महात्मा गाँधी केन्द्रीय विश्वविद्यालय, बिहार
MAHATMA GANDHI CENTRAL UNIVERSITY, BIHAR
(Established by an Act of Parliament)
TempCamp, Zila School Campus Motihari-845 401 District: East Champaran, Bihar
DEPARTMENT OF PHYSICS

Annexure-I

M.Phil. Programme/Ph.D. Course Work in Physics

Course Structure

Sl. No.	Course Code	Course name	Core/ Elective	Credits
Semester-I [M.Phil. Programme/Ph.D. Course Work in Physics]				
1.	PHYS5001	Research Methodology	C	4
2.	PHYS5002	Advanced Physical Tools and Techniques	C	4
3.	PHYS5XXX	Elective Paper	E	4
			Total	12
List of Elective Papers				
4.	PHYS5003	Science and Technology of Thin Films	E	4
5.	PHYS5004	Advanced Computational Physics	E	4
6.	PHYS5005	Emerging Electronic and Optoelectronic Materials and Devices	E	4
7.	PHYS5006	Advanced Spectroscopy	E	4
8.	PHYS5007	Physics of Advanced Materials	E	4
9.	PHYS5008	Energy Storage and Devices	E	4
10.	PHYS5009	Solid State Ionics	E	4
11.	PHYS5010	Nanoscale Magnetic Materials and Devices	E	4
12.	PHYS5011	Amorphous Materials: Properties & Applications	E	4
13.	PHYS5012	Review of Advanced Physics		
Semester-II [only for M.Phil. Programme]				
1.	PHYS5999	Dissertation (10 Credits) and Viva-Voce (2 Credits)		12

Each student has to study a elective paper of 4 credits offered in the first semester. It is to be noted that a student can opt any one of the elective course of his/her area of research interest. The elective courses/papers shall be offered from above list depending upon the availability of the expert faculty.

Total Credit assigned to Ph.D. Course Work: 12

Total Credit assigned to M.Phil. Programme: 24

Notes:

1. Each course is of 100 Marks. Out of 100 marks, Students will be evaluated by Internal assessments which will be done by the course teacher through quiz/seminar/assignments/tests/attendance etc. and End semester examination.
2. Students are required to secure minimum 75% attendance (as per university rules) in each course to qualify for appearing in End semester examination.

Annexure-II

M.Phil. Programme/Ph.D. Course Work in Physics

Detailed Course Content

Semester-I

Course Code: PHYS5001 (CORE Course)

Course Name: Research Methodology

Course Credits: 4

Course Objectives: The primary objective of this course is to develop a research orientation among the scholars and to acquaint them with fundamentals of research methods. Some other objectives of the course are:

- To develop understanding of the basic framework of research process.
- To develop an understanding of various research designs and techniques.
- To identify various sources of information for literature review and data collection.
- To develop an understanding of the ethical dimensions of conducting applied research.
- Appreciate the components of scholarly writing and evaluate its quality.

Course Contents:

Unit - I

Introduction to Research Methodology: Meaning and importance of Research, Selection and formulation of Research Problem, Research Design, Developing a Research Plan – Exploration, Description, Diagnosis, Experimentation, Determining Experimental and Sample Designs. Analysis of Literature Review, Hypothesis, Development of Working Hypothesis, Research Methods: Scientific method vs Arbitrary Method.

Unit - II

Data Collection and Analysis: Sources of Data, Methods of Collecting Data: Observation, field investigations, Direct studies. Sampling methods, Data Processing and Analysis strategies, Graphical representation, Descriptive Analysis, Inferential Analysis, Correlation analysis, Least square methods, Data Analysis using statistical package, Errors classification and analysis.

Unit - III

Scientific Writing & Computer Skills: Language of Science and technology, Technical presentations: design and delivery, Collecting materials for research, Organization and writing skills of research paper/dissertation and Thesis, Citation index, Preparation of a Project Proposal, Use of E-journal and E-Library.

MS Office, LATEX, Scientific graphic design softwares, Statistical Computation using SPSS.

Unit - IV

Ethics in Research and Intellectual Property Rights: Environmental Impacts, Ethical Issues, Reproduction of published material, Plagiarism, Citation and Acknowledgement, Reproducibility and accountability.

Intellectual Property Rights, Patents, Copyright, Royalty.

References:

1. B.L. Garg, R. Karadia, F. Agarwal, and U.K. Agarwal, (2002), An introduction to Research Methodology, RBSA Publishers.
2. C.R. Kothari, (2008). Research Methodology: Methods and Techniques. Second Edition. New Age International Publishers, New Delhi.
3. S.C. Sinha, and A.K. Dhiman, 2002, Research Methodology, Ess Ess Publications.
4. W.M.K. Trochim, 2005. Research Methods: the concise knowledge base, Atomic Dog Publishing.
5. R.A. Day (1992) How to write and publish a scientific paper. Cambridge University press. London.
6. C. Hempel, Philosophy of Natural science Englewood Cliffs, N.J: Prentice Hall, 1966.
7. E.A. Burtt, The Metaphysical Foundations of Modern Science. London, 2003.
8. B. Latour, & Woolgar, Laboratory Life. The construction of scientific facts. 2nd Edition. Princeton: Princeton University Press.1986.
9. S.P. Gupta (2008). Statistical Methods. 37th ed. (Rev) Sultan Chand and Sons. New Delhi. 1470 p.
10. Sundar Sarukkai (2008), Indian Philosophy and Philosophy of Science, Motilal Banarsidass Publishers Pvt.Ltd. New Delhi.
11. A. Kozak, R.A. Kozak, C.L. Staudhammer, and S.B. Watts (2008). Introductory probability and Statistics; Applications for forestry and Natural sciences. CAB International, UK.408p.
12. N.M. Downine, Basic Statistical Methods. New York:¨Harper and Health Row Publishers.
13. H. Frank, Statistics. Concepts and Applications. Cambridge. Althoen, Steven Cambridge University.
14. Leon & Leon (2002). Internet for everyone, Vikas Publishing House.
15. B.L. Wadehra, (2000). Law relating to patents, trade marks, copyright designs and geographical indications. Universal Law Publishing.
16. A. Chandera and T.P. Sexena (2000) Style Manual, New Delhi, Metropolitan Book Comp. Ltd.
17. SPSS – Operating Manual and handbook – Latest version.
18. P.K. Sinha (1992). Computer Fundamentals, BPB Publications, New Delhi.

Course Code: PHYS5002 (Core Course)

Course Name: Advanced Physical Tools and Techniques

Course Credits: 4

Course Objectives: The course involves the basic methods for the synthesis of bulk materials and thin films. The course is also aimed towards the basic principles and instrumentation of modern analytical methods used for characterization.

Course Contents:

Unit - I

Materials sample processing (Bulk & thin films): Introduction to bulk sample processing methods: physical and Chemical methods, essential components of thin films process control: vacuum, pressure gauges and pumps, concepts of thin films, thin film processing using different techniques: physical and chemical methods of deposition, sputtering (RF & DC), Epitaxy etc.

Unit - II

Structural, Microscopic and Spectroscopic Characterizations: Introduction to X-ray Diffraction, experimental methods of Crystal structure determination, Particle size determination, Thermal Analysis Methods: Differential Thermal Analysis and Differential Scanning Calorimetry, Thermal Gravimetric Analysis, Scanning Electron Microscopy, Transmission Electron Microscopy, Scanning Tunneling Microscopy, Atomic Force Microscopy, Magnetic Force Microscopy, UV-visible NIR spectroscopy, Fourier Transform Infrared Spectroscopy, Raman Spectroscopy, Nuclear Magnetic Resonance, Electron Spin Resonance, Photoelectron Spectroscopy (XPS, UPS, PES etc.).

Unit – III

Electrical and Magnetic measurement techniques – VSM – SQUID MOKE – conductivity measurements – Four probe method – Two probe method. Hall effect method – Analysis of Data. Cyclic voltammetric studies – Broadband spectroscopy of Dielectrics.

Unit – IV

Computational methods: Numerical integration, ordinary differential equation (ODE) and partial differential equations (PDE), Introduction to simulation and code writing, exchange potential, Algorithm for linear and non-linear systems, Contemporary simulation tools such as Monte Carlo, Molecular Dynamics (MD) and Density Functional Theory (DFT) techniques.

Reference Books:

1. Charles P. Poole Jr and Frank J. Owens, Introduction to Nanotechnology, Wiley-Interscience, 2003.
2. Jsk Tareen & TRN Kutty, A basic course in Crystallography, University press 2001.
3. H. Gaur, Instrumental methods of Chemical Analysis, Pragati Prakasan, 1st Edn. 2001.
4. Willard Merritt, Instrumental Methods of Analysis, CBS publishers, 2005.

5. J.A. Belk, Electron Microscopy and Microanalysis of Crystalline Materials, Applied Science Publishers, 1979.
6. B. Tareev, Physics of dielectric materials, Mir Publiactions, 1979.
7. B.D. Cullity, Elements of X-ray diffraction, Addison-Wesley Publishing Company, 1956.
8. G. Aruldas, Molecular structure and spectroscopy, PHI, (2007).
9. M. Sayer, A. Mansingh, Measurement Instrumentation and Experiment Design in Physics and Engineering, Prentice Hall of India Private Limited, (2000).
10. K. N. Tu, R. Rosenberg, Analytical Techniques for Thin Films, Academic Press, INC. 1988.
11. R.M. Martin, Electronic Structure: Basic Theory and Practical Methods, (Cambridge University Press 2004).
12. R.G. Parr and Q. Yang, Density Functional Theory of Atoms and Molecules, (Oxford Science Publications 1989).
13. K. Ohno, K. Esfarjani and Y.Kawazoe, Introduction to Computational Material Science: from *ab initio* to Monte Carlo methods, (Springer-Verlag, 1999).
14. Zoe H. Barber, Introduction to Materials Modeling, (Maney Publishing, 2005).
15. M. Meyer and B. Pontikis, Computer Simulation in Material Science: Inter-atomic Potentials, Simulation, Techniques and Applications, (Kluwer Academic,1991).

ELECTIVE Courses

Course Code: PHYS5003

Course Name: Science and Technology of Thin Films

Course Credits: 4

Course Objectives: The central objective of the course is to provide basic understanding of physics and technology behind thin film growth. Possible applications demonstrating novel material designs and case studies in technological areas of current interest will be discussed.

Course Contents:

Unit – I

High vacuum production: Mechanical pumps, diffusion pumps, turbomolecular pumps, Getter and ion pumps, high vacuum system, vacuum system, leak detection, vacuum gauges, Pirani, Penning, cold cathode and ionisation gauges, residual gas analysis.

Unit – II

Thin film preparation: Vacuum evaporation, evaporation theory – rate of evaporation Hertz Knudsen equation, free evaporation and effusion, evaporating mechanisms, directionality of evaporation molecules, vapour sources – wire and metal foils, electron beam gun, flash evaporation, sputtering, DC sputtering, ion beam sputtering, chemical methods, electroplating, ion plating, vapour phase of growth – anodisation, thermal growth, MBE, CVD, ALD, MOCVD.

Unit – III

Thickness measurements, optical methods, FECO, Fizeau's technique, ellipsometry, Vamfo, other techniques, electrical, mechanical, microbalance quartz crystal monitor, film composition analysis, general ideas only. Nucleation theories, capillarity theory, atomistic theory, comparison stages of film growth, incorporation of defects during growth.

Unit - IV

Reflection and transmission at an interface, Reflection and transmission by a single film, reflectivity variation with thickness, anti-reflection coatings, Electrical properties of metallic films, sources of resistivity, Electrical conduction in discontinuous films, Electrical conduction in continuous films, electrical conductionin thin insulating films, possible conduction mechanisms.

Unit – V

Dielectric properties, Simple electrical theory, DC conduction mechanisms. high and low field conduction, temperature dependence, AC conduction mechanisms, relaxation peaks, frequency dependent phenomena, thin film devices, resistor, capacitors, active devices, thin film solar cells, thin film in integrated circuits.

Reference Books:

1. Maissel and Glang, Handbook of thin film technology: McGraw Hill (1970).
2. K.L. Chopra, Thin film phenomena: Robert E. Krieger Publishing Co. NY (1929).
3. Dupy and Cachard, Physics of nonmetallic thin films: Plenum Press (1976).
4. Berry, Hall Harris, Thin film technology: Van Nostrand Reinhold Co. NY (1968).
5. D.R. Lamp, Electrical conduction mechanisms in thin insulating films: Mathew & Co. (1967).
6. A. Goswami, Thin Film Fundamentals: New Age International (P), Ltd. (1996).
7. Joy George, Preparation of Thin Films, Marcel Dekker, NY (1992).

Course Code: PHYS5004

Course Name: Advanced Computational Physics

Course Credits: 4

Course Objectives: Computational physics is an intermediate between theoretical and experimental physics. This course covers

- the study of numerical algorithms
- implementation of algorithms to solve problems
- different optimization methods, probability, random number generation
- understand different methods like kinetic Monte Carlo, Molecular Dynamics, Density Functional Theory etc.

Unit - I

Monte Carlo Simulations: Random number generators – Metropolis rejection technique – Markov Chain – Application of Monte Carlo simulation of 2D Ising model – Limitations of Metropolis algorithm – Wang-Landau algorithm.

Unit - II

Simulating Chaotic Systems: Discrete dynamical systems – Oribits – Lyapunov exponents – Application to logistic map – Continuous dynamical systems – Rossler attractor – Lorenz attractor – Fractal dimension of strange attractors.

Unit - III

Solving Partial Differential Equation, Finite difference method – Explicit and Implicit methods – Stability analysis – Application to diffusion equation – Solving Poisson equation – Introduction to finite volume and finite element methods.

Unit - IV

Fast Fourier Transform, Discrete Fourier transform – Fast Fourier transform – Aliasing – Sampling theorem – Signal processing – Signal to Noise ratio.

Unit - V

Computer Lab: Simulating paramagnetic to ferromagnetic phase transition in 2D Ising model on a square lattice. Chaos in logistic map – Bifurcation diagram, Cobweb diagram, Lyapunov exponent as a function of parameter. FFT of periodic, multi-periodic, quasi-periodic, chaotic and stochastic signals. Fractal dimension of Lorenz attractor, Solution of diffusion equation.

Text Books & References:

1. E. Isacson, H.B. Keller, Analysis of Numerical Methods, Numerical Methods Analysis, John Wiley & Sons, New York 1972.
2. J.M. Thijssen, Computational Physics, Cambridge 1999.
3. Tao Pang, An Introduction to ComputationalPhysics, Cambridge 1997.
4. F.S. Acton, Numerical methods that work, Mathematical Association of America
5. Rubin H. Landau and Manuel J P Mejia, Computational Physics: problem solving with computers, John Wiley 1997.
6. Numerical Recipes in Fortran, Press et al.

Course Code: PHYS5005

Course Name: Emerging Electronic and Optoelectronic Materials and Devices

Course Credits: 4

Course Objectives:

- To gain knowledge of the electronic, dielectric and magnetic properties of materials.
- To understand theories relevant to the engineering principles of materials and devices.
- To understand the fundamental concepts of optoelectronic devices for information technology.

Course Contents:

Unit – I

Solid State Physics fundamentals: Crystal Structures, Reciprocal lattice elastic scattering of waves, crystals and amorphous solids, Ewald constructions, Bragg condition, Direct and indirect bandgap semiconductors Low dimensional Systems – Electron confinement in two and one dimensional well, density of states of low dimensional systems. Excitons, QW lasers, One dimensional devices like LED and UV detectors, nanoparticle based sensors.

Unit – II

Thin Film Transistors: Metal/semiconductor Junctions, ohmic contacts, Schottky barrier Two terminal MOS structures, MOS capacitance voltage characteristics –Basic MOSFET operation Gate Insulator considerations – Channel layer properties – Thin Film Transistors – types of TFT: amorphous and crystalline oxide TFTs, Basics of CMOS.

Unit – III

Organic Electronics: Materials, Electronic Structures and Charge Carrier Generation in Organic Optoelectronic Materials, Charge Transport in conducting polymers, small organic Molecules for electronics and optoelectronics, Application: Flexible electronics degree of flexibility, substrates, thin glass etc. **Fabrication technologies:** Batch processing, roll-roll processing, additive printing, Organic Field effect transistors, Organic Light Emitting Materials and Devices, Organic and polymer Photovoltaics.

Unit - IV

Luminescence: Excitation and emission, Decay mechanism, Theoretical models and mechanisms of luminescence – Harmonic oscillators, two, three, N-level systems, Band to band absorption and luminescence, luminescence in impurity solids, Donor acceptor pair impurity, luminescence of free and bound excitons – Intrinsic luminescence band to band luminescence, Exciton luminescence, Extrinsic luminescence, localized type, unlocalized type, Luminescence of nanomaterials.

Reference Books:

1. A.J. Dekker, Solid State Physics, Macmillan Pub. (1986).
2. M. Ali Omar – Elementary Solid State Physics: Principles and Applications, Addison Wesley (1994).

3. John H. Davies, The physics of Low-dimensional semiconductors, Cambridge University Press (1997).
4. G. Busch and H. Schade, lectures on solid state physics, Pergamon Press (1976).
5. S.V. Gaponenko, Optical Properties of Semiconductor Nanocrystals, Cambridge University Press (1998).
6. D. R. Vij, Luminescence of Solids, Springer (2012).
7. Jin Zhong Zhang, Optical properties and spectroscopy of nanomaterials, World Scientific (2009).
8. Cousins K and Keith Cousins, "Polymers in Electronics", Smithers Rapra Technology Publishers, Akron, 2006.
9. Donald A. Neamen, Semiconductor physics and devices, McGraw Hill (2003).
10. Robert F. Pierret – Semiconductor Device Fundamentals, Pearson (1996).
11. S.M. Sze, Semiconductor Devices Physics and Technology, John Wiley & Sons, Inc. (2003).
12. K.L. Chopra, Thin Film Phenomenon, Krieger Pub. Co. (2008).
13. F.M. Grey, Solid Polymer Electrolytes Fundamentals and Technological Application VCH Publishers, Inc. (1991).
14. Farzad Nasipouri and Alain Nogaret, Nanomagnetsim and Spintronics (Fabrication, Materials, Characterization and Applications), World Scientific Company (2010).
15. C. Kittel, Introduction to Solid State Physics, 7th edition, Publisher: Wiley India Pvt. Ltd.

Course Code: PHYS5006

Course Name: Advanced Spectroscopy

Course Credits: 4

Course Objectives: To impart the knowledge of basic molecular spectroscopy with emphasis on advanced spectroscopic techniques and its applications.

Course Contents:

Unit – I

Fundamentals of Molecular Spectroscopy: Electronic, Vibrational and Rotational Spectroscopy, Electronic absorption and emission spectra, Frank-Condon principle; Fluorescence and Phosphorescence; Fluorescence Spectroscopy, Excited state dipole moments, UV-Vis absorption spectra; Instrumentation of Fluorescence and UV-Vis Spectroscopy, Applications of electronic spectra.

Unit - II

Theory of Infrared Spectroscopy, Vibrating diatomic molecules, harmonic oscillator and anharmonic oscillator, Vibration of polyatomic molecules, Normal coordinates normal vibrations, and their symmetries, Infrared techniques and instrumentation, Fourier Transform Infrared Spectroscopy, sample handling techniques, Applications of infrared spectroscopy in Materials science, Biology and Medicine.

Unit – III

Origin of Raman Spectra, Classical and Quantum theory of Raman scattering, Symmetry elements and point groups, structure determination, Intensity of Raman Spectrum, Effect of Isotope on Raman and IR spectrum. Instrumentation of Raman Spectroscopy technique, Principles of Laser sources for excitation, structure determination using Raman Spectroscopy, Application of Raman Spectroscopy: Materials science, Biology and Medicine.

Unit – IV

Advanced Spectroscopic Techniques: UV-Resonance Raman Spectroscopy, Surface Enhanced Raman Spectroscopy, Tip-Enhance Raman Spectroscopy, Non-linear Spectroscopy: Coherent Anti-Stoke's Raman (CARS) Spectroscopy, Time-resolved Fluorescence and Raman Spectroscopy.

Reference Books:

1. G. Aruldhas, Molecular structure and spectroscopy, PHI, (2007).
2. C. N. Banwell, E. M. McCash, Fundamentals of molecular spectroscopy, McGraw Hill (1972).
3. Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds: Part A: Theory and Applications in Inorganic Chemistry, John Wiley, (1986).

Course Code: PHYS5007

Course Name: Physics of Advanced Materials

Course Credits: 4

Course Objectives:

- To make the students understand the importance of Nanoscience and technology.
- To make the students familiar with the fundamental concepts behind size reduction.

Course Contents:

Unit – I

Quantum Nanostructures and Nano Devices: Quantum dots, wires and wells, preparation, size & dimensionality effects, excitons, single electron tunneling, applications of quantum nanostructures, exchange bias, self assembly, process of self assembly, semiconductor islands, mono layers, Catalysis, surface area of nano particles, porous and colloidal materials, Nano machines and nano devices: Micro-electromechanical systems, Nano electromechanical systems NEMS's.

Unit – II

Nano Particles and Nano Structural Materials: Properties of Individual Nano-particles, metal nano clusters, theoretical modeling of nano particles, magnetic clusters, semiconductor nanoparticles, optical properties, methods of synthesis of nano particles, Carbon nanostructures, carbon nanotube and applications. Bulk nano structured materials: solid disordered nanostructures, methods of synthesis, properties, metal nano-duster composite glasses, porous silicon, Nano structured crystals.

Unit - III

Advanced Materials: Introduction, important characteristics and applications of advanced materials, Linear and non-linear dielectric materials, Ferroelectric, piezoelectric and electro-optic materials, composite materials, Liquid crystals, quasi-crystalline materials, hydride materials.

Reference Books:

1. Charles P. Poole Jr and Frank J. Owens, Introduction to Nanotechnology, Wiley-Interscience, 2003.
2. A. J. Dekker, Solid State Physics, Macmillan, (1986).
3. M. Ali Omar – Elementary Solid State Physics: Principles and Applications, Addison Wesley (1994).
4. C. Kittel, Introduction to Solid State Physics - 7th edition, Publisher: Wiley India Pvt. Ltd.
5. B. Tareev, Physics of Dielectric Materials, Mir Publications, 1979.

Course Code: PHYS5008

Course Name: Energy Storage and Devices

Course Credits: 4

Course Objectives:

This course covers all types of currently-available energy storage systems, which are, or can be, used in the electricity, heat and transport sectors. The various technologies discussed may be categorized as mechanical/kinetic, thermodynamic, electrical, chemical, electrochemical or thermal processes.

Course Contents:

Unit - I

Energy Demands and Energy Sources: World energy consumption, Energy in developing countries, Indian energy sources, Firewood crises, potential of renewable energy sources, Non-conventional renewable energy sources, solar energy, Wind energy, wave energy, Tidal energy etc.

Unit - II

Need of Energy Storage; Different Modes of Energy Storage: Potential energy: Pumped hydro storage; KE and Compressed gas system: Flywheel storage, compressed air energy storage; Chemical Energy storage: Thermo-chemical, photo-chemical, bio-chemical, fossil fuels and synthetic fuels; Solar Ponds for energy storage; Hydrogen for energy storage; Electrical and magnetic energy storage: Capacitors, electromagnets; Electro-chemical energy storage.

Unit - III

Similarities and Differences between Supercapacitor and Batteries for Storing Electrical Energy: Introduction, Faradic and Non-Faradic Processes, Types of Capacitors and Types of Batteries, Comparison of capacitors and batteries, Comparison of charge and discharge behaviour of electrochemical capacitors and battery cells evaluated by cyclic voltammetry.

Unit - IV

Theoretical Treatment and Modelling of the Double Layer at Electrode Interface: Early models, Treatment of diffused layer, Capacitance of diffused part of the double layer, Ion adsorption, solvent as dielectric of the double layer capacitor, Potential profile across the diffuse layer.

Unit – V

Energy Density and Power Density of Electrical Energy Storage Devices: Energy Density and Power Density and their relationship, Ragone plots of Power density vs. Energy Density, Power limitation due to concentration polarization, Relation between C-Rate specification and power density, Optimization of energy density and power density, Some application aspects of power-density factors.

References:

1. J. Twidell and T. Weir “Renewable Energy Resources”, E & F N Spon Ltd, 1986.

2. A.G. Martin "Solar cells: Operating principles, technology and system applications", Prentice Hall Inc, Englewood Cliffs, 1981.
3. H.J. Moller "Semiconductor for solar cells", Artech House Inc, 1993.
4. Ben G. Streetman, "Solid state Electronic Device", Prentice Hall of India Pvt Ltd., 1995.
5. M.A. Kettani, "Direct Energy Conversion", Addison Wesley Reading, 1970.
6. Linden, "Hand book of Batteries and fuel cells", Mc Graw Hill, 1984.
7. Hoogers, "Fuel Cell Technology handbook". CRC Press, 2003.
8. Vielstich, "Handbook of fuel cells: Fuel cell technology and applications", Wiley, CRC Press, 2003.
9. Chetan Singh Solanki, Solar photovoltaics, Fundamentals, Technologies and Applications by, PHI Learning Private Limited, Delhi.
10. Sie-Chin Tjong, Nanocrystalline Materials. Elsevier, 2014.
11. K.L. Chopra, Suhit Ranjan Das, Thin Film Solar Cells, Springer Science, 1983.
12. David Linden, Thomas B. Reddy, Handbook of Batteries, 3rd Edition, Mcgraw Hill, 2002.
13. Fredrik C. Krebs, Polymer Photovoltaics, a practical approach, Spie Press, Bellingham, Washington USA.
14. Wolfgang Tress, Organic Solar Cells, Theory, Experiment, and Device Simulation, Springer.
15. K. Kalyansundaram, Dye Sensitized Solar Cells, EPFL Press, A Swiss academic publisher distributed by CRC press.
16. Leonid A. Kosyachenko, Solar cells: Dye-sensitized Devices, Published by Intech, Janeza Trdine 9, 51000 Rijeka, Croatia.
17. H. A. Kiehne, Marcel Dekker, Battery Technology Handbook Inc., New York, Basel.
18. B.E. Conway, Electrochemical Supercapacitors, Scientific fundamentals and Technological Applications, Kluwer Academic/Plenum Publishers, New York, Boston, Dordrencht, London, Moscow.

Course Code: PHYS5009

Course Name: Solid State Ionics

Course Credits: 4

Course Objectives: The course covers the study of the physical, chemical and technological aspects of rapid ion movements within the bulk of the special class of ionic materials. It is an emerging area of Materials Science, as these solids show tremendous technological scopes to develop wide variety of solid state electrochemical devices such as batteries, fuel cells, supercapacitors, sensors, electrochromic displays (ECDs), memories etc. which the students would be able to understand.

Course Contents:

Unit - I

Introduction: Solid state ionics vis-à-vis solid state electronics, Principles of ionic conduction in ordered and disordered nanostructures.

Unit - II

Classification of Solid State Ionics: Superionic materials classification, Crystalline anionic and cationic conductors, mixed ionic and electronic conductors, structural factors responsible for high ionic conductivity; Brief review on physical techniques for analysis of ion conducting solids.

Unit - III

Ion Conduction Mechanism in Solid State Materials: Transport properties and Ion dynamics; Ion transport in homogeneous and heterogeneous medium – Ion conducting glasses, ceramics, polymers and composites; Ion Transport Models - Phenomenological models, Free volume theory, Configurational entropy model, Jump relaxation and Ion hopping model, Bond percolation model and Effective medium theory; Concepts and feasibility of ion conducting polymer nanocomposites and nanocrystalline ceramics.

Unit - IV

Applications of Superionic Solids: Material problems and processing techniques; Technological applications of ion conducting solids; Design, Working Principles, Fabrication and Performance Evaluation of Solid State Ionic Devices; Batteries (primary, secondary), Supercapacitors (EDLC and Redox), Fuel Cells (PEM Fuel cell, SOFC), Gas sensors and electrochromic display devices. Thermodynamics and mass transport in solid sate batteries. Battery performance and electrode kinetics. Double layer and other polarization effects at solid/solid interface; Fuel Cells as micro-power houses, Power conditioning and control of fuel cell systems, Device protection and packaging (thermal & electronic) protocol, design and implementation.

References:

1. T. Kudo and K. Fueki, Solid State Ionics (VCH, Tokyo, Japan) 1990.
2. S. Chandra, Superionic Solids, North-Holland, Amsterdam, 1981.
3. Lithium Batteries : Research, Technology & Applications, Greger R. Dahlin, Kalle E. Strøm, Nova Science Pub Inc, 2010.

4. C. Kittel, Introduction to Solid State Physics, 7th edition, Publisher: Wiley India Pvt. Ltd.
5. Azaroff; Introduction to Solids (TMH, New Delhi).
6. Energy Storage, R. A. Huggins, Springer, 2010.
7. Electrochemical Supercapacitors: Scientific Fundamentals & Technological Applications, B. E. Conway, Kluwer Academic, 1999.
8. Fuel Cell Technology, Nigel Sammes (ed.), 1st edition, Springer, 2006
9. Clean Energy, R. M. Dell & D. A. J. Rand, Royal Society Publications, 2004
10. Fuel Cell Engines, Matthew M. Mench, John Wiley & Sons, 2008.
11. Solid State Electrochemistry, P. G. Bruce (ed.), Cambridge University Press, 1995
12. The CRC Handbook of Solid State Electrochemistry, P. J. Gellings & H. J. M. Bauwmeester, CRC Press, 1997
13. Solid State Electrochemistry II : Electrodes, Interfaces and Ceramic Membranes, V. V. Kharton (ed.), Wiley-VCH, 2009
14. Fuel Cell Technology Handbook, G. Hoogers (ed.), CRC Press, 2003 (ISBN: 0-8493-0877-1).
15. Fuel Cell Technologies: State & perspectives; N. Sammes, A. Smirnova and O. Vasylyev (eds.), Springer, 2004.
16. H.P. Myers; Introductory Solid State Physics (Viva. New Delhi) 1998.
17. B. V. R. Chowdari, M. A. Careem, M A K L Dissanayake, R M G Rajapakse, V A Seneviratne, "Solid State Ionics: Advanced Materials for Emerging Technologies, (World Scientific Publishing Company) 2006.
18. S. Selvasekarapandian, N.Kalaiselvi, B. Nalini, V. Jozeph, Solid State Ionics and its applications, Bharathiar University (TMH New Delhi) 2006.
19. T. Minami, M. Tatsumisago, M. Wakihara, C. Iwakura, "Solid State Ionics for Batteries" (Springer) 2005.
20. J. Ross Macdonald, Impedance Spectroscopy: emphasizing solid materials and systems, (John Wiley & Sons) 1987.
21. A.R. West, Solid State Chemistry, (John wiley & Sons) 1984.
22. L.L. Hench and J.K. West, Principles of Electronic Ceramics, John Wiley & Sons, New York, 1990.
23. Gholamabbas Nazri, Gianfranco Pistoia, Lithium Batteries – Science and Technology, (Springer) 2004.
24. Walter A. van Schalkwijk, Bruno Scrosati, Advances in Lithium-ion Batteries, (Plenum Publishers) 2002.
25. C.A.C. Sequeira, A. Hooper, Solid State Batteries, (North Atlantic Treaty Organization. Scientific Affairs Division), 2003.
26. Perla B. Balbuena, Yixuan Wang, Lithium-ion Batteries: Solid-Electrolyte Interphase, (Imperial College Press) 2004.

Course Code: PHYS5010

Course Name: Nanoscale Magnetic Materials and Devices

Course Credits: 4

Course Objectives: The objective of this course is

- To understand the basic magnetic parameters, and the importance of property-structure relations in determining the absolute value of these parameters.
- To understand the magneto-transport in nanoscale systems.
- To provide a knowledge of basic mechanisms for tuning the magnetic properties.

Course Contents:

Unit - I

Band Theory of Solids: Origin of bands, band theory of solids, Effective mass, concept of holes, Electronic density of states, distinction between metal, insulator and semiconductor, Fermi level, Hall effect, electronic conduction in nanomaterials, size effect on energy gap- quantum confinement.

Unit - II

Basics of Magnetism: Magnetostatics; dia, para and ferromagnetism; Hysteresis curve, susceptibility, permeability, Magnetic anisotropy; Domains and domain walls; Magnetization processes, soft and hard magnetic materials, Effects of Particle size and Surface Chemistry on Magnetic Properties, exchange coupling.

Unit – III

Electronic Transport in Magnetic Materials: Nanomagnetic materials, conductivity measurements, Magnetoresistance in normal metals and nanomagnetic materials, Magnetoresistance in ferromagnetic materials and multilayers, Giant Magneto Resistance (GMR); Spin Valves; Tunneling Magnetoresistance, Heusler alloys.

Unit - IV

Devices: Magnetic data Storage Devices, Nanosensors, Sensing Mechanisms of different sensors, Fabrication of sensors, Magnetic recording, recording Heads, Magnetic random Access Memories (MRAMs).

Reference Books:

1. Robert Kelsall, Ian Hamley, and Mark Geoghegan (Editors), Nanoscale Science and Technology John-Wiley Publishers.
2. A.S. Edelstein and R.C. Cammarata (edits), Nanomaterials: Synthesis,Properties and Applications, Institute of Physics.
3. Cao, Nanostructures and Nanomaterials-Synthesis, Properties and Applications, Imperial College Press.
4. Nanotechnology-Basic Science and Emerging Technologies.

Text Books:

1. D. Sellmyer (Ed.), R. Skomski, Advanced Magnetic Nanostructures, Springer, 2009.
2. M.A. Reed (Ed.), Magnetic nanostructures, American Scientific Publishers, 2002.

3. D. Shi (Ed.), B. Aktas, L. Pust, F. Mikailov, Nanostructured magnetic materials and their applications, Springer, 2002.
4. B.D. Cullity, Introduction to Magnetic Materials, Wiley, 1972.

Course Code: PHYS5011
Course Name: Amorphous Materials: Properties & Applications
Course Credits: 4

Course Objectives: An introductory course designed to expose students to the fundamental knowledge and concept of different areas of amorphous glass and applications. It is designed to introduce the special characteristics and fabrication methods of different glasses.

Course Contents:

Unit – I

Amorphous Chalcogenide Glasses: Definition of glass, Introduction: definition, brief history, characteristics and fabrication of chalcogenides glasses, Glass formation and structural models, Structure of some representative ChGs, Physico-chemical properties, Photo-induced effects, **Photonics aspects:** IR transmitting medium, Host for doping, Nonlinear optical material, Optical waveguide, Photoresist, **Electronics aspects**: Phase change random access memory, Switching device, Ionics aspects, Models of ionic conduction in ChGs, Survey of fast ion conduction on ChGs.

Unit – II

Thermodynamics and Kinetics of Glasses: Phase transition, Thermodynamics of the Glass Transition, Glass Transition from Dynamics, Glass Forming Tendency, Calorimetric Measurement of the Glass Transition Temperature and Related Thermal Properties, Activation energy, Thermodynamics of melting and quenching, **Crystallization Kinetics:** Crystal Nucleation & Growth.

Unit – III

Phase Change Memories Materials: The Discovery of Phase Change Materials, Pioneers in Phase Change Memory, Scaling Properties of Phase Change Materials, Optical and Electrical Properties of Phase Change Materials.

Unit – IV

Device based Applications: Phase Change Memory Device Modeling, Phase-change Optical Recording and Related Technologies, The Future of Optical Storage, Phase Change Memory Cell Concepts and Designs, **Optoelectronic applications:** holography, optical amplifier, and optical sensors.

Reference Books:

1. M.A. Popescu, Non-Crystalline Chalcogenides.
2. A. Feltz, Amorphous Inorganic Materials and Glasses.
3. A. Ray Hilton, Chalcogenide Glasses for Infrared Optics.
4. V.F. Kokorina, Glasses for Infrared Optics.
5. A. Zakery and S. R. Elliott, Optical Nonlinearities in Chalcogenide Glasses and Their Applications.
6. R. Fairman and B. Ushkov, Semiconducting Chalcogenide Glass I.
7. R. Fairman and B. Ushkov, Semiconducting Chalcogenide Glass II.
8. R. Fairman and B. Ushkov, Semiconducting Chalcogenide Glass III,
9. Z.U. Borisoba, Glassy Semiconductors.
10. R. Zallen, The physics of amorphous solids.

11. Simone Raoux & Matthias Wuttig, Phase Change Materials: Science and Applications.

Course Code: PHYS5012
Course Name: Review of Advanced Physics
Course Credits: 4

Course Objectives: The aim of this course is to make familiar the students with the basic and advanced course in Physics covering Classical Mechanics, Quantum Mechanics, Solid State Physics, Statistical Physics and Group theory.

Course Contents:

Unit – I

Classical Mechanics: Review of Newtonian mechanics, Lagrange's equation and its applications, variational principle, principle of least action, Central force: Equation of motion, Small oscillations: Eigenvalue problem, normal modes, forced vibrations, Hamilton's equations, Canonical transformations, Poisson brackets, Hamilton-Jacobi theory, action-angle variables, Rigid body motion, rotation matrices, relativistic kinematics.

Unit – II

Quantum Mechanics: Operator formalism, Schrodinger equation, applications such as particle in a box, Harmonic oscillator, Hydrogen atom, Angular momentum, L-S coupling, J-J coupling, Clebsch-Gordon coefficients, Pauli matrices, commutation relations, Approximate methods & Perturbation theory: Stark effect, He-atom, α-decay, anomalous Zeeman effect, Relativistic quantum mechanics: Klein-Gordon and Dirac equations.

Unit – III

Solid State Physics: Types of Solids, Unit cell, space lattice, Miller indices, crystal structures, Reciprocal lattice, X-ray diffraction methods and their applications in identification of crystal structures, Einstein and Debye theories of molar heat capacity and their limitations, Band theory of solids, Krönig-Penny model, Brillouin zones, Electronic density of states, physical properties of nanomaterials, Electronic conduction in nanomaterials, Size effect on the properties of nanomaterials, Quantum confinement, Quantum dots.

Unit – IV

Statistical Physics: Microcanonical, Canonical and Grand Canonical ensembles. Partition function and it's applications. Ideal quantum gas. Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics, applications such as Doppler broadening, Einstein coefficients, specific heat of solid, black body radiation, electrons in metal, white dwarf stars, etc. Transport phenomena: Diffusion, random walk, Einstein's relations, Boltzmann transport equation, electrical properties.

Unit - V

Group Theory: Groups Definition and examples, Finite groups, non-abelian groups, permutation groups, mapping between groups. Subgroups, classes, cosets, conjugate and classes. Representation theory, dipole moments equivalent representation reducible and irreducible representation orthogonality theorem characters number of irreducible representations character table group nomenclature product representations physical applications. The symmetry group D2 and D3, Basic ideas on U(1), SO(2) and SO(3).

Suggested reading:

1. H. Goldstein, (1965), Classical Mechanics, Addison-Wesley.
2. H. Goldstein, C.P. Poole, J.L. Safko, (2001), Classical Mechanics, Addison- Wesley.
3. D.J. Griffiths, (2001), Introduction to Quantum Mechanics, Springer Link.
4. L.H. Ryder, (1996), Quantum field theory, Camb. Univ. Press.
5. R.K. Patharia, Statistical Mechanics.
6. L.E. Reichl, (1998), A Modern Course in Statistical Physics, John Wiley & Sons.
7. Landau & Lifshitz, (1980), Classical Theory of Fields, Butterworth-Heinermann