BHARATHIDASAN UNIVERSITY, TIRUCHIRAPPALLI – 620 024.
M.Sc. Physics Course Structure under CBCS

(For the candidates admitted from the academic year 2016-2017 onwards)

Sem	Course	Course Title	Ins. Hrs / Week	Credit	Exam Hrs	Marks		Total
						Int.	Ext	
I	Core Course – I (CC)	Mathematical Physics	6	4	3	25	75	100
	Core Course – II (CC)	Classical Dynamics and Relativity	6	4	3	25	75	100
	Core Course – III (CC)	Electronics	5	4	3	25	75	100
	Core Course – IV (CC)	Methods of Spectroscopy	5	4	3	25	75	100
	Core Practical – I (CP)	Physics Practical – I (General and Electronics)	8	4	3	40	60	100
	TOTAL		**30**	**20**				**500**
II	Core Course – V (CC)	Electromagnetic Theory	6	5	3	25	75	100
	Core Course – VI (CC)	Quantum Mechanics	6	5	3	25	75	100
	Core Practical – II (CP)	Physics Practical – II (Microprocessor and Programming)	8	4	3	40	60	100
	Elective Course – I (EC)	Microprocessor and Microcontroller	5	5	3	25	75	100
	Elective Course – II (EC)	Numerical Methods and C++ Programming	5	5	3	25	75	100
	TOTAL		**30**	**24**				**500**
III	Core Course – VII (CC)	Statistical Mechanics	6	5	3	25	75	100
	Core Course – VIII (CC)	Solid State Physics	6	5	3	25	75	100
	Core Practical – III (CP)	Physics Practical – III (General and Electronics)	8	4	3	40	60	100
	Elective Course – III (EC)	Crystal Growth and Thin Film Physics	5	5	3	25	75	100
	Elective Course – IV (EC)	Nonlinear Optics	5	5	3	25	75	100
	TOTAL		**30**	**24**				**500**
IV	Core Course – IX (CC)	Nuclear and Particle Physics	5	5	3	25	75	100
	Core Course – X (CC)	Advanced Physics	5	5	3	25	75	100
	Core Practical - IV (CP)	Physics Practical – IV (Electronics)	8	4	3	40	60	100
	Elective Course – V (EC)	Nanophysics	5	4	3	25	75	100
	Project		7	4	-	-	-	100
	TOTAL		**30**	**22**				**500**
GRAND TOTAL			**120**	**90**				**2000**

Project : 100 Marks
Dissertation: 80 Marks
Viva Voice : 20 Marks

Core Papers - 10
Core Practical - 4
Elective Papers - 5
Project - 1

Note:

1. Theory	Internal	25 marks	External	75 marks
2. Practical	”	40 marks	”	60 marks

3. Separate passing minimum is prescribed for Internal and External

   a) The passing minimum for CIA shall be 40% out of 25 marks (i.e. 10 marks)
   b) The passing minimum for University Examinations shall be 40% out of 75 marks (i.e. 30 marks)
   c) The passing minimum not less than 50% in the aggregate.

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CORE COURSE I

MATHEMATICAL PHYSICS

OBJECTIVE

- To learn various mathematical concepts and techniques in vector space, groups and functions of special types to solve physical problems.

Unit I Vector Analysis

Concept of vector and scalar fields – Gradient, divergence, curl and Laplacian – Vector identities – Line integral, surface integral and volume integral – Gauss theorem, Green's theorem, Stoke's theorem and their applications – Definitions in linear independence of vectors – Schmidt's orthogonalisation process – Schwartz inequality.

Unit II Matrix Theory and Tensors

Matrix Theory: Characteristic equation of a matrix – Eigenvalues and eigenvectors – Cayley–Hamilton theorem -Reduction of a matrix to diagonal form – Jacobi method – Sylvester's theorem.

Tensors: Contravariant, covariant and mixed tensors – Rank of a tensor – Symmetric and antisymmetric tensors – Contraction of tensor – Quotient law.

Unit III Group Theory

Basic definitions – Multiplication table – Subgroups, cosets and classes – Point and space groups – Homomorphism and isomorphism – Reducible and irreducible representations – Schur's lemma -- The great orthogonality theorem (qualitative treatment without proof) – Formation of character table of C_{2v} and C_{3v} -- Elementary ideas of rotation groups.

Unit IV Complex Analysis

Cauchy-Riemann conditions – Complex integration – Cauchy's integral theorem and integral formula – Taylor's and Laurent's series – Residues and singularities - Cauchy's residue theorem – Evaluation of definite integrals.

Unit V Special Functions

Basic properties of gamma and beta functions -- Legendre, Bessel, Laugerre and Hermite differential equation: Series solution, Rodriguez formula, generating function, recurrence relations and orthogonality relations.

Books for Study (Relevant chapters from)

1. B.D. Gupta, *Mathematical Physics* (Vikas Pub., Noida, 2015) 4th edition.
2. A.K. Sexena, *Mathematical Physics* (Narosa, New Delhi, 2015).
3. A.W. Joshi, *Matrices and Tensors in Physics* (New Age, New Delhi, 2006).
4. G. Aruldhas, *Molecular Structure and Spectroscopy* (PHI, New Delhi, 2009).
5. H.K. Dass and Rama Verma, *Mathematical Physics* (S. Chand, New Delhi ,2008).

Books for Reference

1. L.A. Pipes and L.R. Harvill, *Applied Mathematics for Engineers and Physicists* (McGraw Hill, Singapore, 1967).
2. B.V. Ramana, *Higher Engineering Mathematics* (MaGraw Hill, New Delhi, 2013).

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CORE COURSE II

CLASSICAL DYNAMICS AND RELATIVITY

OBJECTIVE

- To learn various mathematical techniques of classical mechanics and their applications to physical systems and introduce relativistic dynamics.

Unit I Fundamental Principles and Lagrangian Formulation

Mechanics of a particle and a system of particles – Conservation laws – Constraints – Generalized coordinates – D'Alembert's principle and Lagrange's equation – Hamilton's principle – Lagrange's equations of motion – Conservation theorems and symmetry properties – Applications to linear harmonic oscillator, pendulum, compound pendulum, charged particles in an electromagnetic field and Atwood's machine.

Unit II Motion Under Central Force

Conservation of energy and angular momentum – Inverse square law – Kepler's problem – Virial theorem – Scattering in a central force field – Artificial satellites – Geo stationary satellites – Eccentricity of orbit of satellites – Escape velocity.

Unit III Rigid Body Dynamics and Oscillatory Motion

Euler's angles – Moments and products of inertia – Euler's equations - Symmetrical top – Theory of small oscillations – Normal modes and frequencies – Linear triatomic molecule – Wave equation and motion – Phase velocity – Group velocity -- Dispersion.

Unit IV Hamilton's Formulation

Hamilton's canonical equations of motion – Hamilton's equations from variational principle – Principle of least action – Canonical transformations – Poission bracket – Hamilton--Jacobi method – Action and angle variables – Kepler's problem in action-angle variables – Applications of Hamilton's equations of motion to linear harmonic oscillator, pendulum, compound pendulum and charged particles in an electromagnetic field.

Unit V Relativistic Mechanics

Reviews of basic ideas of special relativity – Energy momentum four -vector – Minkowski's four-dimensional space – Lorentz transformation as rotation in Minkowski's space – Composition of Lorentz transformation about two orthogonal directions – Thomas precession – Elements of general theory of relativity.

Books for Study

1. H. Goldstein, C.P. Poole and J.L. Safko, *Classical Mechanics* (Pearson Education and Dorling Kindersley, New Delhi, 2007).
2. S.L. Gupta, V. Kumar and H.V. Sharma, *Classical Mechanics* (Pragati Prakashan, Meerut, 2001).
3. N.C. Rana and P.S. Joag, *Classical Mechanics* (Tata McGraw-Hill, New Delhi, 1991).

Books for Reference

1. V.B. Bhatia, *Classical Mechanics* (Narosa, New Delhi, 1997).
2. T.L. Chow, *Classical Mechanics* (John-Wiley, New York, 1995).

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CORE COURSE III

ELECTRONICS

OBJECTIVE

- To understand the working of advanced semiconductor devices and digital circuits and the utility of OP-AMP and learn the basics of integrated circuit fabrication, applications of timer IC-555 and building block of digital systems.

Unit I Semiconductor Devices

Varactor, Schottky, tunnel, Gunn, optoelectronic, LASER, LED and photo diodes – Hall effect in a semiconductor -- Depletion and enhancement type MOSFFT – Characteristics of UJT and SCR – Power control DIAC and TRIAC.

Unit II Operation Amplifier

Wien bridge and phase-shift oscillators – Triangular, saw-tooth and square-waves generators – Schmitt trigger – Voltage control oscillator – Phase-locked loops -- Weighted resistor and binary R-2R ladder digital to analog converters -- Counter type and successive approximation analog to digital converters -- Solving simultaneous and differential equations

Unit III Digital Circuits-I

Digital comparator – Parity generator/checker – Data selector -- BCD to decimal decoder –Seven segment decoder – Encoders – RS, JK, D and JK master-slave flip-flops.

Unit IV Digital Circuits-II

Serial-in serial-out, serial-in parallel-out and parallel-in serial-out shift registers – Synchronous, asynchronous, ring and up/down (using mod 10) counters -- Multiplexers – Demultiplexers.

Unit V IC Fabrication and IC Timer

Basic monolithic ICs – Epitaxial growth – Masking – Etching impurity diffusion – Fabricating monolithic resistors, diodes, transistors, inductors and capacitors – Circuit layout – Contacts and inter connections – Charge coupled device – Applications of CCDs -- 555 timer: Description of the functional diagram, applications of monostable and astable operations and pulse generation.

Books for Study (Relevant chapters in)

1. T.F. Schubert, E.M. Kim, *Active and Nonlinear Electronics* (John Wiley, New York, 1996).
2. L. Floyd, *Electronic Devices* (Pearson Education, New York, 2004).
3. J. Millman, C. Halkias and C.D. Parikh, *Integrated Electronics, Analog and Digital Circuits and Systems* (TMGH, 2010).
4. D.P. Leach and A.P. Malvino, *Digital Principals and Applications* (Tata McGraw-Hill, New Delhi, 2006).
5. R.A. Gayakwad, *Op-Amps & Linear Integrated Circuits* (Printice Hall, New Delhi, 1999).

Books for Reference

1. R.L. Geiger, P.E. Allen and N.R Strader, *VLSI Design Techniques for Analog and Digital Circuits* (McGraw--Hill, Singapore, 1990).
2. D. Roy Choudhury and S.B. Jain, *Linear Integrated Circuit* (New Age International Publications, New Delhi, 2010).
3. D. Chattopadhyay and P.C. Rakshit, *Electronics Fundamentals and Applications* (New Age International Publications, New Delhi, 2010).

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CORE COURSE IV

METHODS OF SPECTROSCOPY

OBJECTIVE

- To familiarize with the basic principles of various spectroscopic techniques and their applications in the determination of atomic structure, chemical composition and physical properties of materials.

Unit I Atomic Spectroscopy

Quantum states of an electron in atom – Hydrogen atom spectrum – Electron spin -- Stern—Gerlach experiment – Spin-orbit interaction – Two electron system -- LS-JJ coupling schemes – Spectroscopic terms and selection rules - Hyperfine structure – Zeeman and Paschen—Back effect of one and two electron systems – Selection rules – Stark effect.

Unit II Microwave and Infrared Absorption Spectroscopies

Microwave Spectroscopy: Rotation of diatomic molecules – Rotational spectra of polyatomic molecules – Spectrum of nonrigid rotator – Experimental technique – Polyatomic molecules – Linear, symmetric top and asymmetric top molecules.

Infrared Absorption Spectroscopy: Vibrating diatomic molecule – Anharmonic oscillator – Diatomic vibrating rotator – Vibration-rotation spectrum of carbon monoxide – Influence of rotation on the spectrum of polyatomic molecules – Linear and symmetric top molecules – Influence of nuclear spin -- FT techniques.

Unit III Raman Spectroscopy

Quantum theory of Raman effect – Classical theory of Raman effect – Pure rotational Raman spectra – Linear molecules – Symmetric top molecules – Vibration Raman spectra – Rotational fine structure – Structural determination – Raman spectra – Instrumentation – Raman effect and molecular structure – Raman activity of molecular vibrations -- Surface enhanced Raman spectroscopy.

Unit IV Nuclear Magnetic Resonance Spectroscopy

Basic principles -- Bloch equations and solutions – Shielding and deshielding effects – Chemical shift – Spin lattice and spin-spin relaxation – Coupling constants – Experimental technique – Double coil method – Structural diagnosis and hydrogen bonding.

Unit V UV and ESR Spectroscopies

UV: Theory and instrumentation – Types of transition in inorganic work – Change in position and intensity of absorption – Charge transfer transition – Molecular weight data.
ESR: Theory of ESR – Resonance conditions – Experimental study – ESR spectrometer – Crystalline solids and free radicals in solution – Determination of g factor.

Books for Study

1. C.N. Banwell, *Fundamentals of Molecular Spectroscopy* (McGraw Hill, New York, 1981).
2. G. Aruldhas, *Molecular Structure and Spectroscopy* (Prentice Hall, New Delhi, 2006).
3. D.N. Sathyanarayana, *Vibrational* Spectroscopy (New Age International, New Delhi, 2015).

Books for Reference

1. J. Michael Hollas, *Modern Spectroscopy* (Wiley India, New Delhi, 2004).
2. B.P. Straughan and S. Walker, *Spectroscopy* Volumes I--III (Chapman and Hall, New York, 1976).

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CORE PRACTICAL I

PHYSICS PRACTICAL I (GENERAL AND ELECTRONICS)

OBJECTIVE

- Experimental determination of certain physical constants and properties and verification of characteristics and applications of electronic components and devices.

Any **TWELVE** experiments (Six experiments from each part)

A. General Experiments

1. Determination of q, n, σ by elliptical fringes method
2. Determination of Stefan's constant
3. Determination of bulk modulus of a liquid by ultrasonic wave propagation
4. Determination of Rydberg's constant
5. Study of Hall effect in a semiconductor
6. Determination of dielectric constant at high frequency by Lecher wire
7. Michelson interferometer -- Determination of wavelength of monochromatic source.
8. Determination of wavelength of monochromatic source using biprism
9. Charge of an electron by spectrometer
10. Dissociation energy of iodine molecule -- Absorption spectrum
11. Spectrum photo -- Cu/Fe arc spectrum
12. Polarization of light -- Verification of Malus law and Brewster angle of glass
13. BH loop – Energy loss of a magnetic material – Anchor ring using B.G./CRO
14. Determination of e/m of an electron by magnetron method
15. Determination of dielectric loss using CRO

B. Electronics Experiments

1. Construction of dual regulated power supply
2. Astable and monostable multivibrators using IC555
3. Characteristics of UJT
4. Characteristics of SCR
5. Design and study of Wein bridge oscillator using op-amp
6. Design and study of square and triangular waves generators using op-amp
7. Solving ordinary differential equation using op-amp
8. V-I characteristics of a solar cell
9. Up/down counter using mod 10
10. Operation of shift register using serial-in serial-out, serial-in parallel-out and parallel-in serial-out

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CORE COURSE V

ELECTROMAGNETIC THEORY

OBJECTIVE

- To learn the theory for the fields produced by stationary and moving charge and charged systems and propagation of electromagnetic fields.

Unit I Electrostatics and Polarization

Gauss's law – Field due to an infinite, straight, uniformly charged wire – Multipole expansion of a charge distribution -- Field inside a uniformly polarized sphere – Electric field inside a dielectric – Electric displacement and polarizability – Claussius-Mossotti relation – Polarization of polar molecules and Langevin equation and Debye relation – Electrostatic energy.

Unit II Boundary Value Problems in Electrostatics

Boundary conditions – Potential at a point between the plates of a spherical capacitor – Potential at a point due to uniformly charged disc – Method of image charges – Point charge in the presence of a grounded conducting sphere -- Point charge in the presence of a charged, insulated conducting sphere -- Conducting sphere in a uniform electric field – Laplace equation in rectangular coordinates.

Unit III Magnetostatics

Magnetic scalar and vector potentials – Magnetic dipole in a uniform field – Magnetization current – Magnetic intensity – Magnetic susceptibility and permeability – Hysteresis – Correspondences in electrostatics and magnetostatics.

Unit IV Field Equations and Conservation Laws

Continuity equation – Displacement current – Maxwell's equations and their physical significance – Poynting theorem – Energy in electromagnetic fields – Electromagnetic potentials – Maxwell's equations in terms of electromagnetic potentials – Lorentz and Coulomb gauges.

Unit V Electromagnetic Waves and Wave Propagation

Electromagnetic waves in free space – Propagation of electromagnetic waves in isotropic dielectrics and in anisotropic dielectrics – Reflection and refraction of electromagnetic waves: Kinematic and dynamic properties – TM and TE modes – Propagation in rectangular waveguides – Cavity resonator.

Books for Study

1. J.D. Jackson, *Classical Electrodynamics* (John-Wiley, New York, 1999) 3rd edition
2. K.K. Chopra and G.C. Agarwal, *Electromagnetic Theory* (K. Nath & Co., Meerut).
3. E.C. Jordan and K.G. Balmain, *Electromagnetic Waves and Radiating Systems* (PHI, New Delhi, 2015).

Books for Reference

1. D.J. Griffiths, *Introduction to Electrodynamics* (Pearson, Essex, 2014) 4th edition.
2. T.L. Chow, *Electromagnetic Theory* (Jones and Bartlett Learning, 2012).

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CORE COURSE VI

QUANTUM MECHANICS

OBJECTIVE

- To learn the fundamental concepts and certain theoretical methods of quantum mechanics and their applications to microscopic systems.

Unit I Schrödinger Equation and General Formulation

Schrödinger equation and its plane wave solution – Physical meaning and conditions on the wave function – Expectation values – Hermitian operators and their properties – Commutator relations -- Uncertainty relation -- Bra and ket vectors -- Hilbert space – Schrödinger, Heisenberg and interaction pictures.

Unit II Exactly Solvable Systems

Linear harmonic oscillator: Solving the one-dimensional Schrödinger equation and abstract operator method – Particle in a box -- Rectangular barrier potential – Rigid rotator – Hydrogen atom.

Unit III Approximation Methods

Time-independent perturbation theory: Non-degenerate (first-order) and degenerate perturbation theories -- Stark effect – WKB approximation and its application to tunneling problem and quantization rules**.**
Time-dependent perturbation theory: Constant and harmonic perturbations -- Transition probability – Sudden approximation.

Unit IV Scattering Theory and Angular Momentum

Scattering theory: Scattering amplitude and cross-section – Green's function approach -- Born approximation and its application to square-well and screened-Coulomb potentials.
Angular momentum: Components of orbital angular momentum – Properties of $\mathbf{L}$ and $\mathbf{L}^2$ **--** Eigenpairs of $\mathbf{L}^2$ and L_z – Spin angular momentum.

Unit V Relativistic Quantum Mechanics

Klein--Gordon equation for a free particle and its solution – Dirac equation for a free particle and Dirac matrices -- Charge and current densities – Plane wave solution – Negative energy states – Zitterbewegung – Spin of a Dirac particle – Spin-orbit coupling.

Books for Study

1. L. Schiff, *Quantum Mechanics* (Tata McGraw Hill, New Delhi, 2014) 4th edition.
2. P. M. Mathews and K. Venkatesan, *A Text Book of Quantum Mechanics* (Tata McGraw Hill, New Delhi, 1987).
3. S. Rajasekar and R. Velusamy, *Quantum Mechanics I: The Fundamentals* (CRC Press, Boca Raton, 2015).

Books for Reference

1. R. Shankar, *Principles of Quantum Mechanics* (Springer, New Delhi, 2007).
2. A.K. Ghatak and S. Lokanathan, *Quantum Mechanics: Theory & Applications* (Macmillan, Chennai, 2004) 5th edition.

CORE PRACTICAL II

PHYSICS PRACTICAL II

(MICRPROCESSOR AND PROGRAMMING)

OBJECTIVE

- To develop programming skills of microprocessor and C++ programming in solving some mathematical problems and their applications.

Any **FIFTEEN** experiments (At least SIX experiments from each part)

A. Microprocessor (8085)

1. Finding the largest and smallest numbers in a data array
2. Arranging a set of numbers in ascending and descending orders
3. Study of multibyte decimal addition
4. Study of multibyte decimal subtraction
5. Interfacing hexa key board (IC 8212)
6. Study of seven segment display
7. Study of DAC interfacing (DAC 0900)
8. Study of ADC interfacing (ADC 0809)
9. Study of timer interfacing (IC 8253)
10. Study of programmable interrupt controller (IC 8259)
11. Traffic control system
12. Digital clock
13. Generation of square and sine waves using DAC 0800
14. Digital thermometer (temperature controller)
15. Control of stepper motor using microprocessor

B. C++ Programming

1. Least-squares curve fitting – Straight-line fit
2. Least-squares curve fitting – Exponential fit
3. Real roots of one-dimensional nonlinear equations -- Newton Raphson method
4. Complex roots of one-dimensional nonlinear equations -- Newton--Raphson method
5. Interpolation – Lagrange method
6. Numerical integration – Composite trapezoidal rule
7. Numerical integration – Composite Simpson's 1/3 rule
8. Solution of a second-order ODE – Euler method
9. Solution of a first-order ODE – Fourth-order Runge--Kutta method
10. Uniform random number generation – Park and Miller method
11. Gaussian random number generation – Box and Muller method
12. Evaluation of definite integrals – Monte Carlo method
13. Calculation of mean and standard deviation of a set of uniform random numbers
14. Computation of eigenvalues of linear harmonic oscillator by numerically solving Schrödinger equation
15. Monte Carlo simulation of electronic distribution of hydrogen atom

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ELECTIVE COURSE I

MICROPROCESSOR AND MICROCONTROLLER

OBJECTIVE

- To learn basic principles of architecture and functioning of microprocessor and microcontroller and programming and interfacing aspects of them.

Unit I Microprocessor Architecture and Interfacing

Intel 8085 microprocessor architecture – Pin configuration – Instruction cycle – Timing diagram – Instruction and data formats – Addressing modes -- Memory mapping and I/O mapping I/O scheme -- Memory mapping I/O interfacing -- Data transfer schemes -- Synchronous and asynchronous data transfer – Interrupt driven data transfer - Interrupts of Intel 8085.

Unit II Assembly Language Programs (8085 only)

BCD arithmetic -- Addition and subtraction two 8-bit and 16-bit numbers -- Largest and smallest numbers in a data set – Ascending order and descending order – Sum of a series of a 8-bit numbers – Sum of a series of multibyte decimal numbers – Square root of a number – Block movement of data -- Time delay – Square-wave generator.

Unit III Peripheral Devices and Microprocessor Applications

Generation of control signals for memory and I/O devices -- I/O ports -- Programmable peripheral interface -- Architecture of 8255A -- Control word -- Programmable interrupt controller (8259) -- Programmable counter -- Intel 8253 -- Architecture, control word and operation – Block diagram and interfacing of analog to digital converter (ADC 0800) – Digital to analog converter (DAC 0800) – Stepper motor – Traffic control.

Unit IV Microcontroller 8051

Features of 8051 – Architecture – Pin configuration – Memory organization -- External data and program memory -- Counters and timers – Serial data input/output – Interrupt structure – External interrupts – Addressing modes -- Comparison between microprocessor and microcontroller.

Unit V 8051 Instruction Set and Programming

Instruction set – Data transfer, arithmetic and logical instructions – Boolean variable manipulation instructions – Program and machine control instructions – Simple programs – Addition and subtraction of two 8-bit and 16-bit numbers – Division – Multiplication -- Largest number in a set – Sum of a set of numbers.

Books for Study

1. B. Ram, *Fundamentals of Microprocessor and Microcomputers* (Dhanpat Rai Pub., New Delhi, 2006).
2. M.A. Mazidi, J.G. Mazidi and R.D. Mckinlay, *The 8051 Microcontroller and Embbeded Systems using Assembly and C* (Dorling Kindersley, New Delhi, 2013).
3. A.P. Godse and D.A. Godse, *Microprocessors and Microcontrollers* (Technical Pub., Pune, 2008).

Books for Reference

1. R. Gaonkar, *Microprocessor Architecture, Programming and Applications with 8085* (Penram International Publishing , Mumbai, 2006) 5th edition.
2. K. Ayala, *The Microcontroller* (Cengage Learning India, New Delhi, 2013) 3rd edition.

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ELECTIVE COURSE II

NUMERICAL METHODS AND C++ PROGRAMMING

OBJECTIVE

- To learn numerical methods of computing certain mathematical quantities, construction and evaluation of a function and solution of an ordinary differential equation and C++ computer programming necessary for numerical simulation of physical problems.

Unit I Programming in C++

Constants and variables -- I/O operators and statements -- Header files -- Main function – Conditional statements -- Switch statement -- Void function -- Function program -- For, while and do-while statements -- Break, continue and goto statements -- Arrays.

Unit II Curve Fitting and Interpolation

Curve fitting: Method of least-squares - Straight-line fit -- Exponential and power-law fits.

Interpolation: Newton interpolation polynomial: Linear interpolation, Higher-order polynomials and first-order divided differences – Gregory--Newton interpolation polynomials – Lagrange interpolation.

Unit III Solutions of Linear and Nonlinear Equations

Simultaneous linear equations: Upper triangular form and back substitution – Augmented matrix -- Gauss elimination method -- Jordan's modification -- Inverse of a matrix by Gauss--Jordan method.

Roots of nonlinear equations: Newton--Raphson method -- Termination criteria -- Pitfalls – Order of convergence.

Unit IV Numerical Integration and Differentiation

Numerical integration: Trapezoidal and Simpson's 1/3 rules -- Errors in the formulae -- Composite trapezoidal and Simpson's 1/3 rules -- Errors in the formulae.

Numerical differentiation: Two- and four-point formulae for first-order derivative -- Three- and five-point formulae for second-order derivative.

Unit V Numerical Solution of Ordinary Differential Equations

First-order equations: Euler and improved Euler methods – Local and global truncation errors -- Fourth-order Runge--Kutta method -- Geometric description of the formula.

Second-order equations: Euler methods and fourth-order Runge--Kutta method.

Books for Study (Relevant chapters in)

1. J. R. Hubbard, *Programming with C++* (McGraw-Hill, New Delhi, 2006).
2. J.H. Mathews, *Numerical Methods for Mathematics, Science and Engineering* (Prentice-Hall of India, New Delhi, 1998).
3. P.B. Patil and U.P. Verma, *Numerical Computational Methods* (Narosa, New Delhi, 2013).

Books for Reference

1. E. Balagurusamy, *Objected Oriented Programming in C++* (McGraw Hill, New Delhi, 2013) 6th edition.
2. M.K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods for Scientific and Engineering Computation* (New Age International, New Delhi, 1993).

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CORE COURSE VII

STATISTICAL MECHANICS

OBJECTIVES

- To learn the basics of classical and quantum statistical mechanics and to understand some of their applications.

Unit I Thermodynamics

Thermodynamical laws and their consequences – Entropy -- Changes in entropy in reversible processes -- Principle of increase of entropy -- Thermodynamic functions -- Enthalpy, Helmholtz and Gibbs functions -- Phase transitions -- Clausius-Clayperon equation -- van der Wall equation of state.

Unit II Kinetic Theory

Boltzmann transport equation and its validity -- Boltzmann's H-theorem -- Relation between H-function and entropy -- Maxwell--Boltzmann distribution -- Mean free path – Conservation laws -- Transport phenomena – Viscosity of gases -- Thermal conductivity -- Diffusion process.

Unit III Classical Statistical Mechanics

Review of probability theory -- Macro and micro states – Phase space -- Statistical ensembles -- Density function -- Liouville's theorem -- Maxwell--Boltzmann distribution law -- Micro canonical ensemble – Ideal gas – Entropy – Partition function – Equipartition theorem -- Canonical and grand canonical ensembles.

Unit IV Quantum Statistical Mechanics

Basic concepts -- Ideal quantum gas – Bose--Einstein statistics -- Photon statistics -- Fermi--Dirac statistics -- Sackur-Tetrode equation – Equation of state -- Bose--Einstein condensation -- Comparison of classical and quantum statistics.

Unit V Applications of Quantum statistical Mechanics

Ideal Bose System: Photons – Black body and Planck radiation – Specific heat of solids – Liquid helium.
Ideal Fermi System: Properties – Degeneracy – Electron gas -- Pauli paramagnetism.
Ferromagnetism: Ising and Heisenberg models.

Books for Study

1. S.K. Sinha, *Introduction to Statistical Mechanics* (Narosa, New Delhi, 2007).
2. F. Reif, *Fundamentals of Statistical and Thermal Physics* (McGraw Hill, Singapore, 1985).
3. K. Huang, *Statistical Mechanics* (Wiley Eastern Limited, New Delhi, 1963).

Books for Reference

1. Singhal, Agarwal, Prakash, *Thermodynamics and Statistical Physics* (Prakashan, Meerut, 2003).
2. W. Greiner, L. Neise and H. Stocker, *Thermodynamics and Statistical Mechanics* (Springer, New York, 1995).

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CORE COURSE VIII

SOLID STATE PHYSICS

OBJECTIVE

- *To learn the basics of crystal structure and underlying theoretical development for the description of certain properties and phenomena of solid states.*

Unit I Crystal Structure

Basics of crystal systems – Bravias lattices – Defects and Dislocations – Bonding of Solids – Reciprocal lattice – Ewald's sphere construction – Bragg's law – Atomic scattering factor – Diffraction – Structure factor – Experimental techniques – Laue, Powder, Rotation methods – Translational and orientational orders - Kinds of liquid crystalline order and quasicrystals.

Unit II Lattice Vibrations and Thermal Properties

Vibration of monoatomic lattices – Lattices with two atoms per primitive cell – Quantization of lattice vibrations – Phonon momentum – Inelastic scattering of neutrons by phonons – Lattice heat capacity – Einstein model – Density of modes in one-dimension and three dimension – Debye model of the lattice heat capacity – Thermal conductivity – Umklapp process.

Unit III Free Electron Theory, Energy Bands and Semiconductor Crystals

Energy levels and density of orbitals – Fermi-Dirac distribution – Free electron gas in 3D – Heat capacity of electron gas – Electrical conductivity – Motion in magnetic fields – Hall effect – Thermal conductivity – Nearly conductivity of metals – Nearly free electron model – Electron in a periodic potential – Semiconductors – Band gap – Effective mass – Intrinsic carrier concentration.

Unit IV Dia, Para, Ferro and Antiferro-Magnetisms

Langevin classical theory of dia- and para-magnetisms – Weiss theory – Quantum theory of paramagnetism – Paramagnetic susceptibility of conduction electrons – Hund's rules – Ferroelectric order – Curie point and the exchange integral – Temperature dependence of saturation magnetization – Magnons – Ferromagnetic order -- Antiferromagnetic order -- Ferromagnetic domains – Origin of domains – Coercive force and hysteresis.

Unit V Ferroelectricity and Superconductivity

General properties and classification of ferroelectric materials – Dipole theory of ferroelectricity **–** Ferroelectric domains – Occurrence of superconductivity – Meissner effect – Thermodynamics of superconducting transition – London equation – Coherence length – BCS theory – Flux quantization – Type-I and type-II superconductors – Josephson superconductor tunneling – DC and AC Josephson effect – SQUID – Applications of superconductors.

Books for Study

1. C. Kittel, *Introduction to Solid State Physics* (Wiley Eastern, New Delhi, 2007) 7th edition.
2. S.O. Pillai, *Solid State Physics* (New Age International, New Delhi, 2005) 6th edition.
3. H.C. Gupta, *Solid State Physics* (Vikas Publishing House, Noida, 2001) 2nd edition.

Books for Reference

1. N.W, Ashcroft and N.D. Mermin, *Solid State Physics* (Holt, Rinehart and Winston, Philadelphia, 1976).
2. Rita John, *Solid State Physics* (McGraw Hill, New Delhi, 2014).
3. A.J. Dekker, *Solid State Physics* (McMillan, Chennai, 1971).

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CORE PRACTICAL III

PHYSICS PRACTICAL III

(GENERAL AND ELECTRONICS)

OBJECTIVE

- Experimental determination of certain physical constants and properties and verification of characteristics and applications of electronic components and devices.

Any **FIFTEEN** experiments (At least SIX experiments from each part)

A. General Experiments

1. Determination of q, n, σ by hyperbolic fringes method
2. Determination of thermal conductivity of a good conductor – Forbe's method
3. Determination of bulk modulus of a liquid using ultrasonic interferometer
4. Planck's constant - Photoelectric cell
5. Band gap energy of a semiconductor -- Four-probe method
6. Determination of L of a coil by Anderson's method
7. Determination of e/m of an electron by Thomson's method
8. Determinations of wavelength of a laser source using plane diffraction grating and
   thickness of a wire
9. Polarizability of liquids by finding the refractive indices at different wavelengths
10. Study of a fiber optic cable -- Numerical aperture and other parameters
11. Magnetic susceptibility of a paramagnetic solution using Quincke's tube method
12. Determination of specific rotator power of a liquid using polarimeter
13. Four-probe method – Determination of resistivities of powdered samples
14. Determination of magnetic susceptibility of liquid by Guoy method
15. Determination of coefficient of coupling by AC bridge method

B. Electronics Experiments

1. Characteristics of LED and photo diodes
2. Characteristics of laser diode and tunnel diode
3. Digital to analog converters using op-amp
4. Study of phase-shift oscillator using op-amp
5. Design and study of Schmitt trigger using op-amp
6. Flip-flops -- - RS, JK and D
7. Decoder and encoder
8. Temperature coefficient using 555 timer
9. Design of pre-emphasis and de-emphasis circuits
10. Pulse-width and pulse-position modulations

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ELECTIVE COURSE III

CRYSTAL GROWTH AND THIN FILM PHYSICS

OBJECTIVE

- To understand the theoretical concepts involved in crystal growth and thin film sciences and to learn the basic characterizing techniques of materials.

Unit I Basic Concepts, Nucleation and Kinetics of Growth

Ambient phase equilibrium – Super saturation – Equilibrium of finite phases - Equation of Thomson-Gibbs – Types of nucleation – Formation of critical nucleus – Classical theory of nucleation – Homo and heterogeneous formation of 3D nuclei – Rate of nucleation – Growth from vapor phase, solutions and melts – Epitaxial growth – Growth mechanism and classification – Kinetics of growth of epitaxial films – Mechanisms and controls for nanostructures in 0 and 1 dimensions.

Unit II Crystallization Principles and Growth Techniques

Classes of crystal system – Crystal symmetry – Solvents and solutions – Solubility diagram – Super solubility – Expression for super saturation – Metastable zone and induction period – Miers TC diagram – Solution growth – Low and high temperatures solution growth – Slow cooling and solvent evaporation methods – Constant temperature bath as a crystallizer.

Unit III Gel, Melt and Vapor Growth Techniques

Principle of gel technique – Various types of gel -- Structure and importance of gel – Methods of gel growth and advantages -- Melt technique – Czochralski growth – Floating zone – Bridgeman method – Horizontal gradient freeze – Flux growth – Hydrothermal growth – Vapor-phase growth – Physical vapor deposition – Chemical vapor deposition – Stoichiometry.

Unit IV Thin Film Deposition Techniques

Vacuum evaporation -- Hertz-Knudsen equation -- Evaporation from a source and film thickness uniformity -- E-beam, pulsed laser and ion beam evaporations -- Glow discharge and plasmas -- Mechanisms and yield of sputtering processes – DC, rf, magnetically enhanced, reactive sputterings – Spray pyrolysis – Electro deposition – Sol-gel technique.

Unit V Characterization Techniques

X–ray diffraction – Powder and single crystal – Fourier transform infrared analysis – Elemental dispersive X-ray analysis – Transmission and scanning electron microscopy – UV-vis-NIR spectrometer – Chemical etching –

Vickers micro hardness – Basic principles and operations of AFM and STM -- X-ray photoelectron spectroscopy for chemical analysis -- Ultraviolet photoemission spectroscopy analysis for work function of the material -- Photoluminescence – Thermoluminescence.

Books for Study (Relevant chapters in)

1. I.V. Markov, *Crystal Growth for Beginners: Fundamentals of Nucleation, Crystal Growth and Epitaxy* (2004) 2nd edition.
2. P. Santhanaragavan and P. Ramasamy, *Crystal Growth Process and Methods* (KRU Publications, Kumbakonam, 2001).
3. A. Goswami, *Thin Film Fundamentals* (New Age, New Delhi, 2008).
4. H.H. Willard, L.L. Meritt, J.A. Dean, F.A. Sette, *Instrumental Methods of Analysis* (CBS Publishers, New Delhi, 1986).
5. S. Zhang, L. Li and A. Kumar, *Materials Characterization Techniques* (CRC Press, Bota Racon, 2009).

Books for Reference

1. J.C. Brice, *Crystal Growth Process* (John Wiley, New York, 1986).
2. M. Ohring, *Materials Science of Thin Films* (Academic Press, Boston, 2002) 2nd edition.
3. E. N. Kaufmann, *Characterization of Materials, Volume-I* (John Wiley, New Jersey, 2012).

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ELECTIVE COURSE IV

NONLINEAR OPTICS

OBJECTIVE

- To learn the basic principles and working of lasers, basic processes and features of nonlinear optical materials and fiber optics.

Unit I Lasers

Gas lasers – He-Ne, Ar^{+} ion lasers – Solid state lasers – Ruby – Nd:YAG, Ti sapphire – Organic dye laser – Rhodamine – Semiconductor lasers – Diode laser, p-n-junction laser and GaAs laser.

Unit II Basics of Nonlinear Optics

Wave propagation in an anisotropic crystal – Polarization response of materials to light –Harmonic generation – Second harmonic generation – Sum and difference frequency generation– Phase matching – Third harmonic generation – Terahertz -- Bistability – Self-focusing.

Unit III Multiphoton Processes

Two photon process – Theory and experiment – Three photon process - Parametric generation of light – Oscillator – Amplifier – Stimulated Raman scattering – Intensity dependent refractive index -- Optical Kerr effect -- Foucault effect – Photorefractive, electronic and optic effects.

Unit IV Nonlinear Optical Materials

Basic requirements – Inorganics – Borates – Organics – Urea, Nitroaniline – Semiorganics – Thoreau complex – Laser induced surface damage threshold.

Unit V Fiber Optics

Step – Graded index fibers – Wave propagation – Fiber modes – Single and multimode fibers –Numerical aperture – Dispersion – Fiber bandwidth – Fiber losses -- Scattering, absorption, bending, leaky mode and mode coupling losses -- Attenuation coefficient -- Material absorption.

Books for Study

1. K.R. Nambiar, *Lasers: Principles, Types and Applications* (New Age Inter-national Publishers Ltd, New Delhi, 2014).
2. B.B. Laud, *Lasers and Nonlinear Optics*, 3rd Edn. (New Age, New Delhi, 2011).
3. R.W. Boyd, *Nonlinear Optics*, 2nd Edn. (Academic Press, New York, 2003).
4. G.P. Agarwal, *Fiber-Optics Communication Systems*, 3rd Edn. (John Wiley, Singapore, 2003).

Books for Reference

1. W.T. Silvast, *Laser Fundamentals* (Cambridge University Press, Cambridge, 2003).
2. D.L. Mills, *Nonlinear Optics – Basic Concepts* (Springer, Berlin, 1998).

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CORE COURSE IX

NUCLEAR AND PARTICLE PHYSICS

OBJECTIVE

- To learn the various aspects of nucleus and its behavior under various conditions.

Unit I Nuclear Properties

Nuclear energy levels - Nuclear angular momentum, parity, isospin – Nuclear magnetic dipole moment – Nuclear electric quadropole moment - Ground state of deuteron – Magnetic dipole moment of deuteron – Proton-neutron scattering at low energies – Scattering length, phase shift – Nature and properties of nuclear forces – Spin dependence – Charge symmetry – Charge independence – Repulsion at short distances – Exchange forces – Meson theory.

Unit II Radioactive Decays

Alpha emission – Geiger-Nuttal law – Gamow theory – Neutrino hypothesis – Fermi theory of beta decay – Selection rules – Nonconservation of parity – Gamma emission – Selection rules -- Nuclear isomerism -- Gamma ray spectroscopy – Mossbauer effect -- Interaction of charged particles and X-rays with matter – Types and basic principles of particle detectors.

Unit III Nuclear Reactions and Nuclear Models

Reciprocity theorem – Breit-Wigner formula – Resonance theory – Liquid drop model – Shell model -- Evidences for shell model -- Magic numbers -- Harmonic oscillator – Square-well potential -- Spin-orbit interaction – Collective model of a nucleus.

Unit IV Fission and Fusion Reactors

Characteristics of fission – Mass distribution of fragments – Radioactive decay processes – Fission cross-section – Energy in fission – Bohr-Wheeler's theory of nuclear fission – Fission reactors – Thermal reactors – Homogeneous reactors – Heterogeneous reactors – Basic fusion processes -- Characteristics of fusion – Solar fusion – Controlled fusion reactors.

Unit V Particle Physics

Nucleons, leptons, mesons, baryons, hyperons, hadrons, strange particles - Classification of fundamental forces and elementary particles – Basic conservation laws – Additional conservation laws: Baryonic, leptonic, strangeness and isospin charges/quantum numbers – Gell-mann--Nishijima formula - Invariance under charge conjugation (C), parity (P) and time reversal (T) – CPT theorem -- Parity nonconservation in weak interactions – CP violation – Eight-fold way and supermultiplets – SU(3) symmetry and quark model.

Books for Study (Relevant chapters in)

1. K. S. Krane, *Introductory of Nuclear Physics* (John-Wiley, New York, 1987).
2. S. B. Patel, *Nuclear Physics: An Introduction* (New Age, New Delhi, 2009).
3. D. C. Cheng and G. K. O'Neill, *Elementary Particle Physics: An Introduction* (Addison-Wesley, New York, 1979).
4. D.C. Tayal, *Nuclear Physics* (Himalaya Pub. House, New Delhi, 2011).
5. S.L. Kakani and S. Kakani, *Nuclear and Particle Physics* (Anshan Publ., New Delhi, 2009).

Books for Reference

1. R.C. Sharma, *Nuclear Physics* (K. Nath and Co, Meerut, 2004).
2. B. L. Cohen, *Concepts of Nuclear Physics* (Tata McGraw Hill, New Delhi, 1988).

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CORE COURSE X

ADVANCED PHYSICS

OBJECTIVE

- To learn the basics and the advanced applications of physics in the fields of astrophysics, space physics, biomedical science and wireless communication.

Unit I Astrophysics and Radio Astronomy

Astrophysics: Physical properties of stars - Life cycle of a star - End products of stellar evolution – Structure of milky way - Expanding universe - Future prospects.
Radio Astronomy (RA): Radio telescopes - Synchrotron radiation - Spectral lines in RA - Major discoveries in RA - RA in India - Hot big bang cosmology.

Unit II India's Space Programme

Overview - Methodological issues in cost beneficial analysis of space programme - The INSAT system - Broadcasting - Telecommunication - Meteorology - Indian remote sensing programme – Geoinformatics (basic idea only) - The launching programme

Unit III Biomedical Instruments

Ear and hearing Aids: Basic measurements of ear function - Air and bone conduction - Masking - Middle ear impedance audiometry - Oto-acoustic emission - Types of hearing aids and Cochlear implants - Sensory substitution aids - Electrophysiology: Source of biological potentials - Signal size and electrodes - Functions - Features of ECG, EEG and EMG. Cardiac and blood related devices: Pacemakers - Electromagnetic compatibility – Defibrillators - Artificial heart valves - Cardiopulmonary bypass - Haemodialysis.

Unit IV Wireless Communication Technology-I

Cellular Radio: IMTS, AMPS control system - Security and privacy - Cellular telephone specifications and operations - Cell site equipments - Fax and data communication using cellular phones and CDPD - Digital cellular systems. Personal Communication Systems (PCS): Differences between CS and PCS, IS-1 36 TDMA PCS, GSM, IS-95 CDMA PCS - Comparison of modulation schemes - Data communication with PCS.

Unit V Wireless Communication Technology – II

Satellite orbits – Satellites for communication - Satellites and transponders - Signal and noise calculations - InMARST, MSAT system using low - and medium-earth orbit stations. Paging (one-way and two-ways) and messaging system - Voice paging - LAN topologies - Ethernet bridges - Wireless LANs - Radio LANs - Bluetooth - Wireless bridges - Connections using infrared wireless modems - Wireless packet data services.

Books for Study (Relevant chapters in)

1. A.W. Joshi, *Horizons of Physics* (Wiley Eastern Ltd, New Delhi, 2000).
2. R.D. Begamure (Ed.), *Scientific Truths About Our Universe: Know Your Universe: Part I & II* (Pune, 2002).
3. U. Shankar, *The Economics of India's Space Programme – An Exploratory Analysis* (Oxford University Press, Delhi, 2007) 2nd reprint.
4. Mohan Sundar Rajan, Space Today (National Book Trust India, New Delhi, 2012) 5th revised reprint.
5. B.H. Brown, *et a*l, *Medical Physics and Biomedical Engineering* (Overseas Press, New Delhi, 2005).
6. R. Blake, *Wireless Communication Technology* (DELMAR, New Delhi, 2001).

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CORE PRACTICAL IV

PHYSICS PRACTICAL IV

(ELECTRONICS)

OBJECTIVE

- V*erification of characteristics and applications of electronic components and devices.*

Any **FIFTEEN** experiments

1. Characteristics of LVDT
2. Characteristics of LDR
3. Characteristics of strain guage
4. Characteristics of load cell
5. Characteristics of torque transducer
6. Calibration of thermistor
7. Digital to analog converter -- R-2R and weighted method
8. Study of frequency multiplexer using PLL
9. Digital comparator using XOR and NAND gates
10. Study of Hall effect
11. Four bit binary up and down counter using IC 7473
12. BCD to 7 segment display
13. Study of RAM
14. Study of A/D converter -- Counter ramp type method
15. Study of Arithmetic Logic Unit (ALU) -- IC 74181
16. Construction and study of characteristics of Chua's diode
17. Study of nonlinear dynamics of Chua's circuit
18. Construction of memristor
19. Pulse code modulation and demodulation
20. Voltage controlled oscillator using IC 555
21. Microwave IC – Filter Characteristics
22. Characteristics of a voltage dependent resistor (VDR)
23. Transmission characteristics of optical fiber link
24. Design of AC/DC voltage regulator using SCR
25. Characteristics of Gunn diode oscillator

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ELECTIVE COURSE V

NANOPHYSICS

OBJECTIVES

- To learn the structures, properties, characterization and applications of nanomaterials.

Unit I Introduction to Nano and Types of Nanomaterials

Need and origin of nano -- Nano and energetic – Top-down and bottom-up approaches – Introductory ideas of 1D, 2D and 3D nanostructured materials -- Quantum dots -- Quantum wire – Quantum well -- Exciton confinement in quantum dots.

Unit II Carbon Nanostructures

Carbon molecules and carbon bond -- C_{60}: Discovery and structure of C_{60} and its crystal -- Superconductivity in C_{60} -- Carbon nanotubes: Fabrication – Structure – Electrical properties – Vibrational properties – Mechanical properties -- Applications (fuel cells, chemical sensors, catalysts).

Unit III Fabrication of Nanomaterials

Synthesis of oxide nanoparticles by sol-gel method -- Electrochemical deposition method – Electrospinning method – Lithography -- Atomic layer deposition -- Langmuir--Blodgett films -- Zeolite cages -- Core shell structures – Organic and inorganic hybrids.

Unit IV Characterization of Nanomaterials

Principles, experimental set-up, procedure and utility of scanning electron microscopy (SEM), transmission electron microscopy (TEM), scanning tunneling microscope (STM) and scanning probe microscopy (SPM).

Unit V Applications

Molecular electronics and nanoelectronics – Nanorobots -- Biological applications of nanoparticles -- Catalysis by gold nanoparticles – Band-gap engineered quantum devices -- Nanomechanics -- CNT emitters – Photoelectrochemical cells -- Photonic crystals – Plasmon waveguides.

Books for Study

1. T.Pradeep et al., *A Textbook of Nanoscience and Nanotechnology* (Tata McGraw Hill, New Delhi, 2012).
2. R.W. Kelsall, I.W. Hamley and M. Geoghegan, *Nanoscale Science and Nanotechnology* (John-Wiley & Sons, Chichester, 2005).
3. G. Cao, *Nanostructures and Nanomaterials* (Imperial College Press, London, 2004).
4. C.P. Poole and F.J. Owens, *Introduction to Nanotechnology* (Wiley, New Delhi, 2003).

Books for References

1. H.S. Nalwa, *Nanostructured Materials and Nanotechnology* (Academic Press, San Diego, 2002).
2. M. Wilson, K. Kannangara, G. Smith, M. Simmons, B. Raguse, *Nanotechnology: Basic Science and Emerging Technologies* (Overseas Press, New Delhi, 2005).

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