List of PhD Courses with its credit structure detail for the Department of Physics

Sl. No.	Subject Code	Course Name	L	T	P	C
1.	PH7101/PH7201	Mathematical Physics and Numerical Methods	3	0	0	3
2.	PH7102/PH7202	Classical Mechanics and Electrodynamics	3	0	0	3
3.	PH7103/PH7203	Quantum Mechanics and Statistical Mechanics	3	0	0	3
4.	PH7104/PH7204	Experimental Techniques and Scientific Presentation	3	0	0	3
5.	PH7105/PH7205	Fourier Optics	3	0	0	3
6.	PH7106/PH7206	Advanced Course On Semiconductor Devices	3	0	0	3
7.	PH7107/PH7207	Magnetism And Superconductivity	3	0	0	3
8.	PH7108/PH7208	Physics Of Materials	3	0	0	3
9.	PH7109/PH7209	Introduction To The Physics Of Nonlinear Systems	3	0	0	3
10.	PH7110/PH7210	Theory And Applications Of Holography	3	0	0	3
11.	PH7111/PH7211	Photonics Science and Engineering	3	0	0	3
12.	PH6104/PH6204	General Relativity and Cosmology	2	2	0	4
13.	PH6105/PH6205	Quantum Optics & Quantum Information	2	2	0	4
14.	PH6109/PH6209	Ultrafast Optics and Spectroscopy	2	2	0	4
15.	PH6110/PH6210	Magnetism: Fundamentals to Application	2	2	0	4
16.	PH6112/PH6212	Materials for Engineering Applications	2	2	0	4
17.	PH6114/PH6214	Physics of Ultracold Atoms	2	2	0	4
18.	PH6115/PH6215	Scanning Probe Microscopy	2	2	0	4
19.	PH6116/PH6216	Biophotonics	2	2	0	4
20.	PH6117/PH6217	Magnetic Materials and Applications	2	2	0	4
21.	PH6118/PH6218	Fourier Optics and Holography	2	2	0	4
22.	PH6120/PH6220	Particle Physics	2	2	0	4
23.	PH6121/PH6221	Soft Matter Physics	2	2	0	4
24.	PH6122/PH6222	Quantum Materials	2	2	0	4
25.	PH6123/PH6223	Low Temperature Techniques	2	1	2	4
26.	PH6124/PH6224	Nanoscience and Nanocharecterization	2	2	0	4
27.	PH6125/PH6225	Quantum Transport in Mesoscopic Systems	2	2	0	4
28.	PH6126/PH6226	Introductory Biophysics	2	2	0	4
29.	PH6127/PH6227	Spintronics	2	2	0	4
30.	PH6128/PH6228	Advanced Computational Physics	2	1	2	4
31.	PH6129/PH6229	Advanced Quantum Theory of Collisions	2	2	0	4
32.	PH6130/PH6230	Condensed Matter Physics-II	3	1	0	4

Course Number	PH7101/ PH7201
Course Credit	3-0-0-3
Course Title	Mathematical Physics an Numerical Methods
Learning Mode	Lecture
Course Description	The course will provide fundamental and relevant concepts for performig advanced research.
Prerequisite	None
Course Outline	Mathematical Physics Linear Algebra: Vector spaces and its properties, inner product spaces, linear transformation, similarity transformations, orthonormal sets, eigenvalues and eigenvectors. Complex Analysis: Cauchy-Riemann conditions, contour integrals, Residue theorem and applications. Partial differential equations and special functions (Legendre, Hermite and Lauguerre polynomials, Bessel functions, Neumann functions, etc.), Separation of variables in cartesian, spherical and cylindrical coordinates, properties of special functions. Numerical Methods Error analysis. Roots of nonlinear equations: Newton-Raphson method, solution of linear equations: Gauss-Jordan elimination, matrix inversion and LU decomposition, Eigenvalues and Eigenvectors. Interpolation and curve fitting: Least square fitting, linear and nonlinear, application in physics problems. Numerical differentiation and integration: Numerical differentiation formulae, Simpson's rule and Gauss-Legendre integration. Solution of ODE and PDE: Runge-Kutta and finite difference methods.
Assessment Method	Exam, assignment and tutorials
Suggested Readings:	Texts: 1. G. B. Arfken and H. J. Weber, Mathematical Methods for Physicists, Academic Press (1995) 2. K. E. Atkinson, Numerical Analysis , John Wiley, Low Price Edition (2004). References: 1. J. Mathews and R.L. Walker, Mathematical Methods of Physics , Pearson Education (2004) 2. S. C. Chapra and R. P. Canale, Numerical Methods for Engineers , Tata McGraw Hill (2002). 3. E. Kreyszig, Advanced Engineering Mathematics , John Wiley & Sons, Low Price Edition (2001)

Course Number	PH7102/PH7202
Course Credit	3-0-0-3
Course Title	Classical Mechanics and Electrodynamics
Learning Mode	Lecture
Course Description	The course will provide fundamental and relevant concepts for performig advanced research.
Prerequisite	None
Course Outline	Classical Mechanics Review of Newtonian mechanics. Lagrange's equation and its applications, variational principle, principle of least action. Central force: Equation of motion, classification of orbits, Virial theorem, Kepler problem. Rigid body motion: Euler angles, angular momentum and kinetic energy, inertia tensor, Euler equations and applications. Small oscillations: Eigenvalue problem, normal modes, forced vibrations, dissipation. Hamilton's equations, Canonical transformations, Poisson brackets, Hamilton-Jacobi theory, action-angle variables. Electrodynamics Solution of Laplace's and Poisson's equations, multipole expansion and Green's function approach to electrostatic and magnetostatic problems. Maxwell's equations and electromagnetic waves, wave propagation in dielectric and conducting media. Lienard-Wiechert potential, accelerated charges, Bremsstrahlung, electric dipole fields and radiation. Relativistic Electrodynamics: Covariant formalism of Maxwell's equations, transformation laws.
Assessment Method	Exam, assignment and tutorials
Suggested Readings:	Texts: 1. H. Goldstein, Classical Mechanics , Narosa (1985). 2. J. D. Jackson, Classical Electrodynamics , John Wiley (1999). References: 1. N. C. Rana and P. S. Joag, Classical Mechanics , Tata McGraw Hill (1994). 2. L. D. Landau and E. Lifshitz, Mechanics , Butterworth (1995) 3. L. D. Landau and E. M. Lifshitz, Electrodynamics of Continuous Media , Butterworth (1995). 4. G. S. Smith, Classical Electromagnetic Radiation , Cambridge (1997).

Course Number	PH7103/PH7203
Course Credit	3-0-0-3
Course Title	Quantum Mechanics and Statistical Mechanics
Learning Mode	Lecture
Course Description	The course will provide fundamental and relevant concepts for performig advanced research.
Prerequisite	None
Course Outline	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. Perturbation theory: Stark effect, He atom, α- decay, anomalous Zeeman effect. Relativistic quantum mechanics: Klein-Gordon and Dirac equations. Statistical Mechanics 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.
Assessment Method	Exam, assignment and tutorials
Suggested Readings:	Texts: 1. E. Merzbacher, Quantum Mechanics , John Wiley, Low Price Edition (1999). 2. R. K. Pathria, Statistical Mechanics, Butterwort h-Heinemann (1996). References: 1 J. J. Sakurai, Quantum Mechanics , Pearson Education (2002). 2. J.J. Sakurai, Advanced Quantum Mechanics , Pearson Education (2002). 3. S. R. A. Salinas, Introduction to Statistical Physics , Springer (2004). 4. K. Huang, Statistical Mechanics , John Wiley, Low Price Edition (2000)

Course Number	PH7104/PH7204
Course Credit	3-0-0-3
Course Title	Expermental Techniques and Scientific Presentation
Learning Mode	Lecture
Course Description	The course will provide fundamental and relevant concepts for performig advanced research.
Prerequisite	None
Course Outline	Experimental Techniques Low pressure: Rotary, sorption, oil diffusion, turbo molecular, getter and cryo pumps. McLeod, thermoelectric, Penning, hot cathode ionisation and Bayard Alpert gauges. Partial pressure measurement, leak detection, gas flow through pipes and apertures, effective pumping speed, vacuum components, thermal evaporation, e-beam, sputtering and laser ablation systems. Low temperature: Gas liquifiers, cryogenic fluid baths, cryostat design, closed cycle He refrigerator (CCR), low temperature thermometry. Sources, sensors and instruments: Principle and characteristics of LASERs. Classification and principle of various sensors. Signal averaging and lock-in detection. Principle and applications of powder X-ray diffractometer, spectrophotometer; Fourier transform-Infrared (FT-IR) spectrometer, fluorimeter, atomic force microscope, electron microscope, Energy dispersive X-ray analysis (EDAX) and optical spectrum analyzer. Scientific Presentation Art of scientific writing (steps to better writing, flow method, organization of material and style), development of communication skills, presentation of scientific seminars.
Assessment Method	Exam, assignment and tutorials
Suggested Readings:	Texts: 1. A. D. Helfrick and W.D.Cooper, Modern Electronic Instrumentation and Measurement Techniques , PHI (1996). 2. G. K. White, Experimental Techniques in Low Temperature Physics , Clarendon (1993). 3. A. Roth, Vacuum Technology , Elsevier (1990). 4. H. J. Tichy, Effective Writing for Engineers, Managers, Scientists , John Wiley & Sons (1988). References: 1. A. Ghatak and K.Thyagarajan, Optical Electronics , C.U.P. (1991). 2. D. A. Skoog, F. J. Holler and T. A. Nieman, Principles of Instrumental Analysis , Saunders College Publishers (1998)

Course Number	PH7105/PH7205
Course Credit	3-0-0-3
Course Title	Fourier Optics
Learning Mode	Lecture
Course Description	The course will provide fundamental and relevant concepts for performig advanced research.
Prerequisite	None
Course Outline	Coherence and light sources. Theory of diffraction: Fresnel and Fraunhofer diffraction. Theory of interference: two beam interference, division of wavefront and division of amplitude, multiple-beam interference. Optical imaging (coherent and incoherent) and processing: Frequency analysis of optical imaging systems. Fourier transforms, Convolution and correlation. Wavefront modulation, Analog optical information processing. Holography: Types of holography and its applications.
Assessment Method	Exam, assignment and tutorials
Suggested Readings:	Textbooks: • J. W. Goodman, Introduction to Fourier Optics, 3rd Ed. 2005. M. Born and E. Wolf, Principles of Optics, 7th Ed., Cambridge Univ. Press, 1999. • P. Hariharan, Optical Holography: Principles, Techniques, and Applications, 2nd Ed., Cambridge Univ. Press, 1996. • B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, 1991. References • E. G. Steward, Fourier Optics: An Introduction, 2nd Ed., Dover Publ., 2004. • Robert K. Tyson, Principles and Applications of Fourier Optics, IOP Publ., Bristol, UK, 2014. • U. Schnars and W. Jueptner, Springer, 2005. • Joseph Rosen, Holography, Research & Technologies, InTech, 2011.

Course Number	PH7106/PH7206
Course Credit	3-0-0-3
Course Title	Avanced Course On Semiconductor Devices
Learning Mode	Lecture
Course Description	The course will provide fundamental and relevant concepts for performig advanced research.
Prerequisite	None
Course Outline	Energy Bands and Charge Carriers in Semiconductors: Bonding Forces and Energy Bands in solids; Charge carriers in semiconductors; Carrier concentrations; Drift of carriers in electric and magnetic fields; Invariance of Fermi level at equilibrium. Excess carriers in Semiconductors: Optical absorption; Photoluminescence; Electroluminescence; Direct and Indirect recombination of Electrons and Holes; Trapping; Steady State Carrier generation; Quasi Fermi Levels; Continuity Equation of Diffusion and Recombination; Diffusion length; Haynes-Shockley Experiment; Gradients in Quasi Fermi level. Junctions: Fabrication of p-n junction; Contact Potential; Space charge at junction; Forward and Reverse biased junctions; Carrier Injection; Zener and Avalanche breakdown; Time variation of stored charge; Reverse recovery transient; Switching diodes; Capacitance of p-n junction; Varactor diode; Effect of contact potential on carrier injection; Recombination and generation in the transition region; Ohmic losses; Graded junctions; Schottky barriers; Rectifying contacts; Ohmic contacts. Field Effect Transistors: Transistor operation; Junction FET characteristics; High Electron Mobility Transistor; short channel Effects; MISFET operation and characteristics; Ideal MOS capacitor; Effect Real surfaces; Threshold voltage; I-V characteristics of MOS Gate oxide MOS field effect transistor. MOS Field Effect Transistors: Output and Transfer Characteristics; Mobility models; Short channel effect and narrow width effects; Substrate bias Effect; Equivalent circuit of MOSFET; MOSFET scaling and hot electron effects; Drain induced barrier lowering; Gate induced Drain leakage.
Assessment Method	Exam, assignment and tutorials
Suggested Readings:	• B. G. Streetman and S. Banerjee, Solid State electronic devices, 6th Ed, PHI, 2006. • Adel S. Sedra and Kenneth C. Smith, Microelectronic Circuits, Oxford University Press, 6th Edition, 2009 • Robert L. Boylestad and Louis Nashelsky, Electronic Devices and Circuit Theory, Prentice Hall, 7th Edition. • Jacob Millman and Christos C. Halkias, Integrated Electronics: Analog and Digital Circuits and Systems, Tata McGraw Hill, 2008 • D. A. Neamen, Semiconductor physics and devices, 4th Ed, McGrawHill, 2012. • S. M. Sze and Kwok Ng, Physics of Semiconductor Devices, 3rd Ed, Wiley, 2006. • U. K. Mishra and J. Singh, Semiconductor Device Physics and Design, Springer, 2008. • B. Ghosh, Advanced Practical Physics, Volume – II, Sreedhar Publishers, 6th Edition, 2015 **References:**

	Semiconductor Physics And Devices: Basic Principles (Fourth edition) by Donald Neamen. Publisher-McGraw-Hill Education. Publication date-16 March 2011. Device Electronics for Integrated Circuits by Richard S. Muller, Theodore I. Kamins. (Third edition). Publisher-Wiley. Publication date -7 January 2003.

Course Number	PH7107/PH7207
Course Credit	3-0-0-3
Course Title	Magnetism And Superconductivity
Learning Mode	Lecture
Course Description	The course will provide fundamental and relevant concepts for performig advanced research.
Prerequisite	None
Course Outline	Magetism: Review of diamagnetism, paramagnetism, superparamagnetism, ferromagnetism, antiferromagnetism, ferri magnetism. Circular and helical order. Direct, exchange, double exchange, indirect and RKKY interactions, environment effects: crystal field, tetrahedral and octahedral sites; Jahn-Teller effect; Hund's rule and rare earth ions in solids. Consequences of broken symmetry, phase transition, Landau's theory, rigidity, excitation, magnons, domains and domain walls, magnetic hysteresis, pinning effects. Magneto resistance, giant magneto resistance, nuclear magnetic resonance. Technological aspects of magnetic materials: Magnetic sensor, spin valve, magnetic refrigeration, actuator etc. Superconductivity: Properties of conventional (low temperature) superconductors, London and Pippard equation, Type II superconductors, intermediate state, vortex lines, flux pinning, Non ideal behavior of Type II superconductors, Thermodynamics of Type I and II superconductors, Ginzburg Landau (G-L) theory, G-L equations, current density, Josephson equations, superconducting quantum interference device. Cooper pairs and BCS theory, Energy gap, magic number, experimental determination of energy gap from I-V characteristics, McMillan's upper limit of Tc. Properties of high Tc superconductors, flux pinning, current density, granular nature.Technological aspects of superconductors: High magnetic field, Transmission line, Maglev train, MRI, etc.
Assessment Method	Exam, assignment and tutorials
Suggested Readings:	**Text Book:** 1- Magnetism in condensed matter, S. Blundell, New York : Oxford University Press, 2014 2- Superconductivity, Charles P. Poole, Horacio A. Farach, Richard J. Creswick, Ruslan Prozorov, Elsevier, 2007 **Reference Book:** 3- Magnetism:from fundamentals to nanoscale dynamics, Stohr, J.; Siegmann, H. C. Berlin : Springer, 2006 4- Introduction to Magnetic Materials, B. D. Cullity, C. D. Graham, First published:29 February 2008 5- Magnetism:principles and applications, Craik, D. Chichester: John Wiley, 1998 6- Superconductivity, Kelterson, J.B.; Song, S.N. Cambridge : CUP, 1999

	7- Magnetism and superconductivity, Lévy, Laurent-Patrick, 2000, Springer

Course Number	PH7108/PH7208
Course Credit	3-0-0-3
Course Title	Physics of Materials
Learning Mode	Lecture
Course Description	The course will provide fundamental and relevant concepts for performig advanced research.
Prerequisite	None
Course Outline	Materials classification on the basis of physical constitution, crystal structure (e.g.; amorphous & crystalline-poly/nano) and electrical properties; Brief review of crystal structure of materials (e.g.; metals, alloys, ceramics, polymers, composites etc.); Electrical properties of conductors, insulators and semiconductors, Concept of band structure in solid materials; Mechanism of electronic and ionic charge transport in solids; Theories of electrical transport in ionic conductors and semiconductors (e.g.; crystalline and amorphous – polymeric, ceramic and composites); Dielectric and ferroelectric phenomena – polar and non-polar systems (e.g.; oxides); Physics of polarization, resonance, dispersion and relaxation behavior in materials; Frequency response characteristics of charge transport and scaling laws; Microstructure-property correlation in solid materials: Basic concepts of energy-matter interaction in solids; Optical properties of materials: Optical constants, absorption and emission properties; Elastic and thermal properties of materials, Phase transition phenomena – solid-liquid-gas, superfluidity, superconductivity etc.; Magnetic properties of materials, elementary idea of plastic magnets. Suggested Readings:
Assessment Method	Exam, assignment and tutorials
Suggested Readings:	**Text Book** 1- Solid State Physics, Neil Ashcroft, N. Mermin, Brooks/Cole; 2021 2- Introduction to Solid State Physics, Charles Kittel, John Wiley and sons, 2010 **Reference Book** 3- ELEMENTARY SOLID STATE PHYSICS: Principles and Applications, M. Ali. Omar, Pearson, 2014 4- Solid state physics, R. K. Puri and V. K. Babbar, S. Chand, 2010 5- Solid state physics: introduction to the theory, Patterson, J. D.; Bailey, B. C. Switzerland : Springer, 2018 6- Solid state physics, Dekker, A.J. Macmillan, 2009

Course Number	PH7109/PH7209
Course Credit	3-0-0-3
Course Title	Introduction to the Physics of Nonlinear Systems
Learning Mode	Lecture
Course Description	The course will provide fundamental and relevant concepts for performig advanced research.
Prerequisite	None
Course Outline	Linearity and nonlinearity: Origin and Importance, Dispersion, Dissipation. Nonlinear excitations: group velocity dispersion, solitary waves. Examples of Nonlinear equations: Dynamics of a pendulum under the influence of gravity, Inverted pendulum, van der Pol equation, Korteweg-de Vries equation, Navier-Stokes equations,The Richards equation, Sine-Gordon equation, Nonlinear Schrodinger equation, Ginzburg-Landau equation. Nonlinear Optics: Second harmonic generation, Two photon absorption, Four wave-mixing, Spontaneous parametric down conversion, Kerr effect, Pockels effect, Optical Soliton: spatial and temporal solitons, self-phase modulation, modulational instability, optical fiber, selffocusing, dark and bright solitons and solitary waves, dynamics in presence of phase locked source. Atomic systems: Non resonant atomic media, doffing oscillator model, solitons. Bose-Einstein condensate (BEC): Physics behind BEC, Experiments with alkali metal gas, Laser cooling, magnetic trapping, evaporative cooling. Second quantization, scattering length, Gross-Pitaevskii equation. Lower dimensional nonlinear systems, experimental validity. Dynamics of a cigar-shaped BEC: Dark and bright solitons, weak and strong inter-atomic interactions.
Assessment Method	Exam, assignment and tutorials
Suggested Readings:	Text book • W. T. Silvfast, Laser Fundamentals, Cambridge University Press, 2008. • W. Demtroder, Laser Spectroscopy, Vol. 1, Basic Principles, 4th Edition, Springer, 2008. • Robert W. Boyd, Nonlinear Optics, 2nd Edition, Academic Press, 2003.

Course Number	PH7110/PH7210
Course Credit	3-0-0-3
Course Title	Theory and Applications of Holography
Learning Mode	Lecture
Course Description	The course will provide fundamental and relevant concepts for performig advanced research.
Prerequisite	None
Course Outline	Basics of holography, holographic imaging; Wavefront reconstruction: in-line and off-axis holography. Types of holography: Fourier holograms, Fraunhofer holograms, Thin and volume holograms, Reflection, white light, rainbow and wave guided holograms; Theory of plane holograms, magnification, aberrations, coupled wave theory, wavelength and angular selectivity, diffraction efficiency. Recording medium for holograms: silver halides, dichromatic gelatin, photoresist, photoconductor, photorefractive crystals etc. Applications: Displays, microscopy; interferometry, non-destructing testing of engineering objects, particles sizing; imaging through aberrated media, phase amplification by holography; information storage and processing. Holographic Optical Elements: scanners, filters; Optical data processing, holographic solar concentrators; Colour holography: recording with multiple wavelength; Electron holography, acoustic and microwave holography, computer generated holography, digital holography.
Assessment Method	Exam, assignment and tutorials
Suggested Readings:	Textbooks: • P. Hariharan, Optical Holography: Principles, Techniques, and Applications, 2nd Ed., Cambridge Univ. Press, 1996. • B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, 1991. References • U. Schnars and W. Jueptner, Springer, 2005. • Joseph Rosen, Holography, Research & Technologies, InTech, 2011.

Course Number	PH7111/PH7211
Course Credit	3-0-0-3
Course Title	Photonics Science and Engineering
Learning Mode	Lectures
Learning Objectives	The main objective of this course is to learn about the working principles, theoretical aspects, and applications of various lasers and advanced photonic devices.
Course Description	Mainly, this course allows Ph.D. students to learn the necessary details about various lasers and advanced photonic devices to carry out research in different branches of photonics.
Prerequisite	Some fundamentals related to Optics and Photonics
Course Content	**Lasers:** Ultrafast lasers, White light lasers, Quantum cascaded lasers, Single photon sources **Photodetectors:** Photoconductors, Avalanche photodiodes, Photomultiplier tubes, Charge-coupled devices (CCDs), Complementary metal-oxide-semiconductor (CMOS) cameras **Fiber optics:** Electromagnetic theory for optical propagation, Characteristic parameters of optical fiber modes, Fabrication of optical fibers, Losses in optical fibers, Fiber-optic devices (polarizers, attenuators, isolators), Fiber optics lasers, Optical fiber communication, Fiber optic sensors, Fiber-optic endoscopes **Non-linear optics**: Introduction, Stimulated Raman scattering, Four-wave mixing, Optical parametric amplifiers and oscillators, Phase matching, Quasi-phase matching, Z-scan, and Laser-induced transient grating techniques for studying the non-linear properties. **Spatial light modulators (SLMs):** Special properties of SLMs, Multiple quantum well SLMs, Liquid crystal SLMs, Magneto-optic SLMs, and Applications of SLM in generating structured beams carrying orbital angular momentum. **Metal and Metamaterial Optics**: Optical properties of bulk metals, metal thin films, and metal nanostructures, Special properties of metamaterials, metasurfaces, and Applications of metamaterials. **Photonic crystals:** Special properties of photonic crystals, Various techniques for the Fabrication of 1D, 2D, and 3D photonic crystals, Photonic crystal-based waveguides, lasers, sensors, and spectrometers.
Assessment Method	Quizzes, Mid-semester examination, and End-semester examination.
Suggested Readings:	**Textbooks:** [1]. B.E.A. Saleh, and M.C. Teich, "Fundamentals of Photonics", John Wiley & Sons, Inc., 2019. [2]. R. W. Boyd, "Nonlinear Optics", Academic Press", 2022. [3]. Fedor Mitschke, "Fiber optics: Physics and Technology", Springer-Verlag Berlin Heidelberg, 2009. [4]. K. Ionue, K. Ohtaka (Eds.), "Photonic Crystals: Physics, Fabrication and Applications", Springer-Verlag Berlin Heidelberg, 2009. [5]. Uzi Efron, "Spatial Light Modulator Technology", Macel Dekker. Inc. 1995.

Course Number	PH6104/PH6204
Course Credit	2-2-0-4
Course Title	General Relativity and Cosmology
Learning Mode	Lectures
Course Description	This course provides a review of general relativity and presents an introduction to the science of understanding the origin, structure, and evolution of our universe.
Prerequisite	Nil
Course Outline	Brief review of special theory of relativity, equivalence principle, describing curvature – Riemannian spacetime, generalized coordinates, review of tensor algebra and calculus, metric, Christoffel connections, geodesic equation, metric as a classical field, Reimann curvature tensor, Ricci tensor and scalar, Einstein action, Einstein equations, FRW metric, proper distance; Cosmological observations: dark night sky, isotropy and homogeneity, redshift, cosmic particles, cosmic microwave background – overview of the CMB spectrum, recombination, temperature fluctuations; the standard model of the universe (ΛCDM); Friedmann equation, equation of state, cosmological constant, single component universe – spatially flat, radiation, and matter dominated; cosmological parameters – Hubble constant, deceleration parameter; introduction to dark matter; The inflationary universe: flatness problem, horizon problem, monopole problem, the paradigm of inflation, physics of inflation – example of a scalar field driven inflation, advances of inflation model building, confronting inflation models with observation, primordial gravitational waves. Topics for mini-project: Review of differential geometry, black hole solutions, review of numerical relativity, cosmological perturbation theory, symbolic computations in cosmology using xAct packages.
Assessment Method	Assignments, Seminar, Mini-project, Mid-semester,End-semester examination
Suggested Readings:	Textbooks: ▪ Introduction to Cosmology, B. Ryden, Cambridge Univ. Press, 2016. ▪ Modern Cosmology, Scott Dodelson, Academic Press, 2003. ▪ Spacetime and Geometry: An Introduction to General Relativity, S. Carroll, Cambridge, 2019. References: ▪ Cosmology, D. Baumann, Cambridge, 2022. ▪ A First Course in General Relativity, B. Schutz, Cambridge, 2009. ▪ Introduction to Cosmology, J. V. Narlikar, Cambridge Univ. Press, 2002. ▪ Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity, S. Weinberg, Wiley, 1972.

Course Number	PH6105/PH6205
Course Credit	2-2-0-4
Course Title	Quantum Optics & Quantum Information
Learning Mode	Lectures
Course Description	This course provides fundamental knowledge in Quantum Optics required for pursuing research in this area and also it gives an introduction to Quantum Information and its engineering applications.
Course Outline	Basic Concepts in Quantum Optics; Quantization of free electromagnetic field; Fock or number states, Quadrature of the fields, Coherent & Squeezed states, Photon added & subtracted coherent state, Schrodinger cat state and the cat paradox; Q-representation and Wigner-Weyle distribution; First & second order Coherence, Correlation function; Hanbury Brown-Twiss experiments, Atom-field interaction; Laser without inversion, Quantum theory of laser-density operator approach; Atom optics; Open quantum system, Master equation; Cavity quantum electrodynamics (cavity-QED), Jaynes-Cummings model, dispersive atom-field interaction in a cavity; Laser Cooling;Quantum bits (Qubits), Bloch sphere, Quantum gates (single & two qubit); Quantum Entanglement, Bell's Inequality; Quantum Algorithms; Principles of Teleportation;Examples of Quantum information processing in physical systems: cavity-QED, Ultracold neutral atoms; Current research and development in Quantum Optics & Quantum Information; Project assignment on topics: *Quantum Metrology with Light and Matter; Spontaneous Parametric Down-Conversion OR Quantum Entanglement and Uncertainty*.
Assessment Method	Assignments, Quizzes, Seminar, Mid-semester examination, End-semester examination
Suggested Readings:	
Textbooks:	• Quantum Optics, M. O. Scully& M. Suhail Zubairy, Cambridge Univ. Press, New York, 2008. • Quantum Optics, Girish S. Agarwal, Cambridge Univ. Press, New York, 2013. • Quantum Computation & Quantum Information, M. A. Nielsen & I. L. Chuang, Cambridge Univ. Press, UK, 2000.
References:	• Quantum Optics: An Introduction, Mark Fox, Oxford Univ. Press, New York, 2014. • The Quantum Theory of Light, Rodney Loudon, Oxford Univ. Press, New York, 2000. • Quantum Optics, Klauder & Sudarshan.

Course Number	PH6109/PH6209
Course Credit	2-2-0-4
Course Title	Ultrafast Optics and Spectroscopy
Learning Mode	Lectures
Course Description	Students will be equipped with ultrafast lasers, their pulsing methods with linear and non-linear spectroscopic methods. Their usages in applications to research in imaging, nanoscopy and excitonic dynamics
Course Content	Ultrafast optics: Fundamentals of non-linear optics, Linear and nonlinear pulse shaping processeses: second order, third order, higher-order non-linear phenomenon, Dispersion, Pulse compression; Chirped Pulse; Time Resolution, Optical solitons Laser principles: Single- and multi-mode laser dynamics, Q-switching, Active and passive mode-locking. Pulse characterization: Autocorrelation, frequency resolved optical gating (FROG), Spectral phase interferometry for direct electric field reconstruction (SPIDER); Noise in mode-locked lasers and its limitations in measurements; Laser amplifiers, optical parametric amplifiers, and oscillators; Pump-probe techniques, Four-wave Mixing, Time-resolved fluorescence, Up-conversion, THz-TDS, Higher harmonic generation. Applications of ultrafast spectroscopy: Super-resolution imaging, Exciton dynamics in chemistry and material science, Exciton dynamics in semiconductor nanocrystals. Multiphoton spectroscopy. Nanoscopy. Ultrafast transient absorption. Attoscience.
Learning Outcome	Complies with PLO 1a, 2 and 3
Assessment Method	Assignments, Quizzes, Seminar, Mid-semester examination and End-semester examination, Special literature presentation and assignments will be given for section-3.
Suggested Readings:	
Textbooks:	• Laser Fundamentals, W. T. Silfvast, 2nd Ed., Cambridge Univ. Press. • Nonlinear Optics, Robert Boyd, 3rd Ed., Academic Press. • Advanced Time-Correlated Single Photon Counting Applications, Wolfgang Becker, Springer • Ultrafast Dynamical Processes in Semiconductors, Kong-Thon Tsen, Springer. • Ultrafast Infrared Vibrational Spectroscopy, M. D Fayer, CRC Press.
References:	• Recent Advances in Ultrafast Structural Techniques, Sciaini, Appl. Sci. 9, 1427, 2019. • Femtosecond Infrared Spectroscopy of Semiconductors and Semiconductor Nanostructure, Physics Report, 1999, 321, 253. • Ultrafast Studies of Single Semiconductor and Metal Nanostructures through Transient Absorption Microscopy, Chem. Sci. 2010, 1 303.

Course Number	PH6110/PH6210
Course Credit (L-T-P-C)	2-2-0-4
Course Title	Magnetism: Fundamentals to Application
Learning Mode	Lectures
Course Description	Equips the students with the fundaments and applications of magnetism, magnetic materials, measurement techniques and spintronics. It allows them to develop advanced concepts and apply the knowledge in both research and industrial scenarios.
Course Content	Introduction - Magnetic moment, Bohr magnetron, magnetization, Field and Susceptibility; Quantum mechanics of spin: angular momentum, Pauli spin matrices, spin-spin coupling; Magnetic field generation: electromagnet, superconducting magnet; Diamagnetism, Paramagnetism Interactions - Dipolar interaction; Exchange interaction: direct, indirect, double, anisotropic etc.; ferromagnetism: Weiss model, molecular field; Antiferromagnetism; Ferrimagnetism; Helical magnetic order; Superparamagnetism, Spin Glass and frustration, measurements of magnetic order Order and Broken Symmetry - Landau theory of ferromagnetism; Heisenberg and Ising models; consequences of broken symmetry; phase transition; Excitations: magnon, Bloch's $T^{3/2}$ law, Mermin-Wagner-Bereziniskii theorem, Spin waves; Domains: Domain wall, Magnetocrystalline anisotropy, Domain wall width, formation, Stoner-Wohlfarth model, Soft and Hard magnetic materials Magnetism in metals – Free electron model; Pauli paramagnetism; Landau diamagnetism; Magnetism in electron gas; RKKY interaction, Two-dimensional magnets Recitation: This will be on one of the topics listed above. Mini project: This will be on one of the topics listed above. Additional assignments: Related to above listed topics.
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination
Suggested Readings:	
Textbooks:	• Magnetism in Condensed Matter, Stephen Blundell, Oxford Univ. Press. • Introduction to Spintronics, Supriyo Bandyopadhyay, CRC press, Taylor & Francis Group. • Magnetism and Magnetic Materials, J. M. D. Coey, Cambridge Univ. Press. • Introduction to Magnetic Materials, 2nd Edition, L. C. Cullity and C. D. Graham, IEEE Press, Willey. • Handbook of Spin Transport and Materials and Magnetism, Editors, Evgeny Y.Tsymbal and Igor Źutić, CRC Press, Taylor & Francis Group. • Magnetism: From Fundamentals to Nanoscale Dynamics, Joachim Stöhr, Hans Christoph Siegmann, Springer-Verlag . • Principles of Nanomagnetism, Guimarães, Alberto P., Springer, 2009.
References:	• Handbook of Spin Transport and Magnetism, Editors, Evgeny Y. Tsymbal, Igor Zutic, Tailor & Francis, 1st Edition.

	• Advances in Nanoscale Magnetism, Proceedings of the International Conference on Nanoscale Magnetism ICNM-2007, June 25 -29, Istanbul, Turkey, Series: Springer Proceedings in Physics, Vol. 122. • Lectures on Magnetism, Eugene Chudnovsky and Javier Tejada, Rinton Press, 1st Edition. • Introduction to Magnetism and Magnetic Materials, David Jiles, Chapman & Hall, 1998.

Course Number	PH6112/PH6212
Course Credit	2-2-0-4
Course Title	Materials for Engineering Applications
Learning Mode	Lectures
Course Description	This course is designed to provide specialized knowledge related to the field of Materials for Engineering Applications.
Course Outline	Orientation: Why materials? Functionality driven material (re)search; Extraction, synthesis, processing, and characterization of materials. Structural Materials: Introduction to Alloys, Ceramics, Polymers and Composites; Preparation, Processing and Applications; Elastic and Plastic deformation, Residual stress, Hardness, Fracture, Fatigue, strengthening and forming, fracture resistance, fatigue life, creep resistance. Optical Materials: Introduction to optical materials; Interaction of light with electrons in materials; Applications as dielectric coatings, electro-optical devices, optical recording, optical communications. Magnetic Materials: Properties and processing of magnetic materials; Field, Induction, Magnetization and Hysteresis; Applications as Permanent magnets, Magnetic recording and sensing. Electronic Materials: Si as material for microelectronics and photovoltaic, preparation, processing and applications; III-V and II-VI semiconductors and optoelectronic applications; Thermoelectric materials, figure of merit, thermoelectric generators and refrigerators; Superconducting Materials and properties, applications including magnets, magneto-encephalography, Josephson junction, SQUID; Conducting Polymers, synthesis and applications; Ferroelectric materials, piezoelectricity and applications; Shape memory alloys and applications. Recitation: This will be on one of the topics listed above. Mini project: This will be on one of the topics listed above. Additional assignments: Related to above listed topics.
Assessment Method	Assignments, Quizzes, Seminar, Mid-semester examination, End-semester examination
Suggested Readings:	
Textbooks:	• Materials Science for Engineering Students, Traugott Fischer, Academic Press, 2009.
References	• The Structure and Properties of Materials, J.W. Morris, Jr., McGraw Hill, 2005. • Principles of Electrical Engineering Materials and Devices, S. O. Kasap, McGraw-Hill, 2005.

Course Number	PH6114/PH6214
Course Credit (L-T-P-C)	2-2-0-4
Course Title	Physics of Ultracold Atoms
Learning Mode	Lectures
Course Description	This course provides student's both theoretical and experimental aspects of emerging ultra cold atoms physics highlighting BEC and its applications towards modern cutting edge technology in the research area of Quantum Optics.
Course Outline	Introduction to ultracold atoms and Bose-Einstein condensate (BEC), critical temperature Basic Scattering theory; Second quantization, Mean field theory, Gross-Pitaevskii equation; 1D nonlinear Schrödinger equation; weak, strong and higher order interactions; BEC in a trap, trap engineering and condensate density; Bright & dark Solitons, exact solution; Applications & future technologies: BEC optical lattices; Faraday waves, phase transition, BEC in a chip, atomic beam splitter, atom lasers, Negative temperature etc. Alkali metal gases, Introduction to laser cooling, Velocity dependent force, Optical Molasses, Magneto optical trapping (MOT), Limitations of MOT, Different types of trapping, Magnetic and optical trapping, Evaporative cooling techniques in magnetic and optical trap, Applications in quasi-one dimension, Achieving Bose-Einstein Condensates in pure magnetic and optical traps, Hybrid trapping potentials; Various applications in experiments. Project assignment of on topics: *Quantum Simulation with Ultracold Atoms in Optical Lattices; Experimental Generations of self-similar Excitations of Ultracold Atoms.*
Assessment Method	Assignments, Quiz, Mid-semester and End-semester examination
Suggested Readings:	
Textbooks:	C. J. Pethick & H. Smith, Bose-Einstein Condensation in Dilute Gases, Cambridge Univ. Press, 2008. A. Griffin, D. W. Snoke & S. Stringari, Bose-Einstein Condensation, Cambridge Univ. Press, 1995. Robert W. Boyd, Nonlinear Optics, 2nd Edition, Academic press, 2003.
References:	Scully, M. O., and M. S. Zubairy. Quantum Optics. Cambridge Univ. Press, 1997. Harold J. Metcalf, Peter van der Straten, Laser Cooling and Trapping, Springer, 1999. Lambropoulos. P, Petrosyan. D, Fundamentals of Quantum Optics and Quantum Information, Springer, 2007. M. Lewenstein, A. Sanpera, and V. Ahufinger, Ultracold Atoms in Optical Lattices, Oxford Univ. Press, 2012.

Course Number	PH6115/PH6215
Course Credit	2-2-0-4
Course Title	Scanning Probe Microscopy
Learning Mode	Lectures, Assignments, Discussions, Hands-on experience
Learning Objectives	The objective of this course is to present a unified discussion on the fundamentals of atomic force microscopy and scanning tunneling microscopy. This will allow students to learn materials characterization and manipulation at the nanoscale using these probe based techniques.
Course Description	The course covers instrumental aspects of scanning probe microscopy including atomic force microscope and scanning tunneling microscope. The course summarizes the basics of the tip-sample interaction and contact mechanics. In addition, this course introduces probe based physical property measurement of materials with nanoscale resolution.
Course Outline	Tip-Surface Interaction AFMNon-contact regime Intra-molecular Interactions, Electric Dipoles, Inter-molecular interactions: Physical models, ion-dipoles, Keesom forces, Dispersion Force AFM Contact regime Hamaker theory, surface energies, Dejaugin approximation, contact mechanics, Hertz model, JKR model, DMT model. Atomic Force Microscope (AFM) AFM components, AFM calibration, analysis of AFM images in each mode. Force Spectroscopy Cantilever mechanics, Approach-retract curves, Processing Force curves, Modulus and adhesion Maps, Lateral Force Microscopy, Conducting Atomic Force Microscopy, Nanoindentation. Point Mass Model of Dynamic AFM, frequency response, conservative and dissipative interaction forces. Analytical theory of Dynamic AFM : Excited probe interacting with sample (linear theory), Amplitude and Frequency modulation AFM, Non-linear/dissipative interactions, Attractive and Repulsive Regimes and Phase Contrast Modualtion AFM. Scanning Tunneling Microscope (STM) Quantum tunneling, WKB approximation for field emission, STM instruments and its components, Scanning tunneling spectroscopy, Inelastic electron tunneling spectroscopy, STM image analysis. Special AFM techniques for Electrostatics/Magnetic/Biological systems Measuring Electrostatic Forces and Magnetic Forces, Dynamic AFM in Liquid, Scanning non-linear dielectric microscopy (SNDM) for measuring defect state densities at interfaces, Memristive applications, organic electronics and spintronics, Atomic/molecular manipulations, AFM-based lithography, spin-polarized STM. MFM, PFM, NSOM, Other SPM techniques. Recitation: This will be on one of the topics listed above. Mini project: This will be on one of the topics listed above. Additional assignments/lab experiments: 1. Measurement of force-distance curve and estimation of the spring constant of the cantilever. 2. Estimation of local density of states on the surface of metals and semiconductors using STM.

	3. Nanoindentation and hardness measurements on thin films using AFM probe.
Assessment Method	Tutorial, Assignment, Mid-semester and End-semester examination
Suggested Readings:	• Scanning Probe Microscopy: Atomic Force Microscopy and Scanning Tunneling Microscopy, Bert Voigtlander, Springer-Verlag, Berlin, Heidelberg, 2015. • Scanning Probe Microscopy and Spectroscopy: Methods and Applications, Roland Wiesendanger, Cambridge Univ. Press, 1994. • Scanning Probe Microscopy: Electrical and Electromechanical Phenomena at the Nanoscale, Sergei V. Kalinin, Alex Gruverman, Springer-Verlag, New York, 2007.

Course Number	PH6116/PH6216
Course Credit (L-T-P-C)	2-2-0-4
Course Title	Biophotonics
Learning Mode	Lectures
Learning Objectives	Theory and fabrication details of several optical and photonic devices for several biological and biomedical applications
Course Description	This course is designed to provide specialized knowledge related to an emerging field of optics and photonics.
Course Content	• Fundamentals of light-matter interaction [absorption, fluorescence, phosphorescence, Raman scattering, Mie-scattering, Second harmonic generation (SHG), and two-photon absorption], Introduction to biological cells, viruses, protein molecules • Optical imaging of cells (using various optical microscopes): Optical microscopy, Bio-imaging with a confocal fluorescence microscope, evanescent wave microscope, SHG and two-photon microscopes, Different techniques to achieve super-resolution with optical microscopes, Quantum imaging • Biodetection in real-time (using optical biosensors): Importance of biodetection in real time, detection of bioanalytes (viruses/protein molecules) using evanescent based fiber-optic biosensor, photonic crystal biosensor and whispering gallery mode biosensor. • Förster resonance energy transfer (FRET) to study protein-protein interactions. • Supercontinuum sources for Biophotonics applications. • Optical trapping and manipulation for biomedical applications • Advanced photodynamic therapy (APT) • Nanoplasmonic biophotonics: Introduction to Nanoplasmonics, Applications of nanoplasmonics in optical trapping, biosensing, APT, and Raman scattering of nanometer-sized bioanalytes Additional contents for Ph.D. students: Theoretical simulations on the following topics: Rayleigh scattering, Mie scattering, Evanescent field generation and properties, Linearly polarized (LP) modes of optical fibers, FRET, Super-resolution microscopes, Near & Far-field optical properties of single plasmonic nanostructures, Optical properties of metal thin films, and Optical modes of dielectric microresonators
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination
Suggested Readings:	
Textbooks:	• X. Shen and R. V. Wijk, *Biophotonics,* Springer, USA, 2005. • P. N. Prasad, *Introduction to Biophotonics,* Wiley-Interscience, New Jersey, 2003. • X. Shen and R. V. Wijk, *Biophotonics*, Springer, USA, 2005. • L. Pavesi and P. M. Fauchet, *Biophotonics,* Springer, Berlin, 2008. • B. D. Bartolo and J. Collins, *Bio-photonics: Spectroscopy, imaging, sensing and manipulation,* Springer, Netherlands, 2009.
References:	• R. K. Wang and V. V. Tuchin, *Advanced Biophotonics,* CRC press, New York, 2014.

Course Number	PH6117/PH6217
Course Credit (L-T-P-C)	2-2-0-4
Course Title	Magnetic Materials and Applications
Learning Mode	Lectures
Learning Objectives	The objectives of the course are to introduce the student to the importance of magnetic materials and their application. The student will understand the magnetic sensors. Memory devices based on magnetic materials are elaborately taught. Different kinds of magnetoresistance are taught in this material. The physics formulation of magnetism is taught which helps to understand the magnetic materials. The permanent magnet is an integral part of modern technology which is taught in this course. Also, the objective of the course is to understand magnetism at the small size.
Course Description	The course discusses different kinds of magnetic materials. The different kinds of magnetoresistance are discussed here. The physics formulation of magnetism observations is discussed elaborately. Applications of magnetic materials in different technologies are discussed elaborately. Superconductivity is discussed along with its applications.
Course Content	Atomic magnetism, diamagnetism and paramagnetism, Hund's rule, Solid state magnetism, 3d transition metals and 4f rare earths, Magnetic interactions, direct exchange and indirect exchange, Magnetic order, Ferromagnetism, Ferrimagnetism, Antiferromagnetism, Spin glasses; Magneto-crystalline anisotropy, Shape anisotropy, Induced magnetic anisotropy, Stress anisotropy, Magnetic surface and interface anisotropy; Magnetic Domain structures and magnetization dynamics, Domain walls, Closure domains, closure domains, damping processes, ferromagnetic resonance; Magnetoresistivity, Anisotropic Magnetoresistance (AMR), Giant Magnetoresistance (GMR), Colossal Magnetoresistance (CMR), Tunneling Magnetoresistance (TMR), Spin polarization, Andreev reflection, Point contact Andreev reflection (PCAR) spectroscopy, BTK theory; Soft Magnetic Materials , Eddy currents, losses in electrical machines, applications in Transformers, Flux-gate magnetometers, recording heads, magnetic shielding, anti-theft systems; Hard Magnetic Materials, Permanent Magnets, operation and stability, applications in motors, loudspeakers, hard drives, wigglers, undulators; Magnetism in reduced dimensions, Atoms, Clusters, Nano-particles, Nanoscale wires, Thin films, Multilayers, Superparamagnetism, Exchange bias, Interlayer exchange coupling (non-magnetic spacer, AFM spacer), Spin engineering, Spin valves. Recitation: This will be on one of the topics listed above. Mini project: This will be on one of the topics listed above. Additional assignments: Related to above listed topics.
Assessment Method	Assignments, Mini projects, Quiz, Mid-semester examination, End-semester examination.
Suggested Readings:	
Textbooks:	• Magnetic Materials: Fundamentals and Applications, Nicola A. Spaldin, 2nd Edition, Cambridge Univ. Press.
References:	• Magnetism and Magnetic Materials, J.M. D. Coey, 1st Edition, Cambridge Univ. Press, 2010. • Principles of Magnetism and Magnetic Materials, K. H. J. Buschow and F. R. deBoer, Kluwer Academic Publ., New York, 2004.

Course Number	PH6118/PH6218
Course Credit	2-2-0-4
Course Title	Fourier Optics and Holography
Learning Mode	Lectures
Course Description	This course gives introduction to Fourier Transform and its applications towards Holography and Optical image processing.
Course Outline	Signals and systems, Fourier transform (FT), FT theorems, sampling theorem, Space-bandwidth product; Review of diffraction theory: Fresnel-Kirchhoff formulation, FT properties of lenses; Coherent and incoherent imaging. Basics of holography, in-line and off-axis holography, plane and volume holograms, diffraction efficiency; Recording medium for holograms; Applications of holography: display, microscopy; memories, interferometry, Non-destructive testing of engineering objects, Digital Holography, Digital holographic microscope, 3D display; Analog optical information processing: Abbe-Porter experiment, phase contrast microscopy and other simple applications; Coherent image processing: Vander Lugt filter; joint-transform correlator; optical image encryption. Recitation: This will be on one of the topics listed above. Mini project: This will be on one of the topics listed above. Additional assignments: Related to above listed topics.
Assessment Method	Mid-semester examination, End-semester examination, Assignment, Quiz, Seminar
Suggested Readings:	
Textbooks:	• J. W. Goodman, Introduction to Fourier Optics, 3rd Ed. 2005. • M. Born and E. Wolf, Principles of Optics, 7th Ed., Cambridge Univ. Press, 1999. • P. Hariharan, Optical Holography: Principles, Techniques, and Applications, 2nd Ed., Cambridge Univ. Press, 1996. • B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, 1991.
References	• E. G. Steward, Fourier Optics: An Introduction, 2nd Ed., Dover Publs., 2004. • Robert K. Tyson, Principles and Applications of Fourier Optics, IOP Publs., Bristol, UK, 2014. • U. Schnars and W. Jueptner, Springer, 2005. • Joseph Rosen, Holography, Research & Technologies, InTech, 2011

Course Number	PH6120/PH6220
Course Credit	2-2-0-4
Course Title	Particle Physics
Learning Mode	Lectures
Course Description	This course deals with the basic properties of elementary particles, their interactions and decays. Students will learn basics of weak interactions, QCD, symmetries, symmetry breaking, the Standard Model and the origin of mass. This course will help the students to develop the knowledge base necessary to pursue research in elementary particle physics/high energy physics, particle astrophysics.
Course Outline	Natural Units; Basic overview of four fundamental interactions; Elementary Particles and their characteristics. Static model ($SU(3)_f$) of quarks; Eightfold way; Concept of color, Concept of Asymptotic freedom and confinement; Summary of quantum numbers of all quark flavours. *Weak interactions:* Fermi theory, Calculation of decay widths of muon and charged pion ($\pi^{\pm}$). *Structure of Hadrons and QCD:* Elastic electron-proton (e-p) scattering, form factors, Deep-inelastic e-p scattering, structure fuctions, Bjorken scaling, Parton model, Mandelstam variables, Compton scattering and gluon emission scattering amplitudes and cross-sections in terms of Mandelstam variables, scaling violation. *Gauge theory of fundamental interaction:* Internal symmetries, Global and local gauge invariance. *Gauge theory of weak interaction:* Spontaneous symmetry breaking (SSB) and Higgs mechanism, Electroweak unification, Glashow-Weinberg-Salam model of electroweak symmetry breaking (EWSB) - $W^{\pm}$, Z^0 masses and fermion masses. Parity violation, CP violation, Quark Mixing and CKM matrix. Neutrino mass and neutrino oscillations; Reasons for looking Physics Beyond the Standard Model (Qualitative ideas). Collider Experiments: lepton vs Hadron collider (e.g., LEP, LHC etc.). Recitation: This will be on one of the topics listed above. Mini project: This will be on one of the topics listed above. Additional assignments: Related to above listed topics.
Assessment Method	Assignments, Quizzes, Presentation, Mid-semester and End-semester examination
Suggested Readings:	
Textbooks:	Quarks and Leptons: An Introductory Course in Modern Particle Physics, Francis Halzen and Alan D. Martin; John Wiley & Sons, 1984. Introduction to High Energy Physics, D.H.Perkins, Cambridge Univ. Press, 2000. Introduction to Elementary Particles, D. Griffiths, Wiley, 2008. Gauge Theories in Particle Physics, T.-P. Cheng and L.-F. Li, Oxford Univ. Press, 1984.

References:	An Introduction to Quantum Field Theory, M.E. Peskin and D.V. Schroeder; W. Press, 1995. An Introductory Course of Particle Physics, Palash B. Pal; CRC Press, 2014. Introduction to Gauge Field Theory, D. Bailin & A. Love, CRC Press, 1993. Modern Elementary Particle Physics, G. Kane; Addison Wesley, 1987. The Standard Model: A Primer, Burgess and Moore; Cambridge Univ. Press, 2012

Course Number	PH6121/PH6221
Course Credit	2-2-0-4
Course Title	Soft Matter Physics
Learning Mode	Lectures
Course Description	This course deals with the Forces, energies and time scales, Molecular order in soft matter and gives a description of Soft matter in nature
Course Outline	Unit I: Forces, energies and time scales in soft matter Thermodynamic and statistical aspects of intermolecular forces, Boltzmann distribution and chemical potential, pair potential, strong intermolecular forces – covalent and Coulomb interactions, Van der Waals forces, steric forces, hydrogen bonding, response of matter to a shear stress, viscoelastic behavior, relaxation time. Unit II: Molecular order in soft matter Phase transitions, order parameter, liquid crystallinity - nematic, cholesteric, smectic, columnar; colloids and gels, crystallinity in polymeric materials, weight dispersion in polymers, random walk models, dimensions of polymer chains, persistence length of flexible chains, radius of gyration, Flory-Huggins theory. Unit III: Soft matter in nature Supramolecular self-assembly, aggregation in amphiphilic molecules, soluble and insoluble monolayers, critical micellar concentration, effect of dimensionality and geometry, spherical and cylindrical micelles, bilayers and vesicles, biological lipid membranes, nucleic acids and proteins, surfactants, soaps and emulsions, technological applications of soft matter. Recitation: This will be on one of the topics listed above. Mini project: This will be on one of the topics listed above. Additional assignments/lab experiments: 1. Formation and stability of foams for cleaning applications. 2. 2D self-assembly of amphiphilic molecules 3. Observation of phases of liquid crystals using polarizing optical microscope. 4. Adhesion and friction mapping on polymer surfaces.
Assessment Method	Assignments, Quizzes, Seminar, Mid-semester examination, End-semester examination
Suggested Readings:	
Textbooks:	Soft Condensed Matter, R. A. L . Jones, Oxford Univ. Press, 2002. Intermolecular and Surface Forces, Jacob N. Israelachvilli, Academic Press, Elsevier, 2011.
References:	The Physics of Liquid Crystals, P.G. de Gennes and J. Prost, Oxford Univ. Press, 2003. Principles of Condensed Matter Physics, P.M. Chaikin & T.C. Lubensky, Cambridge Univ. Press, 2004.

Course Number	PH6122/PH6222
Course Credit	2-2-0-4
Course Title	Quantum Materials
Learning Mode	Lectures
Course Description	The course covers various quantum mechanical phenomenon occurring in condensed matter systems and the ways to tune and control them, for designing various quantum-controlled operations to develop relevant devices and technologies.
Course Outline	Theories of electronic structure: Fermi Liquid Theory, Model Hamiltonian, Density Functional Theory Quantum ordering: Superconductivity; Quantum Criticality; Magnetism; Spin Ice and magnetic monopoles; Topological materials; Weyl Semimetal; Majorana Fermions; Skyrmions; Quantum hall effect; Dirac Materials and Van der Waals magnet; Moiré lattice and Twistronics; Metamaterials and photonic crystals Application: Qubits; quantum simulation; quantum technology (quantum communications, quantum sensing and metrology, and quantum computing) Experimental Probes: Large scale facilities (ex: Neutron, muon and Angle resolved photoemission spectroscopy, synchrotron beamlines); Local probes for quantum phenomenon Reecitation: This will be on one of the topics listed above. Mini project: This will be on one of the topics listed above. Additional assignments: Related to above listed topics.
Assessment Method	Quiz, Mid-semester examination, End-semester examination
Suggested Readings:	
Textbooks:	• J Annett, Superconductivity, Superfluids and Condensates, Oxford Univ. Press • Quantum Magnetism, edited by Ulrich Schollwöck, Johannes Richter, amian J. J. Farnell, Raymod F. Bishop, Springer • Topological Insulators, Shun-Qing Shen, Springer
References:	• A. Damascelli, Z. Hussain and Z.X. Shen, Rev. Mod. Phys. 75, 473, 2003. • A.J. Schofield, 1999, Contemp. Phys. 40, 95. • D. Shoenberg, *Magnetic Oscillations in Metals*, Cambridge Univ. Press. • C. Bergemann, A. P. Mackenzie, S. R. Julian, D. Forsythe, and E. Ohmichi, Adv. Phys. 52, 639, 2003. • H. Ibach and H. Luth, *Solid-state Physics: An Introduction to Principles of Materials Science*, Springer-Verlag. • N.W. Ashcroft and N.D. Mermin, *Solid State Physics*, Saunders College Publs. • Quantum Information, Stephen Barnett, Oxford Univ. Press • Quantum Hybrid Electronics and Materials edited by Yoshiro Hirayama, Kazuhiko Hirakawa, Hiroshi Yamaguchi, Springer • Principles of Neutron Scattering from Condensed Matter, Andrew T. Boothroyd, , Oxford Univ. Press • Muon Spin Rotation, Relaxation, and Resonance: Applications to Condensed Matter, Alain Yaouanc, Pierre Dalmas de Réotier, Oxford Univ. Press • An Introduction to Synchrotron Radiation: Techniques and Applications, 2nd Edition, Philip Willmott, Wiley.

Course Number	PH6123/PH6223
Course Credit (L-T-P-C)	2-1-2-4
Course Title	Low Temperature Techniques
Learning Mode	Lectures
Learning Objectives	Complies with Program Goals 1, 2 and 3
Course Description	Equips the students with the techniques in Low Temperature Physics and allows them to apply these techniques in both research and industrial scenarios
Course Content	Introduction to low temperature physics: Joule-Thompson Expansion, Generation and measurement of low temperatures; Liquid Nitrogen and Liquid Helium as a cryogen for achieving low temperatures-phase diagram, superfluid Helium and Helium-3; Cooling and Cryogenic Equipment, Dewars, Cryostats and Superconducting Magnets, pumps and plumbing, temperature sensing; Magnetic cooling; Dilution Refrigerators; Variable temperature inserts; Vibration isolation, electric and magnetic isolation; Bridges for susceptibility measurements; Cryogenic electronics, low temperature preamplifier, high frequency methods and electromagnetic compatibility; Materials compatible for low temperature system design; Safety at low temperatures; Applications: NMR, MRI, solid state quantum qubits, Tokamak Recitation: This will be on one of the topics listed above. Mini project: This will be on one of the topics listed above. Additional assignments: Deal with design of a variable temperature insert (VTI)
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination
Suggested Readings:	
Textbooks:	• Robert C. Richardson and Eric N. Smith, Experimental Techniques in Condensed Matter Physics at Low Temperatures, Frontiers in Physics, Addison Wesley, 1988. • P. V. E. McClintock, D. J. Meredith, J. K. Wigmore, Low-Temperature Physics: an introduction for scientists and engineers, Springer Reprint, 2012.
References:	• Frank Pobell, *Matters and Methods at Low Temperature*, 3rd Edition, Springer, 2007. • Randall Barron, *Cryogenic Systems*, 2nd Edition, 2021.

Course Number	PH6124/PH6224
Course Credit (L-T-P-C)	2-2-0-4
Course Title	Nanoscience and Nanocharacterization
Learning Mode	Lectures and hand-on-skills
Course Description	The course first provides the fundamental physics knowledge that is required for the understanding of Nanoparticles, especially its physical properties. These are dealt in Module-1 and Module-2. In Module-3, the approach to synthesis of Nanoparticles is dealt. Module-4 deals with various types of Nanoparticles and it properties. Module-5 discusses about various spin-off field of research related to Nanoparticles. Lastely, Module 6 discusses about nanofabrication technique and nanocharacterization techniques and understanding on results obtained.
Course Outline	Module-1: Background to Nanoscience, length scales and size effects in smaller systems-pre quantum, review of quantum and statistical mechanics, quantum wells, quantum wires and quantum dots, band structure and density of states, inter band transitions; Module-2: Electrical transport in nanostructures – Quantum confinement, Coulomb blockade and Conductance quantization, conduction mechanisms -Thermionic effect, Schottky and Poole-Frenkel effect, Arrhenius type thermally activated conduction, variable range hopping conduction and Polaron conduction; Module-3: Synthesis -Top –down and bottom-up approach, characterization of nanostructures; Module 4: Semiconductor quantum dots, self assembled monolayers, Metal nanoparticles, core-shell nanoparticles, nano-shells, new nanostructures - carbon (fullerenes, CNTs, graphene, nanodiamond), BN nanotubes; Nanotribology and Nanorheology, stiction, van der Waal's and Casimir forces; Module-5: Applications in Nanobiology, Nano sensors, Nanoelectronics, Nanomedicines, Molecular nanomachines. Module 6: hands-on-skills: Measurement of contact resistance using TLM structure, Nanostructure fabrication using colloidal lithography and Hole-colloidal lithography processes, Electrical and Material characterizations, Applications in Nano-gas-sensors. Reports submission.
Assessment Method	Mid-semsester and End-semester examination
Suggested Readings:	• Nano – The Essentials, T. Pradeep, McGraw-Hill Education, 2014. • Introduction to Nanoscience, G. L. Hornyak, J. Dutta, H. F. Tibbals, A. Rao, CRC Press, 2008. • Introduction to Nanoscience and Technology, K. K. Chattopadhyay, A. N. Banerjee , PHI Learning Private Ltd., 2009. • Introductory Nanoscience, Masuro Kuno, Garland Science, 2011. • Introduction to Nanotechnology, Poole and Owen, Wiley Indian Edition, 2010. • Nanophysics and Nanotechnology, Edward L. Wolf, Wiley-VCH, 2006. • Nanotechnology, Lynn E. Foster, Pearson, 2011. • Quantum Mechanics, J. J. Sakurai. • Statistical Mechanics, Kerson Huang. • Fundamentals and Applications of Nanomaterials, Z. Guo and Li Tan. • Nanoelectronics and Information Technology, Rainer Waser, Wiley-VCH, 2005.

Course Number	PH6125/PH6225
Course Credit (L-T-P-C)	2-2-0-4
Course Title	Quantum Transport in Mesoscopic Systems
Learning Mode	Lectures
Course Description	Students will learn theory of quantum transport in low-dimensional systems and apply them to understand and explain experimental observations on electron and thermal transports in mesoscopic systems.
Course Content	Introduction: Introduction to mesoscopic physics, basic length and energy scales, quantum structures, transport regime, Boltzmann transport equation Diffusive transport: Drude model, Einstein relation, classical size effect, weak localization Ballistic transport: Conductance quantization, Landauer Formula, Landauer-Büttiker formalism, Non-Equilibrium Green's function formalism Transport in Coulomb blockade (CB) regime: Rate equations, Sequential tunneling, CB oscillations, CB staircase. Heat Transport: Heat current, thermal conductance, Seebeck and Peltier coefficients Quantum Hall effect: Landau levels, edge states, quantum Hall effect (integer and fractional) Noise in mesoscopic systems: Current fluctuation, phase breaking, thermalization, inelastic scattering Mini-Projects: 1. Computation of zero-bias conductance in some low-dimensional systems usingtight-binding model and NEGF techniques. 2. Computation of I-V characteristics in quantum-dot nano-junctionswithin CB regime using quantum master equation
Assessment Method	Assignments, Quizzes, Mid-semester examination and End-semester examination
Suggested Readings:	
Textbooks:	• Introduction to Mesoscopic Physics, 2nd Edition, Y. Imry, Oxford Univ. Press, 2008. • Mesoscopic Physics: An introduction, C. Harmans, TU Delft, 2003. • Quantum Transport, Lecture Notes, Yuri M. Galperin, Lund University, 1998. • Quantum Transport: Atom to Transistor, S. Datta, Cambridge Univ. Press, 2005. • Quantum Transport. Introduction to Nanoscience, Y.V. Nazarov, Y.M. Blanter. Cambridge Univ. Press, 2009.
References:	• Transport in Nanostructures, David Ferry, Cambridge Univ. Press, 1995. • M. Baldo, Introduction to Nanoelectronics, Lecture Notes, MIT, 2011. • S. Datta, Electronic Transport in Mesocopic Systems; Cambridge Univ. Press, 1995.

Course Number	PH6126/PH6226
Course Credit (L-T-P-C)	2-2-0-4
Course Title	Introductory Biophysics
Learning Mode	Lectures
Course Description	Students will be equipped with thermodynamics at a molecular level, with structure function relation of bio-macromolecules like DNA, RNA, Protein and membranes. The importance of molecular recognition and experimental methods for their determination.
Course Content	Review of basic concepts in thermodynamics and statistical mechanics: Entropy, Free energy, Random walk-in biology, Introduction to force, time and energy at mesoscopic scales. Hydrophobicity, Ficks law of diffusion, Rigidity and elasticity. Bio-macromolecules: Nucleic acid structure and properties, Protein structure, Ramachandran plot, Protein folding problem, Levinthal Paradox, enzyme kinetics, Membrane structure and Ion channels, Central Dogma, Gene Expression, Genetic code. Molecular Recognition: Thermodynamics of Binding, Allostery and Cooperatively, Specificity of macromolecular recognition, Protein-Nucleic acid Interaction, Protein-Protein Interaction. Experimental methods for structure-function relation in biopolymers: Transient absorption and fluorescence, FRET, FCS, Forced spectroscopic technique (optical tweezers, AFM and Magnetic trap).
Assessment Method	Assignments, Quiz, Seminar, Mid-semester examination and End-semester examination. Additional presentation and assignments will be given from the experimental design and analysis.
Suggested Readings:	
Textbooks:	Biophysical Chemistry; Cantor and Schimmel I, II and III. **ISBN-13**: 978-0716711902, ISBN-13: 978-0716711889 and ISBN-13: 978-0716711926. The Physics of Living process; A Mesoscopic Approach. T. A. Waigh**ISBN**: 978-1-118-44994-3. Molecular Biophysics, Structure in Motion. M. Daune. **ISBN-13:** 978-0198577829.
References:	Molecular Driving Forces; Statistical Thermodynamics in Biology, Chemistry, Physics and Nanoscience. Ken A Dill and Sarina Bromberg. ISBN- 0815320515. John Kuriyan, Boyana Konford, and David Wemmer, The Molecules of Life: Physical and Chemical Principles, Garland Science. Random Walks in Biology, Howard C. Berg, Princeton Univ. Press.11

Course Number	PH6127/PH6227
Course Credit	2-2-0-4
Course Title	Spintronics
Learning Mode	Lectures
Course Description	The course starts with the basics of quantum spin and magnetism, thereafter developing on advanced topics in spin-based electronics, different phenomenon, device design, control and applications. It covers areas of modern-day technological developments in this area with advanced materials engineering.
Course Outline	Background and overview of spin electronics: Classes of magnetic materials; The early history of spin (Bohr model, quantization, Stern-Gerlach experiment); Quantum Mechanics of spin; The Bloch sphere; Spin-orbit interaction (ex: Rashba, Dresselhaus interaction) Exchange interaction; Spin Hamiltonians; Spin relaxation mechanisms; spin relaxation in a quantum dots; The spin Galvanic effect; Spin diffusion and lifetime; Hanle Effect; Basic electron transport; Spin-dependent transport; Spin dependent tunnelling; Magnetoresistance, GMR, TMR, Spin-Valve and exchange-bias, Andreev Reflection at ferromagnet and Superconductor interfaces Spin-transfer torques; Spin-transfer drive magnetic dynamics; Current-driven switching of magnetization and domain wall motion; Domain wall scattering and Current-Induced switching in ferromagnetic wires Spin injection; spin accumulation and spin current; Spin hall effect; Silicon based spin electronic devices; Spin transistors and Datta-Das transistor; Materials for spin electronics; Heusler alloy and half-metals Spintronics technology: Read Heads; MRAM; Field Sensors; Spintronic Biosensors; Quantum Computing with spins; 2D material based spintronics; Topological spintronics; superconducting spintronics Reecitation: This will be on one of the topics listed above. Mini project: This will be on one of the topics listed above. Additional assignments: Related to above listed topics.
Assessment Method	Quiz and Assignments, Mid-semester and End-semester examination
Suggested Readings:	
Textbooks:	• Introduction to Spintronics, S. Bandyopadhyay, M. Cahay, CRC Press, 2008. • Nanomagnetism and Spintronics, Ed., Teruya Shinjo, Elsevier, 2009. • Concepts in Spin Electronics, edited by S. Maekawa, Oxford Science Publs., Oxford Univ. Press.
References:	• Handbook of Spintronics, edited by Y. Xu, David Awschalom, J. Nitta, Springer, 2015 • Spintronic Materials and Technology, Y. B. Xu and S.M.Thompson, Taylor & Francis, 2006. • Magnetism in Condensed Matter Physics, Stephen Blundell, Oxford Univ. Press

Course Number	PH6128/PH6228
Course Credit	2-1-2-4
Course Title	Advanced Computational Physics
Learning Mode	Lectures & Laboratory
Learning Objectives	To make students capable of solving specific advanced physics problems using the numerical techniques.
Course Description	The student will learn computationally solving problems related to Quantum scattering, Many-electron formalism, Classical and quantum molecular dynamics, Statistical physics etc. The course has class room discussion which will be completed in computational lab by developing a code based on it.
Course Outline	Recapitulation of numerical techniques and errors of computation (rounding, truncation); Classical molecular dynamics simulations, Verlet algorithm, predictor corrector method, Continuous systems, hydrodynamic equations, particle in a cell and lattice Boltzmann methods; Schrodinger equation in a basis: numerical implementation of Numerov method, matrix methods and variational techniques; applications of basis functions for atomic, molecular, solid-state and nuclear calculations; Elements of Density functional theories; Monte Carlo simulations, Metropolis, critical slowing down and block algorithms with applications to classical and quantum lattice models. Assignments and mini projects on scattering off cylindrical targets, quantum resonance analysis in spherical and cylindrical targets, 1-D and 3-D problems using quantum Monte-Carlo methods, phase transitions in spin systems, additional reading assignments on path integral Monte-Carlo (PIMC) technique, handling symmetry-broken systems using PIMC, usage of Dirac-Fock method for electronic structure studies.
Assessment Method	Mid-semester written examination, Mid- semester laboratory examination, End- semester written examination, End- semester laboratory examination, Quiz
Suggested Readings:	
Textbooks:	• J. M. Thijssen, Computational Physics, Cambridge Univ. Press, 2nd Edition, 2007. • Tao Pang, An Introduction to Computational Physics, Cambridge Univ. Press, 2nd Edition, 2006. • Steven E. Kooning and Dawn C. Meredith, Computational Physics, Westview Press, 1990. • An Introduction to Computer Simulation Methods: Applications to Physical Systems, 3rd Edition, Harvey Gould, Jan Tobochnik, Wolfgang Christian, Addison-Wesley, 2006.
References:	• Rubin H. Landau, Manuel José Páez Mejía, Cristian C. Bordeianu, A Survey of Computational Physics: Introductory Computational Science, Vol. 1, Princeton Univ. Press, 2008. • Werner Krauth, Statistical Mechanics: Algorithms and Computations, Oxford Masters Series in Physics, 2006.

Course Number	PH6129/PH6229
Course Credit	2-2-0-4
Course Title	Advanced Quantum Theory of Collisions
Learning Mode	Lectures
Course Description	The course aims at an advanced level understanding of collision physics. The course starts with elastic scattering of non-Coulombic potentials and the deals with Coulomb scattering. It further deals with resonant scattering and gives an introduction to Feynman diagrams.
Course Outline	Quantum collisions: Optical theorem, Method of Partial wave, Phase shift analysis, Resonances, Integral equation of potential scattering; Lippman-Schwinger equation, Coulomb scattering. Occupation number representation: creation, destruction and number operators, Many-particle Hamiltonian in occupation number representation, The Hartree-Fock method and the free electron gas, Exchange, statistical and Fermi-Dirac correlations, Time dependence and Dirac picture of quantum mechanics, Dyson's perturbation expansion for the evolution operator. Feynman Graphs: Creation and destruction operator in the interaction picture, First order Feynman diagrams, Second and higher order Feynman diagrams. Resonances in Quantum scattering: Scattering of partial wave, Resonances in quantum collisions, Breit-Wigner formalism, Fano parameterization of Breit-Wigner formula, Resonance life time, Time delay in scattering and photoionization. Computational assignments and mini projects on electron scattering off spherical and cylindrical barriers/wells, atom-atom scattering, time-delay in collisions, fitting the Breit-Wigner parameters for atom-atom scattering, Coulomb scattering, phase-shift analysis, theory of light-matter interactions.
Assessment Method	Mid-semester examination, End-semester examination, Assignment, Quiz
Suggested Readings:	
Textbooks:	• Quantum Collision Theory, C. J. Joachain, Elsevier, 1984. • Many-electron Theory, S. Raimes, North-Holland Publishing Company, 1972. • Quantum Theory of Many-Particle Systems, A. L. Fetter and J. D. Walecka, Dover Books, 2003.
References	• Atomic Collisions and Spectra, U. Fano and A. R. P. Rau, Academic Press, 1986. • Relativistic Quantum Theory of Atoms and Molecules, I. P. Grant, Springer, 2007. • Quantum Theory of Scattering, T. Wu and T. Ohumura, Prentice Hall, 1962. • Atomic Structure Theory, W. R. Johnson, Springer, 2007.

Course Number	PH6130/PH6230
Course Credit	3-1-0-4
Course Title	Condensed Matter Physics-II
Learning Mode	Lectures
Course Description	This course deals with review of crystal structures, correlated electrons, Magnetism, Dielectric and Optical properties, ferro electrics and superconductivity
Course Outline	Review of Crystal structures, crystal symmetry, centrosymmetric and non-centrosymmetric crystals and their properties Correlated Electrons: Fermi-Liquid Theory, Hartree-Fock theory and beyond, Density Functional Theory, Model Hamiltonians (Hubbard model, t-j model and etc) Magnetism: Weiss theory of ferromagnetism, Curie-Weiss Law for susceptibility, Heisenberg model for magnetic ordering, Spin chain, XY model, Spin waves and magnons, magnon contribution to specific heat, Bloch's $T^{3/2}$ Law, Antiferromagnetic order, Neel Temperature, Ferromagnetic domains, Magnetic anisotropy energy, hysteresis. Dielectric and Optical properties: The dielectric function: the dielectric function for a harmonic oscillator, dielectric losses of electrons, Kramers-Kronig relations, Interaction of phonons and electrons with photons, Dielectric function of an interacting electron gas (Lindhard's expression), Static screening, Thomas-Fermi theory of Screening, Screened impurity, Kohn effect, Friedel Oscillations and sum rule, Dielectric constant of semiconductor, Plasma oscillations, Optical properties of metals, skin effect and anomalous skin effect. Ferroelectrics: Linear and Non-linear dielectrics, Langevin theory of dielectrics, Ferroelectric crystals, Classification of ferroelectric crystals, Polarization catastrophe, Soft optical phonons, Landau theory of phase transition: first and second order transition. Superconductivity: Ginzburg-Landau theory, BCS wavefunction, Energy gap, BCS ground state, unconventional superconductor, Josephson effect, SQUID Recitation: This will be on one of the topics listed above. Mini project: This will be on one of the topics listed above. Additional assignments: Computational tasks related to above listed topics.
Assessment Method	Mid-semester examination, End-semester examination, Assignment, Quiz
Suggested Readings:	
Textbooks	▪ N. W. Ashcroft and N. D. Mermin, Solid State Physics, HBC Publ., 1976. ▪ C. Kittel, Introduction to Solid State Physics, Wiley India, 2009. ▪ Dielectric Phenomena in Solides, Kao, Elsevier ▪ Broadband Dielectric Spectroscopy, F Karmer & A Schonhals ▪ Principles of the theory of Solids, J.M. Ziman, Cambridge Univ. Press

References	▪ A. J. Dekker, Solid State Physics, Macmillan, 2009. ▪ Dielectric Relaxation in Solids, A. K. Jonscher ▪ M. A. Omar, Elementary Solid State Physics, Addison-Wesley, 2009.