Handbook

Of

Physics

2020

School of Basic Science,

Indian Institute of Technology Mandi

Course Coordinator:

Dr. Ajay Soni (2018 onwards)

Dr. Hari Varma (2015-2018)

Faculty advisors:

Batch 2015-16: Dr. Pradyumna Pathak

Batch 2016-17: Dr. Bindu Radhamany

Batch 2017-18: Dr. Chandra Shekhar Yadav

Batch 2018-19: Dr. Kaustav Mukherjee

Batch 2019-20: Dr. Ajay Soni

Batch 2020-21: Dr. Suman K Pal

Laboratory staff

Ms. Sushma Verma

Program Faculty Group

 **Dr. Ajay Soni** Associate Professor Specialization: Nanomaterials and Experimental Condense Matter Physics Phone: 267154 Email: ajay@iitmandi.ac.in	 **Dr. C.S Yadav** Associate Professor Specialization: Low Temperature Physics Phone: 267135 Email: shekhar@iitmandi.ac.in
 **Dr. Hari Varma** Associate Professor Specialization: Atomic and Molecular physics Phone: 267064 Email: hari@iitmandi.ac.in	 **Dr. Kaustav Mukherjee** Associate Professor Specialization: Experimental Condensed Matter Physics Phone: 267043 Email: kaustav@iitmandi.ac.in
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 **Dr. Suman Kalyan Pal** Associate Professor Specialization: Fast and Ultrafast Laser Spectroscopy Phone: 267040 Email: suman@iitmandi.ac.in	 **Dr. Girish Sharma** Assistant Professor Specialization Theoretical condensed matter physics Phone: 267110 Email: girish@iitmandi.ac.in
 **Dr. Samar** Associate Professor Specialization: Information Theory, Wireless Communications Phone: 267107 Email: samar@iitmandi.ac.in	 **Dr. Sudhir Kumar Pandey** Assistant Professor Specialization: Condensed Matter Physics and Materials Science Phone:267066 Email: sudhir@iitmandi.ac.in
 **Dr. Nitu Kumari** Associate Professor Specialization: Nonlinear dynamics and Chaos Phone: 267109 Email: nitu@iitmandi.ac.in	 **Dr. Pradyuman K Pathak** Associate Professor Specialization: Quantum Optics, Quantum Information and Nanophotonics Email: ppathak@itmandi.ac.in

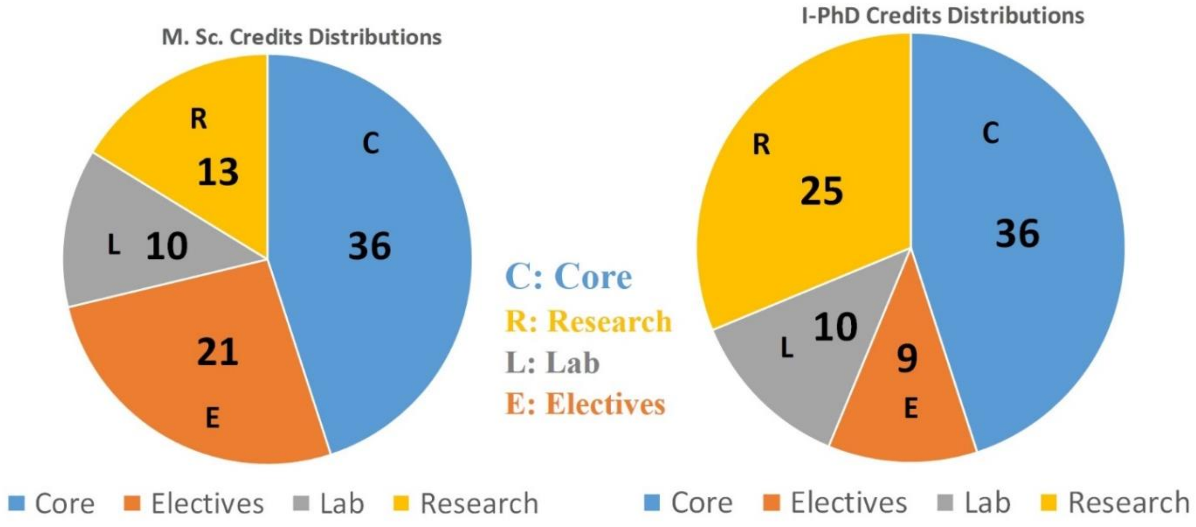
Course Content of I-PhD and M.Sc. Physics

Sem	Course	Credits (L-T-P-C)	M Sc	I-PhD
I	PH 511 Mathematical Physics	4-0-0-4	C	C
	PH 512 Classical Mechanics	4-0-0-4	C	C
	PH 513 Quantum Mechanics	3-0-0-3	C	C
	PH 514 Electronics	3-0-0-3	C	C
	PH 515P Physics Laboratory	0-0-5-3	C	C
	Technical Communications	1-0-0-1	C	C
	Elective (Outside Discipline)	**3-0-0-3**	**E1**	**-**
	PH 516 Research Project I	0-0-4-**2**	-	C
	PH 517 Research Project II (Winter)	**0-0-8-4**	-	C
			21	**20+4**
II	PH 521 Electromagnetic Theory	4-0-0-4	C	C
	PH 522 Statistical Mechanics	4-0-0-4	C	C
	PH 523 Cond. Matter Physics	3-0-0-3	C	C
	PH 524 Atom. Mol. Physics	3-0-0-3	C	C
	PH 525P Electronics Lab. Pract.	0-0-6-3	C	C
	Elective	**3-0-0-3**	**E2**	**-**
	PH 526 Research Project III	0-0-6-3	-	C
	PH 527 Research Project IV (Summer)	0-0-6-3	-	C
			20	**20+3**
III	PH 611P Exp. Res. Techniques	0-0-8-4	C	C
	PH 614 Seminar and Report	0-0-4-2	C	C
	PH 613 Spe. Topics. in QM	3-0-0-3	C	E1
	PH 518P PG Project-I PH 615P Mini Thesis-1	0-0-6-3	C -	- C
	Elective	3-0-0-3	E3	E2
	Elective	3-0-0-3	E4	E3
	Elective-5 (Outside Discipline)	**3-0-0-3**	**E5**	**-**
			21	**18**
IV	PH 621 Comput. Meth. Physics	2-0-4-4	C	C
	PH 519P PG Project-II PH 622 Mini Thesis –II	0-0-16-8 **0-0-16-8**	C -	- C
	Elective	3-0-0-3	E6	E4
	Elective	3-0-0-3	E7	-
			18	**16**
	Over All		***80***	***80***
V-VI	Electives (3) for 9 credits	3-0-0-3		09
			80	**89**

MSc: Total: 35 (T) + 10 (L) + 13 (R) + 21 (E) + 1 (TC) = 80 Credits

I-PhD: Total: 35 (T) + 10 (L) + 25 (R) + 9 (E) + 1 (TC) + 9 (AE) = 89 Credits

Course Credit Distribution for M Sc and I-PhD



List of Discipline Electives

1. PH 502 Optics and Photonics [3-0-0-3]
2. PH-503 Lasers and Applications [3-0-0-3]
3. PH 507 X-rays as a probe to study the material properties [3-0-0-3]
4. PH 508 Magnetism and Magnetic Materials [3-0-0-3]
5. PH 601 Mesoscopic Physics and Quantum Transport [3-0-0-3]
6. PH 603 Advanced Condensed Matter Physics [3-0-0-3]
7. PH 612 Nuclear and Particle Physics [3-0-0-3]
8. PH 701 Introduction to Molecular Simulations [2-0-4-4]
9. PH 706 Introduction to Stochastic Problems in Physics [3-0-0-3]
10. PH 605 Superconductivity
11. PH 591 Special Topics in High energy Physics [1-0-0-1]

Course Name : **Mathematical Physics**

Course Number : **PH-511**

Credits : **4-0-0-4**

Preamble: Mathematical physics provides firm foundation in various mathematical methods Developed and used for understanding different physical phenomena. This course provides mathematical tools to address formalisms used in the core course of masters level physics program.

Course Outline: The course starts with the vector calculus followed by the introduction to tensor analysis, and the concept of linear vectors space. The course continues to introduce differential equations and special function that are used to understand physical phenomena in different geometries. This followed by complex analysis and finally Fourier analysis and integral transforms are discussed.

Modules: Coordinate system, Vector calculus in Cartesian and Curvilinear coordinates, Introduction to Tensor analysis. Linear vector spaces, Gram-Schmidt orthogonalization, Self -adjoint, Unitary, Hermitian Operators, transformation of operators, eigenvalue equation, Hermitian matrix diagonalization. Ordinary differential equation (ODE) with constant coefficients, second order Linear ODE, Series Solution- Frobenius Method, Inhomogeneous linear ODE. Sturm Liouville equation Hermition operators - eigenvalue problem. Special functions: Bessel, Neumann, Henkel, Hermite, Legendre, Spherical Harmonics, Laguerre, Gamma, Beta, Delta functions. Complex analysis, Cauchy- Riemann conditions, Cauchy's Integral theorem, Laurent expansion, Singularities, Calculus of residues, evaluation of definite integrals, Method of steepest descent, saddle point. Fourier series general properties and application, Integral transform, Properties of Fourier transform, Discrete Fourier transform, Laplace transform, Convolution theorem.

Text books:

1. Mathematical methods for physicists by Arfken and Weber (Elsevier Academic Press, 6th edition, 2005)
2. Mathematical Methods in Physical Sciences by Mary L Boas (Willey 3rd edition, 2005)

References: 1. Mathematical Methods for Physics and Engineering: A Comprehensive Guide by K. F. Riley, M. P. Hobson (Cambridge India South Asian Edition, 2009)

2. Mathematical Methods for Physicists by Mathews, J., and Walker, R.L. (Imprint, New edition 1973)
3. Mathematics of Classical and Quantum Physics by F W Byron and R W Fuller (Dover Publication, New edition, 1992)
4. Methods of theoretical Physics Vol. I and II by P M Morse, H. Freshbach (Mc-GrawHill, 1953)
5. Advanced Engineering Mathematics by E Kreyszing (Wiley India Private Limited, 10th edition, 2003)
6. Mathematics for Physicists by Philippe Dennery and Andre Krzywicki (Dover Publications Inc. 1996).

Course Name **: Classical Mechanics**

Course Number **: PH-512**

Credits **: 4-0-0-4**

Preamble: Classical mechanics is one of the backbones of physics which deals with understanding the motion of particles. The present course covers, topics beyond the Newtonian mechanics for a proper base to many other branches of physics.

Course Outline: The course discusses in an abstraction of the mechanics with introduction to Lagrangian mechanics starting from Newtonian mechanics, variational principles of mechanics, Hamiltons equations of motion, canonical transformations, Poisson brackets and Hamilton-Jacobi equations. The concepts are illustrated using examples such as harmonic oscillator, two-body problem,rigid body dynamics, and small oscillations.

Modules: Introduction: Mechanics of a system of particles, Constraints, D'Alembert's Principle and Lagranges Equations, Simple Applications of the Lagrangian Formulation, Hamiltons principle, Some techniques of the calculus of variations, Derivation of Lagranges equations from Hamiltons principle, Conservation theorems and Symmetry properties.

The Central Force Problem: The Equivalent one-dimensional problem, and classification of orbits, Thevirial theorem, The Kepler problem.

The Kinematics of Rigid Body motion: Orthogonal transformations, Eulers theorem on the motion of a rigid body, Finite rotations, Infinitesimal rotations, Rate of change of a vector, Angular momentum andkinetic energy of motion, the inertia tensor and the moment of inertia. Euler equation of motion of rigid body.

Oscillations: Formulation of the problem, the eigenvalue equation and the principal axis transformation, Small oscillations, Frequencies of free vibration, Normal coordinates,Non-linear oscillations and the Chaos.

The Hamilton Equations of Motion: Legendre Transformations and the Hamilton Equations of Motion,Cyclic Coordinates and Conservation Theorems, The Principle of Least action. Canonical Transformations: The examples of canonical transformation Poisson Bracket and Canonical invarients, Liouvilles theorem. Hamilton-Jacobi theory and Action-Angle Variables the Hamilton-Jacobi equation for Hamiltons characteristic function.

Textbooks:

1. Classical Mechanics by H. Goldstein, (Pearson Education; 3 edition (2011))
2. The Variational Principles of Mechanics by Cornelius Lanczos (Dover Publications Inc. 1986)
3. Classical Mechanics by N.C. Rana and P.S. Joag, McGraw Hill Education (India) Private Limited; 1 edition (16 February 2001)

References:

1. Classical Dynamics: A contemporary Approach by J.V.Jose and E.J. Saletan, (Cambridge University Press 2002) 2. Mechanics by L.D. Landau and E.M. Lifshitz, (Butterworth-Heinemann Ltd; 3rd Revised edition edition (29 January 1982)) 3. Classical dynamics D T Greenwood (Dover Publications Inc.; New edition edition (21 October 1997)) 4. Introduction to Dynamics by I.C. Percival and D. Richards (Cambridge University Press (2 December 1982)) 5. A treatise on the analytical dynamics of particles and rigid bodies by E.T. Whittaker, (Forgotten Books (27 September 2015)) 6. Classical mechanics by John R Taylor (University Science Books (15 September 2004)) 7. Classical Dynamics of particles and systems by Thorton and Marion (Cengage; 05 edition (17 December 2012)) 8. Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry and Engineering, Steven H Strogatz (Perseus Books; First Edition edition (1 February 1994)).

Course Name: Quantum Mechanics
Course Number: PH-513
Credits: 3-0-0-3
Preamble: This course is an introductory level course on quantum mechanics covering its basic principles. Several applications of quantum mechanics will be discussed to train students to apply these ideas to model systems in both one-dimension and three-dimensions. **Course outline:** The course begins with a discussion on origins of quantum theory and will introduce the basic postulates. Applications of quantum mechanics on various one dimensional cases will be discussed. Further Dirac notation will be introduced. Applications of quantum mechanics in three dimensions will be discussed. Approximation techniques such as perturbation theory (both time dependent and time independent) and variational methods will be also discussed in this course.
Modules: Origins of quantum theory, Postulates of quantum mechanics, observables and operators, theory of measurement in quantum mechanics, state of the system and expectation values, time evolution of the state, wave-packets, uncertainty principle, probability current, transition from quantum mechanics to classical mechanics-Ehrenfest theorem. Application of Schrodinger equation: scattering, tunnelling, bound states , harmonic oscillator, electrons in a magnetic field in 2D, comparison of classical and quantum results. Basic mathematical formalism of quantum mechanics, Dirac notation, linear vector operators, matrix representation of states and operators, commutator relations in quantum mechanics, commutator and uncertainty relations, complete set of commuting observables. Theory of angular momentum in quantum mechanics, commutator relations in angular momentum, Eigen values and Eigen states of angular momentum, spin-angular momentum. Application of Schrodinger equation in 3-D models, symmetry and degeneracy, central potentials, Schrodinger equation in spherical co-ordinates, solution to hydrogen atom problem. Time independent non-degenerate and degenerate perturbation theory, fine-structure of hydrogen, Zeeman Effect and hyperfine splitting
Text books: 1. Introduction to quantum mechanics-D J Griffith (Pearson, Second edition, 2004). 2. Quantum Mechanics -Vol.1, Claude Cohen-Tannoudji, B Diu, F Laloe (Wiley, First edition. 3. Modern Quantum Mechanics - J J Sakurai (Addison Wesley, revised edition, 1993)1991)
References: 1. Introductory Quantum Mechanics, R Liboff (Pearson, Fourth edition, 2002) 2. Quantum physics of atoms and molecules-R Eisberg and R Resnick (Wiley, 2nd edition, 1985) 3. Quantum Mechanics B. H. Bransden and C. J. Joachain (Pearson, Second edition, 2000) 4. Principles of Quantum Mechanics - R Shankar (Plenum Press, Second edition, 2011) Student Section. 5. The Feynman Lectures in Physics, Vol. 3, R.P. Feynman, R.B. Leighton, and M. Sands (Narosa Publishing House, 1992) 6. Practical Quantum Mechanics - Siegefried Flügge (Springer 1994)

Course Name: Electronics
Course Number: PH-514
Credits: 3-0-0-3
Preamble: To understand the principle of analog and digital electronics.
Course Outline: The course begins with analog electronics involving study of amplifier, oscillators, field effect transistor and operation amplifiers. Then the concept of Boolean algebra and digital electronics is introduced. Consecutively various digital circuits like combinational, clock and timing, sequential and digitally integrated circuit are studied. Further the course will introduce microprocessor.
Modules: Amplifiers: BJT, Classification of Amplifiers, Cascading of amplifiers, Types of power amplifiers, Amplifier characteristics, Feedback in amplifiers, Feedback amplifier topologies, Effects of negative feedback. Oscillators and Multivibrators: Classification and basic principle of oscillator, Feedback oscillator's concepts, Types of oscillator, Classes of multivibrators. Field effect transistors: JFET, MOSFET. Operational amplifiers: OPAMPs, OPAMP applications. Boolean algebra and Digital circuit: Number systems, Boolean algebra, De Morgan's theorem, Logic Gates, Karnaugh Maps, Combinational circuits: Adder, Multiplexer, DE multiplexer, Encoder, and Decoder. Clock and timing circuit: Clock waveform, Schmitt Trigger, 555 Timer-A stable, Monostable, Sequential circuits: Filp-Flops, Registers, Counters, and Memories, D/A and A/D conversions Microprocessor Basics: Introduction, Outline of 8085/8086 processor, Data analysis.
Text Books: 1) Integrated electronics by Millman and Halkias (McGraw-Hill, 2001) 2) Electronic Principles: A. P. Malvino and D. P. Bates (7th Edn) McGraw-Hill (2006) 3) Digital Principles and Applications: D. P. Leach, A. P. Malvino and G. Saha, (6th Edn), Tata McGraw Hill (2007) 4) Digital Electronics-Principles, Devices and Applications: A. K. Maini John Wiley & Sons (2007) 5) R. S. Gaonkar, Microprocessor Architecture: Programming and Applications with the 8085, Penram India (1999). 6) Microelectronic circuits, Sedra and Smith, Oxford publications, sixth edition 2013

Course Name: Physics Laboratory Practicum
Course Number: PH-515P
Credits: 0-0-5-3
Preamble: This experimental course is expected to develop the art of experimentation and analysis skill, understanding the basis of knowledge in physics, and collaborative learning skills among students. Course Outline: The course content includes standard physics experiments from various modules of physics, the theory of which students have learnt during their final year of B. Sc.

Experiments: 1. Hall Effect in Semiconductor Objective: To measure the resistivity and Hall voltage of a semiconductor sample as a function of temperature and magnetic field. The band gap, the specific conductivity, the type of charge carrier and the mobility of the charge carriers can be determined from the measurements.

2. Michelson Interferometer Objective: To determine the wavelength of the light source by producing interference pattern.

3. Fabry-Perot Interferometer Objective: To investigate the multibeam interference of a laser light. Also, the determination of the wavelength of light source and thickness of a transparent foil.

4. Zeeman Effect Objective: To observe the splitting up of the spectral lines of atoms within a magnetic field (normal and anormalous Zeeman effect) and find the value of Bohr's magnetron.

5. Diffraction of ultrasonic waves Objective: To observe Fraunhofer and Fresnel diffraction and determine the wavelength of the ultrasound wave.

6. Frank-Hertz Experiment Objective: To demonstrate the quantization of atomic energy states and determine the first excitation energy of neon.

7. Fourier optics Objective: To observe Fourier transformation of the electric field distribution of light in a specific plan.

8. Dispersion and resolving power Objective: Determination of the grating constant of a Rowland grating based on the diffraction angle (up to the third order) of the high intensity spectral lines. Determination of the angular dispersion and resolving power of a grating.

9. Geiger-Müller-Counter Objective: To study random events, determination of the half-life and radioactive equilibrium. Verification of the inverse-square law for beta and gamma radiation.

10. Scintillation counter Objective: Energy dependence of the gamma absorption coefficient / Gamma spectroscopy.

Books:

1. R. A. Dunlop, Experimental Physics, Oxford University Press (1988). 2. A. C. Melissinos, Experiments in Modern Physics, Academic Press (1996). 3. E. Hecht, Optics, Addison-Wesley; 4 edition (2001) 4. J Varma, Nuclear Physics Experiments, New Age Publishers (2001) 5. E. Hecht, Optics, Addison-Wesley; 4 edition (2001) 6. Worsnop and Flint, Advanced Practical Physics for Students Methusen & Go. (1950). 7. E.V. Smith, Manual for Experiments in Applied Physics. Butterworths (1970). 8. D. Malacara (ed), Methods of Experimental Physics, Series of Volumes, Academic Press Inc. (1988).

Course Title: **Technical Communication**
Course Number: H-S541
Credit: 1-0–0-1
Preamble: Students in general and graduate students in particular are required to share and communicate their academic activities both in written and oral form to their peers and reviewers for their comments and review. The duration of these presentation may vary from few minutes to few hours. The audience may be homogeneous or heterogeneous. This course intends to help students to learn the art of communication in these areas.
Objectives : The course objectives include facilitate learning the skill of preparing poster presentations, slides, abstracts, reports, papers and thesis and their oral presentations through lectures, examples an practices in class. Students are expected to learn structuring of these academic activity and time allotment for each sub-element of the structure of oral presentations.
Major topics:
1) Review of appropriate and correct use of articles, adjectives and adverbs, active and passive voices, affirmative sentences, sentences with positive and negative connotations and presentation styles. Examples and class exercise.
2) Poster preparation and presentation in conferences.
3) Research article for conference and journal and slides for their presentations.
4) Thesis and/or book
5) Job interviews
Reference: Perelman, Leslie C., and Edward Barrett.The Mayfield Handbook of Scientific and Technical Writing. New York, NY: McGraw-Hill, 2003. ISBN: 9781559346474.
General Resources: Carson, Rachel. "The Obligation to endure," chapter 2 inSilent spring. 104th anniversary ed. New York, NY: Mariner Books, 2002. ISBN: 9780618249060. (Originally published in 1962. Any edition will do.)Day, Robert A., and Barbara Gastel.How to Write and Publish a Scientific Paper. 6th ed. Westport, CT: Greenwood Press, 2006. ISBN: 9780313330407.
---.Scientific English: A Guide for Scientists and Other Professionals. 2nd ed. Phoenix, AZ: Oryx Press, 1995. ISBN: 978-0897749893.Hacker, Diana.A Pocket Style Manual.4th spiral ed. New York, NY: Bedford/St. Martin's, 1999. ISBN: 9780312406844. Jackson, Ian C.Honor in Science.Sigma Xi, The Scientific Research Society, Research Triangle Park, N. C., 1992.Klotz, Irving M.Diamond Dealers and Feather Merchants: Tales from the Sciences.Boston: Birkhauser, 1986

Course Name: Research Project I [I-PhD]
Course Number: PH-516
Credits: 0-0-4-2
Preamble: This course is aimed at giving research exposure to students by giving small projects to them in physics related areas
Course outline: Each student will be given a project which they have to complete during their first semester
Modules: Faculty members of physics and related areas can offer this project course. Towards the end of vacation they have to submit their report and must give a seminar based on their work. Evaluation will be based on student's performance during the period and their report and talk. The evaluation will be carried out by the faculty members involved in the program.
Textbooks: As advised by the faculty member
References: As advised by the faculty member

Course Name: Research project II [I-PhD]
Course Number: PH517
Credits: 0-0-8-4

Preamble: This course is aimed at giving research exposure to students by giving small projects to them in physics related areas.
Course outline: Each student will be given a project which they have to complete during their first year winter vacation.

Modules: Faculty members of physics and related areas can offer this project course. Towards the end of vacation they have to submit their report and must give a seminar based on their work. Evaluation will be based on students' performance during the period and their report and talk. The evaluation will be carried out by the faculty members involved in the program.
Textbooks: As advised by the faculty member.
References: As advised by the faculty member.

Course Name: Electromagnetic Theory
Course Number: PH521
Credits: 4-0-0-4

Preamble: The course is intended for the physics students at the advanced undergraduate level, or beginning graduate level. It is designed to introduce the theory of the electrodynamics, mainly from a classical field theoretical point of field.

Course outline: The course content includes electrostatics and magneto statics and their unification into electrodynamics, gauge symmetry, and electromagnetic radiation. The special theory of relativity has been included with four vector fields, and covariant formulation of classical electrodynamics.

Modules: 1) Overview of Electrostatics & Magneto statics: Differential equation for electric field, Poisson and Laplace equations, Boundary value problems, Dielectrics, Polarization of a medium, Electrostatic energy, Differential equation for magnetic field, Vector potential, Magnetic field from localized current distributions

2) Maxwell’s Equations: Maxwell's equations, Gauge symmetry, Coulomb and Lorentz gauges, Electromagnetic energy and momentum, Conservation laws.

3) Electromagnetic Waves: Plane waves in a dielectric medium, Reflection and Refraction at dielectric interfaces, Frequency dispersion in dielectrics and metals, Dielectric constant and anomalous dispersion, Wave propagation in one dimension, Group velocity, and Metallic wave guides.

4) Electromagnetic Radiation: Electric dipole radiation, Magnetic dipole radiation, Radiation from a localized charge, The Lienard-Wiechert potentials

5) Relativistic Electrodynamics: Michelson–Morley experiment, Special theory of relativity, Relativistic kinematics, Lorentz transformation and its consequences, Covariance of Maxwell equations, Radius four-vector in contra variant and covariant form, Four-vector fields, Minkowski space, covariant classical electrodynamics.

Textbooks: 1) Classical Electrodynamics by J.D. Jackson (John Wiley & Sons Inc, 1999) 2) Introduction to Electrodynamics by D.J. Griffiths (Prentice Hall, 1999) 12

References: 1) Classical theory of fields, by L.D. Landau, E.M. Lifshitz and L.P. Pitaevskii (Elsevier,2010) 2) The Feynman Lectures on Physics, by Feynman, Leighton, Sands (CALTECH, 2013) 3) Classical Electrodynamics by W. Greiner (Spinger, 1998) 4) Foundations of Electromagnetic Theory by J.R. Reitz, F.J. Milford and R.W. Christy (Addition- Wesley, 2008)

Course Name: Statistical Mechanics
Course Number: PH 522
Credits: 4-0-0-4
Preamble: Statistical mechanics use methods of probability to extend the mechanics to many-body systems to make statistical predications about their collective behaviour. It also acts as bridge between thermodynamics and mechanics of constituent particles. Statistical mechanics of ideal gas systems provide basic functioning of the formalisms of statical mechanics. Methods of statistical mechanics serves as essential pre-requisite to many advanced topics in various branches of physics where many body systems are dealt with. **Course Outline:** This course starts from introducing the concepts of basic probability theory. Next modules explain the connection between the many body mechanics and phase space to probability theory. This course gives to introduction different statistical ensembles. Also introduces to studies of statical behaviour of classical and quantum systems.
Modules: 1) Review of Thermodynamics: Laws of Thermodynamics, Specific heat, Maxwell relations, Thermodynamic potentials, Ideal gas, Equation of state, van der Waal's equations. 2) Probability concepts and examples - random walk problem in one dimension mean values probability distribution for large N. Probability distribution of many variables. 3) Liouvellie equation-Boltzman ergodic hypothesis, Gibbsian ensemble. Phase space and connection between mechanics and statistical mechanics- Microcanonical ensemble. Classical ideal gas. Gibb’s paradox. 4) Canonical ensemble partition function. Helmholtz free energy, Thermodynamics from the partition function. Classical ideal gas- equipartition and virial theorem. Examples: harmonic oscillator and spin systems, Grand canonical ensemble- density and energy fluctuations- Gibbs free energy. 5) Formulation of quantum statistical mechanics density matrix- micro-canonical, canonical and grand canonical ensembles- Maxwell-Boltzmann , Fermi-Dirac, and Bose-Einstein statistics - comparison 6)Ideal gas in classical and quantum ensembles Ideal Bose and fermi systems Examples of quantum quantum ideal gases, Landau diamagnetism, Pauli paramagnetism, Phonons in solids, Bose-Einstein condensation in Harmonic Trap, White dwarf Star, Phase transformation.
Textbooks: 1. Statistical Mechanics, R K Pathria (Academic Press Inc; 3rd Revised edition edition (25 February 2011)) 2. Statistical Physics by K Huang (Wiley; Second edition (24 September 2008) 3. Concepts in Thermal Physics, Stephen Blundell (OUP UK; 2 editions, 24 September 2009)
References: 1. Fundamentals of statistical and thermal physics, F. Reif (Waveland Press (1 January 2010)) 2. Statistical Physics Part I by L D Landau and E M Lifshitz (Butterworth-Heinemann; 3 edition (22 October 2013)) 3. Statistical physics of particles by Mehran Kardar (Cambridge University Press; 1 edition (7 June 2007)) 4. The principles of Statistical Mechanics R. C Tolman (Dover Publications Inc.; New edition edition (1 June 1980))

Course Name: Condensed Matter Physics
Course Number: PH 523
Credits: 3-0-0-3
Preamble: A basic understanding of solids is important for practicing physicists as well as for many other related disciplines. The course is an introduction to the physics of the solid state matter.
Course Outline: The course emphasizes the large-scale properties of solid materials resulting from their atomic-scale properties. This course provides a basic understanding of what makes solids behave the way they do, how they are studied, and the basic interactions which are important.
Modules: Introduction: Crystal Structures, Reciprocal Lattice, Brillioun Zones, X-ray diffraction and Structure factor, Defects in Crystal structures Lattice Vibrations and Phonons: Monoatomic and Diatomic basis, Quantization of elastic waves, Phonon momentum and Phonon density of states, Einstein and Debye model of heat capacity, Thermal properties of solids. Electrons in Solids: Drude and Somerfield theories, Fermi momentum and energy, Fermi surface, Density of states, Electrical conductivity, Ohm's law, Motion in a magnetic field, Hall Effect, Bloch Theorem and crystal momentum, Electron motion in Solids, Kroning-Pening Model, Formation of band, Effective mass Semiconductors: Intrinsic and extrinsic semiconductors, Acceptor and donor level, Bound State and optical transitions in semiconductors. Degenerate and non-degenerate semiconductor, Optical properties of solids. Magnetism: Introduction, Origin of magnetism, Bohr-Van Leeuwen theorem, Types of magnetism:Diamagnetism,Paramagnetism, Ferro and Anti-ferro magnetism.Superconductivity: Basic phenomena, Meissner effect, Types of superconductors, London equation, Idea of Cooper pair, Flux quantization, Josephson's tunneling.
Textbooks: 1. Introduction to Solid State Physics by C. Kittel, 8th Edition, John Wiley & Sons, Inc, 2005. 2. Solid State Physics by N. W. Ashcroft and N. D. Mermin. 3. Condensed Matter Physics by M. P. Marder, (John Wiley & Sons, 2010).
References: 1) Advanced Solid State Physics by Phillips. (Cambridge University Press, 2012). 2) Solid State Physics, Hook and Hall, Wiley Science 3) Physics of Semiconductor Devices, S. M. Sze.

Course Name: Atomic and Molecular Physics
Course Number: PH-524
Credits: 3-0-0-3

Preamble: This course introduces the basic ideas of atomic and molecular physics. It teaches students how to apply quantum mechanics and extract information from many-electrons atoms and molecules. Introduction to group theory is also provided.

Course outline: The course begins with a review of some of the basic concepts in quantum mechanics and then discusses the time-dependent perturbation theory and its applications. It will then proceed to many-electron atomic systems and then to molecules. Further the course discusses the ideas and concepts associated with various spectroscopy techniques and will also introduce the elementary concepts of group theory.

Modules: 1) Time-independent perturbation theory, Time-dependent perturbation theory and application Fermi- Golden rule. Interaction of electromagnetic radiation with single electron atoms, Rabi flopping, Dipole approximation and dipole selection rules, Transition rates, Line broadening mechanisms, spontaneous and stimulated emissions and Einstein coefficients. 2) Review of atomic structure of H, Atomic structure of two electron system-variational method, alkali system, central field approximation, Slater determinant, Introduction to self-consistent field method, L- S coupling, J-J coupling. General nature of molecular structure, molecular binding, LCAO, BornOppenheimer approximation. 3) General nature of molecular structure, molecular binding, LCAO, Born-Oppenheimer approximation. 4) Introduction to microwave, infra-red and Raman spectroscopy, NMR and ESR, Symmetry and Spectroscopy.

Textbooks: 1. Quantum Mechanics, Leonard Schiff, Mc Graw Hill Education; 3 edition (9 April 2010) 2. Physics of atoms and molecules - Bransden and Joachain (Pearson, second edition, 2011) 3. Fundamentals of molecular spectroscopy- C. Banwell and E. Maccash (Mc Graw Hill, 2013) 4. Introductory Quantum Mechanics, R.L. Liboff, Addison-Wesley (2002).

References: 1. Atoms, Molecules and Photons - Wolfgang Demtroder (Springer, Second edition, 2006).2. Atomic Physics, C. J. Foot (Oxford, First edition 2005) 3. Group theory and Quantum Mechanics-M. Tinkham (Dover Publications, First edition, 2003) 4. Chemical applications of group theory-F Albert Cotton (Willey, Third edition, 2015)

Course Name: Electronics Laboratory Practicum
Course Number: PH-525P
Credits: 0-0-5-3

Preamble: To provide instruction and acquaintance with electronic devices and instrumentation techniques important in the modern physics laboratory. This course will serve as an introduction to practical laboratory electronics by way of covering the application of analog, digital, frequency and mixed signal electronics to experiments in the physical sciences.
Course Outline: The course is a laboratory support to the electronics course PH 414.
List of Experiments 1. To design and use bipolar junction transistor (BJT) as an amplifier and switch, based on common emitter (CE), common collector (CC) and common base (CB) configurations. 2. Design of Integrator, Differentiator, low pass and high pass filter using operational amplifier (Op Amp) IC 741. 3. Design of Wein Bridge and Colpitts oscillator. 4. Verify mathematical expression of De-morgans theorem using electronic circuits. 5. Design of 4-bit Multiplexer and DE multiplexer using flip flops. 6. Design of 4-bit Shift registers and Counters using flip flops. 7. Design and verify A/D and D/A converters using OpAmp. 8. Design of A stable and Mono stable Multivibrator using IC 555. 9. Study of 8085 Microprocessor.
References:1. Basic Electronics, B.L. Thareja 2. Principles of Electronics, V.K. Mehta and Rohit Mehta

Course Name: Research project III [I-PhD]
Course Number: PH526
Credits: (0-0-6-3)
Preamble: This course is aimed at giving research exposure to students by giving small projects to them in physics related areas.
Course outline: Each student will be given a project which they have to complete during their Second semester.
Modules: Faculty members of physics and related areas can offer this project course. Towards the end of vacation they have to submit their report and must give a seminar based on their work. Evaluation will be based on student's performance during the period and their report and talk. The evaluation will be carried out by the faculty members involved in the program.
Textbooks: As advised by the faculty member.
References: As advised by the faculty member

Course Name: Research project IV [I-PhD]
Course Number: PH527
Credits: (0-0-6-3)
Preamble: This course is aimed at giving research exposure to students by giving small projects to them in physics related areas.
Course outline: Each student will be given a project which they have to complete during their first year summer vacation.
Modules: Faculty members of physics and related areas can offer this project course. Towards the end of vacation they have to submit their report and must give a seminar based on their work. Evaluation will be based on student's performance during the period and their report and talk. The evaluation will be carried out by the faculty members involved in the program.
Textbooks: As advised by the faculty member.
References: As advised by the faculty member

Course Name: Experimental Research Techniques
Course Number: PH 611P
Credits: (0-0-7-4)

Preamble: According to Newton's third law, we can just move the earth up and down by just throwing the ball up and down. But why don't we feel it? Its simply because its immeasurable within the uncertainty of the measuring set up. Performing an experiment without the knowledge of uncertainty has no meaning. The students will be given a flavour of what does it really mean by (a) performing an experiment; (b) developing a mini experiment (c) assembling and engineering tools.

Course Outline: The aim of the proposed course is to amalgamate the concepts in Physics through assembling, developing mini experiments and building components.

Modules: Temperature dependence of Electrical resistivity of materials: This experiment involves measuring temperature dependent resistivity of any material using four probe method and Vander Pauw methods. The skills that one will develop are to make fine contacts on the sample, learn the intricacies involved in making this set up.

Electronic properties of material using photoemission technique: Photoemission experiments will be done on any material and its electronic properties will be studied. The skills that one will develop are the intricacies involved in conducting experiments in ultra-high vacuum conditions.

Seebeck coefficient measurement: Develop mini Seebeck coefficient experiment to distinguish n-type and p-type semiconductors from a mixture of it.

Structural properties of matrial using power X-ray diffraction (XRD) technique.

Course Name: Seminar and report
Course Number: PH614
Credits: 0-0-4-2
Preamble: This course is aimed at developing student's self-study and presentation skills which are very much important to build a successful research career.
Course outline: Each student will choose a particular topic for their seminar. Student will be continually preparing in a self-study mode in consultation with faculty members working in physics related topics. Students are also required to write a report.
Modules: Student will be continually preparing during the semester in consultation with faculty members. At the end of the semester students has to give a seminar and a report. Faculty members who are involved in the program will evaluate based on performance of students during the period and their seminar and report.
Textbooks: As advised by the faculty member
References: As advised by the faculty member

Course Name: Special Topics in Quantum Mechanics
Course Number: PH 613
Credits: 3-0-0-3
Preamble: This course introduces some of the advanced level topics on quantum mechanics.
Course outline: The course begins a review of some of the basic concepts in quantum mechanics and then discusses the angular momentum algebra. It will then proceed to discuss the concepts in scattering theory, symmetry principles and second quantisation. Relativistic quantum mechanics will be introduced towards the end of the course.
Modules: 1. Review of basic concepts in quantum mechanics, measurements, observables and generalized uncertainty relations, change of basis, generator of translation 2. Angular Momentum: General theory of angular momentum, Angular momentum algebra, Addition of angular momenta, Clebsch-Gordon coefficients, Tensor operators, matrix elements of tensor operators, Wigner-Eckart theorem 3. Scattering Theory: Non-relativistic scattering theory. Scattering amplitude and cross- section. The integral equation for scattering. Born approximation. Partial wave analysis, optical theorem 4. Symmetries in Quantum Mechanics: Symmetry principles in quantum mechanics, conservation laws and degeneracies, discrete symmetries, parity and time reversal 5. Second Quantization: Systems of identical particles, Symmetric and ant symmetric wave functions. Bosons and Fermions. Pauli's exclusion principle, occupation number representation, commutation relations, applications of second quantization. Instructors may choose any one of the modules given below: 6. Elements of relativistic quantum mechanics. The Klein-Gordon equation. The Dirac equation. Dirac matrices, spinors. Positive and negative energy solutions, physical interpretation. Nonrelativistic limit of the Dirac equation.
Text Book: 1. Modern Quantum Mechanics - J J Sakurai(Addison Wisley, revised edition, 1993) 2. Advanced Quantum Mechanics, J J Sakurai (Pearson, First edition, 2002) 3. Quantum Mechanics, Cohen-Tannoudji, B Diu, F Laloe (Vol. II) (Wiley, second edition 1977)
References: 1. Quantum Mechanics-Vol.1 and II-Messiah (Dover Publications Inc., 2014) 2. Practical Quantum Mechanics - Siegefried Flügge (Springer 1994) 3. Many-electron theory-S. Raimes (North-Holland Pub. Co.1972) 4. Relativistic Quantum Mechanics-W. Greiner and D. A. Bromley (Springer, 3rd edition , 2000) 5. Quantum theory of many-particle systems- Fetter and Walecka (Dover Publications Inc2003) 6. Quantum Mechanics-Merzbacher (Third edition, Wiley, 2011) 7. Quantum mechanics-Landau and Lifshitz (Butterworth-Heinemann Ltd; 3rd Revised edition (18 December 1981)

Course Name: Post-Graduate Project-1 [M Sc]
Course Number: PH 518P
Credits: 0-0-6-3
Preamble: The course is aimed at giving research exposure to students by giving small projects to them in physics related areas.
Course outline: Each student will be given a project which they have to complete during their 1^{st} semester.
Modules: Faculty members of physics and related areas can offer this project course. Towards the end of vacation they have to submit their reports and must give a semester based on their work. Evaluation will be based on student performance during the period and their report and talk. The evaluation will be carried out by the faculty members involved in the program.
Textbooks: As advised by the faculty member
References: As advised by the faculty member

Course Name: Computational Methods for Physicists
Course Number: PH 621
Credits: 2-0-4-4
Preamble: The objective of the proposed course is to introduce students to the basic ideas of numerical methods and programming Course Outline: The course will cover the basic ideas of various numerical techniques for interpolation, extrapolation, and integration, differentiation, solving differential equations, matrices and algebraic equations.
Modules: Basic introduction to operating system fundamentals. 2) Introduction to C: Program Organization and Control Structures loops, arrays, and function, Error, Accuracy, and Stability. 3) Interpolation and Extrapolation - Curve Fitting: Polynomial Interpolation and Extrapolation Cubic Spline Interpolation Fitting Data to a Straight Line, examples from experimental data fitting 4) Integration and differentiation: Numerical Derivatives Romberg Integration Gaussian Quadrature and Orthogonal Polynomials. 5) Root Finding:Newton-Raphson Method Using Derivative - Roots of a Polynomial 6) Ordinary Differential Equations: Runge-Kutta Method, Adaptive Step size Control for Runge- Kutta, Examples from electrodynamics and quantum mechanics 7) Matrices and algebraic equations: Gauss-Jordan Elimination Gaussian Elimination with Back substitution, LU Decomposition 8) Concept of simulation, random number generator.
Textbooks: 1. The C Programming Language by B W Kernighan and D M Richie (PHI Learning Pvt. Ltd, 2011) 2. Elementary numerical analysis: algorithmic approach by S D Conte and C de Boor (McGraw- Hill International, 1980).
References: 1. Computer Programming in C by V. Rajaraman, (PHI Learning Pvt. Ltd, 2011). 2. Numerical Methods by Germund Dalquist and Ake Bjork (Dover Publications, 1974) 3. Numerical Recipes by William H. Press, Saul A. Teukolsky, William T. Vetterling, and Brian P. Flannery, (Cambridge University Press, 1992).

Course Name: Mini-thesis II [I-PhD]
Course Number: PH- 622
Credits: 0-0-6-3

Preamble: The course is aimed at equipping students the necessary knowledge and skills to take up their Ph.D. work.

Course outline: Each student can work with their supervisor where they are expected to do research at an advanced level.

Modules: At the end of semester they have to submit their report and must give a seminar based on their work. A committee shall be formed to evaluate the students' performance during the period and their report and seminar.

Textbooks: As advised by the faculty member.

References: As advised by the faculty member

List of Discipline Elective Courses

Course Name: Magnetism and Magnetic Materials
Course Number: PH508
Credits: 3-0-0-3
Course Preamble: Magnetism is an open field where engineers, material scientists, physicists and others work together. This course is proposed for undergraduate/postgraduate level students. Itstarts with the fundamentals of magnetism and proceeds to explain magnetic materials and their applications.
Course Outline: The course will cover a thorough study about different types of magnetism along with the types of magnetic interactions. Also various types of glassy magnetism and magnetism in low dimensions will be covered. A detailed study about novel magnetic materials which are used for technological application will be carried out. Further, the course will introduce various measurement techniques used for measuring magnetization.
Modules: Introduction History of magnetism, Magnetic units, Classical and quantum mechanical model of magnetic moment of electrons, magnetic properties of free atoms. **Types of magnetism** Classification of magnetic materials, Theories of Diamagnetism, Para magnetism, Theories of ordered magnetism, Quantum theory of magnetism: electron-electron interactions, localized electron theory, itinerant electron theory.
Magnetic interactions Origin of crystal field, Jahn Teller effect, Magnetic dipolar interaction, Origin of exchange interaction, Direct exchange interactions, Indirect exchange interactions in ionic solid and metals, double and anisotropic exchange interaction.
Magnetic domains Development of domain theory, Block and Neel Wall, Domain wall pinning, Magnons, Bloch’s law, Magnetic anisotropy, magneto restriction.
Competing interactions and low dimensionality Frustration, Spin glass, superparamagnetism, one and two dimensional magnets, thin film and multilayers, Heisenberg and Ising models
Novel magnetic materials Colossal and giant magneto resistive materials, magnetic refrigerant materials, Shape memory alloys, multiferroics, spintronics devices and their application in magnetic storage.
Measurements techniques Production and measurement of field, magnetic shielding, Faraday balance, AC susceptometer, Vibration sample magnetometer, torque magnetometer, SQUID magnetometer, Experimental method in low temperature.
Textbooks: 1. B. D. Cullity and C. D. Graham, Introduction to magnetic materials. John Wily & Sons, Inc, 20112. D. Jiles,Introduction to magnetism and magnetic materials. Taylor and Francis, CRC Press 1998.
Reference books: 1.K. H. J. Buschow and F. R. de Boer, Physics of Magnetism and Magnetic Materials. Kluwer Academic Publishers, 2003.2.Stephen Blundell, Magnetism in Condensed Matter. Oxford University Press (2001).3. Mathias Getzlaff, Fundamentals of Magnetism, Springer, 2008

Course Name: Mesoscopic Physics and Quantum Transport
Course Number: PH601
Credits: 3-0-0-3
Course Preamble: Rather a young branch of science, mesoscopic physics already has several exciting and instructive achievements over fundamental understanding and technological applications. This course highlights the mechanisms of the electronic transport at the mesoscopic scales where novel concepts of quantum mechanics are necessary. The course deals with the understanding of how the physics and quantum-rules are operative to the electronic transport in low dimensional structures.
Course Outline: The course is planned to get a broad overview of the world of mesoscopic physics and various approaches to study quantum transport and related phenomena in nanostructures. Among the topics covered are the length scaling in physics, conductance from transmission, scattering approaches, semi classical transport, interference, decoherenceeffects and concludes by emphasizing on the application of the mesoscopic physics with rapid evolution of novel materials and experimental techniques.
Modules: 1. Introduction Drude and Somerfield model for electrons in solids, Quantum mechanics of particle in a box, Bloch states, Density of states and Dimensionality.
2. Mesoscopic physics Mesoscopic phenomena and length scaling in physics,Quantum structures, Tunneling through the potential barrier, Coulomb blockade.
3. Quantum transport and Localization Influence of reduced dimensionality on electron transport: Ballistic and Diffusive Transport, Single channel Landauer formula, Landauer-Buttiker formalism, Localization, Thermal activated conduction, Thouless picture,General and special cases of localization, Weak localization regime.
4. Quantum Hall effect Origin of zero resistance, Two Dimensional Electron Gas, Transport in Graphene and two dimensional systems, Localizations in weak and strong magnetic fields, Quantum Hall effect,Spin Hall Effect.
5. Quantum interference effects in electronic transport Conductance in mesoscopic systems,Shubnikov de Haas-Van and Aharonov-BohmOscillations, Conductance fluctuations.
6. Mesoscopic Physics with Superconductivity Superconducting ring and thin wires, weakly coupled superconductors, Josephson effects, Andreev Reflections, Superconductor-Normal and Superconductor-Normal-Superconductorjunctions.
7. Application of Mesoscopic physics Optoelectronics, Spintronics and Nanoelectronic Devices.
Text Books:1.Y. Imri, Introduction to Mesoscopic Physics,Oxford University Press, 2008.2.S. Datta, Electronic Transport in Mesoscopic Systems, Cambridge University Press, 1997.
Reference Books:
1.S. Datta, Quantum Transport: Atom to transistor, Cambridge University Press, 2005.2.B.L. Altshuler (Editor), P.A. Lee (Editor), R.A. Webb (Editor), Mesoscopic Phenomena in Solids (Modern Problems in Condensed Matter Sciences), North Holland (July 26, 1991).3.D. K. Ferry, S. M. Goodnick, Transport in Nanostructures, Cambridge University Press, 2009.4.N. W. Ashcroft and N. D. Mermin, Solid State Physics, Cengage Learning, 1976.5.P. Harrison, Quantum Wells,Wires & Dots: Theoretical and Computational Physics of Semiconductor Nanostructures, Second Edition, WileyScience, 2009.

Course Name: Advanced Condensed Matter Physics
Course Number: PH603
Credits: 3-0-0-3
Course Preamble: The aim of the proposed course is to introduce the basic notion of the condensed matter physics and to familiarize the students with the various aspects of the interactions effects. This course will be bridging the gap between basic solid state physics and quantum theory of solids. The course is proposed for postgraduate as well as undergrad students.
Course Outline: The course begins with the review of some of the basic concepts of introductory condensed matter physics and then sequentially explores the interaction effects of electron-electron/phonon, optical properties of solids, interaction of light with matter and finally the superconductivity.
Course Modules: 1Second quantization for Fermions and Bosons. Review of Bloch's theorem, tight binding Model, Wannier orbitals, density of states.
2. Born-Oppenheimer approximation. Effects of electron-electron interactions -Hartree-Fock approximation, exchange and correlation effects. Fermi liquid theory, elementary excitations, quasiparticles.
3. Dielectric function of electron systems, screening, random phase approximation, plasma oscillations, optical properties of metals and insulators, excitons, polarons, fluctuation-dissipation theorem.
4. Review of harmonic theory of lattice vibrations, harmonic effects, electron-phonon interaction -mass renormalization, effective interaction between electrons, polarons.
5. Metal-Insulator transition, Mott insulators, Hubbard model, spin and charge density waves, electrons in a magnetic field, Landau levels, integer quantum Hall effect.
6. Superconductivity: phenomenology, Cooper instability, BCS theory, Ginzburg-Landau theory.
Text books:
1. Solid State Physics by N. W. Ashcroft and N. D. Mermin. (Publisher -Holt, Rinehart and Winston, 1976). 2. Quantum Theory of Solids by C. Kittel.(Wiley, 1987). 3. Condensed Matter Physics by M. P. Marder. (John Wiley & Sons, 2010). 4. Solid State Physics by H. Ibach and H. Luth. (Springer Science & Business Media, 2009).

References:
1. Theoretical Solid State Physics by W. Jones and N. H. March.(Courier Corporation, 1985). 2. Advanced Solid State Physics by Phillips. (Cambridge University Press, 2012). 3. Many Particle Physics by G. D. Mahan. (Springer Science & Business Media, 2000). 4. Elementary Excitations in Solids by D. Pines. (Advanced Book Program, Perseus Books, 1999). 5. Lecture Notes on Electron Correlation and Magnetism by Patrik Fazekas. (World Scientific, 1999). 6. Quantum Theory of the Electron Liquid by Giuliani and Vignale. (Cambridge Uni. Press, 2005).

Course Name: Nuclear and Particle Physics
Course Number: PH 612
Credits: (3-0-0-3)
Preamble: The objective of the proposed course is to introduce students to the fundamental principles and concepts of nuclear and particle physics. Students will be able to know the fundamentals of the interaction of high energy particles. This course is expected to provide a working knowledge to real-life problems.
Course Outline: The course begins with basic nuclear phenomenology including stability. Eventually it will explore nuclear models and reactions; experimental methods: accelerators, detectors, detector systems; particle phenomenology: leptons, hadrons, quarks; elements of the quark model: spectroscopy, magnetic moments, masses.
Modules: 1. Properties of Nuclei: Nuclear size, nuclear radius and charge distribution, mass and binding energy, semi empirical mass formula, angular momentum, parity and isospin, magnetic dipole moment, electric quadrupole moment and nuclear shape.
2. Two-body problems: Deuteron ground state, excited states, spin dependence of nuclear forces, two nucleon scattering, charge symmetry and charge independence of nuclear forces, exchange nature of nuclear forces, Yukawa's theory.
3. Nuclear decay: Alpha, Beta and Gamma decay, Gamow theory, Fermi theory, direct evidence for the neutrino.
4. Nuclear models: Liquid drop model, shell model, magic numbers, ground state spin, and collective model.
5. Nuclear Reactions: Different types of reactions, Breit-Wigner dispersion relation, Compound nucleus formation and break-up, nuclear fission, neutron physics, fusion reaction, nuclear reactor.
6. Elementary particles: Fundamental interactions. Particle Zoo: Leptons, Hadrons. Organizing principle: Baryon and Lepton Numbers, Strangeness, Isospin, The eightfold way. Quarks: Colour charge and strong interactions, confinement, Gell-Mann – Okubo mass relation, magnetic moments of Hadrons. Field Bosons: charge carrier. The Standard Model: party non-conservation of weak interaction, Wu's experiment, elementary idea about electroweak unification, Higgs boson and origin of mass, quark model, concept of colour charge, discrete symmetries, properties of quarks and leptons, gauge symmetry in electrodynamics, particle interactions and Feynman diagrams.
Text Books: 1. K.S. Krane, Introductory Nuclear Physics, John Wiley (2008). 2. D. J. Grifths, Introduction to Elementary Particles, John Wiley & Sons Inc. (2008).
References: 1. W. E. Burcham and M. Jobes, Nuclear and particle Physics, John Wiley & Sons Inc.R. R. (1979). 2. W. L. Cottingham and D. A Greenwood, an Introduction to Nuclear Physics, Cambridge UniversityPress (2001). 3. A. Das and T. Ferbel, Introduction to nuclear and particle physics, John Wiley (2003) . 4. M. A. Preston and R. K. Bhaduri, Structure of the nucleus, Addison-Wesley (2008). 5. S. N. Ghoshal, Atomic and Nuclear Physics (Vol. 2) (S. Chand, 2010). 6. Roy and B. P. Nigam, Nuclear Physics: Theory and Experiment, New Age. 7. D. Perkins, Introduction to High Energy Physics, Cambridge University Press; 4th edition (2000). 8. G. L. Kane, Modern Elementary Particle Physics, Westview Press. 9. B. R. Martin, Nuclear and Particle Physics: An Introduction, Wiley (2013).

Course Name: Introduction to Molecular Simulations

Course Number: PH701

Credits: 2-2-0-4

Course content:

Classical statistical mechanics

1) Ensembles: micro canonical, canonical, grand canonical ensembles ideal gas- harmonic oscillator – Spin Systems. Introduction to Stochastic process, Brownian Motion, Langevin equation, Fokker-Planck equation, Introduction to liquid state theory- pair distribution functions- structure factor- coherent and in-coherent scattering- Ornstein-Zernike correlation function Diffusion in a liquid-mean square displacement- self and collective van Hovecorrelation function – Intermediate scattering function and dynamics structure factor.

2) Programing in C and FORTRAN 95 - essential for programming in this course

3) Introduction of Monte Carlo methods: Value of using MC method, Gaussian distribution from 1d random walk, Metrapolis algorithm for construction NVT ensemble, Implementation of ensemble using MC methods.

4) Proj 1. Write a Monte Carlo simulation to simulate model liquid.

5)Introduction to Molecular dynamic simulations: Molecular dynamics simulations, Numerical integration of linear differential equations, Leap-Frog algorithm, Velocity Varlet algorithm, Periodic boundary condition one, two and three dimensions.

6)Proj. 2 Write a MD simulation code for simple liquids and for a polymer chain connected by harmonic spring.

7) Introduction to Brownian and Lengevin dynamics simulations: Simple Brownian dynamicsalgorithm without hydrodynamic interactions. Langevin dynamics simulations.

8)Proj. 3: Write a Brownian dynamics code to simulate colloids in a solution and motion of singlepolymer chain.

9) Analysis data from simulations: Computation of radial distribution function, Structure factor,Time series analysis, Mean square displacement.

10)Proj 4: Using trajectories produced from the earlier simulation to compute: Radial distribution functions. Mean square displacement of center of mass and monomers for a polymer chain. Computation of stress, stress correlation function and viscosity.

Text & Reference Books:

Statistical Mechanics R. K. PathriaIntroduction stochastic process in physics and astronomy, Rev. Mod. Phys. 1 15(1943) what is liquid? Understanding the state of matter, J. A. Barker and D. Henderson, Rev. Mod.Phys. 587 48(1976).Theory of simple liquids by J. P. Hansen and I. R. McDonald Statistical Mechanics by D. A. McQuarrieComputer simulation of liquids by M. P. Allen and D. J. Tildesey Understanding molecular simulation by Daan Frenkel. The art of molecular dynamics simulations by D. C. RappaportA guide to Monte Carlo simulations in statistical Physics by D. P. Landau and Kurt Binder

Experiments in the Physics Laboratory:

Fig: Ultrasonic diffraction

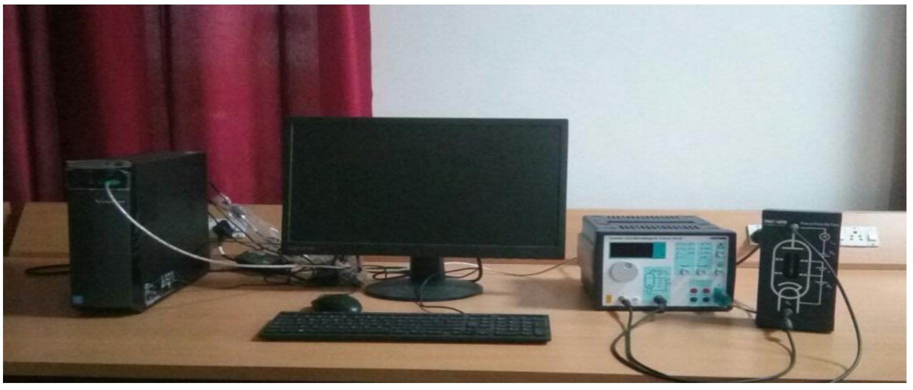


Fig: Frank-Hertz

Fig: Dispersion and resolving power

Fig: Fourier optics

Fig: Fabry-Perot interferometer

Fig: Zeeman Effect with Electromagnet