Rotary Pump & Pirani gauge
6. Measurement of Magnetoresistance of semiconductors
7. Ultrasonic Interferometer - Acousto-optic effect- Determination of ultrasonic velocity in liquid
8. Determination of Elastic constants by Cornu's method
9. Fourier transforms processor
10. Faraday effect and determination of Verdet's constant
11. Four probe – Resistivity measurements
12. Michelson Interferometer

### **Text Books:**

1. B.L. Worsnop and H.T. Flint, Advanced Practical Physics for students, Asia Publishing House, 1971.
2. S.L.Gupta and V. Kumar, Practical Physics, Pragathi Prakash.

# SHA511: Quantum Mechanics I

<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

## **Module 1: Introductory ideas and Mathematical foundations (12 hours)**

Origins of quantum theory, wave function, probability interpretation, Dirac formalism – kets, bra, operators, Hermitian and unitary matrices, eigenvalues and eigenvectors, basis transformations, commutation relations, Born interpretation, measurement theory, expectation values, uncertainty principle, position and momentum representation, time evolution, Hamiltonian operator, Schrödinger, Heisenberg and Interaction pictures, Schrödinger equation, symmetry, conservation laws, degeneracy

## **Module 2: Examples and applications (14 hours)**

One dimensional potential problem, charged particle in external magnetic field, simple harmonic oscillator-operator formalism, raising and lowering operators, eigenvalues and eigenvectors, Schrödinger equation for the oscillator, central potential problem, orbital angular momentum, the hydrogen atom, orbitals, semi-classical approaches – WKB method

## **Module 3: Angular momentum (8 hours)**

Angular momentum and Identical particles: Infinitesimal rotations, rotation operator, angular momentum operators, commutation relations, eigenvalues, matrix representation, orbital and spin angular momentum, addition of angular momenta, Clebsch-Gordon coefficients.

## **Module 4: System of identical particles (8 hours)**

Identical particles, distinguishable and indistinguishable particles, Symmetric and antisymmetric wavefunctions, exchange degeneracy, projection operator, bosons and fermions, Slater determinant, Pauli's exclusion principle

### **Text Books:**

1. Introduction to Quantum Mechanics, by David. J. Griffiths (2<sup>nd</sup> Ed.) Pearson Education (2005)
2. Modern Quantum Mechanics by J. J. Sakurai Addison Wesley, 1999

### **Reference Books:**

1. Principles of Quantum Mechanics, R. Shankar (II Ed.), Springer (1994)
2. Problems in Quantum Mechanics, Constantinescu and Magyari, Pergamon (1974)
3. Quantum Mechanics, L. I. Schiff, (III Ed.) McGraw Hill (1968)

## SHA 512: Statistical Physics

<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

### **Module 1: Basic ideas (12 hours)**

Need for statistical physics, models of macroscopic systems, macro states and micro states, phase space, Liouville's theorem, energy quantization, review of basic probability theory and thermodynamics, fundamental postulate of equilibrium statistical mechanics, microcanonical ensemble, Gibbs paradox and enumeration of microstates, canonical ensemble, partition function, free energy, calculation of thermodynamic quantities, entropy, fluctuations, grand canonical ensemble,

### **Module 2: Applications (10 hours)**

Classical ideal gas, Maxwell-Boltzmann distribution, equipartition theorem, virial theorem, specific heat of gases, real gases, paramagnetism, Langevin and Brillouin functions, Curie's law, nuclear spins, ortho and para hydrogen, negative temperature concept, system of harmonic oscillators.

### **Module 3: Quantum statistics (12 hours)**

Systems of identical, indistinguishable particles, spin, symmetry of wavefunctions, bosons, fermions, Pauli's exclusion principle, Bose-Einstein and Fermi-Dirac distributions, degeneracy, ideal Fermi gas and ideal Bose gas, applications – free electron gas, liquid helium, radiation, specific heat of crystalline materials – Einstein and Debye theories,

### **Module 4: Advanced topics (8 hours)**

Introductory ideas on phase transitions and criticality, models for ferromagnetism – Ising and Heisenberg models, introduction to microscopic simulations – Monte Carlo and molecular dynamics

### **Text Books:**

1. Statistical Mechanics, R. K. Pathria (II Ed.), Butterworth-Heinemann (1996)
2. Equilibrium Statistical Mechanics, E. Atlee Jackson, Prentice-Hall (1968)

### **Reference Books:**

1. Fundamentals of Statistical and Thermal Physics, F. Reif, McGraw-Hill (1985)
2. Statistical Mechanics, Kerson Huang, II Ed, John Wiley (1987)
2. Thermodynamics (II Ed.) Herbert B. Callen, Wiley

## SHA 513 Electronics II (Microprocessors, Microcontrollers and Embedded Systems)

L	T	P	C
3	0	0	3

### **8088/8086 MICROPROCESSORS:**

#### **Module 1: Architecture, Instruction set and Instructions (8 hours)**

Organization of 8086 CPU; 8086 memory locations; physical and logical memory; grouping 8086 registers into a BIU and EU; 8086 addressing modes, Moving data; logical, mathematical operations; jump instructions; sequential programs; looping programs; Procedures; stack operations; calling operations.

#### **Module 2: Memory, Input/output interface and Interrupt interface (10 hours)**

The minimum and maximum mode systems; interface signals; bus cycles and time states; hardware organization of the memory address space; memory control signals; read and write bus cycles; memory interface circuits; types of input/output; isolated input/output interface; Interrupt mechanism, types and priority; interrupt instructions; enabling/disabling of interrupts; external hardware-interrupt interface signals and sequence; software interrupts and interrupts instructions; BIOS and DOS interrupts and their uses.

#### **Module 3: Microcontrollers (12 hours)**

Introduction: 8051 Microcontroller Hardware – Input/Output Pins, Ports and Circuits – Counter and Timers – Serial Data Input/Output – Interrupts. Instructions: Moving Data; Addressing Modes; External Data Moves; Code Memory Read-Only Data Moves; Push and Pop Op-codes; Data Exchanges; Byte-Level Logical Operations; Bit-Level Logical Operations; Rotate and Swap Operations; Flags-Incrementing and Decrementing ; Addition; Subtraction; Multiplication and Division; the jump and Call Program Range; Jumps – Calls and Subroutines – Interrupts and Returns.

#### **Module 4: Embedded systems (12 hours)**

Introduction to embedded systems hardware needs; general characteristics; typical application listing; memories (RAM, ROM, EPROM); embedded system design – major subtasks; design requirements; real time requirements; major components in embedded systems; Tristate devices; Buses, DMA, UART and PLD's; Built-ins on the microprocessor; Interrupts basics, ISR; Context saving, shared data problem. Atomic and critical section, Interrupt latency; Survey of software architectures, Round Robin, Function queue scheduling architecture, Use of real time operating system.

#### **Text Books:**

1. K J.Ayala: The 8086 microprocessor programming and interfacing the PC, Penram International, 1995.
2. B B.Brey: The Intel microprocessors, Ed 4, Prentice Hall India, 1997.
3. K.J.Ayala: The 8051 Microcontroller: Architecture, Programming and Applications, Ed II.
4. D. A.Simon: An Embedded Software Primer, Pearson Education.
5. A W. Triebal and A.Singh: The 8086 and 8088 microprocessors, Ed IV, Prentice Hall of India, 2003.
6. D. W.Lewis: Fundamentals of Embedded Software:Where C and Assembly Meet, Pearson Education.
7. M.Predko, Programming and Customizing the 8051 Microcontroller, TMH, 1999.

## SHA 514: Modern Optics

<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

### **Module 1: Electromagnetic waves and polarization (10 hours)**

Basic laws of Electromagnetic theory, Maxwell's equations, Electromagnetic waves, energy and momentum. Electromagnetic wave in a conducting medium. Total internal reflection. Polarization, mathematical description of Polarization.

### **Module 2: Interference (10 hours)**

Interference-general consideration. Condition for Interference. Michelson interferometer, Mach-Zehnder Interferometer. Interference by multiple reflections, Fabry-Perot interferometer, Multi-layer interference coating and interference filters.

### **Module 3: Geometrical Optics (10 hours)**

Fermat's Principle, application of Fermat's Principle, Lens design and matrix algebra. Geometrical optics of resonators. Guided waves-guided modes

### **Module 4: Coherence (12 hours)**

Spatial and temporal coherence. Fourier Optics – one and two dimensional transforms. The lens as a Fourier transformer. Dirac delta function – displacement and Phase Shifts. Optical applications

### **Text Books:**

3. Robert Guenther, Modern Optics 1<sup>st</sup> Edition John Wiley & Sons (1990)
4. Eugene Hecht, Optics 4th Edition. Pearson Education Publishers (2002)

## SHA 593: Electronics Lab II

<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>0</b>	<b>0</b>	<b>6</b>	<b>2</b>

1. 8086: Assembly language programming
2. Instrumentation amplifiers
3. Phase-Lock Loop (PLL) characteristics and typical applications
4. Log and Antilog amplifiers
5. Signal conditioning using sensors (temperature, light intensity, magnetic field, force & displacements etc.)
6. Opto-isolators
7. Microcontroller-8051 family- programming and interfacing, DAC & ADC, display system interfacing, Lab View Programming
8. Temperature measurement system using USB based DAQ
9. IEEE 488 & USB electrical interfacing & measurement system (Demo)-FPGA implementation for simple circuits

### **Text Books:**

1. Robert Boylestad and Louis Nashelsky, Electronic Devices and Circuit Theory, 9<sup>th</sup> Edn, Prentice Hall India, 2005 (ISBN: 978-81-203-2967-6)
2. Allen Mottershead, Electronic Devices and Circuits – An Introduction, Prentice Hall India (ISBN: 81-203-0124-2)
3. Kenneth. J. Ayala, The 8051 Microcontroller Architecture Programming & Applications, Penram International Publishing (India), 1999 (ISBN: 81-31-50-2007)
4. H.K.P. Neubert, Instrument Transducers, Clarendon Press, 1975.
5. R.A. Gayakwad, Op-amps and Linear Integrated Circuits, VI Ed, (

## SHA 594: Optics Lab-1

<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>0</b>	<b>0</b>	<b>6</b>	<b>2</b>

1. Principles of Physical Optics.  
Experiments based on polarization, Reflection, Refraction, Diffraction, Interference and Coherence.

### **Text Books:**

1. M. Born and E. Wolf, Principles of Optics, (VI Edition), Pergamon, 1989.
2. A. Ghatak and K. Tyagarajan, Introduction to Optics, Cambridge University Press, 1999.
3. A. Yariv, Optical Electronics.
4. A. Ghatak and K. Tyagarajan, Optical Electronics, Cambridge University Press, 1999.
5. J.W. Goodman, Introduction to Fourier Optics, McGraw Hill, 1968.
6. D.L. Clark and J.F. Grainger, Polarised light and Optical measurement, Pergamon Press, 1971.

<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

## SHA 602 Quantum Mechanics II

### **Module 1: Approximation methods (14 hours)**

Stationary perturbation theory, first and second order approximation to wave function and energy eigenvalue, degenerate perturbation theory, applications to- harmonic oscillator, Zeeman effect, Stark effect. Time dependent perturbation – method of variation of constants, transition rate, sudden and adiabatic approximations, Fermi golden rule, application – H atom ionization, decay of an unstable state, scattering theory, scattering cross section, Born approximation, partial wave analysis, low energy scattering, optical theorem, variational method – variational theorem, application to He atom

### **Module 2: Semi-classical radiation theory (12 hours)**

Maxwell's equations, plane waves and perturbation theory, transition probability, absorption and emission, dipole transitions and selection rules, forbidden transitions, spontaneous emission, simulated emission, radiation field, adiabatic approximation and Berry's phase

### **Module 3: Advanced topics (6 hours)**

Density matrix, pure and mixed states, connection to partition function, introduction to path-integral formalism, harmonic oscillator in path integral formalism

### **Module 4: Relativistic quantum mechanics (10 hours)**

Relativistic effects, Klein-Gordon equation, Dirac equation, Dirac matrices, spinors, positive and negative energy solutions, physical interpretation, nonrelativistic limit of the Dirac equation

### **Text Books:**

1. Introduction to Quantum Mechanics, by David. J. Griffiths (2<sup>nd</sup> Ed.) Pearson Education (2005)
2. Modern Quantum Mechanics by J. J. Sakurai Addison Wesley, 1999
3. Principles of Quantum Mechanics, R. Shankar (II Ed.), Springer (1994)

### **Reference Books:**

1. Quantum Mechanics, L. I. Schiff, (III Ed.) McGraw Hill (1968)
2. Problems in Quantum Mechanics, Constantinescu and Magyari, Pergamon (1974)

# SHA 603 : CONDENSED MATTER PHYSICS

L	T	P	C
3	0	0	3

## Module I : Internal Structure of Solids (8 hours)

Diffraction of X rays by crystals, Bragg condition. Geometrical structure factor, Ideas of wave vector and vector space. Reciprocal lattice and reciprocal lattice vector, Bragg condition in vector form. Ewald's Construction, Brillouin zones. Radial distribution functions.

Bonding and internal structure of solids: The van der Waals forces, Dispersion, Orientational and Inductive interactions. Ionic, covalent and metallic bonds – stability considerations. The hydrogen bond, Forces of repulsion. Coordination number. Polymorphism. Imperfections and defects of the crystal lattice.

## Module II: Thermal properties of solids (6 hours)

Normal modes of lattice and its normal mode spectrum. Debye frequency and temperature. Phonons, momentum of phonons, inelastic scattering of photons by phonons. Heat capacity of solids – Einstein and Debye models. Thermal conductivity: lattice conductivity, electronic contribution – Thermal conductivity of metals – high, low, and very low temperature range values.

## Module III : Free Electron Theory and Band Theory of Solids (16 hours)

Density of States, Fermi-Dirac statistics, Sp.heat, Relaxation time, Mean free path, Mobility, Thermal conductivity, Drude model,

Electrical conductivity, Temperature dependence of Electrical resistance. Electron Scattering, scattering probability and relaxation time; collisions; Boltzmann equation; Wiedemann-Franz law; Scattering due to impurities; Matthiessen's rule

Fermi surface. Cyclotron resonance and Hall effect

### Band theory of Solids

Dependence of electron energy on the wave vector, E-K diagram, periodic potential, Density of states, Bloch theorem, Bloch functions; Kronig-Penny Model; Electrons in periodic potential; orbitals in a band, Band symmetry and Brillouin zones. Fermi Surfaces and Metals: Reduced and Periodic zone schemes; Fermi surfaces, electron hole and open orbits; Tight Binding method; Wigner-Seitz method; Pseudopotentials; Quantization of orbits in a magnetic field; De Haas-Van Alphen effect; other Fermi surface probes

## Module IV : Magnetic properties of solids and Superconductivity (12 hours)

Quantum theories of diamagnetism and paramagnetism. Weiss theory of ferromagnetism. Spin waves and magnons. Domain structure of Ferromagnetic substances. Antiferromagnetism. Ferri magnetism and Ferrites.

Excitations in solids: Magnons, helicons, spin waves in electron gas, Electron phonon interaction. Excitons and Polarons. Mossbauer effect

Superconductivity:

Meissner effect, London equation, Type I and II superconductors, thermodynamics, Superconducting band gap, Cooper pairs, flux quantization. BCS theory (qualitative). Josephson Effect, SQUIDS.

### REFERENCES:

Michael Marder : *Condensed Matter Physics*, Wiley (2004)

P. M. Chaikin: [\*Principles of Condensed Matter Physics\*](#). Cambridge University Press (2000)

Ashcroft and Mermin, *Solid State Physics*, Harcourt Asia, 2001.

Kittel, C.: *Introduction to Solid State Physics*, Wiley (2007)

Rosenberg: *Introduction to Solid State Physics*, Oxford University Press (1995)

## SHA 604: Laser Physics

L	T	P	C
3	0	0	3

### Module I

Light matter interaction –Einstein coefficients and light amplification – Line broadening mechanism.  
Laser rate equations – three level system and four level system. Variation of laser power around threshold.  
Optimum output coupling

(11 hrs)

### Module II

Optical resonators – modes of a rectangular cavity and the open and planar resonators. Quality factor.  
Ultimate line width of a laser. Transverse and longitudinal mode. CW laser and pulsed laser. Q switching  
and mode locking. Different type of resonator system. Pulse compression.

(11 hrs)

### Module III

Characteristics of Laser beam – Gaussian beam. Spot size and radius of curvature of a Gaussian beam.  
Characteristics of Gaussian Beam. Laser propagation through arbitrary optical system. Focusing of a  
Gaussian beam.

(10 hrs)

### Module IV

Types of lasers – Ruby laser - He-Ne laser- Solid state lasers - CO<sub>2</sub> laser- Dye lasers- semiconductor  
lasers. Applications of lasers- Laser in science- Laser in industry – laser in communication - laser in  
Holography and spatial frequency filtering.

(10 hrs)

#### Text Books:

1. K.Thyagarajan and A.K. Ghatak , *Laser theory and applications* 1<sup>st</sup> Edition Macmillan India Ltd.(1984)
2. Yariv, *Quantum Electronics*, John Wiley (1988)
3. F L Pedrotti, L M Pedrotti and L S Pedrotti *Introduction to Optics* 3<sup>rd</sup> Edition Prentice-Hall (1987)

<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**Module 1: Atomic Structure**

Review of Hydrogen atom structure, Two electron atoms, variational method, many-electron atoms, Central field approximation, Independent particle approximation, Hartree-Fock approximation, LS and JJ coupling schemes, Thomas-Fermi model of atom.

**Module 2: Atom-Light interaction**

Review of electromagnetic field, transition probability, absorption and emission, dipole transitions, polarization, oscillator strength, and their spectral distribution, line intensities and line shape, excited state lifetime.

**Module 3: Molecular structure and spectra**

Molecules, Born-Oppenheimer approximation, diatomic molecular structure, molecular binding, LCAO method, molecular orbitals, symmetry and structure, structure of polyatomic molecules, spectra of diatomic molecules, electronic, rotational, vibrational etc.), Raman effect, modern experimental tools of spectroscopy.

**Module 4: scattering and advanced topics**

Basic concepts - channels and coupling, potential scattering, scattering states, applications of atomic and molecular physics – lasers / masers, laser cooling and trapping, Bose-Einstein condensation, atom optics.

**Text Books:**

1. Physics of Atoms and Molecules, B.H.Bransden and C.J. Joachain (II Ed.), Pearson Education 2004.
2. Molecular Quantum Mechanics- P.W.Atkins and R.S.Friedman, (3<sup>rd</sup> Ed.) Oxford Univ. Press (1997).
3. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, Tata McGraw Hill (1994)

**Reference Books:**

1. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles, R. Eisberg and R. Resnick, John Wiley, New York (1974).
2. Introduction to Atomic Spectra, H. E. White, McGraw Hill, Kogakusha, Tokyo (1934).
3. Basic Atomic and Molecular Spectroscopy, J. Michael Hollas, (Royal Society of chemistry)

<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
<b>3</b>	<b>0</b>	<b>0</b>	<b>3</b>

**Module I: Introduction to Communications Systems:**

Communication Systems: Information, Transmitter, Channel Noise, Receiver; Modulation: Description, Need for Modulation; Bandwidth Requirements: Sine Wave and Fourier Series Review; Frequency Spectra of Nonsinusoidal Waves; Noise: External Noise: Atmospheric Noise, Extraterrestrial Noise, Industrial Noise ; Internal Noise: Thermal Agitation Noise, Shot Noise, Transit-Time Noise, Miscellaneous Noise; Noise Calculations: Addition of Noise due to Several Sources, Addition of Noise due to Several Amplifiers in Cascade, Noise in Reactive Circuits; Noise Figure: Signal-To-Noise Ratio, Definition of Noise Figure, Calculation of Noise Figure, Noise Figure from Equivalent Noise Resistance, Noise Figure from Measurement, Noise Temperature

**Module II: Modulation:****Amplitude Modulation**

Theory: Frequency Spectrum of the AM Wave, Representation of AM, Power Relations in the AM wave, Generation of AM: Basic Requirements—Comparison of Levels, Grid- Modulated class C Amplifier, Plate-Modulated class C Amplifier, Modulated Transistor Amplifiers; Single-sideband (SSB) techniques: Evolution and Description of SSB, Suppression of Carrier - Effect of Nonlinear Resistance on Added Signals, The Balanced Modulator, Suppression of Unwanted Sideband - Filter System, Phase-Shift Method, The “third” Method

**Frequency Modulation:**

Description of systems, Mathematical representation of FM, Frequency spectrum of the FM wave, Phase modulation, Intersystem comparisons, Noise and frequency modulation- Effects of noise on carrier - Noise triangle, Pre-emphasis and de-emphasis, Other forms of interference, Comparison of wideband and narrowband FM, Stereophonic FM multiplex system; Generation of frequency modulation - FM methods, Direct methods, Stabilized reactance modulator – AFC, Indirect method

**Pulse Modulation:**

The Sampling Process, Pulse–Amplitude Modulation, Time–Division Multiplexing, Pulse–Position Modulation, Bandwidth–Noise Trade–off, Quantization Process, Pulse-Code Modulation, Noise Considerations in PCM Systems, Virtues, Limitations, and Modifications of PCM;

**Module III: Digital Communication:**

**Digital modulation techniques:** Coherent Binary Modulation Techniques: PSK, FSK, QPSK; Non-Coherent Techniques- DPSK;

**Digital Signal Processing:**

Discrete- time signals, LTI systems, Stability and Causality, Linear Difference Equations with Constant coefficients, Frequency domain representation, z- transform and its properties, system function, flow graph and matrix representation of networks, basic network structures of IIR and FIR systems, IIR and FIR filters; O&S: relevant topics and sections

**Module IV: Advanced Communication Systems:**

Satellite Communications; Mobile Radio; Broadband ISDN, Emerging views of Telecommunications.

**Reference Books**

Kennedy D., Davis G.: Electronic Communication Systems; IV edition; Tata- Mc-Graw-Hill (1999),  
 Haykin S., Communication Systems, III Ed., John Wiley & Sons, (1995),  
 Haykin S.: Digital Communications, John Wiley & Sons, (2000),  
 Oppenheim A. V., Schaffer R. W. : Digital Signal Processing, Prentice Hall of India, IV printing (1991)  
 Haykin S., Introduction to Analog and Digital Communications, John Wiley & Sons;  
 Taub H. and Schilling D. L.: Principles of Communication Systems, II Ed., Tata McGraw Hill (1994).  
 Shanmugam K. S.: Analog and Digital Communications, John Wiley and Sons.  
 Lathi B. P.: Communication Systems, Wiley Eastern.  
 Bracewell R. N., Fourier Transform and Its Applications, II Ed., Mc-Graw Hill, (1

## SHA 691: Numerical Methods and Computational Physics (Lab)

L	T	P	C
0	0	6	2

1. Introduction to MatLab – Graphics and curve plotting with MatLab, plotting simple functions, writing simple MatLab codes, Interpolation and curve fitting, Zeros of functions - Newton-Raphson method.
2. Linear Algebra and matrix methods with MatLab – Solving linear equations (Gaussian elimination, Gauss Jordan method etc.) and matrix eigenvalue problems ( also problems related to Quantum Mechanics and small oscillations).
3. Elements of C and FORTRAN 90 programming with simple examples for implementation.
4. Integration and methods for solving ODE - Trapezoidal rule, Simpsons' rule, Euler's method, mid-point method, Runge-Kutta method implemented in C or FORTRAN.
5. Fourier Transforms and FFT: Implementation using MatLab and FORTRAN, applications.
6. Introduction to Labview and applications to physics problems, interfacing and computation with Labview, interfacing MatLab with Labview.
7. Advanced topics – Monte Carlo simulations, Molecular Dynamics
8. Mini project on computational problem relevant to physics.

### **Text Books:**

1. A.Raiston: First course in numerical analysis - Anthony Ralston, Philip Rabinowitz (II Edition – revised) (Dover Publications).
2. Press, Teucholsky, Vetterling, Flannery: Numerical Recipes in C / FORTRAN (III Edition) (Cambridge University Press)
3. Hamming, Numerical Methods for Scientists and Engineers (Dover)
4. Numerical Methods for Physics, 2nd Edition, A.L. Garcia, Prentice Hall (2000).
5. An Introduction to Programming and Numerical Methods in MATLAB, Springer-Verlag, 2005
6. Web resources: The Third Branch of Physics, Essays on Scientific Computing by Norbert Schörghofer. An insightful manuscript on some aspects of computational physics:  
<http://www2.hawaii.edu/~norbert/compphysics.html>