CURRICULUM

OF

PHYSICS

BS/MS

(Revised 2013)

HIGHER EDUCATION COMMISSION
ISLAMABAD.

CURRICULUM DIVISION, HEC

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PREFACE

The curriculum, with varying definitions, is said to be a plan of the teaching-learning process that students of an academic programme are required to undergo. It includes objectives & learning outcomes, course contents, scheme of studies, teaching methodologies and methods of assessment of learning. Since knowledge in all disciplines and fields is expanding at a fast pace and new disciplines are also emerging; it is imperative that curricula be developed and revised accordingly.

University Grants Commission (UGC) was designated as the competent authority to develop, review and revise curricula beyond Class-XII vide Section 3, Sub-Section 2 (ii), Act of Parliament No. X of 1976 titled "Supervision of Curricula and Textbooks and Maintenance of Standard of Education". With the repeal of UGC Act, the same function was assigned to the Higher Education Commission (HEC) under its Ordinance of 2002, Section 10, Sub-Section 1 (v).

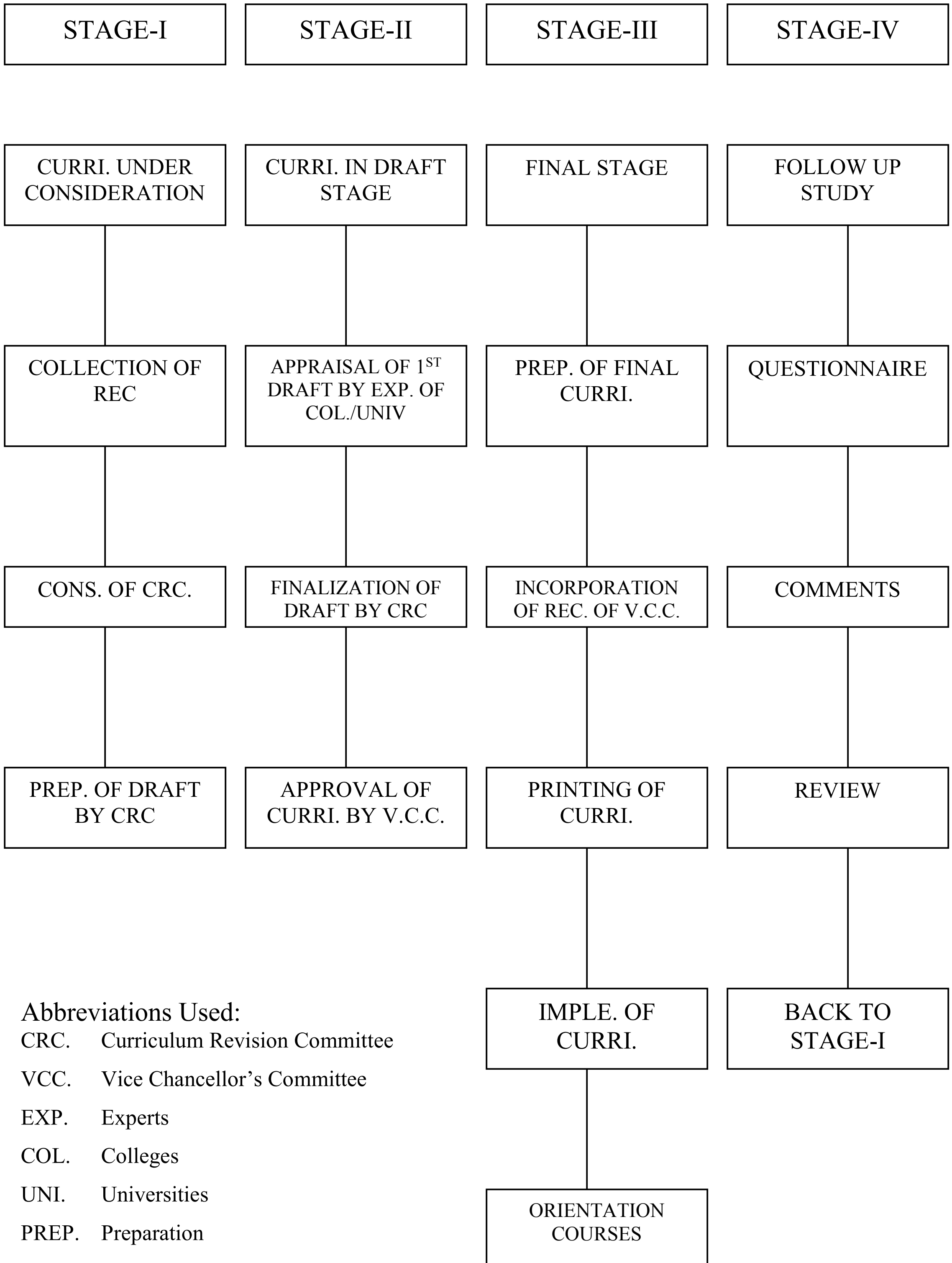
In compliance with the above provisions, the Curriculum Division of HEC undertakes the revision of curricula after every three years through respective National Curriculum Revision Committees (NCRCs) which consist of eminent professors and researchers of relevant fields from public and private sector universities, R&D organizations, councils, industry and civil society by seeking nominations from their organizations.

In order to impart quality education which is at par with international standards, HEC NCRCs have developed unified templates as guidelines for the development and revision of curricula in the disciplines of Basic Sciences, Applied Sciences, Social Sciences, Agriculture and Engineering in 2007 and 2009.

It is hoped that this curriculum document, prepared by the respective NCRC's, would serve the purpose of meeting our national, social and economic needs, and it would also provide the level of competency specified in Pakistan Qualification Framework to make it compatible with international educational standards. The curriculum is also placed on the website of HEC (www.hec.gov.pk).

(Fida Hussain)
Director General (Academics)

CURRICULUM DEVELOPMENT PROCESS



Abbreviations Used:

CRC.	Curriculum Revision Committee
VCC.	Vice Chancellor's Committee
EXP.	Experts
COL.	Colleges
UNI.	Universities
PREP.	Preparation
REC.	Recommendations

Introduction:

The final meeting of National Curriculum Revision Committee in the discipline of Physics was held on March 19-21, 2013 at HEC Regional Centre, Peshawar. The purpose of the meeting was to finalize the draft curriculum of Physics reviewed in the Preliminary meeting held on October 17-19, 2012 at the HEC Regional Centre, Lahore. The following members attended the meeting:-

1.	Dr. Iftikhar Ahmad, PhD (USA) Professor & Chairman, Department of Physics, University of Malakand, Chakdara, Dir.	Convener
2.	Prof. Dr. Syed Zafar Ilyas, Professor & Chairman, Department of Physics, AIOU, Islamabad.	Member
3.	Prof. Dr. Muhammad Nawaz Tahir (T.I), Professor & Chairman, Department of Physics, University of Sargodha, Sargodha.	Member
4.	Prof. Dr. Muhammad Aslam Khan, HEC Foreign Professor, Department of Physics, CIIT, Islamabad	Member
5.	Prof. Dr. Muhammad Saleem Shaikh, Professor, Department of Physics, Preston University, Islamabad	Member
6.	Prof. Dr. Salamat Ali, Professor, Department of Physics, Government College University, Lahore	Member
7.	Prof. Dr. Saqib Anjum, Professor & Chairman, Department of Physics, NED University of Engineering & Technology, Karachi	Member

8.	Prof. Dr. Qurban Ali Bhatti, Professor & Chairman, Department of Physics, Shah Abdul Latif University, Khairpur.	Member
9.	Prof. Dr. Muhammad Hassan Sayyad, Professor, Faculty of Engineering Sciences, GIK Institute of Engineering & Technology, Topi, Swabi, KPK.	Member
10.	Prof. Dr. Anwar Latif, Professor, Department of Physics, University of Engineering & Technology, Lahore.	Member
11.	Dr. Waqar Adil Syed, Associate Professor & Chairman, Department of Physics, International Islamic University, H-10, Islamabad	Member
12.	Dr. Khizar-ul-Haq, Assistant Professor & Registrar, Department of Physics, Mirpur University of Sciences & Technology, AJK.	Member
13.	Dr. Abdul Manan, Assistant Professor, Department of Physics, University of Science and Technology, Bannu.	Member
14.	Dr. Afzal Khan, Assistant Professor, Institute of Physics & Electronics, University of Peshawar, Peshawar.	Member
15.	Dr. Rizwan Khalid, Assistant Professor, Department of Physics, Centre for Advanced Mathematics & Physics (CAMP), NUST, Islamabad	Member

Following preliminary members did not attend the final meeting:

1.	Prof. Dr. Mrs. Farhat Saleemi, Dean, Faculty of Engineering and Technology, Department of Physics, Lahore College for Women, University, Lahore.
2.	Prof. Dr. Sher Mohammad Nasir, Professor & Chairman, Department of Physics, University of Balochistan, Quetta.
3.	Dr. Iqbal Ahmed Khan, Professor, Department of Physics, Hamdard Institute of Information Technology, Hamdard University, Karachi.
4.	Dr. M. Khalid, Professor, Department of Physics, Gomal University, D.I. Khan.
5.	Dr. Nazish Rubab, Assistant Professor, Department of Materials Science and Engineering, Institute of Space Technology, Islamabad.
6.	Dr. Muhammad Atif, Assistant Professor, Department of Physics, Air University, Islamabad.
7.	Dr. Muhammad Riaz, Assistant Professor, Department of Physics, University of the Punjab, Lahore.
8.	Dr. Imran Ahmad Siddiqui, Assistant Professor, Department of Physics, University of Karachi, Karachi.

9.	Dr. Hamdullah Khan Tareen, Assistant Professor, Department of Physics, Balochistan University of Information Technology, Engineering & Management Sciences, Quetta.
10.	Dr. Ghulam Jaffar, Head of Department (Space Science), Institute of Space Technology (IST), Islamabad.
11	Prof. Dr. Abdul Majid, Professor & Chairman, Department of Physics, University of AJK, Muzaffarabad
12.	Dr. Muhammad Sabieh Anwar, Chair of Physics Department, Lahore University of Management Sciences, (LUMS), Lahore.

3. The meeting started with the recitation of Holy Verses from the Holy Quran by Dr. Abdul Manan, Assistant Professor, University of Science & Technology, Bannu, followed by welcome address by Mr. Zaheer Ahmed Awan, Director, HEC Regional Centre, Peshawar. He briefed the aims and objectives of the meeting with particular focus on the revision and finalizing the curriculum of Physics so as to bring it in line with the international standards keeping in view the national needs. After brief introduction of participants, the Convener of NCRC viz. Prof. Dr. Iftikhar Ahmed, Professor & Chairman, Department of Physics, University of Malakand, Chakdara Dir, was requested to conduct the further proceeding of the meeting for three days.

4. Before further proceeding of the meeting, the Convener of NCRC requested the house to elect the Secretary of meeting since Dr. Muhammad Sabieh Anwar did not join the final meeting. The house unanimously elected Dr. Rizwan Khalid, Assistant Professor, NUST Islamabad, as the Secretary of the meeting. The Convener and Secretary of NCRC thanked the HEC for providing an opportunity to review/finalize the curriculum of Physics and recalled the proceeding of preliminary meeting. They further requested the participants to give their suggestions/inputs for the improvement of the curriculum and opened the house for discussion. After thorough and detailed deliberation, the Committee unanimously approved the curriculum of Physics for BS, MS/MPhil and PhD.

5. The Committee also recommended that HEC may allow the universities to initiate MPhil leading to PhD programme as well which was very successful across the country.

6. Convener and Secretary of the Committee thanked all the members for sparing their valuable time and quality contribution towards finalization of the curriculum. The Committee highly admired the efforts made by the officials of HEC as well for making excellent arrangements to facilitate the smooth work by the Committee and their comfortable accommodation/stay at Peshawar.

7. The meeting ended with the vote of thanks to the Chair as well as participants of the meeting.

Course Outlines & Course Codes in Physics

Simplicity is the best way to approach complex situations. In order to simplify the physics curriculum it is divided into two main categories, 1) Undergraduate studies (BS), and 2) Graduate studies (PhD. and MPhil.). The courses up to 499 level maybe considered for undergraduate taught courses, while 500 will be research project. For uniformity with all the universities the graduate courses may be above 600. For the course codes Phys xxx, specifically for the BS program, the left letter shows the year, like first year 1xx, third year 3xx and fourth year 4xx (except for project 500), while middle letter for specific subject (example electrodynamics is 2 (Phys x2x), Quantum mechanics is 3 (Phys x3x) etc.) and the last letter shows the sequence of the course. The middle letter for foundation courses maybe be 0, i.e. phys x0x. It may be noted that there is no hard and fast rule for the right side two letters and can be arranged in any convenient way but the left side letter definitely shows the hardship level i.e. year of the course. The course codes for some subjects are presented here so that uniform pattern can be defined for all universities. The courses not mentioned here can be coded in the same pattern:

Subject		**Hardship level**	**Course code**
Mechanics	BS foundation (x0x)	1st Semester, Year: 1 (1xx)	Phys 101
Mechanics Lab.	BS foundation (x0x)	1st Semester, Year: 1 (1xx)	Phys 101L
Electricity & Magnetism	BS foundation (x0x)	2nd Semester, Year: 1 (1xx)	Phys 102
Electricity & Magnetism Lab.	BS foundation (x0x)	2nd Semester, Year: 1 (1xx)	Phys 102L
Waves and Oscillations	BS foundation (x0x)	3rd Semester, Year: 2 (2xx)	Phys 203

Waves and Oscillations Lab.	BS foundation (x0x)	3rd Semester, Year: 2 (2xx)	Phys 203L
Modern Physics	BS foundation (x0x)	3rd Semester, Year: 2 (2xx)	Phys 204
Optics	BS foundation (x0x)	4th Semester, Year: 2 (2xx)	Phys 205
Optics Lab.	BS foundation (x0x)	4th Semester, Year: 2 (2xx)	Phys 205L
Classical Mechanics (x1x)	BS major course	5th Semester, Year: 3 (3xx)	Phys 311
Classical Mechanics (x1x)	M.Phil. course	M.Phil. 1st semester (6xx)	Phys 612
Electrodynamics I (x2x)	BS major course	5th Semester, Year: 3 (3xx)	Phys 321
Electrodynamics II (x2x)	BS major course	6th Semester, Year: 3 (3xx)	Phys 322
Electrodynamics I (x2x)	MPhil course	M.Phil. 1st semester (6xx)	Phys 623
Electrodynamics II (x2x)	MPhil course	M.Phil. 2nd semester (6xx)	Phys 624
Quantum Mechanics I (x3x)	BS major course	6th Semester, Year: 3 (3xx)	Phys 331
Quantum Mechanics II (x3x)	BS major course	7th Semester, Year: 4 (3xx)	Phys 432
Atomic and molecular physics (x3x)	BS major course	7th Semester, Year: 4 (3xx)	Phys 433
Quantum Mechanics I (x3x)	MPhil course	MPhil 1st semester (6xx)	Phys 634
Quantum Mechanics II (x3x)	MPhil/PhD course	MPhil/PhD course (6xx)	Phys 635
Quantum Optics-I (x3x)	MPhil/PhD course	MPhil/PhD course (7xx)	Phys 736
Quantum Optics-II (x3x)	MPhil/PhD course	MPhil/PhD course (7xx)	Phys 737
Quantum Information Theory-I (x3x)	MPhil/PhD course	MPhil/PhD course (7xx)	Phys 738
Solid State Physics I (x4x)	BS major course	7th Semester, Year: 4 (3xx)	Phys 441
Solid State Physics II (x4x)	BS major course	8th Semester, Year: 4 (3xx)	Phys 442

Condensed Matter Theory I (x4x)	MPhil/PhD course	MPhil/PhD course (7xx)	Phys 743
Condensed Matter Theory II (x4x)	MPhil/PhD course	MPhil/PhD course (7xx)	Phys 744
Magnetism in Condensed Matter (x4x)	MPhil/PhD course	MPhil/PhD course (7xx)	Phys 745
Optical properties of Solids (x4x)	MPhil/PhD course	MPhil/PhD course (7xx)	Phys 746
Mathematical Methods of Physics I (x5x)	BS major course	5th Semester, Year: 3 (3xx)	Phys 351
Mathematical Methods of Physics I (x5x)	BS major course	6th Semester, Year: 3 (3xx)	Phys 352
Mathematical Methods of Physics (x5x)	MPhil course	MPhil course (6xx)	Phys 653
Statistical Physics (x6x)	BS major course	6th Semester, Year: 3 (3xx)	Phys 361
Statistical Physics (x6x)	MPhil course	MPhil course (6xx)	Phys 662
Electronics I (x9x) (all other physics)	BS major course	5th Semester, Year: 3 (3xx)	Phys 391
Electronics Lab.	BS major course	5th Semester, Year: 3 (3xx)	Phys 391L
Modern Physics, atomic physics and spectroscopy and electronic materials Lab.	BS foundation (x0x)	6th Semester, Year: 2 (2xx)	Phys 392L
Miscellaneous experiments in solid state physics	BS major course	7th Semester, Year: 4 (3xx)	Phys 493L
Electronics II (x9x) (all other physics)	BS major course	6th Semester, Year: 3 (3xx)	Phys 392
Nuclear Physics (x9x) (all other physics)	BS major course	8th Semester, Year: 4 (4xx)	Phys 493
Introduction to relativity (x9x) (all other physics)	BS major course	8th Semester, Year: 4 (4xx)	Phys 494
BS research project		7th + 8th Semester, Year: 4	Phys 500

OBJECTIVES OF THE BS PROGRAMME

The main educational objectives of BS (4-year) degree programme are:

1. to impart students with a conceptual understanding of the fundamental principles of physics, natural laws and their interpretation, as well as mathematical formulation of the physical phenomena in nature,
2. to develop critical skills necessary for solving unknown problems from our physical surroundings,
3. to develop the capability of analyzing, addressing and posing solutions to problems of natural importance and to instill a deep appreciation of the need for optimum utilization of natural resources and environment,
4. to instill in students the habit of independent thinking, deep inquiry, and motivation for self-education,
5. to sharpen our students' mathematical prowess making them capable of modelling, analyzing and predicting the behaviour of physical processes,
6. to enhance our students skills in scientific communication and the ability to clearly present physics and science in simple and clear language,
7. to introduce to students the spirit of working in interactive groups with the necessary requirements of scientific and professional ethics,
8. to develop hands-on experience in different laboratory techniques, modern instrumentation,
9. to enhance student competence in the design and conduct of experiments and analysis and presentation of experimental data and results,
10. to provide an in-depth understanding of some specialized area of physics through the option of elective courses.
11. to equip students with the necessary skill set for pursuing careers in physics education, research and industry in government or private organizations.

LAYOUT FOR BS (4-YEAR) PHYSICS

Compulsory Requirements		General Education Requirements		Foundation Courses in the Major subject	
9 courses		**7-8 courses**		**11-13 courses**	
25 Credit hours		**21-24 Credit hours**		**36-42 Credit hours**	
Subject	**Cr. hr**	**Subject**	**Cr. hr**	**Subject**	**Cr. Hr**
• English-i	3	GOF-I	3	• Mechanics	4
• English-ii	3	GRF-I	3	• Waves and Oscillations	3
• English-iii	3	Math-III	3	• Heat & Thermodynamics	3
• English-iv[1]	3	GOF-II	3	• Electricity & Magnetism	4
• Pakistan studies	2	GOF-III	3	• Modern Physics	3
• Islamic studies/ ethics	2	GRF-II	3	• Optics	3
• Math-i	3	Math-IV	3	• Lab-I	1
• Math-ii	3			• Lab-II	1
• Introduction to Computing	3			• Lab-III	1
				• Lab-IV	1
	25		21		24

[1] University has the option to recommend any other course in lieu of English-VI

Core courses in the major subject including Research Project/Internship requirements		Elective Courses in the Major Subject	
11-13 courses		**4 courses**	
36-42 Credit hours		**12 Credit Hours**	
Subject	**Cr. hr**	**Subject**	**Cr. hr**
• Quantum Mechanics – I	3	• Elective-I	3
• Quantum Mechanics – II	3	• Elective-II	3
• Classical Mechanics	3	• Elective-III	3
• Electronics I	3	• Elective–IV	3
• Electronics II	3		
• Mathematical Methods of Physics–I	3		
• Mathematical Methods of Physics–II	3		
• Electrodynamics-I	3		
• Electrodynamics-II	3		
• Statistical Physics	3		
• Nuclear Physics	3		
• Solid State Physics I	3		
• Solid State Physics II	3		
• Atomic and molecular physics	3		
• Research Project	3		
• Lab-V	2		
• Lab-VI	2		
• Lab-VII	2		
	51		12

Total Credit Hours: 133

GOF = General Subjects from Faculties other than Sciences
GRF = General Subjects from Science Faculty

SCHEME OF STUDIES FOR BS (4-YEAR) PROGRAMME IN PHYSICS

Semester-I

Title	Cr. Hrs.	Remarks
English-I	3	Comp-1
Calculus-I	3	Comp-2
Introduction to Computing	3	Comp-3
Mechanics	4	Found-1
GOF/GRF	3	Gen-1
Lab-I	1	Found-2
Total	17	

Semester-II

Title	Cr. Hrs.	Remarks
English-II	3	Comp-4
Calculus-II	3	Comp-5
Electricity & Magnetism	4	Found-3
Heat & Thermodynamics	3	Found-4
GOF/GRF	3	Gen-2
Lab II	1	Found-5
Total	17	

Semester-III

Title	Cr. Hrs.	Remarks
English-III	3	Comp-6
Linear Algebra	3	Gen-3
Waves & Oscillations	3	Found-6
Modern Physics	3	Found-7
GOF/GRF	3	Gen-4
Lab-III	1	Found-8
Total	16	

Semester-IV

Title	Cr. Hrs.	Remarks
Islamic Studies	2	Comp-7
English IV	3	Comp-8
Differential Equations	3	Gen-5
Probability & Statistics	3	Gen-6
Optics	3	Found-9
GOF/GRF	3	Gen-7
Lab-IV	1	Found-10
Total	18	

Semester-V

Title	Cr. Hrs.	Remarks
Mathematical Methods of Physics-I	3	Maj-1
Electrodynamics-I	3	Maj-2
Classical Mechanics	3	Maj-3
Electronics-I	3	Maj-4
Pak study	2	Comp-9
Lab-V	2	Maj-5
Total	16	

Semester-VI

Title	Cr. Hrs.	Remarks
Mathematical Methods of Physics-II	3	Maj-6
Quantum Mechanics-I	3	Maj-7
Electrodynamics –II	3	Maj-8
Electronics-II	3	Maj-9
Statistical Physics	3	Maj-10
Lab-VI	2	Maj-11
Total	17	

Semester-VII

Title	Cr. Hrs.	Remarks
Quantum Mechanics-II	3	Maj-12
Atomic & Molecular Physics	3	Maj-13
Solid State Physics-I	3	Maj-14
Elective-I	3	Elective
Nuclear Physics / Introduction to Relativity	3	Maj-15
Lab-VII	2	Maj-16
Total	17	

Semester-VIII

Title	Cr. Hrs.	Remarks
Elective-II	3	Elective
Elective-III	3	Elective
Research Project	3	Maj-17
Solid State Physics-II	3	Maj-18
Elective-IV	3	
Total	15	

Total Credit Hours: 133

Notes:

- A total of two GOF and three GRF courses must be taken
- The order of Linear Algebra and Differential Equation can be swapped
- The university can reshuffle the courses within semesters to suit their particular needs

RECOMMENDED CURRICULUM
FOR BS PHYSICS COURSES

MECHANICS

Credit Hours: Four (4)

Objectives:

The main objective of this course is to understand the different motions of objects on a macroscopic scale and to develop simple mathematical formalisms to analyze such motions. This is a calculus-based introductory course with maximum emphasis on applying the acquired knowledge to solving problems.

Basic Concepts: Units and Dimensions, SI Units, Changing Units, Scalars and Vectors, Adding Vectors: Graphical as well as Component Method, Multiplying Vectors: Dot and Cross Products.

Motion in One, Two and Three Dimensions: Position & Displacement, Velocity and Acceleration, Motion under Constant Acceleration, Projectile Motion, Uniform Circular Motion, Relative Velocity and Acceleration in One and Two Dimensions, Inertial and Non-Inertial Reference Frames.

Newton's Laws: Newton's Laws of Motion and their Applications involving some particular forces including Weight, Normal Force, Tension, Friction, and Centripetal Force, Newton's Law of Gravitation, Gravitational Potential Energy, Escape Velocity, Kepler's Laws, Satellite Orbits & Energy.

Work and Kinetic Energy: Work done by Constant and Variable Forces: Gravitational and Spring Forces, Power, Conservative and Non-conservative Forces, Work and Potential Energy, Isolated Systems and Conservation of Mechanical Energy, Work Done by External Forces including Friction and Conservation of Energy.

System of Particles: Motion of a System of Particles and Extended Rigid Bodies, Center of Mass and Newton's Laws for a System of Particles, Linear Momentum, Impulse, Momentum & Kinetic Energy in One and Two Dimensional Elastic and Inelastic Collisions.

Rotational Motion: Rotation about a Fixed Axis, Angular Position, Angular Displacement, Angular Velocity and Angular Acceleration, Rotation under Constant Angular Acceleration, relationship between Linear and Angular Variables, Rotational Inertia, Parallel-axis Theorem, Torque and Newton's Law for Rotation, Work and Rotational Kinetic Energy, Power, Rolling Motion, Angular Momentum for a single Particle and a System of Particles, Conservation of Angular Momentum, Precession of a Gyroscope, Static

Equilibrium involving Forces and Torques, Determination of moment of inertia of various shapes i.e. for disc, bar and solid sphere.

Angular Momentum: Angular Velocity, Conservation of angular momentum, effects of Torque and its relation with angular momentum.

Simple Harmonic Motion (SHM): Amplitude, Phase, Angular Frequency, Velocity and Acceleration in SHM, Linear and Angular Simple Harmonic Oscillators, Energy in SHM, Simple Pendulum, Physical Pendulum, SHM and Uniform Circular Motion, Damped Harmonic Oscillator.

Special Theory of Relativity: Inertial and non-inertial frame, Postulates of Relativity, The Lorentz Transformation, Derivation, Assumptions on which inverse transformation is derived, Consequences of Lorentz transformation, Relativity of time, Relativity of length, Relativity of mass, Transformation of velocity, variation of mass with velocity, mass energy relation and its importance, relativistic momentum and Relativistic energy, (Lorentz invariants) $E^2=c^2 p^2+m^2_o c^4$

Recommended Books:

1. D. Halliday, R. Resnick and J. Walker, “Fundamentals of Physics”, John Wiley & Sons, 9th ed. 2010.
2. R. A. Serway and J. W. Jewett, “Physics for Scientists and Engineers”, Golden Sunburst Series, 8th ed. 2010.
3. R. A. Freedman, H. D. Young, and A. L. Ford (Sears and Zeemansky), “University Physics with Modern Physics”, Addison-Wesley-Longman, 13th International ed. 2010.
4. F. J Keller, W. E. Gettys and M. J. Skove, “Physics: Classical and Modern, McGraw Hill. 2nd ed. 1992.
5. D. C. Giancoli, “Physics for Scientists and Engineers, with Modern Physics”, Addison-Wesley, 4th ed. 2008.

ELECTRICITY AND MAGNETISM

Pre-requisite: **Mechanics, Calculus I**
Co-requisite: **Calculus II**
Credit Hours: **Four (4)**

Objectives:

The main objective of this course is to understand the Physics of Electromagnetism and to develop simple mathematical formalisms to analyze the electromagnetic fields and interactions. This is a calculus-based introductory course with maximum emphasis on applying the acquired knowledge to solving problems.

Electrostatics: Electric Charge, Conductors and Insulators, Coulomb's Law, Electric Fields due to a Point Charge and an Electric Dipole, Electric Field due to a Charge Distribution, Electric Dipole in an Electric Field, Electric Flux, Gauss' Law and its Applications in Planar, Spherical and Cylindrical Symmetry.

Electric Potential: Equipotential Surfaces, Potential due to a Point Charge and a Group of Point Charges, Potential due to an Electric Dipole, Potential due to a Charge Distribution, Relation between Electric Field and , Electric Potential Energy.

Capacitors and Capacitance: Parallel Plate, Cylindrical and Spherical capacitors, Capacitors in Series and Parallel, Energy Stored in an Electric Field, Dielectrics and Gauss' Law (1 week).

DC Circuits: Electric Current and Current Density, Resistance and Resistivity, Ohm's Law, Power in Electric Circuits, Semiconductors and Superconductors, Work, Energy, and EMF, Resistances in Series and Parallel, Single and Multi-loop Circuits, Kirchhoff's Rules, RC Circuits, Charging and Discharging of a Capacitor.

Magnetic Field and Magnetic Force: Crossed Electric and Magnetic Fields and their Applications, Hall Effect, Magnetic Force on a Current Carrying Wire, Torque on a Current Loop, Magnetic Dipole Moment, Magnetic Field Due to a Current, Force between two Parallel Currents, Ampere's Law, Biot-Savart Law: Magnetic Field due to a Current, Long Straight Wire carrying Current, Solenoids and Toroids, A current-carrying Coil as a Magnetic Dipole, Inductance, Faraday's Law of Induction, Lenz's Law, Induction and Energy Transfers, Induced Electric Fields, Inductors and Inductances, Self Inductance, RL Circuits, Energy Stored in a Magnetic Field, Energy Density, Mutual Induction.

Alternating Fields and Currents: LC Oscillations, Damped Oscillations in an RLC circuit, Alternating Currents, Forced Oscillations, Resistive, Capacitive, and Inductive Loads, RLC series Circuit, Power in AC Circuits, Transformers, Gauss' Law for Magnetism, Induced Magnetic Fields, Displacement Current, Spin & Orbital Magnetic Dipole Moment, Diamagnetism, Paramagnetism, Ferromagnetism, Hysteresis.

Recommended Text Books:

1. D. Halliday, R. Resnick and J. Walker, "Fundamentals of Physics", John Wiley & Sons, 9th ed. 2010.
2. R. A. Serway and J. W. Jewett, "Physics for Scientists and Engineers", Golden Sunburst Series, 8th ed. 2010.
3. R. A. Freedman, H. D. Young, and A. L. Ford (Sears and Zeemansky), "University Physics with Modern Physics", Addison-Wesley-Longman, 13th International ed. 2010.

4. F. J Keller, W. E. Gettys and M. J. Skove, “Physics: Classical and Modern, McGraw Hill. 2nd ed. 1992.
5. D. C. Giancoli, “Physics for Scientists and Engineers, with Modern Physics”, Addison-Wesley, 4th ed. 2008.

HEAT AND THERMODYNAMICS

Pre-requisites: **Mechanics**
Co-requisites: **Calculus-II**
Credit Hours: **Four (4)**

Objective(s):

To understand the fundamentals of heat and thermodynamics.

Basic Concepts and Definitions in Thermodynamics: Thermodynamic system, Surrounding and Boundaries. Type of systems. Macroscopic and microscopic description of system. Properties and state of the substance: Extensive and Intensive properties, Equilibrium, Mechanical and Thermal Equilibrium. Processes and Cycles: Isothermal, Isobaric and Isochoric. Zeroth Law of Thermodynamics, Consequence of Zeroth law of Thermodynamics. The state of the system at Equilibrium.

Heat and Temperature: Temperature, Kinetic theory of ideal gas, Work done on an ideal gas, Review of previous concepts. Internal energy of an ideal gas: Equipartition of Energy, Intermolecular forces, Qualitative discussion, The Virial expansion, The Van der Waals equation of state.

Thermodynamics: First law of thermodynamics and its applications to adiabatic, isothermal, cyclic and free expansion. Reversible and irreversible processes. Second law of thermodynamics, Carnot theorem and Carnot engine. Heat engine, Refrigerators. Calculation of efficiency of heat engines. Thermodynamic temperature scale: Absolute zero, Entropy, Entropy in reversible process, Entropy in irreversible process. Entropy and Second law of thermodynamics, Entropy and Probability. Thermodynamic Functions: Thermodynamic functions (Internal energy, Enthalpy, Gibb’s functions, Entropy, Helmholtz functions), Maxwell’s relations, TdS equations, Energy equations and their applications. Low Temperature Physics, Joule-Thomson effect and its equations. Thermoelectricity: Thermocouple, Seabeck’s effect, Peltier’s effect, Thomson effect.

Introduction to Statistical Mechanics: Statistical distribution and mean values, Mean free path and microscopic calculations of mean free path. Distribution of Molecular Speeds, Distribution of Energies, Maxwell distribution, Maxwell Boltzmann energy distribution, Internal energy of an ideal gas, Brownian Motion Legvaian equation, Qualitative description.

Recommended Books:

1. D. Halliday, R. Resnick and K. Krane, “Physics”, John Wiley, 5th ed. 2002.
2. D. Halliday, R. Resnick and J. Walker, “Fundamentals of Physics”, John Wiley, 9th ed. 2010.
3. M. W. Zemansky, “Heat and Thermodynamics”, Mc Graw Hill, 7th ed. 1997.
4. M. Sprackling, “Thermal Physics” McMillan 1991.
5. B. N. Roy, “Principle of Modern Thermodynamics”, Institute of Physics, London 1995.

WAVES AND OSCILLATIONS

Pre-requisites: **Mechanics, Calculus II**
Credit Hours: **Three (3)**

Objective(s):

To develop a unified mathematical theory of oscillations and waves in physical systems.

Simple and Damped Simple Harmonic Oscillation: Mass-Spring System, Simple Harmonic Oscillator Equation, Complex Number Notation, LC Circuit, Simple Pendulum, Quality Factor, LCR Circuit.

Forced Damped Harmonic Oscillation: Steady-State Behavior, Driven LCR Circuit, Transient Oscillator Response, Resonance.

Coupled Oscillations: Two Spring-Coupled Masses, Two Coupled LC Circuits, Three Spring Coupled Masses, Normal Modes, Atomic and Lattice Vibrations.

Transverse Waves: Transverse Standing Waves, Normal Modes, General Time Evolution of a Uniform String, Phase velocity, Group Velocity.

Longitudinal Waves: Spring Coupled Masses, Sound Waves in an Elastic Solid, Sound Waves in an Ideal Gas.

Traveling Waves: Standing Waves in a Finite Continuous Medium, Traveling Waves in an Infinite Continuous Medium, Energy Conservation, Transmission Lines, Reflection and Transmission at Boundaries, Electromagnetic Waves.

Wave Pulses: Fourier Series and Fourier Transforms, Bandwidth, Heisenberg’s Uncertainty Principle.

Multi-Dimensional Waves: Plane Waves, Three-Dimensional Wave Equation, Laws of Geometric Optics, Waveguides, Cylindrical Waves.

Interference and Diffraction of Waves: Double-Slit Interference, Single-Slit Diffraction.

Recommended Books:

1. J. Pain, “The Physics of Vibrations and Waves”, John Wiley, 6th ed. 2005.
2. P. French, “Vibrations and Waves”, CBS Publishers (2003).
3. F. S. Crawford, Jr., “Waves and Oscillations”, Berkeley Physics Course, Vol. 3, McGraw-Hill, 1968.
4. A. Hirose, and K. E. Lonngren, “Introduction to Wave Phenomena”, Krieger Publications, 2003.

MODERN PHYSICS

Pre-requisites: Mechanics, Electricity and Magnetism
Credit Hours: Four (3)

Objective(s):

To understand the non-classical aspects of Physics, the emphasis is on the applications of Quantum Physics in microscopic-scale Physics, atomic and molecular structure and processes.

Motivation for Non--Classical Physics: Quantum interference, blackbody radiation and ultraviolet catastrophe, Planck's quantization.

Wace-Particle Duality: Photoelectric effect, Compton effect, production and properties of X-rays, diffraction of X-rays, concept of matter waves, de Broglie relationship, electrons are waves, electron diffraction, particulate nature of matter, contributions of Faraday (atoms exist), Thomson (electron exists), Rutherford (nucleus exists) and Bohr (quantization of energies inside an atom), wave packets and wave groups, dispersion, Heisenberg uncertainty principle, direct confirmation of quantization through Franck-Hertz experiment and spectroscopy, working of electron microscopes.

Quantum Mechanics in One Dimension: The concept of a wavefunction, time independent Schrodinger equation and interpretation of the equation, solving the Schrodinger equation for a free particle, for a particle inside an infinite box, relationship between confinement and quantization, working of a CCD camera.

Quantum Mechanical Tunneling: Concept of tunneling, reflection and transmission of wave functions from barriers, applications: radioactivity, scanning tunneling microscope, decay of black holes.

Quantum Mechanics in Three Dimensions: The Hydrogen atom, orbitals, angular momentum and its quantization, orbital magnetism, Zeeman effect, concept of spin, Pauli's exclusion principle, Building of the periodic table, magnetic resonance and MRI, why is iron magnetic? White dwarfs, and neutron stars.

From Atoms to Molecules and Solids: Ionic bonds, covalent bonds, hydrogen bonds, molecular orbitals, how crystals are different from amorphous solids? Why and how do metals conduct electricity? Bands in solids, semiconductors, introduction to LED's and lasers, introducing grapheme.

Nuclear Structure: Size and structure of nucleus, nuclear forces, radioactivity and nuclear reactions, radiocarbon dating.

Recommended Books:

1. R.A. Serway, C.J. Moses and C.A. Moyer, "Modern Physics", Brooks Cole, 3rd ed. 2004.
2. Paul A. Tipler and Ralph A. Llewellyn, "Modern Physics", W H Freeman and Company 6th ed. 2012.
3. Arthur Beiser, "Concepts of Modern Physics", McGraw-Hill, 6th ed. 2002.
4. R. M. Eisberg and R. Resnick, "Quantum Physics of Atoms, molecules, Solids, Nuclei and Particles", John Wiley, 2nd ed. 2002.

OPTICS

Pre-Requisites: Waves and Oscillations
Credit Hours: Three (3)

Objective(s):

To understand the optical phenomena and their uses in physical systems

Propagation of Light & Image Formation: Huygens' Principle, Fermat's Principle, Laws of Reflection and Refraction, Refraction at a Spherical Surface, Thin Lenses, Newtonian Equation for a Thin Lens.

Matrix Methods in Paraxial Optics: Ray Transfer Matrices, Thick Lens, Significance of System Matrix Elements, Cardinal Points of an Optical System with examples, Optical Instruments including Simple Magnifiers, Telescopes and Microscopes, Chromatic and Monochromatic Aberrations, Spherical Aberrations, Coma, Distortion, Stops, Pupils, Windows.

Superposition & Interference: Standing Waves, Beats, Phase and Group Velocities, Two-Beam and Multiple-Beam Interference, Thin Dielectric Films, Michelson and Fabry-Perot Interferometers, Resolving Power, Free-Spectral Range.

Polarization: Jones Matrices, Production of Polarized Light, Dichroism, Brewster's Law, Birefringence, Double Refraction.

Fraunhofer Diffraction: from a Single Slit, Rectangular and Circular Apertures, Double Slit, Many Slits, Diffraction Grating, Dispersion, Resolving Power Blazed Gratings.

Fresnel Diffraction: Zone Plates, Rectangular Apertures, Cornu's Spiral

Coherence & Holography: Temporal Coherence, Spatial Coherence, Holography of a Point object and an Extended Object

Laser Basics: Stimulated Emission, Population Inversion, Resonators, Threshold and Gain, Multi-layered Dielectric Films.

Recommended Books:

1. F. Pedrotti, L. S. Pedrotti and L. M. Pedrotti, "Introduction to Optics", Pearson Prentice Hall, 3rd ed. 2007.
2. E. Hecht and A. Ganesan, "Optics", Dorling Kindersley, 4th ed. 2008.
3. M. V. Klein and T. E. Furtak, "Optics", John Wiley, 2nd ed. 1986.
4. K. K Sharam, "Optics: Principles and Applications", Academic Press, 2006.
5. C. A. Bennett, "Principles of Physical Optics", John Wiley, 2008.

MATHEMATICAL METHODS OF PHYSICS-I

Pre-requisite: **Mechanics, Differential Equations, Linear Algebra**
Credit Hours: **(Three) 3**

Objective(s):

To develop the mathematical background of student in vectors, tensors, matrices and some of their uses in the world of physics, to give basic understanding of group theory and complex variables used in physics.

Partial Differential Equations: Introduction to important PDEs in Physics (wave equation, diffusion equation, Poisson's equation, Schrodinger's equation), general form of solution, general and particular solutions (first order, inhomogeneous, second order), characteristics and existence of solutions, uniqueness of solutions, separation of variables in Cartesian coordinates, superposition of separated solutions, separation of variables in curvilinear coordinates, integral transform methods, Green's functions

Complex Analysis: Review (polar form of complex numbers and de Moivre's theorem, complex logarithms and powers), functions of a complex variable, Cauchy-Riemann conditions, power series in a complex variable and analytic continuation with examples, multi-valued functions and branch cuts, singularities and zeroes of complex functions, complex integration, Cauchy's theorem, Cauchy's integral formula, Laurent series and residues, residue integration theorem, definite integrals using contour integration.

Recommended Books:

1. G. Arfken, H. J. Weber, and F. E. Harris, "Mathematical Methods for Physicists", Academic Press, 7th ed. 2012.
2. K. F. Riley, M. P. Hobson, S. J. Bence, "Mathematical Methods for Physicists", Cambridge University Press, 2006.
3. E. Kreyszig, "Advanced Engineering Mathematics", John Wiley, 8th ed. 1999.

ELECTROMAGNETIC THEORY-I

Pre-requisites: Electricity and Magnetism, Calculus-II
Credit Hours: Three (3)

Review of Calculus: vector algebra and calculus, Cartesian coordinates spherical coordinates.
(1 week).

The Dirac Delta Function: Review of vector calculus using example of Dirac Delta function, the divergence of r/r^2, the one-dimensional and the three-dimensional Dirac delta functions. The theory of vector fields: the Helmoholtz theorem, potentials.

Electrostatics: The electric field: introduction, Coulomb's law, the electric field, continuous charge distributions. Divergence and curl of electrostatic fields: field lines, flux and Gauss's law, the divergence of E, applications of Gauss's law, the curl of E. Electric potential: introduction to potential, comments on potential, Poisson's equation and Laplace's equation, the potential of a localized charge distribution, summary, electrostatics boundary conditions, Work and energy in electrostatics: the work done to move a charge, the energy of a point charge distribution, the energy of a continuous charge distribution, comments on electrostatic energy. Conductors: basic properties, induced charges, surface charge and the force on a conductor, capacitors.

Special Techniques: Laplace's equation: introduction, Laplace's equation in one, two and three dimensions, boundary conditions and uniqueness theorems, conductors and second uniqueness theorems.

The Method of Images: The classic image problem, induced surface charge, force and energy, other image problems.

Multi-pole Expansion: Approximate potential at large, the monopole and dipole terms, origin of coordinates in multi-pole, expansions, the electric field of a dipole.

Electric Fields in Matter: Polarization: dielectrics, induced dipoles, alignment of polar molecules, polarization. The field of a polarized object: bound charges, physical interpretation of bound charges, and the field inside a dielectric. The electric displacement: Gauss's law in the presence of dielectrics, a deceptive parallel, boundary conditions. Linear Dielectrics: susceptibility, permittivity, dielectric constant, boundary value problems with linear dielectrics, energy in dielectric systems, forces on dielectrics.

Magnetostatics: The Lorentz Force law: magnetic fields, magnetic forces, currents. The Biot-Savart Law: steady currents, the magnetic field of a steady current. The divergence and curl of B: straight-line currents, the divergence and curl of B, applications of Ampere's law, comparison of magnetostatics and electrostatics. Magnetic Vector Potential: the vector potential, summary, magnetic boundary conditions, multi-pole expansion of the vector potential.

Magnetic Fields in Matter: Magnetization, diamagnets, paramagnets, ferromagnets, torques and forces on magnetic dipoles, effect of a magnetic field on atomic orbits, magnetization. The Field of a Magnetized Object: bound currents, physical interpretation of bound currents, and the magnetic field inside matter. The auxiliary field H: Ampere's law in magnetized materials, a deceptive parallel, boundary conditions. Linear and nonlinear media: magnetic susceptibility and permeability, ferromagnetism.

Recommended Books:

1. D. J. Griffiths, "Introduction to Electrodynamics", Prentice Hall, 3rd ed. 1999.
2. M. N. O. Sadiku, "Elements of Electromagnetics", Oxford University Press, 5th ed. 2009.
3. F. Melia, "Electrodynamics", University of Chicago Press, 2001.
4. Hearld J and W. Muller-Kristen, "Electrodynamics", World Scientific Publishing, 2nd ed. 2011.

CLASSICAL MECHANICS

Pre-requisites: Mechanics
Credit Hours: Three (3)

Review of Newtonian Mechanics: Frame of reference, orthogonal transformations, angular velocity and angular acceleration, Newton's laws of motion, Galilean transformation, conservation laws, systems of particles, motion under a constant force, motions under variable force, time-varying mass system.
The Lagrange Formulation of Mechanics and Hamilton Dynamics: Generalized co-ordinates and constraints, D'Alembert's principle and Lagrange's Equations, Hamilton's principle, integrals of motion, non conservative system and generalized potential, Lagrange's multiplier method, the Hamiltonian of a dynamical system, canonical equations, canonical transformations, Poisson brackets, phase space and Liouville's theorem.

Central Force Motion: The two-body problem, effective potential and classification of orbits, Kepler's laws, stability of circular orbits, hyperbolic orbits and Rutherford scattering, center of mass co-ordinate system, scattering cross-sections.

Motion in Non-inertial Systems: Accelerated translational co-ordinate system, dynamics in rotating co-ordinate system, motion of a particle near the surface of the earth.

The Motion of Rigid Bodies: The Euler angles, rotational kinetic energy and angular momentum, the inertia tensor, Euler equations of motion, motion of a torque-free symmetrical top, stability of rotational motion.

Recommended Books:

1. T. L. Chow, "Classical Mechanics", John Wiley, 1995.
2. T. Kibble and F. Berkshire, "Classical Mechanics", World Scientific, 5th ed. 2004.

ELECTRONICS-I

Pre-requisites: Modern Physics
Credit Hours: Three (3)

The Semiconductor Diode: Metals, insulators and semiconductors, Conduction in Silicon and Germanium, The forbidden energy gap, n and p type semiconductors, the junction diode, diode voltage-current equation, Zener diodes, light emitting diodes, photodiodes, capacitance effects in the pn junction.

The Diode as Rectifier and Switch: The ideal diode model, the half wave rectifier, the full wave rectifier, the bridge rectifier, measurement of ripple factor in the rectifier circuit, the capacitor filter, the ∏ filter, the ∏-R filter, the voltage doubling rectifier circuit, rectifying AC voltmeters, diode wave clippers, diode clampers.

Circuit Theory and Analysis: Superposition theorem, Thevenin's Theorem, Norton's Theorem, Model for circuit, one port and two-port network, Hybrid parameter equivalent circuit, Power in decibels.

The Junction Transistor as an Amplifier: Transistor voltage and current designations, the junction transistors, the volt-ampere curve of a transistor, the current amplification factors, the load line and Q point, the basic transistor amplifiers, the common emitter amplifier, the trans-conductance g_m, performance of a CE amplifier, relation between A_i and A_v, the CB amplifier, the CC amplifier, comparison of amplifier performance.

DC Bias for the Transistor: Choice of Q point, variation of Q point, fixed transistor bias, the four resistor bias circuit, design of a voltage feedback bias circuit, Common emitter, common collector, common base biasing.

Field Effect Transistor: What is /field effect transistor, JFET: Static characteristics of JFET, Metal oxide semiconductor Field Effect Transistor (MOSFET of IGFET): enhancement and depletion mode, FET biasing techniques, Common drain, common source and common gate, fixed bias and self-bias configurations, Universal JFET bias curve, Darlington pair.

Operational Amplifiers: The integrated amplifier, the differential amplifier, common mode rejection ratio, the operational amplifier, summing operation, integration operation, comparator, milli-voltmeter.

Recommended Books:

1. Thomas L. Floyd, "Electronics Fundamentals: Circuits, Devices and Applications", Prentice Hall, 8th ed., 2009.
2. B. Grob, "Basic Electronics", McGraw-Hill, Tch ed. 1997.
3. B. Streetman and S. Banerjee "Solid State Electronics Devices", Prentice Hall, 6th ed. 2005.
4. A. Bar-lev, "Semiconductor and Electronics Devices", Prentice Hall, 3rd ed. 1993.
5. D. H. Navon and B. Hilbert, "Semiconductor Micro-devices and Materials", CBS College Publishing, 1986.
6. A. P. Malvino, "Electronic Principles", McGraw-Hill, 7th ed. 2006.
7. R. T. Paynter, "Introductory Electric Circuits", Prentice Hall, 1998.

MATHEMATICAL METHODS OF PHYSICS-II

Pre-requisite: **Mathematical Methods of Physics-I**
Credit Hours: **Three (3)**

Objective(s):

To give the understanding of Differential equations and their uses in Physics, Introduction to special functions, Fourier Series, Fourier Transforms, Solution of Boundary value problems and their uses.

Group Theory and Representations for finite groups: Transformations, groups definitions and examples, subgroups and Cayley's theorem, cosets and Lagrange's theorem, conjugate classes, invariant subgroups, factor groups, homomorphism, direct products, mappings, linear operators, matrix representations, similarity transformation and equivalent matrix representations, group representations, equivalent representations and characters, construction of representations and addition of representations, invariance of functions and operators, unitary spaces and Hermitian matrices, operators: adjoint, self-adjoint, unitary, Hilbert space, reducibility of representations, Schur's lemmas, orthogonality relations, group algebra, expansion of functions in basis of irreducible representations, Kronecker product, symmetrized and anti-symmetrized representations, adjoint and complex-conjugate representations, real representations, Clebsch-Gordan series and coefficients, applications of these ideas to classification of spectral terms, perturbation theory and coupled systems

Tensor Analysis: Vector calculus (differentiation, integration, space curves, multi-variable vectors, surfaces, scalar and vector fields, gradient, divergence and curl, cylindrical and spherical corrdinates, general curvilinear coordinates), change of basis, Cartesian tensor as a geometrical object, order/rank of a tensor, tensor algebra, quotient law, pseudotensors, Kronecker delta and Levi cevita, dual tensors, physical applications, integral theorems for tensors, non-Cartesian tensors, general coordinate transformations and tensors, relative tensors, Christoffel symbols, covariant differentiation, vector operators in tensor form, absolute derivatives along curves, geodesics.

Recommended Books:

1. G. Arfken, H. J. Weber, and F. E. Harris, "Mathematical Methods for Physicists", Academic Press, 7th ed. 2012.
2. E. Kreyszig, "Advanced Engineering Mathematics", John Wiley, 8th ed. 1999.
3. M. Hamermesh, "Group Theory and its Applications to Physical Problems", Dover Publications 1989.

QUANTUM MECHANICS-I

Pre-requisites: **Modern Physics**
Credit Hours: **Three (3)**

Waves and Particles: Introduction to the fundamental ideas of quantum mechanics: Electromagnetic waves and photon, material particles and matter waves, quantum description of a particle, wave packets, particle in a time-independent scalar potential, order of magnitude of the wavelength associated with material particles, constraints imposed by uncertainty relations, one-dimensional Gaussian wave packet: Spreading of the wave packet, stationary states of a particle in one-dimensional square potential, behavior of a wave packet at a potential step

The Mathematical Tools of Quantum Mechanics: One-particle wave function space, state space, Dirac notation, representations in the state space, observable, representations, review of some useful properties of linear operators, unitary operators, study of the $\{|r\rangle\}$ and $\{|p\rangle\}$ representations, some general properties of two observable, *Q* and *P*, whose commutator is equal to $i\hbar$, the two-dimensional infinite well

The Postulates of Quantum Mechanics: Statement of the postulates and their physical interpretation, the physical implications of the Schrodinger equation, the superposition principle, particle in an infinite potential well, study of the probability current in some special case, root-mean-square deviations of two conjugate observables, the density and evolution operators, Schrodinger and Heisenberg pictures, Gauge invariance, bound states of a particle in a potential well of arbitrary shape, unbound states of a particle in the presence of a potential well or barrier of arbitrary shape, quantum properties of a particle in a one-dimensional periodic structure

Application of The Postulates to Simple Cases: Spin ½ And Two-Level Quantum Systems: Spin ½ particles, quantization of the angular momentum, illustration of the postulates in the case of a spin ½, general study of two level systems, Pauli matrices, diagonalization of a 2×2 hermitian matrix, System of two spin ½ particles, Spin ½ density matrix, Spin ½ particle in a static magnetic field and a rotating field, Magnetic resonance

The One-Dimensional Harmonic Oscillator: Importance of the harmonic oscillator in physics, eigenvalues and eigenstates of the Hamiltonian, mean value and root-mean-square deviations of *X* and *P* in state $|\varphi_n\rangle$, Some examples of harmonic oscillators, study of the stationary states in the $\{|r\rangle\}$ representation, Hermite polynomials, solving the Eigenvalues of the harmonic oscillators by the polynomial method, study of the stationary states in the $\{|p\rangle\}$ representation, isotropic three-dimensional harmonic oscillator, charged harmonic oscillator placed in a uniform electric field, coherent states, Normal vibrational modes of coupled harmonic oscillators, vibrational modes of an infinite linear chain of coupled harmonic oscillators, phonons, one-dimensional harmonic oscillator in thermodynamics equilibrium at a temperature *T*

General Properties of Angular Momentum in Quantum Mechanics: concept of angular momentum in quantum mechanics, commutation relations, application to orbital angular momentum, spherical harmonics, rotation operators, rotation of diatomic molecules, angular momentum of stationary states of a two-dimensional harmonic oscillator, charged particle in a magnetic field and Landau levels

Particle in a Central Potential: The Hydrogen atom, Stationary states of a particle in a central potential, motion of the center of mass and relative motion for a system of two interacting particles, Hydrogen atom, Hydrogen-like systems, A solvable example of a central potential: the isotropic three-dimensional harmonic oscillator, probability currents associated with the stationary states of the hydrogen atom, The hydrogen atom placed in a uniform magnetic field, para-magnetism and diamagnetism, Zeeman effect, study of some atomic orbitals, vibrational-rotational levels of diatomic molecules.

Recommended Books:

1. D.J. Griffiths, "Introduction to Quantum Mechanics", Addison-Wesley, 2nd ed. 2004.R. Liboff, "Introductory Quantum Mechanics", Addison-Wesley, 4 ed. 2002.
2. N. Zettili, "Quantum Mechanics: Concepts and Applications", John Wiley, 2nd ed. 2009.

ELECTROMAGNETIC THEORY-II

Pre-requisites: Electromagnetic Theory-I
Credit Hours: Three (3)

This course is the second part of the core level undergraduate course on Electromagnetic Theory and a previous knowledge of Electromagnetic Theory I is expected.

Electrodynamics: Electromotive force: Ohm’s law, electromotive force, motional emf, electromagnetic induction: Faraday’s law, the induced electric field, inductance, energy in magnetic fields, Maxwell’s equations: electrodynamics before Maxwell, how Maxwell fixed Ampere’s law, Maxwell’s equations, magnetic charges, Maxwell’s equations in matter, boundary conditions.

Conservation Laws: Charge and energy: the continuity equation, Poynting's theorem, momentum: Newton's third law in electrodynamics, Maxwell's stress tensor, conservation of momentum, angular momentum.

Electromagnetic Waves: Waves in one dimension: the wave equation, sinusoidal waves, boundary conditions, reflection and transmission, polarization, electromagnetic waves in vacuum: the wave equation for E and B, monochromatic plane waves, energy and momentum in electromagnetic waves, electromagnetic waves in matter: propagation in linear media, reflection and transmission at normal incidence, reflection and transmission at oblique incidence, absorption and dispersion: electromagnetic waves in conductors, reflection at a conducting surface, the frequency dependence of permittivity, guided waves: wave guides, the waves in a rectangular wave guide, the coaxial transmission line.

Potentials and Fields: The potential formulation: scalar and vector potentials, gauge transformations, Coulomb gauge and Lorentz gauge, continuous distributions: retarded potentials, Jefimenko's equations, point charges: Lienard-Wiechert potentials, the field of a moving point charge.

Radiation, Dipole Radiation: What is radiation, electric dipole radiation, magnetic dipole radiation, radiation from an arbitrary source, point charges: power radiated by a point charge, radiation reaction, the physical basis of the radiation reaction.

Electrodynamics and Relativity: The special theory of relativity: Einstein's postulates, the geometry of relativity, the Lorentz transformations, the structure of space-time, relativistic mechanics: proper time and proper velocity, relativistic energy and momentum, relativistic kinematics, relativistic dynamics, relativistic electrodynamics: magnetism as a relativistic phenomenon, how the field transform, the field tensor, electrodynamics in tensor notation, relativistic potentials.

Recommended Books:

1. D. J. Griffiths, "Introduction to Electrodynamics", ed. Prentice Hall, 3rd ed. 1999.
2. M. N. O. Sadiku, "Elements of Electromagnetics", Oxford University Press, 5th ed. ed. 2009.
3. F. Melia, "Electrodynamics", University of Chicago Press, 1st ed. 2001.
4. Hearld J and W. Muller-Kristen, "Electrodynamics", World Scientific Publishing, 2nd ed. 2011.

ELECTRONICS-II

Pre-requisites: **Electronics-I**
Credit Hours: **Three (3)**

Amplifiers and their Frequency Response: Cascade amplifier, The Amplifier pass band, The frequency plot, Low frequency plot, Low frequency limit, The un-bypassed emitter resistor, high frequency equivalent circuit, The Miller Effect, high frequency limit of transistor, bandwidth of a cascade amplifier.

Feedback: Positive and Negative feedback, Principle of feedback amplifier, stabilization of gain by negative feedback, Bandwidth improvement with negative feedback, Reduction of nonlinear distortion, control of amplifier output and input resistance, current series feedback circuit, voltage shunt feedback circuit.

Oscillators: Introduction, Classification of oscillators, Damped and undamped oscillators, the oscillatory circuit, frequency stability of an oscillator, essentials of a feedback LC oscillator, tuned base oscillator, Hartley oscillator, Colpitis oscillator, crystal oscillator.

Power Amplifiers: Introduction, Power relation in class-A amplifiers, effect of thermal environment, determination of the output distortion, class-B amplifier, efficiency of class-A and class-B amplifiers.

Modulation and Demodulation: Introduction, carrier wave modulation, Need for modulation, radio Broadcasting, Methods of modulation, amplitude modulation, Forms of amplitude modulation, single side band system of modulation, Diode for linear detector for amplitude modulation, High power level amplitude modulation, automatic volume control, Frequency modulation.

Multivibrators: Multivibrators, Basic types of Multivibrators, uses of Multivibrators, Astable Multivibrators, Mono-stable Multivibrators, Bi-stable Multivibrators, Schmitt Trigger Circuit.

Integrated Circuits: Introduction, Integrated circuit advantages and drawbacks, scale of integration, classification of integrated circuit by structure, Classification of integrated circuit by function, comparison between different integrated circuit. Integrated circuit terminology, Integrated circuit fabrication, Basic processing steps. Silicon device processes Silicon wafer preparation, diffusion, Oxidation photolithography, Chemical vapour deposition, Metallization, Circuit probing, Scribing and separating into chips, Mounting and packing applications of integrated circuit.

Digital Circuits: Decimal, Binary, Octal, hexadecimal number systems, conversion of decimal numbers to any other number system and vice-versa, Binary codes, OR, AND, NOT, NAND, NOR logic gates, Boolean Algebra. Boolean expressions, simplification of Boolean expression using Boolean Algebra.

Recommended Books:

1. Thomas L. Floyd, “Electronics Fundamentals: Circuits, Devices and Applications”, Prentice Hall, 8th ed. 2009.
2. B. Grob, “Basic Electronics”, McGraw-Hill, Tch ed. 1997.
3. B. Streetman and S. Banerjee “Solid State Electronics Devices”, Prentice Hall, 6th ed. 2005.
4. A. Bar-lev, “Semiconductor and Electronics Devices”, Prentice Hall, 3rd ed. 1993.
5. D. H. Navon and B. Hilbert, “Semiconductor Micro-devices and Materials”, CBS College Publishing, 1986.
6. A. P. Malvino, “Electronic Principles”, McGraw-Hill, 7th ed. 2006.
7. R. T. Paynter, “Introductory Electric Circuits”, Prentice Hall, 1998.

STATISTICAL MECHANICS

Pre-requisites: Heat and Thermodynamics, Calculus-II, Probability and Statistics
Credit Hours: Three (3)

Review of Classical Thermodynamics: States, macroscopic vs. microscopic, "heat" and "work", energy, entropy, equilibrium, laws of thermodynamics, Equations of state, thermodynamic potentials, temperature, pressure, chemical potential, thermodynamic processes (engines, refrigerators), Maxwell relations, phase equilibria.

Foundation of Statistical Mechanics: Phase Space, Trajectories in Phase Space, Conserved Quantities and Accessible Phase Space, Macroscopic Measurements and Time Averages, Ensembles and Averages over Phase Space, Liouville's Theorem, The Ergodic Hypothesis, Equal a priori Probabilities. Specification of the state of a system, concept of ensembles, elementary probability calculations, distribution functions, statistical interpretation of entropy (Boltzmann theorem).

Statistical Ensembles: Microcanonical ensemble, canonical ensemble and examples (e.g., paramagnet), calculation of mean values, calculation of partition function and its relation with thermodynamic quantities, the grand canonical ensemble and examples (e.g. adsorption), calculation of partition function and thermodynamic quantities.

Simple Applications of Ensemble Theory: Monoatomic ideal gas in classical and quantum limit, Gibb's paradox and quantum mechanical enumeration of states, equipartition theorem and examples (ideal gas, harmonic oscillator), specific heat of solids, quantum mechanical calculation of para-magnetism.

Quantum Statistics: Indistinguishability and symmetry requirements, Maxwell-Boltzmann statistics, Bose-Einstein and photon statistics, Fermi-Dirac statistics (distribution functions, partition functions). Examples: polyatomic ideal gas (MB), black body radiation (photon statistics), conduction electrons in metals (FD), Bose condensation (BE).

Systems of Interacting Particles: Lattice vibrations in solids, van der Waals gas, mean field calculation, ferromagnets in mean field approximation.

Recommended Books:

1. F. Reif, "Fundamentals of Statistical and Thermal Physics", Waveland Pr Inc, 2008.
2. W. Brewer, F. Schwabl, "Statistical Mechanics", Springer, 2nd ed. 2006.
3. T. L. Hill, "Statistical Mechanics", World Scientific Publishing Company, (2004).
4. K. Huang, "Statistical Mechanics", John Wiley, 2nd ed. 1987.

QUANTUM MECHANICS-II

Pre-requisites: Quantum Mechanics-I
Credit Hours: Three (3)

Addition of Angular Momenta: Total angular momentum in classical mechanics, total angular momentum in quantum mechanics, addition of two spin ½ angular momenta, addition of two arbitrary angular momenta, Clebsch-Gordon coefficients, sddition of spherical harmonics, vector operators, Wigner-Eckart theorem, electric Multi-pole moments, Evolution of two angular momenta J_1 and J_2 coupled by an interaction $aJ_1 . J_2$.

Stationary Perturbation Theory: Description of the method, perturbation of a non-degenerate level, perturbation of a degenerate level, one-dimensional harmonic oscillator subjected to a perturbing potential, interaction between the magnetic dipoles of two spin ½ particles, Van der waals forces, volume effect and The influence of the spatial extension of the nucleus on the atomic levels, variational method, energy bands of electrons in solids, a simple example of the chemical bond: The H_2^+ ion

Applications of Perturbation Theory to Atomic Systems: fine and hyperfine structure of atomic levels in hydrogen, Calculation of the mean values of the spin-orbit coupling in the 1*s*, 2*s* and 2*p* levels, hyperfine structure And the Zeeman effect for muonium and positronium, Stark effect.

Approximation Methods for Time-Dependent Problems: Statement of the problem, approximate solution of the Schrodinger equation, An important special case: Sinusoidal or constant perturbation, Interaction of an atom with electromagnetic waves, linear and non-linear response of a two-level system subjected to a sinusoidal perturbation, Ooscillations of a system between two discrete states under the effect of a resonant perturbation, Rabi flopping, decay of discrete state resonantly coupled to a continuum of final states, Fermi's golden rule

Systems of Identical Particles: Identical particles, Permutation operators, The symmetrization postulate, difference between bosons and fermions, Pauli's exclusion principle, many-electrons atom and their electronic configurations, energy levels of the helium atom, configurations, terms, multiplets, spin isomers of hydrogen (ortho and parahydrogen)

Scattering by a Potential: Importance of collision phenomena, Stationary scattering states, scattering cross section, scattering by a central potential, method of partial waves, phenomenological description of collisions with absorption.

Recommended Books:

1. D.J. Griffiths, "Introduction to Quantum Mechanics", Addison-Wesley, 2nd ed. 2004.
2. R. Liboff, "Introductory Quantum Mechanics", Addison-Wesley, 4th ed. 2002.
3. N. Zettili, "Quantum Mechanics: Concepts and Applications", John Wiley, 2nd ed. 2009.

ATOMIC AND MOLECULAR PHYSICS

Pre-requisites: Quantum Mechanics I
Co-requisite: Quantum Mechanics II
Credit Hours: Three (3)

Objective(s):

To provide an introduction to the structure and spectra of atoms and molecules. To prepare students for more advanced courses on Physics of Atoms, Molecules and Photons.

One Electron Atoms: Review of Bohr Model of Hydrogen Atom, Reduced Mass, Atomic Units and Wavenumbers, Energy Levels and Spectra, Schrodinger Equation for One-Electron Atoms, Quantum Angular Momentum and Spherical Harmonics, Electron Spin, Spin-Orbit interaction. Levels and Spectroscopic Notation, Lamb Shift, Hyperfine Structure and Isotopic Shifts. Rydberg Atoms.

Interaction of One-Electron Atoms with Electromagnetic Radiation: Radiative Transition Rates, Dipole Approximation, Einstein Coefficients, Selection Rules, Dipole Allowed and Forbidden Transitions. Metastable Levels, Line Intensities and Lifetimes of Excited States, Shape and Width of Spectral Lines, Scattering of Radiation by Atomic Systems, Zeeman Effect, Linear and Quadratic Stark Effect.

Many-Electron Atoms: Schrodinger Equation for Two-Electron Atoms, Para and Ortho States, Pauli's Principle and Periodic Table, Coupling of Angular Momenta, L-S and J-J Coupling. Ground State and Excited States of Multi-Electron Atoms, Configurations and Terms.

Molecular Structure and Spectra: Structure of Molecules, Covalent and Ionic Bonds, Electronic Structure of Diatomic Molecules, Rotation and Vibration of Diatomic Molecules, Born-Oppenheimer Approximation. Electronic Spectra, Transition Probabilities and Selection Rules, Frank-Condon Principle, H2+ and H2. Effects of Symmetry and Exchange. Bonding and Anti-bonding Orbitals. Electronic Spin and Hund's Cases, Nuclear Motion: Rotation and Vibrational Spectra (Rigid Rotation, Harmonic Vibrations). Selection Rules. Spectra of Triatomic and Polyatomic Molecules, Raman Spectroscopy, Mossbauer Spectroscopy.

Recommended Books:

1. C. J. Foot, "Atomic Physics", Oxford University Press, 2005.
2. B. H. Bransden and C. J. Joachain, "Physics of Atoms and Molecules", Pearson Education, 2nd ed. 2008.
3. W. Demtroder, "Atoms, Molecules and Photons", y, Springer, 2nd ed. 2010.
4. C. N. Banwell and E. M. McCash, "Fundamentals of Molecular Spectroscopy", McGraw-Hill, 4th ed. 1994.
5. J. M. Hollas, "Basic Atomic & Molecular Spectroscopy", John Wiley, 2002.

SOLID STATE PHYSICS I

Pre-requisites: Quantum Mechanics I, Statistical Mechanics
Credit Hours: Three (3)

Crystal Structure: Lattices and basis, Symmetry operations, Fundamental Types of Lattice, Position and Orientation of Planes in Crystals, Simple crystal structures.

Crystal Diffraction and Reciprocal Lattice: Diffraction of X-rays, Neutrons and electrons from crystals; Bragg's law; Reciprocal lattice, Ewald construction and Brillouin zone, Fourier Analysis of the Basis.

Phonons and Lattice: Quantization of Lattice Vibrations, Phonon momentum, inelastic scattering by phonons, Lattice Vibrations for Mono-atomic and diatomic basis, Optical Properties in the Infrared Region.

Thermal Properties of Solids: Lattice heat Capacity, Classical model, Einstein Model, Enumeration of normal modes, Density of state in one, two or three dimensions, Debye model of heat capacity, Comparison with experimental results, thermal conductivity and resistivity, Umklapp processes.

Electrical Properties of Metals: Classical free electron theory of metals, energy levels and density of orbital's in one dimension, effect of temperature on the Fermi–Dirac distribution function, properties of the free electron gas, electrical conductivity and Ohm's Law, thermal and electrical conductivities of metals and their ratio, motion of free electrons in magnetic fields, cyclotron frequency, static magneto conductivity and Hall Effect along with applications.

Recommended Books:

1. C. Kittle, "Introduction to Solid State Physics", John Wiley, 8th ed. 2005.
2. N. W. Ashcroft and N. D. Mermin, "Solid State Physics", Rinehart & Winston, 1976.
3. S. R. Elliott, "The Physics and Chemistry of Solids", John Wiley, 1998
4. M. A. Omar, "Elementary and Solid State Physics", Pearson Education, 2000.
5. H. M. Rosenberg, "The Solid State", Oxford Science Publication, 3rd ed. 1988.
6. M. A. Wahab, "Solid State Physics", Narosa Publishing House, 1999.

SOLID STATE PHYSICS II

Pre-requisites: Solid State Physics I
Credit Hours: Three (3)

Dielectric Properties of Solids: Polarization, Depolarization, Local and Maxwell field, Lorentz field, Clausius-Mossotti relation, Dielectric Constant and Polarizability, Masurement of dielectric constant, ferro electricity and ferroelectric crystals, Phase Transitions, First and 2nd order phase transitions, Applications

Semiconductors: General properties of semiconductors, intrinsic and extrinsic semiconductors, their band structure, carrier statistics in thermal equilibrium, band level treatment of conduction in semiconductors and junction diodes, diffusion and drift currents, collisions and recombination times

Optical Properties: Interaction of light with solids, Optical Properties of Metals and Non-Metals, Kramers Kronnig Relation, Excitons, Raman Effect in crystals, optical spectroscopy of solids.

Magnetic Properties of Materials: Magnetic dipole moment and susceptibility, different kinds of magnetic materials, Langevin diamagnetic equation, Paramagnetic equation and Curie law, Classical and quantum approaches to paramagnetic materials. Ferro-magnetic and anti – ferromagnetic order, Curie point and exchange integral, Effect of temperature on different kinds of magnetic materials and applications.

Superconductivity: Introduction to superconductivity, Zero-Resistance and Meissner Effect , Type I and Type II superconductors, Thermodynamic fields, Tow fluid model, London equations , BCS and Ginzburg Landau Theory, Vortex Behaviour, Critical Current Density, Josephson effect and applications.

Recommended Books:

1. C. Kittle, "Introduction to Solid State Physics", John Wiley, 8th ed. 2005.
2. N. W. Ashcroft and N. D. Mermin, "Solid State Physics", Rinehart & Winston, 1976.
3. G. Burns, "High Temperature Superconductivity: An Introduction", Academic Press, 1992.
4. M. Fox, "Optical Properties of Solids", Oxford University Press, 2nd ed. 2010.
5. N. A. Spaldin, "Magnetic Materials: Fundamentals and Device Applications", Cambridge University Press, 2nd ed. 2010.

NUCLEAR PHYSICS

Pre-Requisites: Modern Physics
Credit Hours: Three (3)

Objective(s):
To understand the nuclear structure using different nuclear models. To understand the nature of nuclear forces. To give understanding of radioactivity and nuclear reactions.

History: Starting from Bacqurel's discovery of radioactivity to Chedwick's neutron.

Basic Properties of Nucleus: Nuclear size, mass, binding energy, nuclear spin, magnetic dipole and electric quadrupole moment, parity and statistics.

Nuclear Forces: Yukawa's theory of nuclear forces. Nucleon scattering, charge independence and spin dependence of nuclear force, isotopic spin.

Nuclear Models: Liquid drop model, Fermi gas model, Shell model, Collective model.

Theories of Radioactive Decay: Theory of Alpha decay and explanation of observed phenomena, measurement of Beta ray energies, the magnetic lens spectrometer, Fermi theory of Beta decay, Neutrino hypothesis, theory of Gamma decay, multipolarity of Gamma rays, Nuclear isomerism.

Nuclear Reactions: Conservation laws of nuclear reactions, Q-value and threshold energy of nuclear reaction, energy level and level width, cross sections for nuclear reactions, compound nucleolus theory of nuclear reaction and its limitations, direct reaction, resonance reactions, Breit-Wigner one level formula including the effect of angular momentum.

Recommended Books:

1. E. Segre, “Nuclei and Particles”, Bejamin-Cummings, 2nd ed. 1977.
2. Kaplan, “Nuclear Physics”, Addison-Wisely, 1980.
3. Green, “Nuclear Physics”, McGraw-Hill, 1995.
4. K. S. Krane, “Introducing Nuclear Physics”, John Wiley, 3rd ed. 1988.
5. B. Povh, K. Rith, C. Scholtz, F. Zetsche, “Particle and Nuclei”, 1999.

DETAIL OF ELECTIVE COURSES FOR BS 4 YEAR PROGRAMME

These elective courses can be chosen from the list or new elective course may be offered according to the availability of staff and necessary infrastructure.

University may also tailor these courses according to their facilities.

PLASMA PHYSICS

Pre-requisite: **Electromagnetic Theory-II, Waves and Oscillations**
Credit Hours: **Three (3)**

Objective(s):

To learn about the importance of the plasma along with the basic concept of plasma. To know fluid description of the plasma.

Introduction: Occurrence of plasma, Concept of temperature, Debye shielding, the plasma parameter, Criteria for plasma.

Applications of Plasma Physics: Single-particle motion in electromagnetic field, Uniform and non-uniform E and B fields, Time-variant E and B fields, Fluid description of plasma, Wave propagation in plasma, Derivation of dispersion relations for simple electrostatic and electromagnetic modes, Introduction to Controlled Fusion, Basic nuclear fusion reactions, Reaction rates and power density, radiation losses from plasma, operational conditions.

Recommended Books:

1. F. F. Chen, "Introduction to Plasma Physics", 2nd ed. Plenum, 1995.
2. D. A. Gurnett and A. Bhattacharjee, "Introduction to Plasma Physics: with space and laboratory application", Cambridge University Press, 2005.
3. T. J. M. Boyd and J. J. Sanderson, "The Physics of Plasmas", Cambridge University Press, 2003.

METHODS OF EXPERIMENTAL PHYSICS

Credit Hours: **Three (3)**

Objective(s):

To learn about the vacuum techniques. To learn the detection techniques about radiation, temperature. To learn about the measuring techniques along with data analysis.

Vacuum Techniques: Gas Transport: Throughout, Pumping Speed, Pump down Time Ultimate pressure. Fore-Vacuum Pumps: Rotary Oil pumps, sorption pumps. Diffusion pumps, sorption pumps (High Vacuum). Production of ultrahigh vacuum, Fundamental concepts, guttering pumps, Ion pumps, Cryogenic pumps, Turbo molecular pumps. Measurement of total pressure in Vacuums Systems, Units pressure ranges, Manometers, Perini gauges, The McLoad gauges, Mass spectrometer for partial measurement of pressure. Design of high Vacuum system, Surface to Volume ratio, Pump Choice, pumping system design. Vacuum Components, Vacuum valves, vacuum Flanges, Liquid Nitrogen trap, Mechanical feed throughs & Electrical feed throughs Leak detection: Basic consideration, leak detection equipment, Special Techniques and problems, Repair Techniques.

Radiation Detection and Measurement: GM tubes, scintillation detector, channeltron, photo multipliers, neutron detectors, alpha/beta detectors, x-rays/gamma detectors, cosmic rays detectors, Spectrographs and Interferometers.

Sensor Technology: Sensors for temperature, pressure displacement, rotation, flow, level, speed, rotation position, phase, current voltage, power magnetic field, tilt, metal, explosive and heat.

Electronics and Electronic Instruments: Operational amplifiers, summing amplifiers, difference amplifiers, Differentiators, Integrators, Logarithmic amplifiers, current to voltage converter, Spectroscopy amplifiers, charge sensitive pre-amplifiers, Coincidence circuits, Isolators, Ramp Generators, and single channel analyzer. Power supplies, Signal Generators, Counters, Multichannel analyzer, Lock in Amplifiers, Boxcar averages.

Computer Introduction: Introduction to computers, GPIB Interface, RS 232. Interfacing, DA/AD conversion, Visual c/visual Basic.

Data Analysis: Evaluation of measurement: Systematic Errors, Accuracy, Accidental Errors, Precision, Statistical Methods, Mean Value and Variance, Statistical Control of Measurements, Errors of Direct measurements, Rejection of data, Significance of results, Propagation of errors, preliminary Estimation, Errors of Computation. Least squares fit to a polynomial. Nonlinear functions. Data manipulation, smoothing, interpolation and extrapolation, linear and parabolic interpolation.

Recommended Books:

1. F. James, “Statistical Methods in Experimental Physics”, World Scientific Company, 2nd ed. 2006.
2. M. H. Hablanian, “High-Vacuum Technology”, Marcel Dekker, 2nd ed. 1997.
3. P. Bevington and D. K. Robinson, “Data Reduction and Error Analysis for Physical Science”, McGraw-Hill, 3rd ed. 2002.

4. S. Tavernier, “Experimental Techniques in Nuclear and Particle Physics”, Springer, 2010.
5. J. B. Topping, “Errors of Observations and Their Treatment”, Springer, 4th ed. 1972.

ENVIRONMENTAL PHYSICS

Credit Hours: Three (3)

Objective(s):

To become familiar with the essentials of environment and Global climate.
To learn to use spectroscopy for environments.

Introduction to the Essentials of Environmental Physics: The economic system, living in green house, enjoying the sun, Transport of matter, Energy and momentum, the social and political context.

Basic Environmental Spectroscopy: Black body radiation, The emission spectrum of sun, The transition electric dipole moment, The Einstein Coefficients, Lambert – Beer’s law, The spectroscopy of bi-molecules, Solar UV and life, The ozone filter.

The Global Climate: The energy Balance, (Zero-dimensional Greenhouse Model), elements of weather and climate, climate variations and modeling.

Transport of Pollutants: Diffusion, flow in reverse, ground water. Flow equations of fluid Dynamics, Turbulence, Turbulence Diffusion, Gaussian plumes in air, Turbulent jets and planes.

Noise: Basic Acoustics, Human Perceptions and noise criteria, reducing the transmission of sound, active control of sound.

Radiation: General laws of Radiation, Natural radiation, interaction of electromagnetic radiation and plants, utilization of photo synthetically active radiation.

Atmosphere and Climate: Structure of the atmosphere, vertical profiles in the lower layers of the atmosphere, Lateral movement in the atmosphere, Atmospheric Circulation, cloud and Precipitation, The atmospheric greenhouse effect.

Topo Climates and Micro Climates: Effects of surface elements in flat and widely unduling areas, Dynamic action of seliq. Thermal action of selief.

Climatology and Measurements of Climate Factor: Data collection and organization, statistical analysis of climatic data, climatic indices, General characteristics of measuring equipment. Measurement of temperature, air humidity, surface wind velocity, Radiation balance, precipitation, Atmospheric Pressure, automatic weather stations.

Recommended Books:

1. E.t Booker and R. Van Grondelle, "Environmental Physics", John Wiley, 3rd ed. 2011.
2. G. Guyot, "Physics of Environment and Climate", John Wiley, 1998.

INTRODUCTION TO QUANTUM COMPUTING

Pre-requisite: Quantum Mechanics-I, Computational Physics
Credit Hours: Three (3)

Objective(s):

To be familiar with the quantum computing. To learn about the Quantum circuits, and cryptography.

Computer technology and historical background, Basic principles and postulates of quantum mechanics: Quantum states, evolution, quantum measurement, superposition, quantization from bits to qubits, operator function, density matrix, Schrodinger equation, Schmidt decomposition, EPR and Bell's inequality, Quantum Computation: Quantum Circuits, Single qubit operation, Controlled operations, Measurement, Universal quantum gates, Single qubit and CNOT gates, Breaking unbreakable codes: Code making, Trapdoor function, One time pad, RSA cryptography, Code breaking on classical and quantum computers, Schor's algorithm, Quantum Cryptography: Uncertainty principle, Polarization and Spin basis, BB84, BB90, and Ekert protocols, Quantum cryptography with and without eavesdropping, Experimental realization, Quantum Search Algorithm.

Recommended Books:

1. M. A. Nielson and I. L. Chuang, "Quantum Computation and Quantum Information", Foundation Books, 2007.
2. C. P. Williams and S. H. Clearwater, "Exploration in Quantum Computation" Springer, 2nd ed. 2011. .
3. P. Bouwmester, A. Ekert, and A. Zeilinger, "The Physics of Quantum Information: Quantum Cryptography, Quantum Teleportation, Quantum Computation", Springer, 2010.
4. R. K. Brylinsky and G. Chen, "Mathematics of Quantum Computation" by Chapman & Hall/CRC, 2002.

QUANTUM INFORMATION THEORY

Pre-requisites: Quantum Mechanics I
Credit Hours: Three (3)

Objective(s):

To understand the fundamental concepts of quantum information, communication, computation, and physical protocols for quantum computation.

Review of Quantum Mechanics and overview of Quantum information: Postulates of quantum mechanics, quantum states and observables, Dirac notation, projective measurements, density operator, pure and mixed states, entanglement, tensor products, no-cloning theorem, mixed states from pure states in a larger Hilbert space, Schmidt decomposition, generalized measurements, (CP maps, POVMs), qualitative overview of Quantum Information.

Quantum Communication: Dense coding, teleportation, entanglement swapping, instantaneous transfer of information, quantum key distribution.

Entanglement and its Quantification: Inseparability of EPR pairs, Bell inequality for pure and mixed states, entanglement witnesses, Peres-Horodecki criterion, properties of entanglement measures, pure and mixed state entanglement, relative entropy as entanglement measure, entanglement and thermodynamics, measuring entanglement.

Quantum Information: Classical information theory (data compression, Shannon entropy, von Neumann entropy), fidelity, Helstrom's measurement and discrimination, quantum data compression, entropy and information, relative entropy and its statistical interpretation, conditional entropy, Holevo bound, capacity of a quantum channel, relative entropy and thermodynamics, entropy and erasure, Landauer's erasure.

Quantum Computation: Classical computation (Turing machines, circuits, complexity theory), quantum algorithms (Deutsch's algorithm, Oracles, Grover's algorithm, factorization and quantum Fourier transform), role of entanglement in algorithms (search algorithm), modeling quantum measurements, Bekenstein bound, quantum error correction (general conditions, stabilizer codes, 3-qubit codes, relationship with Maxwell's demon), fault tolerant quantum computation (overview).

Physical Protocols for Quantum Information and Computation: Ion trap, optical lattices, NMR, quantum optics, cavity QED.

Recommended Books:

1. V. Vedral, “Introduction to Quantum Information Science”, Oxford University Press, 2007.
2. M. Nielsen and I. Chuang, “Quantum Computation and Quantum Information”, Cambridge University Press, 10th Anv. ed. 2010.
3. W. Steeb and Y. Hardy, “Problems and Solutions in Quantum Computing and Quantum Information”, World Scientific Publishing, 3rd ed. 2011.
4. Book on general quantum mechanics: A. Peres, Quantum Theory: Concepts and Methods, Kluwer Academic Publishers (2002).
5. Seth Lloyd’s notes on quantum information available online at: *web.mit.edu/2.111/www/notes09/spring.pdf*

QUANTUM FIELD THEORY

Pre-requisites: Quantum Mechanics-II
Credit Hours: Three (3)

Lagrangian Field Theory: Classical Field Theory. Canonical Quantization. Noether's theorem. (3 week)

Klein-Gordon Field: Real Klein-Gordon field. Complex Klein-Gordon field. Covariant commutation relations. Meson propagator

Dirac Field: Number representation for fermions. Quantization of Dirac field. Spin-statistics theorem. Fermion propagator

Electromagnetic Field: Classical electromagnetic field. Covariant quantization. Photon propagator

Interacting Fields: Interaction Lagrangian and gauge invariance. Interaction picture. S-matrix expansion. Wick’s theorem. Feynman Diagrams. Feynman rules for QED. Cross sections and decay rates.

Recommended Books:

1. F. Mandl and G. Shaw, “Quantum Field Theory”, Wiley, 2nd ed. 2010.
2. M. E. Peskin and D. V. Schroeder, “An Introduction to Quantum Field Theory”, Addison Wesley, 1995.
3. S. Weinberg, “The Quantum Theory of Fields”, Vol. 1, Cambridge University Press, 1999.
4. N. N. Bogoliubov and D. V. Shirkov, “Introduction to the Theory of Quantized Fields”, John Wiley, 1980.

DIGITAL ELECTRONICS

Pre-requisites: **Electronics-II**
Credit Hours: **Three (3)**

Objective(s):

To learn the basics of digital electronics such as Boolean Algebra. To develop logic circuit using the Boolean Algebra. To understand the computer interface and micro-controller along with the embedded systems.

Review of Number Systems: Binary, Octal and Hexadecimal number system, their inter-conversion, concepts of logic, truth table, basic logic gates.

Boolean Algebra: De Morgan's theorem, simplification of Boolean expression by Boolean Postulates and theorem, K-maps and their uses. Don't care condition, Different codes. (BCD, ASCII, Gray etc.). Parity in Codes.

IC Logic Families: Basic characteristics of a logic family. (Fan in/out, Propagation delay time, dissipation, noise margins etc. Different logic based IC families (DTL, RTL, ECL, TTL, CMOS).

Combinational Logic Circuit: Logic circuits based on AND – OR, OR-AND, NAND, NOR Logic, gate design, addition, subtraction (2's compliments, half adder, full adder, half subtractor, full subtractor encoder, decoder, PLA. Exclusive OR gate.

Sequential Logic Circuit: Flip-flops clocked RS-FF, D-FF, T-FF, JK-FF, Shift Register, Counters (Ring, Ripple, up-down, Synchronous) A/D and D/A Converters.

Memory Devices: ROM, PROM, EAPROM, EE PROM, RAM, (Static and dynamic) Memory mapping techniques

Micro Computers: Computers and its types, all generation of computers, basic architecture of computer, micro processor (ALU, UP Registers, Control and Time Section). Addressing modes, Instruction set and their types, Discussion on 8085/8088, 8086 processor family, Intel Microprocessor Hierarchy

Micro-controller/ Embedded System: Introduction to Embedded and microcontroller based systems, The Microprocessor and microcontroller applications and environment, microcontroller characteristics, features of a general purpose microcontroller, Microchip Inc and PIC microcontroller, Typical Microcontroller examples:, Philips 80C51 & 80C552 and Motorola 68Hc05/08, Interfacing with peripherals.

Recommended Books:

1. M. M. Mono, “Digital Logic and Computer Design”, Prentice Hall, 1995.
2. R. Tokheim, “Digital Electronics”, McGraw Hill, 7^{th} ed. 2007.
3. B. B. Brey, “The Intel Microprocessors: Architecture, Programming and Interfacing”, Merril, 2^{nd} ed. 1991.
4. Thomas L. Floyd, “Electronics Fundamentals: Circuits, Devices and Applications”, Prentice Hall, 8^{th} ed. 2009.
5. T. Wilmshurst, “The Design of Small-Scale Embedded Systems”, Palgrave, 2001.

LASERS

Pre-requisite: **Quantum Mechanics-II, Atomic and Molecular Physics**
Credit Hours: **Three (3)**

Objective(s):

Develop fundamental concepts about lasers. Learn the principles of spectroscopy of molecules and semi-conductors. Understand the optical resonators and laser system. Applications of lasers.

Introductory Concepts: Spontaneous Emission, Absorption, Stimulated Emission, Pumping Schemes, Absorption and Stimulated Emission Rates, Absorption and Gain Coefficients, Resonance Energy Transfers. Properties of Laser Beam: Monochromaticity, Coherence, Directionality, Brightness

Spectroscopy of Molecule and Semiconductors: Electronic Energy Levels, Molecular Energy Levels, Level Occupation at Thermal Equilibrium, Stimulated Transition, Selection Rules, Radiative and Nonradiative Decay, Semiconductor

Optical Resonators: Plane Parallel (Fabry-Perot) Resonator, Concentric (Spherical) Resonator, Confocal, Resonator, Generalized Spherical Resonator, Ring Resonator, Stable Resonators, Unstable Resonators. , Matrix Formulation of Geometrical Optics, Wave Reflection and Transmission at a Dielectric Interface, Stability Condition Standing and Traveling Waves in a two Mirror Resonator, Longitudinal and Transverse Modes in a Cavity, Multilayer Dielectric Coatings, Fabry-Perot Interferometer. Small Signal Gain and Loop Gain

Pumping Processes: Optical pumping: Flash lamp and Laser, Threshold Pump Power, pumping efficiency, Electrical Pumping: Longitudinal Configuration and Transverse Configuration, Gas Dynamics Pumping, Chemical Pumping.

Continuous Wave (CW) and Pulsed Lasers: Rate Equations, Threshold Condition and Output Power, Optimum Output Coupling, Laser Tuning, Oscillation and Pulsations in Lasers, Q-Switching and Mode-Locking Methods, Phase Velocity, Group Velocity, and Group-Delay Dispersion, Line broadening.

Lasers Systems: Solid State Lasers: Ruby Laser, Nd: YAG & Nd: Glass Lasers and Semiconductor Lasers: Homojunction Lasers Double-Heterostructure lasers, Gas lasers**:** Helium Neon laser, CO_2 laser, Nitrogen Laser and Excimer Lasers, Free-Electron and X-Ray Lasers.

Laser Applications: Material Processing: Surface Hardening, Cutting, Drilling, Welding etc. Holography, Laser Communication, Medicine, Defense Industry, Atmospheric Physics.

Recommended Books:

1. O. Svelto, "Principles of Lasers", Springer, 5th ed. 2009.
2. J. Eberly and P. Milonni, "Lasers Physics", John Wiley, 2nd ed. 2010.
3. M. O. Scully and M. S. Zubairy, "Quantum Optics", Cambridge University Press, 1997.
4. W. T. Silfvast, "Laser Fundamentals", Cambridge University Press, 2nd ed. 2008.
5. W. M. Steen, J. Mazumder and K. G. Watkins, "Laser Material Processing", Springer, 4th ed. 2010.

LASER ENGINEERING

Pre-requisites: **Modern Physics, Optics, Waves and Oscillations, Electricity and Magnetism**
Credit Hours: **Three (3)**

Objective(s):

Deep understanding of Laser and its components, Designing of Laser.

Introduction: What is laser, brief history of laser development, principle components of laser, types of lasers, properties of laser beam, an overview of laser technology, energy states in atom, transition between energy states (absorption, spontaneous and stimulated emission), principles of laser, power and energy, special features of laser beam (directionality, diffraction, intensity, monochromaticity, coherency, line-width).

General Principles of Laser Operation: Thermal equilibrium, Einsteincoefficients, condition for large stimulated emissions, condition for light amplification, population inversion, energy state, metastable state, three level laser, four level laser, line broadening, laser rate equations (two, three, and four level systems), generic laser, gain medium, pumping source, resonant cavity

Generic Laser: Amplification and gain, optical resonator, laser action, gain of active medium (mathematical treatment), threshold condition, gain calculation, conditions for steady state oscillation, cavity resonance frequencies, laser modes (longitudinal and transverse), single mode operation, examples

Optical Resonators: Resonator (cavity) configuration, fabry-perot resonator or plane parallel cavity, confocal resonator, hemispherical cavity or combination of plane and spherical resonator, long radius cavity, stability criterion, examples (stable and unstable resonator)

Pumping Source and Active Medium: What is pumping, pumping methods, optical pumping, electric pumping (direct discharge), electric pumping for semiconductor laser, chemical pumping, flash lamps, optical pumping configuration, optical pumping assembly, active mediums (atoms, molecules, liquids, dielectric solids, semiconductor material)

Gas Lasers (theory, working, design and construction), Metal Vapor Lasers: Gas lasers, atomic lasers, ionic lasers, molecular lasers, basic concepts of discharge tube, Brewster angle cut discharge tube, electrical circuits for gas lasers, high voltage power supplies for gas lasers, He-Ne laser, design problems related to He-Ne laser, Argon Ion laser, Krypton Ion laser, CO2 (carbon dioxide) laser, N2 (nitrogen) laser, Excimer laser, He-Cd laser, Copper vapor laser, Gold vapor laser.

Chemical and Dye Lasers: Introduction to chemical laser, HF (hydrogen and fluoride) laser, Chemical Oxygen-Iodine laser (COIL), military applications of COIL, dye lasers, Rhodamine dye laser.

Solid State Lasers (concepts, working, design and construction): Introduction to solid state laser, Ruby laser, Nd:YAG laser, Nd:Glass laser, electronics for solid state laser, cooling system for solid state laser, cavity design and pumping concepts for solid state laser, brief overview to commercial Nd:YAG lasers, Ti:Sapphire laser, tunable solid state laser (Alexandrite laser).

Semiconductor Laser, and Free-Electron Laser: Introduction to semiconductor laser, homojunction laser, heterojunction laser, semiconductor laser array, quantum well laser, vertical cavity surface emitting laser (VCSEL), brief introduction to free-electron laser.

Control of Laser Output (Q-switching and mode locking): Introduction to control of laser output beam, frequency selection, generation of high power pulses, Q-factor, Q-switching and giant pulses, methods of Q-switching, active Q-switching (mechanical Q-switching, acousto-optic Q-switching, electro-optic Q-switching), passive Q-switching (saturable absorber, cavity dumping), introduction to mode-locking, mode-locking techniques (active mode-locking, passive mode-locking), Q-switched Nd:YAG laser system.

Ultrafast Lasers: What is ultrafast laser, Ti: Sapphire laser, chirped pulse amplification (CPA) laser system, ultrafast laser systems, ultrafast diagnostics, mode-locked Ti: Sapphire laser system, basic concepts to Ti: Sapphire CPA laser system, ultrafast phenomenon, applications of ultrafast lasers.

Laser Applications: Industrial applications, material processing (laser drilling, laser cutting, laser welding), LIDAR (laser imaging detection and ranging), photolithography, medical applications (LASIK surgery, laser seizer), isotope separation using laser, Nuclear fusion, brief overview of major laser facility (NIF facility), laser holography, military applications.

Recommended Books:

1. K. J. Kuhn, “Laser Engineering”, Prentice Hall, 1997.
2. O. Svelto, “Principles of Lasers”, Springer, 5^{th} ed. 2009.
3. W. T. Silfvast, “Laser Fundamentals”, Cambridge, 2^{nd} ed. 2008.
4. K. R. Nambiar, “LASERS: Principles, Types and Applications”, New Age, 2009.
5. W. Koecher, “Solid-State Laser Engineering”, Springer, 2009.
6. R. F. Walter, “Gas Lasers (Optical Science and Engineering)”, CRC Press, 2006.
7. C. Rulliere, “Femtosecond Laser Pulses: Principles and Experiments”, Springer, 2^{nd} ed. 1998.
8. K. Thyagarajan, “Lasers: Fundamentals and Applications”, Springer, 2^{nd} ed. 2010.

EXPERIMENTAL TECHNIQUES IN PARTICLE AND NUCLEAR PHYSICS

Pre-requisites: **Particle Physics, Nuclear Physics**
Credit Hours: **Three (3)**

Objective(s):

To give students with the practical hand on the experimental techniques, Physically understand the nuclear phenomena.

Review of Basic Concepts: Units used in particle physics, Definition used in particle physics, Types of particles to be detected, Cross section, Decay width, Lab Frame and CM frame, Pseudo rapidity, History of Accelerator, Linear accelerators, Circular accelerators, Introduction to RHIC, Tevatron, LEP, LHC.

Introduction to Accelerators: Lattice and geometry, The arcs, Periodicity, Aperture, Beam crossing angle, Luminosity, RF cavities, Power requirements, Longitudinal feedback system, Injection, Injection scheme, PS, SPS, Magnets, Cryogenics, Vacuum system.

Introduction to Detectors: Introduction to detectors, Need of detectors, Passage of radiation through matter, Cross-section, Interaction probability in a distance x, Mean free path, Energy loss of heavy charged particles by atomic collisions, Bohr's, calculation – classical case - The Bethe Bloch formula, Cherenkov radiation, Energy loss of electron and photon, Multiple coulomb scattering, Energy straggling, The interaction of photons, The interaction of neutrons.

General Characteristics of Detectors and Gas Detectors: Sensitivity, Detector response, Energy resolution The Fano-factor, The response function, Response time, Detector efficiency, Dead time- Ionization detectors, Gaseous ionization detectors, Ionization & transport phenomenon in gases, Transport of electrons and ions in gases, Avalanche multiplication, The cylindrical proportional counter, The multi-wire proportional counter, The drift chambers, Time projection chambers, Liquid ionization detector.

Scintillators, Photomultipliers, Semi-conductor Detectors: Scintillation detectors, Organic scintillation, Inorganic crystals, Gaseous scintillators Glasses, Intrinsic detector efficiency for various radiations, Photomultipliers, Basic construction and operation, The photocathode, The electron-optical input system, Semiconductor detectors, Silicon diode detectors, Introduction to CMS and its detectors.

Detector Software and Physics Objects: Introduction to Linux operating system, Introduction to CMS software (CMSSW), Basic infrastructure of software, Introduction to PYTHIA, Introduction to GEN, SIM, DIGI, RECO, reconstruction of final state objects.

Recommended Books:

1. The Large Hadron Collider Conceptual Design CERN**/AC/95-05 (LHC)**
2. Detector performance and software, **Physics Technical Design Report, Volume1**
3. Techniques for Nuclear and Particle Physics Experiments by **W.R. Leo**
4. R. Fernow, "Introduction to experimental particle physics", Cambridge University Press, 1989.
5. D. H. Perkins, "Introduction to High Energy Physics", Cambridge University Press, 4th ed. 2000.
6. **MIT website** http://mit.edu

ELECTRONIC MATERIALS AND DEVICES

Pre-requisite: **Electronics-I, Optics**
Credit Hours: **Three (3)**

Objective(s):
To understand the relation between electrical, optical and magnetic devices.

Semiconductor Fundamentals: Composition, purity and structure of semiconductors, energy band model, band gap and materials classification, charge, effective mass and carrier numbers, density of states, the Fermi function and equilibrium distribution of carriers, doping, *n* and *p*-type semiconductors and calculations involving carrier concentrations, E_F etc., temperature dependence of carrier concentrations, drift current, mobility, resistivity and band bending, diffusion and total currents, diffusion coefficients, recombination-generation, minority carrier life times and continuity equations with problem solving examples.

Device Fabrication Processes: Oxidation, diffusion, ion implantation, lithography, thin-film deposition techniques like evaporation, sputtering, chemical vapour deposition (CVD), epitaxy etc.

***PN* Junction and Bipolar Junction Transistor:** Junction terminology, Poisson's equation, qualitative solution, the depletion approximation, quantitative electrostatic relationships, ideal diode equation, non-idealities, BJT fundamentals, Junction field effect transistor, MOS fundamentals, the essentials of MOSFETs.

Dielectric Materials: Polarization mechanisms, dielectric constant and dielectric loss, capacitor dielectric materials, piezoelectricity, ferroelectricity and pyroelectricity.

Optoelectronic Devices: Photoconductors, photovoltaics and photodetectors, photodiodes and photovoltaics, solar cell basics, LEDs, Lasers, displays, LCDs.

Magnetism and Magnetic Materials: Basics of magnetism, hysteresis loops, magnetic domains and anisotropy, hard and soft magnetic materials, transformers, DC motors and data storage.

Recommended Books:

1. R. F. Pierret, "Semiconductor Device Fundamentals", Addison Wesley, 2nd ed. 1996.
2. N. Braithwaite, and G. Weaver, "Electronic Materials", MA: Butterworth, 2nd ed. 1990.

3. S. O. Kasap, “Electronic Materials and Devices”, McGraw-Hill, 3rd ed. 2005.
4. R. C. O'Handley, “Modern Magnetic Materials: Principles and Applications”, Wiley Inter-Science, 1999.
5. D. Jiles, “Introduction to Magnetism and Magnetic Materials”, Chapman & Hall, 2nd ed. 1998.

FLUID DYNAMICS

Pre-requisites: Mechanics, Calculus-I, Differential Equations
Credit Hours: Three (3)

Objective(s):
Physical understanding of fluid dynamics.

Phenomenological introduction to fluid dynamics

Kinematics and conservation laws

Ideal fluids, the Euler equations, ir-rotational flow

The Navier-Stokes equations

Viscous flow: Stokes flow, drag, lubrication theory, thin film flow

Waves: surface waves, internal gravity waves, nonlinear waves. solitons, shocks

Instabilities: linear stability analysis, Kelvin-Helmholts instability, Rayleigh-Bénard convection, other instabilities

Other topics depending on interest and as time permits possibly: airfoil theory, granular flows, biophysical flows.

Recommended Books:
1. D. J. Acheson, “Elementary Fluid Dynamics”, Oxford University Press, 1990.
2. P. K. Kundu and I.M. Cohen, “Fluid Mechanics”, Academic Press, 4th ed. 2010.
3. D. J. Tritton, “Physical Fluid Dynamics”, Clarendon, 2nd ed. 1988.
4. L. D. Landau and E. M. Lifschitz, “Fluid Mechanics”, Butterworth-Heinemann, 2nd ed. 1987.

INTRODUCTION TO PHOTONICS

Pre-requisites: **Waves and Oscillations, Optics, Linear Algebra, Electronics-I**
Credit Hours: **Three (3)**

Objective(s):

To study the application of light, Studying the photonic devices including detectors.

Guided Wave Optics: Planar slab waveguides, Rectangular channel waveguides, Single and multi-mode optical fibers, waveguide modes and field distributions, waveguide dispersion, pulse propagation

Gaussian Beam Propagation: ABCD matrices for transformation of Gaussian beams, applications to simple resonators

Electromagnetic Propagation in Anisotropic Media: Reflection and transmission at anisotropic interfaces, Jones Calculus, retardation plates, polarizers

Electro-optics and Acousto-optics: Linear electro-optic effect, Longitudinal and transverse modulators, amplitude and phase modulation, Mach-Zehnder modulators, Coupled mode theory, Optical coupling between waveguides, Directional couplers, Photoelastic effect, Acousto-optic interaction and Bragg diffraction, Acousto-optic modulators, deflectors and scanners

Optoelectronics: p-n junctions, semiconductor devices: laser amplifiers, injection lasers, photoconductors, photodiodes, photodetector noise.

Recommended Books:

1. B. E. A. Saleh and M. C. Teich, “Fundamentals of Photonics”, John Wiley, 2nd ed. 2007.
2. J-M. Liu, “Photonic Devices”, Cambridge University Press, 2009.
3. A. Yariv and P. Yeh, “Photonics: Optical Electronics in Modern Communications”, Oxford University Press, 2006.
4. E. Hecht, “Optics”, Addison-Wesley, 4th ed. 2001.

INTRODUCTION TO MATERIALS SCIENCE

Pre-requisites: Solid State Physics-I
Credit Hours: Three (3)

Objective(s):

To understand the important aspects of materials. Moving towards microstructures.

Atomic Structure of Materials: The packing of atoms in 2-D and 3-D, unit cells of the hexagonal close packing (hcp) and cubic closed packing (ccp) structures, interstitial structures, density computation, lattices and symmetry elements, indexing lattice directions and lattice planes, interplanar spacing, lattices and crystal systems in 3-D, symmetry, crystallographic point groups and space groups, Bragg's law and the intensities of Bragg reflections.

Imperfections in Solids: Vacancies, impurities, dislocations, interfacial defects, bulk or volume defects, atomic vibrations.

Microstructure: Microstructure and microscopy, pressure vs. temperature phase diagrams, temperature vs. composition phase diagrams, equilibrium, thermodynamic functions, variation of Gibbs energy with temperature and composition, general features of equilibrium phase diagrams, solidification, diffusion mechanisms, nucleation of a new phase, phase diagrams of Fe-C system and other important alloys, materials fabrication.

Mechanical Behavior of Materials: Normal stress and normal strain, shear stress and shear strain, elastic deformation, plastic deformation, Young's modulus, shear modulus, Poisson's ratio, elastic strain energy, thermal expansion, estimate of the yield stress, dislocations and motion of dislocations, slip systems, dislocations and strengthening mechanisms, fracture mechanics, ductile fracture, brittle fracture, Griffith criterion, ductile fracture, toughness of engineering materials, the ductile-brittle transition temperature, cyclic stresses and fatigue, creep.

Polymers: Polymer basics, polymer identification, polymer molecules, additional polymerization, step growth polymerization, measurement of molecular weight, thermosetting polymers and gels, rubbers and rubber elasticity, configuration and conformation of polymers, the glassy state and glass transition, determination of Tg, effect of temperature and time, mechanical properties of polymers, case studies in polymer selection and processing.

Biomaterials: Introduction to biomaterials, materials selection, biopolymers, structural polysaccharides, hard materials, biomedical materials.

Recommended Books:

1. W. D. Callister, "Materials Science and Engineering: An Introduction", Wiley, 7th ed. 2006.
2. W. D. Callister and D. G. Rethwisch "Fundamentals of Materials Science and Engineering: An Integrated Approach", Wiley, 4th ed. 2012.
3. J. F. Shackelford, "Introduction to Materials Science for Engineers", Prentice Hall, 7th ed. 2008.
4. http://www.msm.cam.ac.uk/teaching/index.php,
5. http://www.doitpoms.ac.uk/

INTRODUCTION TO NANO SCIENCE AND NANOTECHNOLOGIES

Pre-requisite: **Solid State Physics-II, Quantum Mechanics-II**
Credit Hours: **Three (3)**

Objective(s):

Introduce the concept and applications of nano sciences and nanotechnologies. Nano structures and nano technologies.

Introduction: Feynman talks on small structures, Nano scale dimension, Course goals and objectives.

Quantum Effects: Wave particle duality, Energy quanta, Uncertainty principle, De Broglie relation, Quantum Dots, Moore's law, tunneling.

Surfaces and Interfaces: Interfaces, Surface chemistry and physics, Surface modification and characterization, Thin Films, Sputtering, Self-assembled films.

Material Properties: Subatomic physics to chemical systems, types of chemical bonds, solid state physics / Material properties.

Tools and Instrumentation: STM, AFM, Electron Microscopy, Fluorescence methods, Synchrotron Radiation.

Fabricating Nano Structures: Lithography (photo and electron beam), MBE, Self-assembled masked, FIB, Stamp technology, Nano junctions.

Electrons in Nano Structures: Variation in electronic properties, free electron model, Bloch's theorem, Band structure, Single electron transistor, Resonant tunneling.

Molecular Electronics: Lewis structures, Approach to calculate Molecular orbitals, Donor Acceptor properties, Electron transfer between molecules, Charge transport in weakly interacting molecular solids, Single molecule electronics.

Nano Materials: Quantum dots, nano wires, nano photonics, magnetic nano structures, nano thermal devices, Nano fluidic devices, biomimetic materials.

Nano Biotechnology: DNA micro-arrays, Protein and DNA Assembly, Digital cells, genetic circuits, DNA computing.

Nanotechnology the Road Ahead: Nanostructure innovation, Quantum Informatics, Energy solutions.

Recommended Books:

1. S. Lindsay, "Introduction to Nanoscience", Oxford University Press, 2009.
2. C. Binns, "Introduction to Nanoscience and Nanotechnology (Wiley Survival Guides in Engineering and Science)", Wiley, 2010.

PARTICLE PHYSICS

Pre-requisites: **Quantum Mechanics-II, Nuclear Physics**
Credit Hours: **Three (3)**

Introduction to Elementary Particles: Fundamental building blocks and their interactions. Quantum Electrodynamics. Quantum Chromodynamics. Weak interactions. Decays and conservation laws.

Relativistic Kinematics: Lorentz transformations. Four-Vectors. Energy and momentum. Particle collisions. Mandelstam variables.

Symmetries: Symmetries and conservation laws, Spin and orbital angular momentum. Flavour symmetries. Parity. Charge conjugation. CP Violation. Time reversal and TCP Theorem.

Quantum Electrodynamics: Klein-Gordon equation. Dirac equation. Solution of Dirac equation. Bilinear covariants. Feynman rules for QED. Casimir's trick. Cross sections & lifetimes.

Neutrino Oscillations: Solar neutrino problem. Oscillations, Neutrino masses. PMNS mixing matrix.

Gauge Field Theories: Lagrangian in Relativistic Field Theory. Gauge Invariance. Yang-Mills Theory. The mass term. Spontaneous symmetry breaking. Higgs mechanism. Higgs boson. Grand Unification. Supersymmetry. Extra dimensions. String theory. Dark energy. Dark Matter.

Recommended Books:

1. D. Griffiths, "Introduction to Elementary Particles", Wiley-VCH, 2nd ed. 2008.
2. F. Halzen and A.D. Martin, "Quarks and Leptons: An introductory course in modern Particle Physics", John Wiley, 1984.
3. D. H. Perkins, "Introduction to High-Energy Physics", Cambridge University Press, 4th ed. 2000.
4. V. D. Barger and R. J. N. Phillips, "Collider Physics", Addison-Wesley, 1996.

COMPUTER SIMULATIONS IN PHYSICS

Pre-requisites: **Calculus-II, Linear Algebra, Probability and Statistics, Differential Equations, Introduction to Computing, Mechanics.**
Credit Hours: **Three (3)**

Objective(s):

The aim is to develop the ability to turn theoretical ideas of mathematics and physics into computer simulations of real-world systems.

Programming for Scientific Computation: unix/linux basics, the editing-coding-compiling-debugging-optimizing-visualizing-documenting production chain, Fortran95.

Numerical Programming: Functions: approximation and fitting, Numerical calculus. Ordinary differential equations, Matrices, Spectral analysis, Partial differential equations.

Modeling and Simulation: Molecular dynamics simulations, modeling continuous media Monte Carlo simulations.

Project: A project will be chosen by the student in consultation with the instructor. Selection of the project should be done soon after the module on modelling and simulation starts and continue over the course of the rest of the semester. The final part of the course is reserved for presentation of preliminary and final results.

Recommended Books:

1. T. Pang, "An Introduction to Computational Physics", Cambridge University Press, 2008.
2. R. Landau, M. Paez, C. Bordeianu, "A Survey of Computational Physics", Princeton University Press, 2008.

SURFACE SCIENCES

Pre-requisite: **Solid State Physics-II**
Credit Hours: **Three (3)**

Objective(s):
To understand the basics of surface physics. Strengthen the previous knowledge of Solid State Physics and Quantum Mechanics.

Basics of Surface Science: Surface reactions, Heterogeneous catalysis, Semiconductor technology, Corrosion, Nanotechnology, Surface Structure and Reconstruction: Classification of solids, Crystal structure, Unit cell, Bravais lattices, Electronic Structure of Surfaces: Band structure of metals, insulators and semiconductors, Fermi level, Screening, Work Function, Surface States, Electron Affinity, Ionization Potential, Surface Chirality, Thermodynamics of Surfaces, Equilibrium Crystal Shape.

Quantum confinement of Electrons at Surfaces: Interference of Electron Waves, Quantum size effects, Quantum wells, Mechanical Quantum Wells, Quantum Wires, Chemist's Approach, Bonds to Bands.

Surface Dynamics: Nucleation and growth of nanostructures and films, Surface Magnetism and magnetic imaging, Diamagnetism, Paramagnetism, Anti-Ferromagnetism, Magnetism in thin films, Kerr microscopy (MOKE), Spin Polarized Photoemission (SP-PEEM), Magnetic Force Microscopy (MFM).

Surface Study Techniques: Surface Sensitivity and specificity, Explanation and comparison of Low-Energy Electron Diffraction (LEED) and Reflection High-Energy Electron Diffraction (RHEED), Explanation of Near-Edge X-ray Absorption Fine Structure (NEXAFS), High-Resolution Electron Energy Loss Spectroscopy (HREELS), Introduction to Desorption Techniques, Thermal Desorption Spectroscopy (TDS), Electron Stimulated Desorption (ESD), Electron Stimulated Desorption Ion Angular Distribution (ESDIAD), Photon Stimulated Desorption (PSD), Electron Spectroscopy, Theory: Mean free path, Koopman's Theorem, Spin orbit coupling effects, chemical shifts, binding energy, Auger Electron Spectroscopy (AES), X-Ray Photo-electron Spectroscopy, Electron Analyzer, Electron optics, Scanning Tunneling Microscopy (STM), History, Theory, Electronics and applications.

Case Studies: Silicon Surfaces: Geometric and Electronic Structure, Molecular Adsorption on Semiconductor Surfaces, Adsorption Properties of CO on Metal Single-Crystal Surfaces, Molecular or dissociative adsorption, Chemical bonding and Orientation, Adsorption Site as a function of coverage, Over layer long-range order, Ammonia Synthesis, Oxide Surfaces.

Photovoltaic and Organic Electronics: Different types of semiconductors (organic, inorganic, conjugated polymers), Prototypes (OLEDs etc), intra-molecular bonding, Van der Waals, electronic properties, polarization effects, Field effect Transistors, basics of excitonic solar cells.

Recommended Books:

1. A. Zangwill, “Physics at Surfaces”, Cambridge University Press, 1988.
2. D. P. Woodruff and T. A. Delchar, “Modern Techniques of Surface Science”, Cambridge University Press, 2nd ed. 1994.
3. D. Briggs and M. P. Seah, “Practical Surface Analysis”, Vol-I, John Wiley, 2nd ed. 1990.
4. J. B. Hudson, “Surface Science, an Introduction”, Wiley-Interscience, 1998.
5. H. Luth, “Surfaces and Interfaces of Solids”, Springer-Verlag, 2nd ed. 1993.
6. M. Prutton, “Introduction to Surface Physics”, Oxford University Press, 1994.
7. R. I. Masel, “Principles of Adsorption and Reaction on Solid Surfaces”, Wiley-Interscience, 1996.

COMPUTATIONAL PHYSICS

Credit Hours: Three (3)

Objective(s):

Introduction of computer languages. To know the use of computer in numerical analysis. Computer simulation and modeling.

Computer Languages: A brief introduction of the computer languages like Basic, C. Pascal etc. and known software packages of computation

Numerical Methods: Numerical Solutions of equations, Regression and interpolation, Numerical integration and differentiation. Error analysis and technique for elimination of systematic and random errors

Modeling & Simulations: Conceptual models, the mathematical models, Random numbers and random walk, doing Physics with random numbers, Computer simulation, Relationship of modeling and simulation. Some systems of interest for physicists such as Motion of Falling objects, Kepler's problems, Oscillatory motion, Many particle systems, Dynamic systems, Wave phenomena, Field of static charges and current, Diffusion, Populations genetics etc.

Recommended Books:

1. M. L. De Jong, ”Introduction to Computational Physics”, Addison Wesley, 1991.
2. S. T. Koonini, “Computational Physics”, the Benjamin-Cummings, 1985.
3. H. Gould, J. Tobochnik and W. Christian, “An Introduction to Computer Simulation Methods”, Addison Wesley, 3rd ed. 2006.
4. S. C. Chapra and R. P. Chanle, ”Numerical Methods for Engineers with Personal Computer Applications”, McGraw-Hill,1990.
5. S. C. Chapra, “Applied Numerical Methods with MATLAB for Engineers and Scientists”, McGraw-Hill, 2nd ed. 2006.

LABORATORY COURSES IN BS PHYSICS

Students will take seven laboratory courses, Lab-I through Lab VII. Labs I, II, III and IV are one credit hour each while Labs V, VI and VII are two credit hours. The learning outcomes of the laboratory courses are given below:

Mathematical and conceptual outcomes:

1. Demonstrate a keen appreciation of physical quantities, their dimensions and units.
2. Perform simple statistical analysis of data including calculating means, mean squares, root mean squares, standard deviations and correlations between groups of data.
3. Mathematically understand physical processes and fitting them with linear, exponential, sinusoidal and polynomial models.
4. Accurately represent experimental data in the form of tables and graphs.
5. Understand errors, uncertainties and their propagation from basic to deduced quantities. Students must possess the ability to calculate uncertainties and appreciate types A and B of uncertainties. Students must appreciate when experiments are repeatable and reproducible, determine and understand the concepts of precision and accuracy, resolution and time for measurement.
6. Students must be able to develop a keen sense of measurement theory in accordance with the guidelines presented in the "Guide to the Expression of Uncertainties in Measurement" as formulated by ISO's Joint Committee for Guides in Metrology (as of November 2012, these guides are downloadable from http://www.iso.org/sites/JCGM/GUM-introduction.htm).
7. Students must possess the ability to present an idea in the following equivalent forms: (a) equations and formulas, (b) words, (c) graphs, (d) pictures and sketches.
8. Develop an appreciation of energy, its myriad manifestations and inter-conversion.

Engineering and Practical Outcomes:

1. Perform experiments to test physical ideas, corroborate physical theories, find correspondence between theory and experiment, understand the limitations of theoretical descriptions and the role of approximations in physics.
2. Design simple experiments to test physical ideas.
3. Understand the significance of various kinds of materials (ceramics, plastics, metals, conductors, insulators) in the design of hardware.
4. Perform experiments safely.
5. Demonstrate the ability to work in teams.
6. Use locally available resources including materials and craftsmanship to build new projects.
7. Familiarity with mechanical workshop and ability to interpret basic engineering drawings.
8. Specializing in the skill of logging laboratory activity and producing high quality reports of experimental work.
9. Obtaining basic familiarity with advanced scientific instrumentation and its role in the progress of physics and science. Students must also possess the appreciation of limitations in accuracy and precision of the apparatus they use and the ability to suggest improvements in the equipment, the experimental procedure and the processing of data.
10. Students should be invariably introduced at some stage during the lab courses to these modern techniques that have now become routine in laboratories worldwide: (a) data acquisition which is the transfer of experimental data from the physical apparatus to the computer using analog-to-digital converters, (b) use of some modern software (e.g. Matlab, Origin, Mathematica, C++) for statistical processing and presentation of data.

Institutes can develop the contents of the laboratory courses dependent on the facilities and equipment available and committed resources. The guidelines that follow are in line with best practices and holistically map with the scheme of studies for the four year BS Physics programme outlined in the previous pages.

The learning outcomes enumerated above are to be addressed throughout all the laboratory courses and are not specific to a particular course. It is the role of the institute to ensure that these outcomes are adequately achieved and the assessment and student grading is conducted in accordance with the outcomes.

Also note that a one-credit hour laboratory entails at least three hours of practical work each week during the semester and a two-credit hour laboratory requires at least six hours of practical work each week.

Course	Semester	Credit Hours	Themes
Lab-I	1	1	• Measurement and uncertainties • Mechanics, fluids
Lab-II	2	1	• Measurement and uncertainties • Electricity and Magnetism
Lab-III	3	1	• Heat, waves, sound
Lab-IV	4	1	• Optics
Lab-V	5	2	• Electronics
Lab-VI	6	2	• Modern Physics • Advanced optics, atomic physics and spectroscopy • Electronic materials
Lab VII	7	2	• Miscellaneous advanced experiments in modern physics, atomic physics, solid state physics, electronics

Sample experiments and areas of exploration for various themes are listed here.

Mechanics and Fluids: experiments with pendulums, stop watches, one-dimensional motion and verification of Newton's laws of motion, measurement of forces, speed, acceleration and linear momentum, collisions and conservation of momentum, impacts, free fall and acceleration due to gravity, gyroscopes, rotational motion, conservation of angular momentum, friction, static and dynamic equilibrium, compound pendulum, rolling motion along inclined planes, simple harmonic motion, masses attached to springs and Hooke's law, damped motion and the regimes of damping (overdamped, underdamped and critically damped), pressure in fluids, experiments demonstrating continuity, Bernoulli's principle, buoyancy and Archimedes's principle, Atwood machine, fluid viscosity, surface tension.

Electricity and Magnetism: Static charge and electric fields, direct and alternating currents, electrical measurement instrumentation (voltmeters, ammeters, power supplies, variable transformers, cathode ray oscilloscope, electrometer), passive electronic components (resistors, capacitors, inductors), measurement of resistance, capacitance and inductance, electromagnetic induction, inductors and transformers, motors, magnetic fields due to currents and permanent magnets, ferromagnetism and ferroelectricity, determination of hysteresis curves, determination of Curie point, magnetic susceptibility and its temperature dependence, dielectric properties measurement, mapping of magnetic fields using Hall sensors, experiments on noise, properties of the light bulb.

Heat: calorimetry, heat transfer, Newton's cooling under ambient and forced convection and radiation, measurement of temperature using Si diodes, thermistors, thermocouples and RTD's, blackbodies, heat pumps and heat engines, investigation of gas laws and laws of thermodynamics, thermal conductivity by pulsed heating of a metal rod, measurement of latent heats and specific heat capacities, temperature control using PID (proportional-integral-derivative) schemes, thermal expansivity and its measurement using strain gauges.

Waves and Oscillations, Sound: resonance in a stretched string, normal modes of oscillation, dispersion relations for mono and diatomic lattice, coupled oscillators, nonlinear oscillations exemplified by resistance-inductance-diode circuits, magnetic pendulums, accelerometers, measurement of the speed of sound under conditions of varying temperature, solitons, Lorentz pendulum, waves in water, beats, super-positions of harmonic motion (Lissajous patterns), sonometer.

Optics (basic and advanced) and Spectroscopy: Sources of light including bulbs, light emitting diodes, laser diodes and gas lasers, experiments demonstrating optical phenomena such as interference, diffraction, linear motion, reflection, refraction, dispersion, Michelson interferometry, measurement of refractive index using interferometry, measurement of the speed of light, diffraction gratings and multiple-slit interference, thin film interference and Newton's rings, use of digital cameras for optics experiments, mode structure of lasers, use of spectrometers and monochromators, wavelength tuning of laser diodes, rainbows, emission spectroscopy of low-pressure gases (hydrogen), alkali spectra and fine structure, hyperfine structure of rubidium, vibrational spectrum of nitrogen, Lambert-Beer's law, optical polarization, magneto-optical Faraday rotation.

Electronics: DC voltages and current measurement, simple DC circuits, generating and analyzing time-varying signals, opamps and comparators, amplifier design, RC transients, filters, frequency response, LC circuits, resonance, transformers, diodes, modulation and radio reception, MOSFET characteristics and applications, principles of amplification, bipolar transistors and amplifiers, digital logic circuits, gates and latches, D-flip flops and shift registers, JK flip-flops and ripple counters.

Modern Physics: photoelectric effect, Frank-Hertz's quantization of energy levels, determination of Planck's constant (e.g. using a light bulb), verification of Moseley's law using X-ray fluorescence, Compton effect, Millikan's experiment for determination of charge of electron, properties of nuclear radiation (absorption in different media and response to external magnetic fields), statistical nature of radioactivity, determination of the half-life of radio-isotopes, Geiger-Muller tubes, cloud chambers, energy spectroscopy of gamma rays, experiments on medical physics.

Electronic Materials: measurement of electrical conductivity by two-probe and four-probe methods, band gap estimation of intrinsic and extrinsic semiconductors, carrier lifetimes and mobilities, Hall effect and its application in measuring magnetic fields, thermoelectric effects.

Advanced Experiments: nuclear magnetic resonance, electron spin resonance, Zeeman effect, optical pumping, lifetime of muons, surface plasmon resonance, Brownian motion, experiments with vacuum, low temperature physics, superconductivity, synthesis of nanomaterials and their characterization, electromagnetically induced transparency, Mossbaeur spectroscopy.

Recommended Books:

1. A. C. Melissinos and J. Napolitano, “Experiments in Modern Physics”, Academic Press, 2nd ed. 2003.
2. J. H. Moore, C. C. Davis, M. A. Coplan, and S. C. Greer, "Building Scientific Apparatus", Cambridge University Press, 4th ed. 2009.
3. J. R. Taylor, "An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements", University of Science Books, 2nd ed. 1996.
4. L. Kirkup and R. B. Frenkel, “An Introduction to Uncertainty in Measurement”, Cambridge University Press, 2006.
5. G. L. Squires, "Practical Physics", Cambridge University Press, 4th ed. 2001.
6. Y. Tsividis, "A First Lab in Circuits and Electronics", John Wiley 2001.

Course of Studies for Graduate Degrees in Physics (MPhil and PhD in Physics)

Semester wise Scheme for MPhil in Physics

	Semester-I		
Code	**Title of the Course**	**Cr Hrs**	**Remarks**
Phys 634	Quantum Mechanics-I	3	Compulsory
Phys 623	Electrodynamics-I	3	Compulsory
Phys 612	Classical Mechanics	3	Compulsory
Phys 653	Mathematical Methods of Physics	3	Compulsory
	Total	12	

	Semester-II		
Code	**Title of the Course**	**Cr Hrs**	**Remarks**
Phys 662	Statistical Physics	3	Compulsory
	Graduate Level Physics Course	3	Elective I
	Graduate Level Physics Course	3	Elective II
	Graduate Level Physics Course	3	Elective III
	Total	12	

Semester wise Scheme for PhD in Physics

	Semester-I		
Code	**Title of the Course**	**Cr Hrs**	**Remarks**
	Graduate Level Physics Course	3	Elective I
	Graduate Level Physics Course	3	Elective II
	Graduate Level Physics Course	3	Elective III
	Total	9	

	Semester-II		
Code	**Title of the Course**	**Cr Hrs**	**Remarks**
	Graduate Level Physics Course	3	Elective I
	Graduate Level Physics Course	3	Elective II
	Graduate Level Physics Course	3	Elective III
	Total	9	

Note: Courses can be swapped according to the resources of the University.

COURSES FOR GRADUATE STUDIES
(MPhil and PhD) IN PHYSICS

Mathematical Methods of Physics 3 Cr.hr

Fourier series: introduction and general properties, convergence of trigonometric series, Gibbs phenomenon, Parseval's theorem, applications to various phenomena.

Integral transform, development of the Fourier integral, Fourier transform, inversion theorems, Fourier transform of derivatives, convolution theorem, momentum representation, transfer functions.

Complex arguments in Fourier transforms. Laplace transform, Laplace transform of derivatives, convolution products and Faltung's theorem, inverse Laplace transform.

Partial differential equations. Separation of variables in three dimensions, method of characteristics. Boundary value problems.

Integral transforms, generating functions, Neumann series, separable (degenerate) kernels, Hilbert–Schmidt theory, integral equations.

Calculus of variations: dependent and independent variables, Euler-Lagrange equation and applications, several independent and dependent variables, Lagrange multipliers, variational principle with constraints, Rayleigh–Ritz variational technique, application to discrete mesh.

Nonlinear methods and chaos, the logistic map, sensitivity to initial conditions and parameters, nonlinear differential equations.

Probability: definitions and simple properties, random variables, binomial distribution, Poisson distribution, Gauss's normal distributions, statistics.

Recommended Texts:

1. *Mathematical Methods for Physicists*, Arfken & Weber (Academic Press, 6th edition, 2005).
2. *Mathematical Methods for Physicists,* Tai L. Chow (Cambridge University Press, 2002).

Classical Mechanics 3Cr.hr

Survey of the elementary principles, Variational principles and Lagranges's equations, Oscillations, The classical mechanics of the special theory of relativity, Hamiltonian equations of motion, canonical transformations, Hamilton-Jacobi theory and Action angle variable, Classical Chaos, Canonical perturbation theory, Introduction to the Lagrangian and Hamiltonian formulations for continuous systems and fields, Classical mechanics of liquids and deformable solids; stress, deformation and strain flow.

Recommended Textbook:

1. Classical Mechanics (3rd Edition) by Herbert Goldstein, Charles P. Poole Jr., and John L. Safko, Pearson International Edition, 2001.

Quantum Mechanics I 3 Cr.hr

Waves and particles: Introduction to fundamental idea of Quantum mechanics.

Electromagnetic waves and photons; Light quanta and the plank-Einstein relations, wave particle duality, Analysis of young double slit experiment, Quantum unification of two aspect of light, The Principle of spectral decomposition, Material particle and matter waves; The de Broglie relations, Wave functions: the Schrodinger equation, Quantum description of a particle Wave packets; Free particle, Form of the wave packet at given time, Heisenberg uncertainty relation, Time evolution of free wave packet, Particle in a time independent Scalar potential; Separation of variables. Stationary states, one dimensional square potential.

Order of magnitude of the wave length associated with the material particle, Constraints imposed by the uncertainty relation, the uncertainty relation and the atomic parameters, An experiment illustrating the uncertainty relation, A simple treatment of a two dimensional wave packet, the relation between one and three dimensional problem, One dimensional Gaussian wave packet: spreading of wave packet, Stationary state of a particle in one dimensional square well, behaviour of wave packet at a potential step.

The mathematical tool of quantum mechanics:
One particle wave function space; Structure of the wave function space, Discrete orthonormal basis in wave function space, Introduction of basis not belonging to wave function space, State Space: Dirac notation; introduction, ket vectors and bra vectors, Linear operators, Hermitian conjugation Representation in the state space; Relation characteristic of an orthonormal basis, Representation of kets and bras, Representation of operators, Eigen value equation: Observables; Eigen values and Eigen vectors of an operators, Observables, Sets of commuting observables, Two important example of representation and observables; {Ir>} and {Ip>} repsentations, The R and P representation.

The Schwartz inequality, Review of some useful properties of linear operator, Unitary operators, A more detail study of {Ir>} and {Ip>} repsentations, Some general properties of two observables, Q and P, The parity operator.

The postulates of quantum mechanics:
Introduction, Statement of the postulates; Description of the state of the system, Description of a physical quantaties, the measurement of a physical quantaties, time evolution of a system, Quantization rule, The physical interpretation of the postulates, Postulates concerning observables and their measurements, Quantization of certain physical quantaties, The measurement process, mean value of an observable, The root mean square deviation, Compatibility of observables, The physical implication of the Schrodinger equation; General properties of Schrodinger equation, The case of conservative system, The superposition principle and Physical prediction; Probability amplitudes and interference effects, Case in which several states can be associated with the same measurement result.

Practical in infinite potential well, Study of the probabity current in some special cases, Root mean square deviation of two conjugate observables, measurements bearing on only one part of a physical system, The density operator, The evolution operator, The Schrodinger and Heisenberg picture, The Gauge invariance, Propagator for the Schrödinger equation.

Application of the postulate to the simple cases: Spin1/2 and two level system.

Spin1/2 particle:
Experimental demonstration, Quantization of the angular momentum, theoretical description, Illustration of the postulate in the case of a spin1/2; Actual preparation of a various spin states, spin measurements, Evolution of spin ½ in a uniform magnetic field, General study of two level system; Outline of the problem, Static aspect, Dynamical aspect: oscillation of the system between two unperturbed state.

Pauli matrices, Diagnalization of 2cross2 matrices, Fictitious spin1/2 associated with two level system, system of two spin ½ particles, spin ½ density matrix, spin ½ particles in a static magnetic field and a rotating field, A simple model of ammonia molecule, coupling between a stable and unstable state.

The one-dimensional harmonic oscillator:
Introduction; Importance of harmonic oscillator in physics, the harmonic oscillator in classical mechanics, General properties of quantum mechanical Hamiltonian, Eigen values of the Hamiltonian; Notation, Determination of the spectrum, Degeneracy of the eigen values,

Eigen State of the Hamiltonian; The $\{|\phi_n\rangle\}$ representation, Wave function associated with the stationary state, Discussion; Mean value and root mean square deviation of X and P in a state $\{|\phi_n\rangle\}$, Properties of the ground state, Time evolution of mean values.

Some example of harmonic oscillator, Study of the stationary state in the {Ir>} representation, Solving the eigen value equation of the harmonic oscillator by the polynomial method, Study of the stationary state in the {Ip>} representation, The isotropic three dimensional harmonic oscillator, A charged harmonic oscillator in uniform electric field, Coherent quasi classical state of harmonic oscillator.

General properties of angular momentum in Quantum mechanics:
Introduction; The importance of angular momentum, Commutation relation; Orbital angular momentum, Generalization. definition of angular momentum, Statement of the problem, General theory of angular momentum;. Definition and notation, Eigen values of J^2 and J_z, Standard {Ik, j, m>} representation, Application to the orbital angular momentum; Eigen values and eigen function of L^2 and L_z, physical consideration.

Spherical harmonics, Angular momentum and rotation, Rotation of diatomic molecules, Study of the stationary state in the {Ip>} representation, Angular momentum of stationary state two dimensional harmonic oscillator, A charged particle in magnetic field: Landau levels.

Particle in a central potential: the hydrogen atom:
Stationary state in a central potential; Outline of the problem, Separation of variable, Stationary state of the particle in a central, Motion of the centre of mass and Relative motion for a system of two Interacting particle; Motion of the centre of mass and Relative motion in Classical mathematics, Separation of variable in Quantum mechanics, The hydrogen atom; Introduction, The Bohr model, Quantum mechanical theory of the hydrogen atom, Discussion of the result.

Hydrogen like system, a soluble example of the central potential, Probability current associated with the stationary state of the hydrogen atom, the hydrogen atom placed in a uniform magnetic field, Study of some atomic orbitals. Hybrid orbitals, Vibrational –rotational levels of diatomic molecules.

Recommended Textbook:

1. Quantum Mechnics (Vol. 1) by Claude Cohen-Tannoudji, Bernard Diu, Frank Laloe, Wiley-VCH, 1992.

Recommended Books:

1. Modern Quantum Mechanics (2nd Edition) by J. J. Sakurai, Jim J. Napolitano, Addison-Wesley, 2010.
2. Principles of Quantum Mechanics (2nd Edition) by R. Shankar, Plenum Press, 1994.
3. Quantum Mechanics by Dirac, P. A. M (Oxford University Press

Statistical Physics 03 Cr.hr

Intensive and extensive quantities, thermodynamic variables, thermodynamic limit, thermodynamic transformations.

Classical ideal gas, first law of thermodynamics, application to magnetic systems, heat and entropy, Carnot cycle.

Second law of thermodynamics, absolute temperature, temperature as integrating factor, entropy of ideal gas.

Conditions for equilibrium, Helmholtz free energy, Gibbs potential, Maxwell relations, chemical potential. First-order phase transition, condition for phase coexistence.

The statistical approach: phase space, distribution function, microcanonical ensemble, the most probable distribution, Lagrange multipliers.

Maxwell-Boltzmann distribution: pressure of an ideal gas, equipartition of energy, entropy, relation to thermodynamics, fluctuations, Boltzmann factor.

Transport phenomena: collisionless and hydrodynamic regimes, Maxwell's demon, non-viscous hydrodynamics, sound waves, diffusion, conduction, viscosity.

Quantum statistics: thermal wavelength, identical particles, Fermi and Bose statistics, pressure, entropy, free energy, equation of state, Fermi gas at low temperatures, application to electrons in solids and white dwarfs.

The Bose gas: photons, phonons, Debye specific heat, Bose-Einstein condensation, equation of state, liquid helium.

Canonical and grand canonical ensembles, partition function, connection with thermodynamics, fluctuations. minimization of free energy, photon fluctuations, pair creation.

The order parameter, Broken symmetry, Ising spin model, Ginsburg Landau theory, mean-field theory, critical exponents, fluctuation-dissipation theorem, correlation length, universality.

Recommended Textbooks:

1. *Introduction to Statistical Physics*, Kerson Huang, (Taylor and Francis, 2001).
2. *Statistical Mechanics*, Raj Kumar Pathria, 2nd edition (India, 1996).

Electrodynamics I 3 Cr.hr

Introduction to Electrostatics:
Coulomb's Law , Electric Field , Gauss's Law , Differential Form of Gauss's Law , Another Equation of Electrostatics and the Scalar Potential ,Surface Distributions of Charges and Dipoles and Discontinuities in the Electric Field and Potential , Poisson and Laplace Equations, Green's Theorem, Uniqueness of the Solution with Dirichlet or Neumann Boundary Conditions

Formal Solution of Electrostatic Boundary-Value Problem with Green Function, Electrostatic Potential Energy and Energy Density; Capacitance, Variational Approach to the Solution of the Laplace and Poisson Equations, Relaxation Method for Two-Dimensional Electrostatic Problems

Boundary- Value Problems in Electrostatics I:

Method of Images, Point Charge in the Presence of a Grounded Conducting Sphere, Point Charge in the Presence of a Charged, Insulated, Conducting Sphere, Point Charge Near Conducting Sphere at Fixed Potential, Conducting Sphere in a Uniform Electric Field by Method of Images, Green Function for the Sphere; General Solution for the Potential, Conducting Sphere with Hemispheres at Different Potentials, Orthogonal Functions and Expansions, Separation of Variables; Laplace Equation in Rectangular Coordinates, A Two-Dimensional Potential Problem; Summation of Fourier Series, Fields and Charge Densities in Two-Dimensional Corners and Along Edges, Introduction to Finite Element Analysis for Electrostatics.

Boundary- Value Problems in Electrostatics II:

Laplace Equation in Spherical Coordinates, Legendre Equation and Legendre Polynomials, Boundary-Value Problems with Azimuthal Symmetry, Behaviour of Fields in a Conical Hole or Near a Sharp Point, Associated Legendre Functions and the Spherical Harmonics, Addition Theorem for Spherical Harmonics, Laplace Equation in Cylindrical Coordinates; Bessel Functions, Boundary-Value Problems in Cylindrical Coordinates, Expansion of Green Functions in Spherical Coordinates, Solution of Potential Problems with the Spherical Green Function.

Expansion, Expansion of Green Functions in Cylindrical Coordinates, Eigenfunction Expansions for Green Functions, Mixed Boundary Conditions, Conducting Plane with a Circular Hole, Multi-poles, Electrostatics of Macroscopic Media, Dielectrics:

> Multi-pole Expansion, Multi-pole Expansion of the Energy of a Charge Distribution in an External Field, Elementary Treatment of Electrostatics with Ponderable Media, Boundary-Value Problems with

Dielectrics, Molecular Polarizability and Electric Susceptibility, Models for Electric Polarizability, Electrostatic Energy in Dielectric Media. Magnetostatics, Faraday's Law, Quasi-Static Fields:

Introduction and Definitions, Biot and Savart Law, Differential Equations of Magnetostatics and Ampere's Lawn Vector Potential, Vector Potential and Magnetic Induction for a Circular Current Loop, Magnetic Fields of Localized Current Distribution, Magnetic Moment, Force and Torque on and Energy of a Localized Current Distribution in an External Magnetic Induction , Macroscopic Equations, Boundary Conditions on B and H, Methods of Solving Boundary-Value Problems in Magnetostatics, Uniformly Magnetized Sphere, Magnetized Sphere in an External Field; Permanent Magnets, Magnetic Shielding, Spherical Shell of Permeable Material in a Uniform Field, Effect of a Circular Hole in a Perfectly Conducting Plane with an Asymptotically Uniform Tangential Magnetic Field on One Side, Numerical Methods for Two-Dimensional Magnetic Fields, Faraday's Law of Induction , Energy in the Magnetic Field, Energy and Self- and Mutual Inductances, Quasi-Static Magnetic Fields in Conductors; Eddy Currents; Magnetic Diffusion, Maxwell Equations, Macroscopic Electromagnetism, Conservation Laws:

Maxwell's Displacement Current; Maxwell Equations, Vector and Scalar Potentials, Gauge Transformations, Lorenz Gauge, Coulomb Gauge, Green Functions for the Wave Equation , Retarded Solutions for the Fields: Jefimenko's Generalizations of the Coulomb and Biot-Savart Laws; Heaviside-Feynman Expressions for Fields of Point Charge, Derivation of the Equations of Macroscopic Electromagnetism, Poynting's Theorem and Conservation of Energy and Momentum for a System of Charged Particles and Electromagnetic Fields, Poynting's Theorem in Linear Dissipative Media with Losses, Poynting's Theorem for Harmonic Fields; Field Definitions of Impedance and Admittance, Transformation Properties of Electromagnetic Fields and Sources Under Rotations, Spatial Reflections, and Time Reversal, On the Question of Magnetic Monopoles, Discussion of the Dirac Quantization Condition , Polarization Potentials (Hertz Vectors).

Recommended Textbook:

1. Classical Electrodynamics by J. D. Jackson (3rd Edition), Wiley 1998.

Quantum Mechanics II` 3 Cr.hr

Pre-requisites: Quantum Mechanics I

An elementary approach to quantum theory of scattering by potential:

Introduction: Importance of collision phenomena, scattering by potential, Definition of scattering cross section, Organization of this chapter, Stationary scattering state. Calculation of the cross section, Definition of stationary scattering state, Calculation of the scattering cross section using probability current, Integral scattering equation. The Born approximation, scattering by central potential method of partial waves; Principle of the method of partial wave, Stationary state of the free particle, Partial wave in the potential, Expression for the cross section in terms of phase shift.

Electron spin:

Introduction of electron spin; Experimental evidence, Quantum description: postulates of the Pauli theory, Special properties of an angular momentum1/2; Non relativistic description of Spin1/2 particles; Observables and state vectors, Rotation operator for spin ½ particle.

Addition of angular momenta:
Introduction; Total angular momentum in classical mechanics, the importance of total angular momentum in Quantum mechanics, Addition of two ½ spin elementary method; Statement of the problem, The eigen values of S_z and their degree of Degeneracy, Diagnalization of S^2, Results: triplet and singlet, Addition of two arbitrary angular momenta; Review of the General theory of angular momentum, Statement of the problem, Eigen values of J^2 and $J,$ Common Eigen vectors of J^2 and J_z. Example of addition of angular momenta, Addition of Spherical harmonics, Vector operator: The Wigner Eckert theorem, Electron multi-pole moments, Evolution of two angular momenta.

Stationary perturbation theory:
Description of the method ; Statement of the problem, Approximate solution of the H(λ) eigenvalue equation, Perturbation of non-degenerate levels; First order correction, Second order correction, Diagnalization of S^2, Results: triplet and singlet, Perturbation of degenerate levels.

A one dimensional harmonic oscillator subjected to a perturbing potential in x, x^2, x^3, Interaction between the magnetic dipole of two spin1/2 particles, Van der wall forces, The Vabriational method, Energy band of electron in solids, A simple example of the chemical bond: The H ion.

An application of perturbation theory: the fine and hyperfine structure of hydrogen atom:

Introduction; Additional terms in the Hamiltonian; The fine structure of Hamiltonian, Magnetic interaction related to proton spin: The hyperfine Hamiltonian, The fine structure of n=2 levels; Statement of the problem, Matrix representation: The fine structure of Hamiltonian, Resurts: The fine structure of n=2 levels, The hyperfine structure of n=1level; Statement of the problem, Matrix representation of W_f in the 1slevel, The hyperfine structure of n=1level.

The Magnetic hyperfine Hamiltonian, Calculation of the mean value of fine structure of Hamiltonian in the 1s, 2s,and 2p state, The influence of the electron spin on the Zeeman effect of the hydrogen resonance line, The stark effect for the hydrogen atom.

Approximation method for time dependent problems:

Statement of the problem; Approximate solution of the Schrodinger equation; The Schrodinger equation in the $\{|\phi_n>\}$, Perturbation equation, An important special case: Sinusoidal or constant perturbation; Application of the general formulas, Sinusoidal perturbation which couple two discrete States: the resonance phenomena, Coupling with the state of continuous spectrum. Interaction of an atom with the electromagnetic wave, Linear and non-linear response of the two level system subjected to a sinusoidal perturbation, Oscillation of the system between two discrete states under the effect of resonant perturbation, Decay of discrete state resonantly coupled to a continuum of the final state.

System of identical particles:

Statement of the problem; Identical particles: definition, Identical particles in classical mechanics, Identical particles in quantum mechanics, Permutation operators; Two particle system, System containing an arbitrary number of particles, The symmetrization postulate; Statement of the postulate, Removal of exchange degeneracy, Construction of physical kets, Application of the other postulates, Discussion; Difference between bosons and fermions. Pauli's exclusion principle, Consequences of particle indistinguishablility on the calculation of physical predictions. Many electron atoms. Electron configuration, Energy level of the helium atom, Physical properties of an electron gas. Application to solids.

Electrodynamics II 3 Cr.hr

Pre-requisites: Electrodynamics I

Plane Electromagnetic Waves and Wave Propagation. Plane Waves in a Non-conducting Medium, Linear and Circular Polarization; Stokes Parameters, Reflection and Refraction of Electromagnetic Waves at a Plane Interface Between Two Dielectrics, Polarization by Reflection, Total Internal Reflection; Goos-Hanchen Effect, Frequency Dispersion Characteristics of Dielectrics, Conductors, and Plasmas, Simplified Model of Propagation in the Ionosphere and Magnetosphere, Magnetohydrodynamic Waves, Superposition of Waves in One Dimension; Group Velocity , Illustration of the Spreading of a Pulse As It Propagates in Dispersive Medium, Causality in the Connection Between D and E; Kramers-Kronig Relations, Arrival of a Signal After Propagation Through a Dispersive Medium, Waveguides, Resonant Cavities, and Optical Fibers:

Fields at the Surface of and Within a Conductor, Cylindrical Cavities and Waveguides, Waveguides, Modes in a Rectangular Waveguide, Energy Flow and Attenuation in Waveguides, Perturbation of Boundary Conditions, Resonant Cavities, Power Losses in a Cavity; Q of a Cavity, Earth and Ionosphere as a Resonant Cavity: Schumann Resonances, Multimode Propagation in Optical Fibers, Modes in Dielectric Waveguides, Expansion in Normal Modes; Fields Generated by a Localized Source in a Hollow Metallic Guide, Radiating Systems, Multi-pole Fields and Radiation:

Fields and Radiation of a Localized Oscillating Source, Electric Dipole Fields and Radiation, Magnetic Dipole and Electric Quadrupole Fields, Center-Fed Linear Antenna, Multi-pole Expansion for Localized Source or Aperture in Waveguide, Spherical Wave Solutions of the Scalar Wave Equation, Multi-pole Expansion of the Electromagnetic Fields, Properties of Multi-pole Fields, Energy and Angular Momentum of Multi-pole Radiation, Angular Distribution of Multi-pole Radiation, Sources of Multi-pole Radiation; Multi-pole Moments, Multi-pole Radiation in Atoms and Nuclei, Multi-pole Radiation from a Linear, Center-Fed Antenna 444.

Scattering and Diffraction:

Scattering at Long Wavelengths, Perturbation Theory of Scattering, Rayleigh's Explanation of the Blue Sky, Scattering by Gases and Liquids, Attenuation in Optical Fibers, Spherical Wave Expansion of a Vector Plane Wave, Scattering of Electromagnetic Waves by a Sphere, Scalar Diffraction Theory, Vector Equivalents of the Kirchhoff Integral, Vectorial Diffraction Theory, Babinet's Principle of Complementary Screens, Diffraction by a Circular Aperture; Remarks on Small Apertures, Scattering in the Short-Wavelength Limit, Optical Theorem and Related Matters.

Special Theory of Relativity:
The Situation Before 1900, Einstein's Two Postulates, Some Recent Experiments, Lorentz Transformations and Basic Kinematic Results of Special Relativity, Addition of Velocities; 4-Velocity, Relativistic Momentum and Energy of a Particle, Mathematical Properties of the Space-Time of Special Relativity Matrix Representation of Lorentz Transformations, Infinitesimal Generators, Thomas Precession, Invariance of Electric Charge; Covariance of Electrodynamics, Transformation of Electromagnetic Fields, Relativistic Equation of Motion for Spin in Uniform or Slowly Varying External Fields Note on Notation and Units in Relativistic Kinematics, Dynamics of Relativistic Particles and Electromagnetic Fields:

Lagrangian and Hamiltonian for a Relativistic Charged Particle in External Electromagnetic Fields, Motion in a Uniform, Static Magnetic Field, Motion in Combined, Uniform, Static Electric and Magnetic Fields, Particle Drifts in Non-uniform, Static Magnetic Fields, Adiabatic Invariance of Flux Through Orbit of Particle, 12.6 Lowest Order Relativistic Corrections to the Lagrangian for Interacting Charged Particles: The Darwin Lagrangian, Lagrangian for the Electromagnetic Field, Proca Lagrangian; Photon Mass Effects, Effective "Photon" Mass in Superconductivity; London Penetration Depth , Canonical and Symmetric Stress Tensors; Conservation Laws, Solution of the Wave Equation in Covariant Form; Invariant Green function.

Recommended Textbook:
Classical Electrodynamics by J.D. Jackson (3^{rd} Edition), Wiley 1998.

Advanced Quantum Mechanics **3 Cr. Hr.**

Pre-requisite: **Quantum Mechanics – I**

Relativistic Quantum Mechanics:
Paths to relativistic quantum mechanics; The Dirac Equation; Symmetries of the Dirac equation; Solving with a central potential; Relativist quantum field theory. Relativistic Quantum Mechanics of Spin ½ Particles. Probability conservation in relativistic quantum mechanics; The Dirac equation; Simple solution; nonrelativistic approximations, plane waves; Relativistic covariance; Bilinear covariance; Dirac operators in the Heisenberg representation; Zitterbewegung and negative energy solutions; Central force problems; the hydrogen atom; Hole theory and charge conjuagation; quantization of the Dirac field; Weak interactions and parity nonconservation; the two-component neutrino.

Covariant Perturbation Theory:
Natural units and dimensions; s-matrix expansion in the interaction representation; First-order process: Mott scattering and hyperon decay; Two-photon annihilation and Compton scattering: the electron propagator;

Feynman's space-time approach to the electron propagator; Moller scattering and the photon propagator: one-meson exchange interactions; Mass and charge renormalization: radiative corrections.

Text Books:

1. Advanced Quantum Mechanics by J. J. Sakurai and Jim Napolitano, (2^{nd} Edition).
2. Modern Quantum Mechanics by J. J. Sakurai and Jim Napolitano (2^{nd} Edition).

Methods and Techniques of Experimental Physics.

(03 Cr.hr)

Numerical methods. Solutions of equations by the method of iteration (Newton-Rapson method). Solution of differential equations of higher order. Gaussian quadrature. Random numbers. Monte-Carlo methods. Resume of theory of errors and experimental statistics. Least-squares fit to a polynomial. Nonlinear functions. Data manipulation, smoothing, interpolation and extrapolation, linear and parabolic interpolation. High vacuum techniques. Physical principles of diffusion and rotary pumps. Ultra high vacuum by ionization. Sorption and cryogenics. Measurement of pressure. Leak detection. X-ray. Electron and neutron diffraction techniques. Methods of recording diffraction patterns. Examples of structure determination. Analysis of results.

Recommended Books:

1. Methods of Experimental Physics by R. L. Horovitz and V. A. Johnson, (Academic press).
2. Methods of Experimental Physics by D. Williams, (Academic).
3. Elements of X-Ray Crystallography by L. V. Azaroff, (McGraw-Hill).
4. High Vacuum Technique by J. Yarwood (Chapman Hall).

Optical properties of Solids **03 Cr.hr**

Introduction, classical propagation, interband absorption, excitons, luminescence, semiconductor quantum wells, free electrons, molecular materials, luminescence centers, phonons, non linear optics

Recommended Textbook:

1. Optical properties of solids by Mark Fox (latest edition)

Magnetism in Condensed Matter 03 Cr.hr

Introduction to magnetism, Isolated magnetic moments, Environments, Interactions, Order and Magnetic structures, Order and Broken symmetry, Magnetism in Metals

Recommended Textbook:

1. Magnetism in Condense Matter by Stephen Blundell.

Recommended Books:

1. *Magnetism in Condensed Matter*, by Stephen Blundell, Oxford Press 2001.
2. *Introduction to the theory of Ferromagnetism* by Amikam Aharoni, Oxford Press, 1998.
3. *Permanent Magnetism* by R. Skomski and J. M. D. Coey, IOP Publishing, 1999.
4. *The Physical Principles of Magnetism* by Allan H. Morrish, John Wiley 1965.
5. *Introduction to Solid State Physics* by Charles Kittel, John Wiley 8th Edition.

Quantum Optics-I 03 Cr.hr

Field Quantization: Quantization of a single-mode field, Quantum fluctuations of a single-mode field, Quadrature operators for a single mode field, multimode fields, Thermal fields, Vacuum fluctuations and zero point energy, The quantum phase.

Coherent state: Eigenstates of the annihilation operator and minimum uncertainty states, Displaced vacuum states, Wave packet and time evolution, Generation of coherent states, Phase space pictures of Coherent states, Density operators and phase space probability distribution, Characteristic functions.

Emission and Absorption of Radiation by Atoms: Atom-field interactions, Interaction of an atom with classical field, Interaction of an atom with quantized field, The Rabi model, Fully quantum-mechanical model: the Jaynes-Cumming model, the dressed states, Density operator approach: application to thermal states, The Weisskopf-Wigner theory of spontaneous emission between two atomic levels.

Quantum Coherence Functions: Classical coherence functions, Quantum coherence functions, Young's interference, Higher-order coherence functions.

Textbooks/References:

1. Introductory Quantum Optics, Christopher C. Gerry and Peter L. Knight, Cambridge University Press (2005)
2. Quantum Optics, Marlan O. Scully and M. Suhail Zubairy, Cambridge University Press (1997).
3. Fundamentals of Quantum Optics and Quantum Information, Peter Lambropoulos and David Petrosyan, Springer-Verlag Berlin Heidelberg (2007)

Condensed Matter Theory-I **03 Cr.hr**

Introduction: Overview of modern condensed matter physics, more is different, emergent properties.

Broken symmetry, quasiparticles and collective phenomena: Symmetry, importance of broken symmetry, adiabatic continuity and universality.

Landau's Fermi liquid theory: The free electron theory, why does the free electron theory work so well? Adiabatic continuity applied to Fermi systems, Landau's Fermi liquid theory, physical consequences.

Second quantization and its applications: Bosons, Fermions, Fermion operators, quantum magnetism, spin waves and magnons, Su-Shriefer-Heeger model of a conducting polymer chain.

Electron interactions: Hartree and Hartree-Fock theory, Metals in the Hartree-Fock approximation, correlation energy of jellium, Wigner crystallization, Inhomogeneous electron systems, Kohn-Hohenberg theory, The Kohn-Sham equation, Exchange-correlation functional.

Response functions: An overview of modern experimental techniques, linear response theory, fluctuation-dissipation theorem, dielectric response function.

Luttinger liquid theory: Why is 1D special? The Luttinger model, spin-charge separation.

Electron-lattice interactions: harmonic chain, electron-phonon interaction, electrical conduction, effective electron-electron coupling.

Recommended Textbooks:

1. *Advanced Solid State Physics*, by P. Philips, publisher: Westview Press; 1st edition, (2003).
2. *Condensed Matter Field Theory*, by A. Altland and B. Simons, publisher: Cambridge University Press, 1st edition (2006).
3. *Advanced Condensed Matter Physics*, by L. M. Sander, publisher: Cambridge University Press, 1st edition (2009).

Quantum Information Theory-I **03 Cr.hr**

Review of Classical Information Theory: Information and Physics, Quantifying Information, Shannon Entropy, Data Compression, Huffman Coding, Relative Entropy, Joint Entropy, Conditional Entropy, Mutual Information, Shannon's noiseless channel coding theorem.

Review of Quantum Mechanics: Pure and Mixed States, Density Operator, Trace and Partial Trace Operations, Postulates of Quantum Mechanics in Density Operator Formulism.

Basics of Quantum Information Theory: Von-Neumann Entropy, Quantum Data Compression, Relative Entropy, Conditional Entropy and Mutual Information.

Quantum circuits, operation of quantum computer, universal gates for quantum computation, building blocks of a quantum computer, quantum algorithms, Deutsch algorithm and Deutsch-Jozsa algorithm.

Physical implementations of quantum computation: Physical requirements for the physical implementation of quantum information processing, Rydberg atoms in microwave cavity, Ion trap quantum computer, cavity QED based quantum computer, optical quantum computer.

Quantum Cryptography: Review of Classical Cryptography, Quantum Key Distribution Protocols, privacy amplification and information reconciliation, security of quantum key distribution.

Text/Reference Books:

1. Elements of Information Theory, T.M. Cover and J.A. Thomas, John and Wiley Sons (1991)
2. Quantum Computation and Quantum Information, M.A. Nielson and I.I Chuang, Cambridge University Press (2000)
3. Introduction to Quantum Information Science, Vlatko Vedral, Oxford University Press (2006).

Materials Science **03 Cr.hr**

Interatomic Bonding in Materials:
Bonding in Elemental Materials (Covalent, Metallic and van der Waals Bonding), Bonding in Multielement Materials (Ionic, Mixed Ionic-Covalent Bonding, Hydrogen Bonding), Effects of Nature of Bonding on Materials Properties.

Structure of Crystalline Solids:
Basic Structural and Symmetry Concepts, Concept of Diffraction in a Periodic Lattice, Structural Information from X-ray Diffraction and other Diffraction Techniques. Crystal Structures of Metals and Ceramic Materials.

Defects and Imperfections in Crystalline Solids:
Point Defects (vacancies, interstitials, impurities, F-centres) and their stability Line and Extended Defects (Dislocations, Grain Boundaries, Stacking Faults, Interfacial, Surface and Volumetric Defects). Effect of Defects on the Properties of Materials.

Non Crystalline Solids:
Amorphous Materials/Glasses (Glass formation, Glass Transition and Crystallization of Glasses, Various Glass Forming Systems). Random Closed Packing in Metallic Glasses, Continuous Random Network in Covalent Glasses.

Phase Diagrams and Phase Transformations:
Basic Concepts, Equilibrium Phase Diagrams, Phase Transformations – Basic Concepts, Kinetics, Metastable versus Stable Transformations, Microstructure Development, Precipitation and Dispersion Hardening, Multi Component and Multi Phase Systems, Alloys, Equilibrium Structures, Phase Separation.

Surfaces and Interfaces:
Geometry of Interfaces, Coherent and Commensurate Interfaces, Stacking Period and Interplanar Spacing, Defects on Surfaces, Experimental Determination and Creation of Surfaces, Surface Characterization Techniques (LEED, RHEED, MBE, STM and AFM) and Their Principles.

Soft Condensed Matter:
Introduction to Soft Matter, Colloidal Dispersions, Gels and Gelation, Liquid Crystals; Structures and Textures in Liquid Crystals. Polymers; Molecular Weight, Molecular Structure, Stereo and Geometric Isomerism, Thermoplastics, Thermosets and Elastomers, Crystallinity of Polymers, Copolymers, Biological Molecules, Concept of Self Assembly in Block Copolymers and Biomolecules.

Text / Reference Books:

1. *Materials Science and Engineering an Introduction*, by W. D. Callister, Jr., publisher John Wiley & Sons Inc (2007)
2. *The Physics and Chemistry of Materials*, by J. I. Gersten and F. W. Smith, publisher John Wiley & Sons Inc (2001)
3. *Fundamentals of Ceramics,* by M. W. Barsoum, IOP Publishing Ltd (2003)
4. *The Physics of Amorphous Solids*, by Richard Zallen, publisher John Wiley & Sons Inc. (1998).
5. *An Introduction to Polymer Physics*, D. I. Bower, publisher Cambridge University Press, Cambridge (2002).
6. *Materials Science of Thin Films,* by M. Ohring, (2nd edition) publishers Academic Press (2002)
7. *Soft Condensed Matter,* R. A. L. Jones, publishers Oxford University Press(2002)

8. *Solid State Physics,* by J.S. Blakemore (2nd Edition), publishers Cambridge University Press (1995)
9. *Introduction to Solid State Physics,* Charles Kittel, 7th Edition, publisher Wiley & Sons Inc.(1996).

Plasma Physics-I **03 Cr.hr**

Relation between fluid equations and guiding center drifts, diamagnetic drift in uniform and non-uniform magnetic fields, polarization current in the fluid model and parallel pressure balance.

Single fluid magneto hydrodynamic equations, quasi-neutrality approximation, small Larmor radius approximation, approximation of infinite conductivity of plasma, conservation of magnetic flux and energy, MHD equilibrium, magnetic pressure: the concept of plasma beta, the cylindrical pinch: the cylindrical tokamak.

Diffusion in fully and partially ionized plasmas, diffusion as a random walk, the diffusion equation, steady state solutions, diffusion across a magnetic field, diffusion in fully ionized plasma, Bohm diffusion and solution of diffusion equation.

Classification of instabilities, two-streaming instability, the Rayleigh-Taylor and flute instabilities, the gravitational R-T instability, physical mechanisms of R-T instability, Flute instability due to field curvature, MHD stability of the tokamak.

Kinetic theory of plasmas, the need for a kinetic theory, the particle distribution function, the Boltzmann-Vlasov equation, the Vlasov-Maxwell equations, kinetic effects on plasma waves: Vlasov's treatment, the linearized Valsov equation for electrostatic perturbations, time asymptotic solutions, simplified derivation for electrostatic waves for Maxwellian and non-Maxwellian plasmas: Langmuir waves, ion-sound waves and Landau damping.

Text/Reference Books:

1. *Introduction to Plasma Physics*, by R. J. Goldston and P. H. Rutherford, publisher: IoP, Bristol and Philadelphia; 1st Edition, (1995).
2. *Principles of Plasma Physics*, by N. A. Krall and A. W. Trivelpiece, publisher: McGraw-Hill Book Company, New York; 1st Edition, (1973).

Group Theory 03 Cr.hr

Finite Groups: groups and representations, the regular representations, irreducible representations, transformation groups and applications, Schur's lemma, orthogonality relations, characters, eigenstates, tensor products.

Lie groups: generators, Lie algebras, Jacobi identity, the adjoint representation, simple algebras and groups, states and operators.

SU(2): eigenstates of J3, raising and lowering operators, tensor products. Tensor operators: orbital angular momentum, Wigner Eckart theorem and examples, product of tensor operators.

Isospin: charge independence, creation operator, number operators, isospin generators, symmetry of tensor products, the deuteron, superselection rules. Roots, weights and SU(3): Gellmann matrices, weights and roots of su(3), positive weights, simple roots, constructing the algebra, Dynkin diagrams and examples, the Cartan matrix, the trace of generator, fundamental representation of SU(3), constructing the states, the Weyl group, complex conjugation and example of other representation.

Tensor method: lower and upper indices, tensor components and wave functions, irreducible representation and symmetry, invariant tensor, Clebsch-Gordon decomposition, triality, matrix elements and operators, normalization, tensor operators.

Hypercharge and strangeness: the eight-fold way, the Gellmann-Okubo formula, hadron resonances, quarks.

Young tableaux and SU(n): raising and lowering indices, Clebsch-Gordan decomposition, U(1), generalization of Gell-mann matrices, SU(N) tensors, dimensions, complex representations

The Lorentz and Poincare groups and space-time symmetries: generators and the Lie algebra, irreducible representation of the proper Lorentz group, unitary irreducible representation of the Poincare group, relation between representation of the Lorentz and Poincare groups, relativistic wave functions, fields and wave equations.

Recommended Textbooks:

1. *Lie algebras in Particle Physics: From Isospin to Unified Theories,* Westview Press; 2nd Edition, 1999.
2. *Group Theory in Physics*, Wu-Ki-Tong, World Scientific, 1985.

Superconductivity 03 Cr.hr

Introductory survey: basic phenomenon; lossless currents, energy gap, Meissner effect, critical fields, currents etc.

Phenomenology of superconductivity with applications: a: London equations; magnetic field penetration into a superconductor. Penetration depth and coherence length; non-local effects. Thermodynamics of superconductors. b: Ginzburg-Landau model . Energy of NS boundary in GL theory. Type I and type II superconductors. Proximity effect, critical field of thin films and other applications of GL equations.

Microscopic theory (introductory): Formation of superconducting pairs, pairing energy and energy gap. Introduction to the basics of BCS theory. Flux quantization. Josephson effects AC and DC; SIS, SNS junctions; weak links.

Applied superconductivity: Vortices in Type II superconductors, critical fields Hcm, Hc1, Hc2 and Hc3. Structure of a vortex. Vortex pinning. Motion of vortices, flux flow. Bardeen-Stephan model.

Advanced topics:
a: High Tc superconductors and physics of 2D superconductors; 2D penetration depth and vortices in 2D superconductors.
b: BKT transition: Coulomb gas analogy and Critical behavior of the resistance above the transition and current-voltage characteristics below.
c: Fluctuation effects in superconductors.

Recommended Books:

1. *Introduction to Superconductivity*, by M. Tinkham, publishers Dover Publications (Second Edition) 1996.
2. *The Physics of Superconductors, Introduction to Fundamentals and Applications*, by V.V. Schmidt, publisher Springer Books 1982.
3. *Superconductivity of Metals and Alloys*, by P. G. De Gennes, publishers Westview Press, 1999.
4. Special Reading: G. Blatter. “Vortices in high-temperature superconductors”, Rev. Mod. Phys.66, 1125 (1994).

Particle Physics 03 Cr.hr

Relativistic quantum mechanics, Klein Gordon and Dirac equations. Pauli and Weyl representations of gamma matrices, antiparticles, Majorana representation, left and right handed particles, zitterbewung.

Continuous symmetries and the Noether theorem, space reflection, time reversal, charge conjugation, and other discrete symmetries.

Scattering matrix, relation to crosssections, crossing symmetry, dispersion relations, Cutkosky rules.

Minimal coupling to electromagnetic field, diagrammatic perturbation theory, Ruther, Moller, and Bhabha scattering.

Introduction to the gauge principle, non-abelian transformations, examples of SU(2) and SU(3) gauge theories.

The parton model, deep inelastic scattering, running of the coupling constant, beta function, limitations of the perturbative approach.

V-A Theory of weak interactions, beta decay, tests of **C** and **P-**violation, time reversal invariance, leptonic and semileptonic decays.

Spontaneous symmetry breaking, Goldstone theorem, Higgs mechanism, standard model, experimental tests of standard model of particle physics.

Neutrino oscillations, mass matrices and mixing, tests for generations beyond three.

Recommended Texts:

1. *Quarks and Leptons*, An Introductory Course in Modern Particle Physics" by F. Halzen and A.D. Martin, Publisher: Wiley; 1st edition (January 6, 1984)
2. *An Introduction to Quantum Field Theory*, by M.E. Peskin and D.V. Schroeder, Publisher: Addison Wesley Publishing Company, 1995.
3. *Collider Physics,* by V.D. Barger, R.J.N. Phillips, Publisher: Westview Press; Upd Sub edition (December 17, 1996)
4. *A Modern Introduction to Particle Physics*, Fayyazuddin and Riazuddin, Publisher: World Scientific Pub Co Inc. 2nd Edition, September 29, 2000.

Plasma Physics-II **03 Cr.hr**

Basic concepts of inertial and magnetic confinement fusion schemes, fusion reactor physics, thermonuclear fusion reaction criteria and driver requirements, scenario for ICF, fusion fuel burn physics.

The physics of hydrodynamic compression, plasma hydrodynamic, shock wave propagation in plasmas, isentropic compression, hydrodynamic stability of the implosion process, equation of state models, and ablation driven compression.

Energy transport in ICF plasmas, electron thermal conduction, thermal conduction inhibition, spontaneous magnetic field generation, suprathermal electron transport, radiation transport models.

Nonlinear mechanisms in plasmas, solitary waves and solitons, ion-acoustic solitary wave, the Korteweg-de-Vries (KdV) equation, ion-acoustic and Alfven wave solitons, Nonlinear Schrodinger equation, Nonlinear Landau damping, Bernstein-Greene-Kruskal (BGK) modes, and introduction to dusty plasmas with applications.

Recommended Textbooks:

1. *Inertial Confinement Fusion*, by J. J. Duderstadt and G. A. Moses, publisher: John Wiley & Sons, New York; 1st edition, (1982).
2. *Plasma Waves*, by D. G. Swanson, publisher: IoP, Bristol and Philadelphia; 2nd edition, (2003).
3. *Introduction to Dusty Plasma Physics*, by P. K. Shukla and A. A. Mamun, publisher: IoP, Bristol and Philadelphia; 1st edition, (2002).

General Relativity and Cosmology **03 Cr.hr**

Principles of special relativity and relativistic mechanics: the addition of velocities and Michelson-Morley experiment, Einstein's resolution and its consequences, space-time, time dilation and twin paradox, Lorentz boosts, four vectors, special relativistic kinematics and dynamics, variational principle for free particle motion, light rays, observers and observations.

The curved space time of general relativity: testing of equality of gravitational and inertial mass, equivalence principle, geodesics, metric coordinate transformations, Christoffel symbols, geodesics and coordinate transformations.

The physics and geometry of geodesics: geodesic equation from variational principle, the Newtonian limit, the gravitational red-shift, locally inertial and Riemann normal coordinates, affine and non-affine parameterization.
Tensor algebra and tensor analysis: from Einstein equivalence principle to the principle of general covariance, tensor algebra, tensor density, the covariant derivative of vector fields, extension of covariant derivative and other tensor fields, main properties of covariant derivatives, the principle of minimal coupling, covariant differentiation along a curve, parallel transport and geodesics, generalizations.

Physics in a gravitational field: particle mechanics and electrodynamics in a gravitational field, conserved quantities from covariantly conserved currents and tensors.

Lie derivatives, symmetries and Killing vectors: symmetries of a metric, the Lie derivative for scalars, vector fields, tensor fields, metric and Killing vectors.

Curvature: the Riemann curvature tensor, intrinsic geometry, parallel transport, geodesic derivative equations, Einstein equations, weak field limit, Bianchi identities, cosmological constant, Weyl tensor, Einstein-Hilbert action, the matter Lagrangian and consequence of the variational principle.

Tests of general relativity: black holes, relativistic star models, cosmological models, early stages of evolution of the universe, gravitational waves.

Recommended Textbooks:

1. *Gravity: an Introduction to Einstein's General Relativity,* J. B. Hartle (Addison-Wesley 2003).
2. *Space-Time and Geometry: An Introduction to General Relativity*, Sean Caroll (Addison-Wesley 2004).
3. *Gravitation and Cosmology*, S. Weinberg (Wiley, 1972).

Condensed Matter Theory-II **03 Cr.hr**

Interacting Bosons and superfluidity: Quantum liquids, Bose-Einstein condensation, the macroscopic wave function, superfluid properties of He II, flow quantization and vortices, quasiparticle excitations, Landau-Ginzburg theory of phase transitions, the macroscopic coherent state, spontaneous symmetry breaking, off-diagonal long range order, macroscopic quantum interference, the weakly interacting Bose gas, Bogoliubov's theory.

Conventional superconductivity: Phenomenology, electron-phonon effective interaction, Cooper pairs, pair amplitude, BCS ground state, pair fluctuations, ground state energy, critical magnetic field, energy gap, quasiparticle excitations, thermodynamics, experimental applications, Josephson tunneling.

Superfluid 3He and unconventional superconductivity: The Fermi liquid normal state of 3He, the pairing interaction in liquid 3He , superfluid phases of 3He, unconventional superconductors.

Quantum Hall effects: Introduction, Landau levels, the role of disorder, currents at the edge, Laughlin state and its quasiparticles, effective Chern-Simons theory for quantum Hall states.

Quantum phase transitions: Quantization with path integral methods, the path integral for Bosons, the path integral for Fermions, quantum rotor models, symmetry breaking transition and Mott insulator in a quantum rotor model, scaling, mean field solution.

The renormalization group: The one-dimensional Ising model, general theory of renormalization group, Berezinskii-Kosterlitz-Thouless transition.

Recommended Textbooks:

1. *Advanced Solid State Physics*, by P. Philips, publisher: Westview Press; 1st edition, (2003).
2. *Condensed Matter Field Theory*, by A. Altland and B. Simons, publisher: Cambridge University Press, 1st edition (2006).
3. *Superconductivityy, Superfluids and Condensates*, by J. F. Annett, publisher: Oxford University Press, 1st edition (2004).

Experimental Plasma Physics **03 Cr.hr**

Pinch, and plasma focus devices. Cold plasma generation, characteristics of DC glow discharge, RF discharges and cold plasma reactors.θPlasma generation: Energy storage and transfer for high temperature plasma generation and current drive techniques. Z-pinch,

Probes for plasma diagnostics: Rogowski coil, high voltage probe, magnetic probe, Langmuir probe, voltage loops and Mirnov coils.

Charged particle and neutron diagnostics: Faraday cups and solid state nuclear track detectors for detection and analysis of charged particles, Time-resolved and time-integrated neutron measurement.

Laser as a diagnostic tool Propagation of (optical frequency) electromagnetic wave through plasma both in the absence and presence of magnetic field, shadowgraphy and schlieren imaging, interferometry and determination of plasma density, measurement of magnetic field by Faraday rotation, Thomson and Rayleigh scattering.

X-ray diagnostics of plasmas: X-ray emission from plasmas, absorption filters and their selection, time-resolved x-ray detectors, pinhole imaging camera, estimate of plasma electron temperature.

Plasma Spectroscopy: Radiative processes in plasmas, Collisional processes in plasmas, statistical plasma models, plasma optical spectroscopy, and evaluation of plasma parameters.

Recommended Books:

1. *Industrial Plasma Engineering,* by J. Reece Roth, Institute of Physics Publishing Bristol (2000).
2. *Principles of Plasma Diagnostics*, by I. H. Hutchinson, Cambridge University Press New York (1999).
3. *Handbook of Radiation Effects*, by A. H. Siedle and L. Adams, Oxford University Press (2002).
4. *Principles of Plasma Processing*, F. F. Chen and J. P. Chang, Kluwer Academic/Plenum Publishers New York (2003).

5. *Principles of Plasma Spectroscopy,* by Hans R. Griem, Cambridge University Press (1997).
6. *Fundamentals of Plasma Physics*, by J. A. Bittencourt. Pergamon Press Oxford (1995).
7. *Plasma Diagnostics*, by Orlando Auciello and Daniel L. Flamm, Academic Press Boston (1989).
8. *Tokamaks*, by John Wesson, Clarendon Press Oxford (2004).

Quantum Optics-II **03 Cr.hr**

Beam Splitters and interferometers: Experiment with single photon, Quantum Mechanics of Beam splitters, Interferometry with a single photon, Interaction free measurement, Intereferometry with coherent states of light.

Nonclassical Light: Quadrature squeezing, Generation of quadrature squeezed light, Detection of quadrature squeezed light, Amplitude (or number) squeezed states, Photon antibunching, Schrodinger cat states, Two-mode squeezed vacuum states.

Atomic Coherence and Interference: Coherent trapping-dark states, Electromagnetically induced transparency, Lasing without inversion, Refractive index enhancement via quantum coherence.

Cavity Quantum Electrodynamics: Rydberg atoms, Rydberg atoms interaction with a cavity field, Experimental realization of the Jaynes-Cummings model-micromaser, Generation of number state in high-Q cavity, creating entanglement in cavity Quantum electrodynamics.

Quantum theory of damping: General reservoir theory, Atomic decay by thermal and squeezed reservoirs, Field damping.

Optical Test of Quantum Mechanics: Photon sources-spontaneous parametric down conversion, The Houng-Ou-Mandal Interferometer, The quantum eraser, Induced coherence, Superluminal tunneling of photons, Optical test of local realistic theories and Bell’s theorem.

Recommended Text/References:

1. Introductory Quantum Optics, Christopher C. Gerry and Peter L. Knight, Cambridge University Press (2005)
2. Quantum Optics, Marlan O. Scully and M. Suhail Zubairy, Cambridge University Press (1997).
3. Fundamentals of Quantum Optics and Quantum Information, Peter Lambropoulos and David Petrosyan, Springer-Verlag Berlin Heidelberg (2007)

Atomic Physics 03 Cr.hr

One-electron atoms: Energy levels and wavefunctions of hydrogen atom. Fine and Hyperfine Structure. Extension to other single valence electron atoms

Two-electron atoms. Helium atom. Independent particle model. Energy level structure, Configuration interaction, Doubly excited states and inner-shell excitations. Many electron atoms. Autoionization. Fano's description for an isolated autoionizing resonance.

Multi-channel Quantum Defect Theory. Multi-channel Quantum Defect Theory (Cooke and Cromer approach). Interaction between two closed channels, one open and one closed channels. Photoionization cross sections.

Angular Momentum. Angular Momentum Coupling Schemes (LS, LK, jK and jj), Spherical Tensor Operators. Angular Momentum Algebra (3j, 6j and 9j symbols), Wigner Eckart Theorem.

Atoms in External fields:
Hydrogen Atom in electric field (spherical and parabolic states, energy levels, field ionization). Nonhydrogenic atoms (Quantum defects and energy levels, avoided crossings and "classical' ionization. Landau Zener Effect and pulsed field ionization).

Magnetic Fields (Classical Methods of Coherent Spectroscopy: RF resonance spectroscopy, level crossing spectroscopy, Anti-crossing spectroscopy, Quantum Beats and wave packets).

Atoms in Intense radiation fields.
Multiphoton Absorption, Above threshold Ionization; High Harmonic Generation. Laser Cooling and Trapping.

Doppler Cooling; Optical molasses and traps; Sub Doppler Cooling

Recommended Textbooks:

1. *Atomic Physics* by C.J. Foot, 1st Edition (Oxford University Press) 2005.
2. *Atomic and Molecular Spectroscopy*, by S. Svanberg. 4th Ed. (Springer) 2004
3. *Spectra of Atoms and Molecules*, by P.F. Bernath, 2nd Ed. (Oxford), 2005
4. *Physics of Atoms and Molecules*, by Bransden and Joachain, (Longman), 1985
5. *Atomic Spectroscopy*, by Heckmann and Trabert (Springer), 1995
6. *Laser Spectroscopy*, by W. Demtroeder (Springer), 2004
7. *Rydberg Atoms* by T.F. Gallagher, (Cambridge Uni. Press), 1994

8. *Highly Excited Atoms*, by J.P. Connerade, (Cambridge Uni. Press), 1998

Quantum Information Theory-II 03 Cr.hr

Quantum noise and quantum operation: Classical noise and Markov processes, quantum operations, environment and quantum operations, operator sum representation, axiomatic approach to quantum operations Strokes parameterization. Examples of quantum noise and quantum operations: Bit-flip and phase flip channels, depolarizing channel, amplitude damping channel, phase damping channel.

Schumacher's noiseless channel coding theorem, Holevo bound. Distance measures for quantum information: Distance measures for classical information, Trace distance, fidelity. Quantum Measurement: Distinguishing quantum states, Generalized measurements, Projective measurements, POVM. Quantification of entanglement as a resource, entanglement of formation, concurrence, Wootter's criteria.

Reference Books:

1. Elements of Information Theory, T.M. Cover and J.A. Thomas, John and Wiley Sons (1991)
2. Quantum Computation and Quantum Information, M.A. Nielson and I.I Chuang, Cambridge University Press (2000)
3. Introduction to Quantum Information Science, Vlatko Vedral, Oxford University Press (2006)

Accelerator Techniques for Materials: (2+1) credit hours

03 Cr.hr

Theory: 2 credit hours

Introduction to Ion-Solid Interactions:
Type of ion solid interactions; Low and High energy ions; Nuclear Energy loss and electronic energy; Defects production using ion beam techniques; The applications of introduced defects on material properties.

Accelerators and Applications:
Introduction to Electrostatic Accelerators; Relevant detectors and instrumentation; Accelerators for industrial and medical applications; Ion Implantation and ion beam analysis techniques: Rutherford Backscattering Spectroscopy (RBS), Proton Induced X-Ray Emission (PIXE), Elastic Recoil Detection analysis (ERD).

Rutherford and Non-Rutherford Backscattering Spectroscopy:
Introduction, Applications, Kinematics [Kinematic factors, Rutherford scattering cross section, RBS system, mass resolution, energy resolution, depth resolution basic concepts, Energy loss, Analysis of thin and thick target

samples, measurement of film thickness, depth profiling of impurities in the deposited films and of implanted species.

Elastic Recoil Detection analysis (ERDA) and Nuclear reaction analysis (NRA):
Introduction, Kinematics, Applications, Depth profiling of light elements in heavy materials, Techniques for profiling H; Using standard for concentration measurement and methods to improve the experimental statistics.

Proton Induced X-Ray Emission (PIXE):
Proton Induced X-Ray Emission: Principle, Application, Analysis of spectrum, Quantitative Spectrum fitting, experimental setup, use of external beam, Nuclear microprobe, Analysis of single Aerosol Particle.

Experiments: 1 credit hour

Experiments will be conducted at 5-UDH tandem Accelerator Lab in Experimental Physics Labs (EPD). The proposed list of experiments for the basic understanding and learning of ion beam analysis techniques is as follows:

1. Ion implantation and sample preparation for Rutherford Backscattering Spectroscopy
2. Channels to energy calibration and measurements of deposited film thickness
3. Concentration determination of incorporated impurities and implanted species in the substrate
4. Hydrogen depth profiling
5. Particle Induced X-ray Emission
6. Gamma ray spectroscopy using NaI detector

Reference Books:

1. *Ion Beams for Materials Analysis*, by J. R. Bird and J. S. Williams Academic Press, Sydney, 1989.
2. *Characterization of Materials* Vol. I, II by Elton N. Kaufmann, Publisher John Wiley & Sons, 2003.
3. *Backscattering Spectrometry* by Wei-Kam Chu, Academic Press, New York,1978.
4. *Particle Induced X-Ray Emission Spectrometry (PIXE),* by Seven A. E. Johansson, Publisher John Wiley & Sons, 1995.
5. *Electrostatic Accelerators Fundamentals and Applications,* by Kai Siegbahn, Publisher Springer, Heidelberg, 2005.
6. *Introduction to Solid State Physics* by Charles Kittle, 7^{th} Edition, Publisher John Wiley & Sons, Singapore, New York, 2003.

APPENDIX

CALCULUS-I (Calculus for Functions of one variable)

Functions and graphs (shifting and stretching), limits and continuity, differentiation (rates of change, slope of the tangent to a curve, rules for differentiation, chain rule, implicit differentiation, extrema of functions, mean value theorem, simple problems in optimization, use of derivatives in sketching, asymptotic behavior of functions, L'H'opital's rule), integration (indefinite integrals, introduction to the idea of differential equations and their solution – the initial value problem, techniques of integration, Riemann sums and definite integrals, physical interpretation as areas, mean value theorem, areas between curves, finding volumes by slicing, volumes of solids of revolution, arc lengths, areas of surfaces of revolution, centres of mass and higher moments, work), differentiation and integration of transcendental functions (exponential and logarithmic functions and applications to growth and decay problems, trigonometric and inverse trigonometric functions, hyperbolic functions), infinite series (limits of sequences of numbers, series, tests of convergence, power series, Taylor and Maclaurin series).

CALCULUS-II (Calculus for Functions of Several Variables)

Motivation and geometric background (conic sections, parametrized curves, polar coordinates, vectors and analytic geometry in space, examples of vector fields in space relevant to physics), partial derivatives (limits and continuity, partial derivatives, chain rule, role of constraints, directional derivatives – gradient vectors and tangent planes, extrema and saddle points, Lagrange multipliers, Taylor's expansion of a multi-variable function), multiple integrals (double and triple integrals, centres of mass and higher moments, areas and volumes, integration in spherical and cylindrical coordinate systems), calculus of vector fields with emphasis on physical interpretation (line integrals and work, circulation and curl, conservative fields and gradients, surface and volume integrals, divergence of a vector field, Green's theorem in a plane, Stoke's theorem, divergence theorem).

Recommended Books:

1. G. B. Thomas, R. L. Finney, “Calculus and Analytic Geometry”, National Book Foundation, 9th ed.
2. G. Strang, “Calculus”, Wellesley-Cambridge, 2nd ed., 2010.
3. E. W. Swokowski, M. Olinick, D. Pence, and J. A. Cole, “Calculus”; Pws Pub Co; 6th ed. 1994.

DIFFERENTIAL EQUATIONS

Introduction to ODEs (physical motivation), First order ODEs (separable variables, homogeneous equations, exact equations, linear equations, Bernoulli equation and other examples), applications of first order ODEs linear and non-linear, linear differential equations of higher order (initial value and boundary value problems, linear dependence and independence, solutions of linear equations, constructing a second solution from a known solution, homogeneous linear equations with constant coefficients, undetermined coefficients, variation of parameters), applications of second order ODEs (simple harmonic motion, damped and forced oscillators, electrical circuits and springs), differential equations with variable coefficients (Cauchy-Euler equation, power series solution of differential equations – solutions about ordinary and singular points-Legendre's and Bessel's equations as examples), Laplace transform (Laplace transform and its inverse and properties, use in solving differential equations, Dirac delta function).

Recommended Books:

1. D. G. Zill and M. R. Cullen, "Differential Equations with Boundary Value Problems", 3rd ed. National Book Foundation.
2. E. Kreyszig, "Advanced Engineering Mathematics", John Wiley, 8th ed. 1999.
3. K. F. Riley, M. P. Hobson and S. J. Bence, "Mathematical Methods for Physicists", Cambridge University Press 2006.

LINEAR ALGEBRA

Review of vectors in 3 dimensions[(arrows) with a view of abstraction into properties of vector spaces in N dimensions (closure, associativity and commutativity of addition, existence of identity and inverse, distributivity of scalar multiplication), idea of vector norm in 3 dimensions, orthogonality, expansion in a basis, multiplication of vectors in 3 dimensions, applications of vector algebra to geometry and physics], vector spaces in N dimensions (definition, basis, inner product), linear operators, matrices (matrix algebra, functions of matrices, transpose, complex and Hermitian conjugates, trace, determinant, inverse, rank, special types of matrices diagonal, triangular, symmetric and antisymmetric, orthogonal, Hermitian and anti-Hermitian, unitary, normal, eigenvalue problem, similarity transformations and change of basis, diagonalisation, simultaneous linear equations), normal modes (oscillatory systems, elementary use of symmetries to guess normal modes, Rayleigh-Ritz method), Fourier series as an application of the ideas of linear algebra to the space of periodic functions (identification of the space of periodic functions of a certain period as a linear vector space, identification of sinusoidal functions as basis vectors in this infinite dimensional vector space, properties of Fourier series, Parseval's theorem, handling of non-Periodic functions via extending the domain of definition of function), sets of functions, eigenvalue problem in the context of differential operators, adjoint and Hermitian operators, properties of Hermitian operators (reality of eigenvalues, orthogonality of eigenfunctions, completeness of eigenfunctions - eigenbasis), Sturm-Lioville equations (Hermitian nature of Sturm-Lioville operator, transforming an equation into Sturm-Lioville form, Fourier-Legendre and Fourier-Bessel series).

Recommended Books:

1. K. F. Riley, M. P. Hobson and S. J. Bence, “Mathematical Methods for Physicists”, Cambridge University Press 2006.
2. Peter V. O'Neil, “Advanced Engineering Mathematics”, 7th ed. CL Engineering, 2011.