UNIVERSITY OF THE PUNJAB

NOTIFICATION

It is hereby notified that the Syndicate at its meeting held on 15-11-2021 has approved the recommendations of the Committee constituted by the Academic Council at its meeting dated 04-01-2021 regarding approval of the revised Curriculum/Syllabi & Courses of Reading for BS Computational Physics at the Centre for High Energy Physics w.e.f. the Academic Session, 2021-2025 and onwards.

The Curriculum/Syllabi & Courses of Reading for BS Computational Physics is enclosed herewith, vide Annexure-'A'

Sd/-

Muhammad Rauf Nawaz
Registrar

Admin. Block,
Quaid-i-Azam Campus,
Lahore.
No. D/ 69 /Acad.

Dated: 06-01-/2022.

Copy of the above is forwarded to the following for information and further necessary action: -

1. Dean, Faculty of Sciences.
2. Director, Centre for High Energy Physics.
3. Controller of Examinations
4. The Director, Quality Enhancement Cell
5. Deputy Registrar (Affiliation)
6. Admin. Officer (Statutes)
7. Secretary to the Vice-Chancellor.
8. Secretary to the Pro-Vice Chancellor
9. P.S. to the Registrar
10. Assistant Syllabus.

Assistant Registrar (Academic)
for Registrar

Curriculum BS Computational Physics

Centre for High Energy Physics
University of the Punjab
Lahore, PAKISTAN

(Revised BS Computational Physics Curriculum 2019)

Table of Contents

Curriculum BS Computational Physics

Introduction

Research in Theoretical High Energy Physics at the Punjab University Physics Department was initiated in 1968. Starting with hardly any facility, a nucleus was generated in the next decade.

In view of the outstanding contributions of the High Energy Group, the Centre for High Energy Physics (CHEP) was established in November 1982. CHEP was thus entrusted with the objective of carrying out teaching and research in this field leading to M. Phil. and Ph.D. degrees.

High Energy Physics

Fundamental Physics gives us an insight into the nature of matter. This serves as the foundation on which stands the entire structure of technology. Research in fundamental physics always introduces new dimensions, which pave the way for further technological advances.
High Energy Physics is one of the most fascinating branches of fundamental physics. It is concerned with unraveling the ultimate constituents of matter and with the elucidation of forces between them. The experimental research in High Energy Physics is exceeding expensive and involves millions and billions of dollars.
High Energy physicists trained at the Centre will make their contribution to the various research organizations of Pakistan and to the various educational institutions where they will impart education in a much more effective way as High Energy Physics is the most fundamental area in Physics. If teachers conduct research in theoretical High Energy Physics, their capacity of grasping and understanding all other areas of physics will certainly enhance. Consequently the teachers who are trained in CHEP and will be scattered in various universities and colleges of Pakistan will be able to communicate more effectively the basic concepts of physics to their students. This will boost up the level of Physics, and therefore the technological potential of our country.

RESEARCH AREAS

- Hadronic Physics.
- Perturbative and non-perturbative QCD.
- Quark-Gluon plasma.
- Neutrino Physics.
- Lattice Gauge Theory.
- Meson-Meson Physics.
- Experimental High Energy Physics (Data Analysis).
- Parallel Processing and High Performance Computation.
- Medical Physics (Modeling and Simulation).
- Computational Analysis of Physical Properties of Solids.

Academic Programs in High Energy Physics

The Centre offers following programs in the field of High Energy Physics

1. **M.Phil. High Energy Physics**

Duration	2 years
Teaching system	Semester system
Admission Criteria	M.Sc. Physics, Applied Mathematics and Space Science

2. **Ph.D. High Energy Physics**

Duration	3 to 5 years
Admission Criteria	M.Sc./M.Phil. in Physics, Applied Mathematics and Space Science
Merit Criteria	(consult office for details)

Computational Physics

Computational physics deals with the tools used to solve the complex problems of physics on computer systems. The problems which computational physics addresses are either impossible to solve by alternative means or vary laborious. A computational physicist not only understands the problem-solving tools but also the relevant physics, mathematics and the working of computers. Computational physics is not just another discipline in physics; rather it has recently emerged as an approach to physics significantly as much important as the traditional approaches of theoretical and experimental physics.

Careers in Computational Physics

The rapid increase in the power and use of computers has been the driving force in recent developments in science and technology. Yet there are a few graduates which have strong enough backgrounds in computational physics to play an effective role in doing science particularly physics using computers. Graduates in computer science understand the working of computers but do not have enough background of physics and mathematics that is required for technical fields. On the other hand the graduates in physics or applied mathematics do not have any exposure to technical use of computers for doing physics. However, the graduates in computational physics possess competent education in physics, mathematics, computer science and valuable skills of solving complex problems by computers.

With a graduate degree in Computational Physics, you could opt a career in:

- Scientific computing, in the energy and aerospace sectors
- Research in academic institutions
- Research in national laboratories
- Teaching.

With a degree in computational physics, you can also opt the careers in many related fields where computation plays key roles; oceanography, material science, computer science, applied mathematics, geophysics, medicine, telecommunication, or finance.

Objectives of the Programs in Computational Physics

Our objective is to have the students understanding how to perform scientific computations with high-performance computers. When successful, the mathematical and physical ideas become alive before the students' eyes, and the students understand physical systems at a level usually attained only in a research environment.

With the program student will:

1. Acquire a strong physics background through computer simulations.
2. Learn the necessary applied mathematics
3. Learn computer hardware and programming languages.
4. Learn to use scientific problem solving environments.
5. Learn to use various visualization techniques.
6. Learn the use to networked computer systems, shared resources and variety of operating systems.
7. Gain experience of developing computer simulations of physical systems.
8. Gain experience of computation with parallel supercomputer.

Academic Programs in Computational Physics

The Centre offers following academic programs in computational physics

1. **BS (4-years) in Computational Physics**

Duration	4 years
Teaching system	Semester system
Admission Criteria	F.Sc., ICS, A-Level (physics & mathematics) or equivalent

Vision of Centre for High Energy Physics:

The vision of the CHEP is to be a research institution of local and nationwide renown, whose contribution in the areas of Physics education and research are widely recognized. We see teaching and research environment as a place of discovery, critical thinking, and collaboration.

Mission of Centre for High Energy Physics:

CHEP is committed to producing competitive physicists abreast of state-of-the-art in computer technology who can serve as the technically qualified workforce needed by the industry, academia, and other government non-government organizations.

List of Faculty Members

Sr. No.	Name	Designation	Area of Specialization/ Research Interests
1.	Dr. Bilal Masud	Director & Professor	High Energy Physics: Meson-Meson Physics, Lattice-Gauge Theory, Bosonic string theory, Quark-Gluon Plasma, Philosophy of Science
2.	Dr. Maqsood Ahmad	Professor	High Energy Physics: Parallel Programming and High Performance Computation Simulation, Graphical Programming and Data Acquisition
3.	Dr. Rashid Ahmed	Professor	High Energy Physics, Computational Analysis of Properties of Condense Matter
4.	Dr. Qadeer Afzal Malik	Associate Professor	Experimental High Energy Physics, Hadronic Physics, Computational Physics
5.	Dr. Faisal Akram	Associate Professor	High Energy Physics: Particle Physics Phenomenology, Quantum chromodynamics, Schwinger-Dyson equations, Heavy ion collision Physics, Neutrino Physics
6.	Dr. Talab Hussain	Assistant Professor	Experimental High Energy Physics
7.	Dr. Irfan Mahmood	Assistant Professor	Theoretical Physics
9.	Dr. Teeba Rashid	Assistant Professor	Experimental High Energy Physics, Structure of Hadrons
10.	Dr. Sohail Afzal Tahir	Assistant Professor	High Energy Physics, Hadronic Physics, Internetworking, and data communication
11.	Dr. Abdul Aziz Bhatti	Assistant Professor	High Energy Physics
12.	Dr. Bushra Kanwal	Assistant Professor (On Adhoc)	Experimental High Energy Physics
13.	Dr. Muhammad Atif Sultan	Assistant Professor (On Adhoc)	High Energy Physics
14.	Muhammad Anjum Javed	Lecturer	High Energy Physics
15.	Dr. Bushra Shafaq	Lecturer	High Energy Physics: Neutrino Physics.
16.	Mr. Tariq Mahmood	Lecturer	Computer Science
17.	Mr. Amjad Afzaal	Lecturer	Computer Science

Teacher Student Ratio

17 Teachers for 206 students Ratio is 12.11

Examination System

1. There shall be two semesters (Fall & Spring) in an academic year.
2. Each semester shall be of 18 working weeks – sixteen weeks for teaching, two weeks for examinations.
3. During the summer break, university may offer summer session of 6-8 weeks with subject of its choice which will provide opportunity to students who have failed or have withdrawn from a course and those who wish to improve their GPA to qualify to the next semester. A maximum of 09 credit hours courses will be offered during summer semester by each Department / Centre / Institute/ College.
4. The contact hours during the summer session will be doubled to ensure that the course is fully covered in a summer session with half of the duration compared to a regular (Fall or Spring) semester.

Detail of Courses

1. SCHEME OF COURSES OF BS COMPUTATIONAL PHYSICS

Semester 1:

Courses	**Cr. Hr.**
PHYS 1101: Mechanics	3
PHYS 1102: Physics Lab I	1
MATH 1101: Differential Calculus	4
COMP 1101: Introduction to Computer Science	2
HUM 1101: Islamic Studies/Ethics	2
HUM 1102: English Comprehension	2
HUM 1103: Language course	2
(Any one out of Arabic, Chinese German, French; choice is subjected to availability of a teacher.)	
Total	**16**

Semester 2:

Courses	**Cr. Hr.**
PHYS 1201: Waves and Oscillations	3
PHYS 1202: Thermal Physics & Bulk properties of matter	3
PHYS 1203: Physics Lab II	1
MATH 1201: Analytical Geometry and Integral Calculus	4
MATH 1202: Linear Algebra	4
HUM 1202: Communication Skills	2
Total	**17**

Semester 3:

Courses	**Cr. Hr.**
PHYS 2301: Electricity and Magnetism	3
PHYS 2302: Physics Lab III	1
STAT 2301: Statistics and Probability	3
MATH 2301: Vector Algebra and Analysis	3
MATH 2302: Applied Differential Equations	4
CHEM 2301: Chemistry	3
Total	**17**

Semester 4:

Courses	**Cr. Hr.**
PHYS 2401: Modern Physics	3
PHYS 2402: Physics Lab IV	1
PHYS 2403: Electronics	3
PHYS 2404: Electronics Lab	1
COMP 2401: Computer Programming (2+1)	3
MATH 2401: Discrete Mathematics	2
BIO 2401: Introductory Biology	2
HUM 2401: Pakistan Studies	2
Total	**17**

Semester 5:

Courses	**Cr. Hr.**
PHYS 3501: Classical Mechanics	4
PHYS 3502: Physics Lab V	2
PHYS 3503: Digital Electronics	3
COMP 3501: Advanced Computer Programming	3
COMP 3502: Numerical Linear Algebra	3
MATH 3501: Mathematical Methods I	3
Total	**18**

Semester 6:

Courses	**Cr. Hr.**
PHYS 3601: Electromagnetic Theory	4
PHYS 3602: Quantum Mechanics I	3
PHYS 3603: Physics Lab VI	2
COMP 3601: Scientific Computation	3
COMP 3602: Numerical Analysis	3
MATH 3601: Mathematical Methods II	3
Total	**18**

Semester 7:

Courses	**Cr. Hr.**
PHYS 4701: Quantum Mechanics II	3
PHYS 4702: Statistical Physics	3
PHYS 4703: Relativity	2
COMP 4701: Computational Physics Simulations	3
COMP 4702: Computational Physics Simulations Lab	2
PHYS 47XX: Thesis/Optional course 1	3
Total	**16**

Semester 8:

Courses	**Cr. Hr.**
PHYS 4801: Solid State Physics	4
PHYS 4802: Nuclear Physics	4
COMP 4801: Quantum Physics Simulations	3
COMP 4802: Quantum Physics Simulations Lab	2
HUM 4801: Philosophy of Science	2
PHYS 480X: Thesis/Optional course 2	3
Total	**18**

Total Credits:	**137**

2. LIST OF ELECTIVE COURSES

There are 2 groups of elective courses. A student can select any one of the groups.

Group 1:

PHYS 4704: Particle Physics I	Cr. Hrs. 3
PHYS 4803: Particle Physics II	Cr. Hrs. 3

Group 2:

PHYS 4705: Detector Physics	Cr. Hrs. 3
PHYS 4804: Accelerator Physics	Cr. Hrs. 3

3. MATH COURSES OF BS COMPUTATIONAL PHYSICS

MATH 1101: Differential Calculus
Cr. 4: Prerequisite: F.Sc./A-Level Math

Course Objectives

The course introduces the subject of differential calculus at undergraduate level. After the completion of the course students will be able to:

1. Understanding the concepts of functions, limit and differentiation.
2. Study the application of differentiation.
3. Be able to solve relevant numerical problems.
4. Be able to use calculus in physics and advance courses in mathematics.

Main Theme / Topics

Preliminaries: Real Number and Real line; Properties of Real Numbers; Absolute value and inequalities; Solution of equation containing inequalities. Functions: Function; Bounded sets and functions; Graphs of functions; Shifting Graph; Trigonometric functions. Limit and Continuity: Limits; Rules for finding limits; Target value and formal definition of limit; Continuity; Properties of continues functions. Derivatives: Derivation of a function; Rules of differentiations; Derivatives of algebraic and transcendental functions; Implicit Differentiation and Rational exponent; Higher Derivatives; Leibniz theorem; Rolle's theorem; Mean Values theorems. Applications of Derivatives: Increasing and Decreasing Functions; Maxima and Minima; Test of Local extreme values; Concavity; Graphing in Cartesian and Polar coordinates; Arc length Intrinsic and Pedal equations; Curvature; Evolute; Envelope; Optimization; Linearization and differentials; Newton's Method. Multivariable function and partial derivations: Functions of Several variables; Limits and Continuity; Partial Derivatives; Differentiability; Linearizations; Chain rules; Implicit functions; Directional derivatives; Partial derivatives with constrained variables.

Books to be followed:

1. Calculus, H. Anton, I. Bevens, S. Davis (9th Edition), *Laurie Rosatone* (2009)
2. Calculus with Analytic Geometry, E. W. Swokowski, *PWS Publishers*, *Boston* (1988).
3. Calculus and Analytic Geometry (9th Edition), G.B. Thomas and R.L. Finney, *Addison-Wesley Publishing Company* (1995).
4. Calculus and Analytics Geometry, C. H. Edward and E. D Penney, *Prentice Hall* (1988).

MATH 1201: Analytical Geometry and Integral Calculus
Cr. 4: Prerequisite: MATH 1101

Course Objectives

The course introduces the subject of analytical geometry and integral calculus at undergraduate level. After the completion of the course students will be able to:

1. Introduce plane analytical geometry and analytical geometry in 3D.
2. To study the concept of integration, relevant theorems, and techniques of evaluating integrals.
3. Study definite integrals and its applications.
4. Study multiple integrals and its applications.

Main Theme / Topics

Plane Analytical Geometry: Translation and rotation of rectangular axes; General equations of second degree; Polar coordinates; Polar equations of conics; Properties of parabola, ellipse and hyperbola; Tangents and normals; Parametric representations of Curves. Analytic Geometry of 3D: Rectangular coordinate system in space; Direction angles; Direction numbers; Equations of lines and planes in scalar and vector form; Skew lines; Shortest distance b/w skew lines; Cylindrical and spherical coordinates; Surfaces; Equation of sphere, cylinder, cone, ellipsoid paraboloid and hyperboloid; Tangent planes and normal of surfaces. Integration: Antiderivative and indefinite integral; The definite integral as limit of a sum; Fundamental theorem of integral calculus; integration of various mathematical functions. Techniques of Evaluating Integrals: Basic Integration Formulas; Integration by Parts; Trigonometric substitution; Substitution in definite integral. Application of Integration: Area under the curve; Area between the curves; Finding volumes by slicing; Volumes of solids of Revolution; Length of plane curves; Area of surface of Revolution. Multiple Integral: Double and Triple Integrals; Area and Volume; Moment of Inertial; Centre of Mass. Infinite Sequences and series: Sequences; Limits of sequences of Number; Theorems for calculating the limits of sequences; Series; Infinite series; Convergence of infinite series; Integral test; Comparison test; Ratio and Root tests; Alternative series; Absolute Convergence; Conditional Convergence. Power Series; Taylor's Series; Maclaurin Series; Convergence of Taylor series; Error Estimate.

Books to be followed:

1. Calculus, H. Anton, I. Bevens, S. Davis (9th Edition), *Laurie Rosatone* (2009)
2. Calculus with Analytic Geometry, E. W. Swokowski, *PWS Publishers*, *Boston* (1988).
3. Calculus and Analytic Geometry (9th Edition), G.B. Thomas and R.L. Finney, *Addison-Wesley Publishing Company* (1995).
4. Calculus and Analytics Geometry, C. H. Edward and E. D Penney, *Prentice Hall* (1988).

MATH 1202: Linear Algebra
Cr. 4: Prerequisite: F.Sc./A-Level Math

Course Objectives

The course introduces the subject of linear algebra at undergraduate level. After the completion of the course students will be able to:

1. Learn the concept of vector spaces and related theorem.
2. Studying representation theory, theory of matrices and determinants.
3. Studying groups, related theorems and representations of groups.

Main Theme / Topics

Linear Vector Spaces: Definition and examples of LVS; Linear independence; Basis Vector; Subspace; Linear functional on a LVS; Dual spaces. Inner Product LVS: Definition of inner product spaces; examples; Orthogonality; The Gram-Schmidt process; The Schwarz inequality; Length of a vector. Linear Operator: Definition and examples Linear transformation; Related Theorems; Operator algebra; polynomial of operators; Functions of operators; Commutations; Operator valued function and derivative of operators; Conjugation of operators; Hermitian and unitary operators; Projection operators. Representation Theory and Matrices: Representation of linear operators by matrices; Related theorems for the translation of operator algebra into Matrix algebra; Operations on Matrices; Change of bases and similarity transformations (Definition of Matrix; Algebra of matrices; some types of matrices; Determinate of a square matrix; Evaluation of determinates; Equivalence; Adjoint and inverse of a matrix). Determinants and Traces: Determinant of a Matrix; Related Theorem; Inverse of a Matrix; Related Theorems; Elementary operations; Row-echelon form; Determinants of Products of Matrices; The Trace; Related Theorems; Direct sums and invariant subspaces; Solution of linear algebraic (homogeneous and non-homogeneous) systems of equations by the use of matrices. Spectral Decomposition and Diagonalizations: Eigenvalues and Eigenvectors; Related Theorems; Eigen values of Hermitian Operators; Related Theorems. Group Theory: Group; Subgroup; Cyclic group; Permutations; Group of permutations; homomorphism and isomorphism.

Books to be followed

1. Elementary Linear Algebra (11^{th} edition), Howard Anton, *John Wiley & Sons* (2013).
2. Foundations of Mathematical Physics, Sadri Hassani, *Prentice-Hall International* (1991).
3. Linear Algebra, G. Hadley, *Addison-Wesley* (1987).
4. Elements of Modern Algebra (8^{th} edition), L. Gilbert and G. Gilbert, *Cengage Learning* (2014).

STAT 2301: Statistics and Probability
Cr. 3: Prerequisite: F.Sc./A-Level Math

Course Objectives

The course introduces the subject of statistics and probability at undergraduate level. After the completion of the course students will be able to:

1. Learn the concept of descriptive statistics.
2. Studying the theory of probability. Its fundamental concepts and probability distributions.
3. Learning the concepts of statistical inference.
4. Learning the theory of error.

Main Theme / Topic

Descriptive Statistics: Tabular representation of samples; Frequency; Graphical representation of samples; Mean and variance of a sample. Probability Theory: Fundament Concepts; Random experiments, Sample space, Events, Union and intersection of Events, Mutually exclusive events, Classical concept of Probability, Concept of Probability in statistics, Conditional probability, Independent events, Permutations and Combinations, Probability Distributions; Random variables, Discrete distribution, Continuous distributions, Mean and Variance of a distribution, Binomial, Poisson and Gaussian distributions, Probability distributions of several random variables. Statistical Inference: Introduction to Confidence Intervals, Testing of Hypothesis and Goodness of Fit; Correlation analysis. Theory of Error: Types of errors; Causes of errors, Correlated and un-correlated errors, Propagation of errors.

Books to be followed:

1. Statistics (A guide to use statistical methods in the physical sciences), R. J. Barlow, *John Wiley & Sons* (1989).
2. A practical guide to data analysis for physical science students, Louis Lyons, *Cambridge University Press* (1993).
3. Introductory mathematical statistics, Erwin Kreyszig, *John Wiley & Sons* (1970).
4. Modern Mathematical Statistics, Edward J. Dudewicz, *John Wiley & Sons* (1988).

MATH 2301: Vector Algebra and Analysis
Cr. 3: Prerequisite: MATH 1101, MATH 1201

Course Objectives

The course introduces the subject of Vector Algebra and Analysis at undergraduate level. After the completion of the course students will be able to:

1. Learn the basic concepts of vector algebra and its application.
2. Studying vector differentiation and integration.
3. Studying vector differential operator (Gradient, Divergence and Curl).
4. Studying integral theorem.
5. Introducing curvilinear coordinates and Cartesian tensor.

Main Theme / Topic

Vector Algebra: Vectors in the Plane; Cartesian coordinates; Vectors in space; Dot and Cross Product; Lines and Planes in Space; Cylinder and Quadric Surfaces; Cylindrical and spherical coordinates. Vector functions and Motion in Space: Vector valued function and Space curves; Modeling projectiles motion; Arc length and the unit tangent vector; curvature; torsion. Vector Differentiations: Ordinary Derivatives of Vectors; Space curves; Continuity and differentiability; Differentiation formulas; Partial Derivatives of Vectors; Differentials of vectors. Gradient, Divergence and Curl: The vector differential operator del. Gradient. Divergence. Curl. Physical interpretation of these operators. Vector Integrations: Ordinary integral of vectors. Line integral. Surface integral; Volume integrals. Divergence and Stokes' theorem: The divergence theorem of Gauss; Stokes' theorem; Green's theorem in the plane. Curvilinear Coordinates: Transformation of coordinates; Orthogonal curvilinear coordinates; unit vectors in curvilinear systems; Arc length and volume element; Gradient, Divergence and Curl in Cylindrical and Spherical coordinates.

Books to be followed:

1. Calculus and Analytic Geometry (9^{th} edition), G.B. Thomas and R.L. Finney, *Addison-Wesley Publishing Company* (1996).
2. Vector Analysis Schaum's outlines (2^{nd} Edition), Murray R. Spiegel, *McGraw-Hill International* (2009).
3. Calculus (5^{th} edition), Howard Antony, *John Wiley and Sons* (1995).
4. Foundations of Mathematical Physics by Sadri Hassani, *Prentice-Hall International* (1991).
5. Vector Analysis, G. D. Smith, *Oxford University Press* (1962).

MATH 2302: Applied Differential Equations
Cr. 4: Prerequisite: MATH 1101, MATH 1201

Course Objectives

The course introduces the subject of Differential equations at undergraduate level. After the completion of the course students will be able to:

1. Learning the classification of differential equations.
2. Techniques of solving various differential equations.
3. Getting familiarize with different differential equations used in physics.

Main Theme / Topic

Classification of Differential equations: Ordinary and partial differential equations (DE); Classification of ordinary differential equations; Linear and Nonlinear differential equation; Initial value and Boundary value problem; Formation of a differential equations. ODE's of First Order and First Degree: General first order ordinary differential equation (FODE); Normal form of FODE; Integrating factor & exact FODE; General first order ordinary linear differential equation (FOLDE) (homogeneous and inhomogeneous) Application of FOLDE (Simple Electric Network, Linear Rate Equations, Fluid Flow, Radioactive Decay, Population Growth, Compound Interest, Newton's law of cooling); non-linear FODE; (1) Separable FODE (2) Homogeneous FODE (3) Exact FODE (4) Bernoulli's FODE (5) Lagrange FODE. Ordinary differential equations (ODE's) of first order (FO) and higher degree (HD): DE's of FO and HD; Methods of solution; (1) Equation solvable for *y*` (2) Equation solvable for *x* (3) Equation solvable for *y* (4) Clairaut's equations. Orthogonal Trajectories: Family of curves and trajectories; Orthogonal trajectories in Cartesian form; Orthogonal trajectories in polar form. SOLDE: General properties of second order ordinary linear differential equation (SOLDE); Linearity; Superposition & uniqueness & related theorems; The Wronskian; inhomogeneous SOLDE, Exact homogeneous SOLDE; The Riccati. Higher order ordinary linear DE with constant coefficients: Homogeneous nth-order ordinary linear differential equation (NOLDE); Inhomogeneous NOLDE and transfer function; Application to Undamped and damped motion; Electric circuit; Spring-Mass system (Forced and damped). Cauchy-Euler Differential Equation: Cauchy-Euler Differential Equation. Simultaneous DE's in two variables with constant coefficients: Linear system of equations; Euler's method for homogeneous linear system; Linear independence of solutions. SODE's with variable Coefficients: With a part of the complementary function in know; Variation of parameters; Changing the independent variable; changing the dependent variable; Exact differential equations. Power Series Solutions: Power series solutions of first and second order DE's; recursion formula. Laplace transform: Laplace transform for simple functions; inverse Laplace transform; Application of Laplace transformation to ODEs.

Books to be followed:

1. Differential Equations, A system Approach by Jack Goldberg, *Prentice-Hall International* (1998).
2. Differential Equations with Applications and Programs, S. B. Rao, *Universities Press, India* (1996).
3. Foundations of Mathematical Physics by Sadri Hassani, *Prentice-Hall International* (1991).

4. Elementary Differential Equation and Boundary Value Problems, C.H. Edward, *Prentice-Hall International* (1996).

MATH 2401: Discrete Mathematics
Cr. 2: Prerequisite: F.Sc./A-Level Math

Course Objectives

The course introduces the subject of Discrete Mathematics at undergraduate level. After the completion of the course students will be able to:

1. Introduce the concepts of Calculus of proposition, set theory and functions
2. Study the methods of mathematical reasoning
3. Learn the concepts of relations and their properties
4. Learn the concepts of Graphs and Trees

Main Theme / Topic

The Foundations: Calculus of Propositions; Simple and compound propositions; Connectives (AND, OR, XOR); truth tables; Tautologies and contradictions; Logical Equivalence; Propositional Functions and Quantification, The pigeon-hole Principle. Sequences and Summations: Sequences from set of non-negative integers to set of integers; Summations; Summation indices. Mathematical Reasoning: Methods of proof; Mathematical induction; Recursive definitions and recursive algorithms. Counting: The basics of counting; The pigeonhole principle; Permutations and Combinations. Relations: Relations and their properties; Representing Relations; Equivalence relations; Partial ordering. Graphs: Introduction to graphs; Graphs terminology and Graphs isomorphism; Connectivity; Euler's and Hamilton's path; Shortest Path Problems. Trees: Introduction to Trees, Tree reversal, spanning trees and Minimum spanning trees. Applications of Trees.

Books to be followed:

1. Discrete Mathematics and its Applications (4th Edition), Kenneth H. Rosern, *William C Brown Pub.* (1998).
2. Discrete Mathematics, K.A. Ross & C.R.B. Wright, *Prentice-Hall* (2003).
3. Discrete Mathematical Structures with Application to Computer Science, J.P. Trembley & *R*. Manoher, *McGraw-Hill* (1988).
4. Discrete Mathematics, Gary Chartrand and Ping Zhang, *Waveland Pr Inc* (2011).

MATH 3501: Mathematical Methods I
Cr. 3: Prerequisites MATH 1101, MATH 1201, MATH 1202, MATH 2301

Course Objectives

The course introduces the subject of Mathematical Methods at graduate level. After the completion of the course students will be able to:

1. Learning vector analysis in curvilinear coordinate systems and tensor analysis.
2. Studying finite and infinite dimensional vector spaces.
3. Studying Fourier series and transforms.
4. Studying the theory of complex variable and analysis.

Main Theme / Topic

Tensors Analysis: Tensors, Coordinate transformation, Cartesian tensors, Tensor algebra, Covariant and Contravariant tensors, Metric tensor, Christoffel symbols, Equation of geodesic, Riemann tensor. Infinite Dimensional Vector Spaces: Convergence issue, Hilbert space, space of square-integrable functions, Generalized functions, Dirac delta function (1D and 3D) and its properties.
Fourier Series and Transforms: Fourier series and its complex form, Applications of Fourier series, Fourier transforms, Fourier integral theorem, Applications of Fourier transforms. Laplace transform. Complex Variables: Complex functions; Analytic functions; Properties of analytic functions; Derivative of analytic functions, Cauchy-Riemann equations, Laplace equation, Line integral in the complex plane, Cauchy's integral theorem, Cauchy's integral formula, Taylor and Laurent series, Residues, The residues theorem and its applications, Poles on the real axis, branch points and integrals of multivalued functions.

Books to be followed:

1. Foundations of Mathematical Physics, S. Hassani, *Allyn and Bacon* (1999).
2. Mathematical Methods for Physics (4th edition), G. Arfken, *Academic Press, NY* (1995).
3. Vector Analysis (3rd edition), K. L. Mir, *Ilmi Kitab Khana, Lahore* (2001).
4. Advanced Engineering Mathematics (8th Edition), E. Keyszig, *J. Wiley* (2001).
5. Mathematical Physics, E. Butkov, *Addison-Wesley* (1973).

MATH 3601: Mathematical Method II
Cr. 3: Prerequisite MATH 3501

Course Objectives

The course introduces the subject of Mathematical Methods at graduate level. After the completion of the course students will be able to:

1. Studying the partial differential equations of physics
2. Studying complex differential equations
3. Studying special functions.
4. Studying the Sturm-Liouville systems and the theory of green functions

Main Theme / Topic

Partial Differential Equations in Physics: Common partial differential equations in Physics; Variable separation in Cartesian, Cylindrical, and spherical coordinates. Power Series Method: Power series solution of standard SOLDE (Bessel, Legendre, Hermit, Laguerre, Chebyshev, Hypergeometric DE's); Convergence of solutions; Special cases of polynomial solutions. Special functions: Bessel function; Modified Bessel function; Spherical Bessel functions; Legendre function; Associate Legendre function. Study of the various Properties of these special functions including Generating functions, Recurrence relations, Orthonormalization, Asymptotic forms, and related properties. Hermit functions; Laguerre functions, Chebyshev Polynomials, Hypergeometric functions, Gamma and beta functions. The Sturm-Liouville Systems: Self-adjoint ODEs; Hermitian Operators; Properties of Hermitian operators; Sturm Liouville DE's and systems; Applications of properties of Sturm Liouville Systems. Green Functions: Green's functions in one dimension; Green's functions for second-order linear differential operators; Properties of Green's functions; Eigen function expansion of Green's functions; Green functions in 3 dimensions.

Books to be followed:

1. Foundations of Mathematical Physics, Sadri Hassani, *Allyn and Bacon* (1999).
2. Mathematical Methods for Physics (4th edition), G. Arfken, *Academic Press, NY* (1995).
3. Advanced Engineering Mathematics (8th Edition), E. Keyszig, *J. Wiley* (2001)
4. An Introductory Course in Differential Equations, K.L. Mir, *Ilmi Kitab Khana* (1999).
5. Mathematical Physics, E. Butkov, *Addison-Wesley* (1973).

4. PHYSICS COURSES OF BS COMPUTATIONAL PHYSICS

PHYS 1101: Mechanics
Cr. 3: Prerequisite: F.Sc/A-Level Physics

Course Objectives

1. Understanding basic principles of mechanics and its applications.
2. Be able to solve relevant numerical problems.
3. Be able to use calculus in studying the mechanics systems.

Main Theme / Topic

Preliminary: Position, velocity and acceleration vectors, motion with constant acceleration in 1 and 3 dimensions, force, Newton's laws of motion, weight, projection motion, uniform circular motion. Applications of Newton's laws of motion. Tension and normal forces, frictional forces, the dynamics of uniform circular motion, Non-inertial frame & pseudo forces; Limitation of Newton's laws. Momentum: Linear momentum, Impulse and momentum, conservation of momentum, two body collision, elastic and inelastic collisions. Work Done by a Constant Force and Variable forces; Kinetic Energy and the Work-Energy Theorem; Power. System of Particles: System of many particles, Centre of mass of solid objects; Linear momentum of system of particles and its conservation; System of variable mass and rocket motion. Rotational Kinematics: Rotational motion & its variables; Relation b/w linear angular variables. Rotational Dynamics: Torque, rotational inertia and Newton's 2nd law of motion, rotational inertia of solid objects, torque due to gravity, equilibrium and nonequilibrium applications of Newton's law for rotational motion, combined rotational and translational motion. Angular momentum and its conservation: Angular momentum of a particle and a system of particles, angular momentum and angular velocity, conservation of angular momentum and its applications. The spinning top. Work and kinetic energy: Work, work done by variable force, work kinetic energy theorem, work and kinetic energy in rotational motion, kinetic energy in collisions. Potential energy Conservative forces, potential energy, conservation of mechanical energy. Conservation of energy: Work done on a system by external forces, internal energy in a system of particles, frictional work, conservation of energy in a system of particles. Gravitation: Newton's law of universal gravitation, gravity near the surface of earth, The shell theorems, gravitational potential energy, the motion of planets and satellites.

Book to be followed:

1. Physics Vol.1 (4th edition), Halliday and Resnick, *John Wiley and Sons* (1992).
2. Physics Vol.1 (5th edition), Halliday and Resnick, *John Wiley and Sons* (2002).
3. Fundamentals of Physics (5th edition), Halliday and Resnick, *John Wiley and Sons* (1999).
4. Physics for Scientists and Engineers (Extended version), P. M. Fishbane, *Prentice-Hall International Editions* (2016).
5. Classical Mechanics Simulations, Bruce Hawkins and Randall Jones, *John Wiley & Sons* (1995)

PHYS 1102: Physics Lab I
Cr. 1: Accompanying PHYS 1101

Course Objectives

The Lab will cover the experiment in Mechanics. After the completion of the Lab the students will be able to:

1. Verify the various laws of mechanics.
2. Learns different techniques of analyzing and presenting scientific data.

Experiments in Mechanics, Oscillations, Waves and Optics.

1. To determine the value of "g" by compound pendulum/Kater's Pendulum.
2. To study the dependence of Centripetal force on mass, radius, and angular velocity of a body in circular motion.
3. To study the law of conservation of momentum.
4. To study the laws of sliding friction.
5. To study the laws of drag force.
6. Determination of moment of inertial of a solid/hollow cylinder and a sphere etc.
7. To study the laws of gyroscope.

PHYS 1201: Waves and Oscillations
Cr. 3: Prerequisite: PHYS 1101

Course Objectives

1. Understand basic principles of mechanics related to its applications on oscillating systems.
2. Understand the basic equation of wave in elastic medium and its properties.
3. Be able to solve relevant numerical problems.

Main Theme/ Topic

Oscillations: Simple Harmonic Motion; Energy considerations in SHM; Applications of SHM; Oscillation with two degree of freedom; Spring system and coupled pendulum.
Damped Vibrations; forced vibrations; Resonance; Phase of Resonance; Quality Factor.
Wave in Physical Media: Mechanical waves; Traveling waves; Phase velocity; Group velocity and dispersion; Wave speed; Principle of superposition; Interference of wave; Standing wave; Resonance. Sound Waves: Beats (analytical treatment); The Doppler effect. Light Waves: Nature of light; Speed of light in matter; Doppler effect for light. Mirror and Lenses: Image formation by mirrors and Lenses, Plane mirror, spherical mirrors, spherical refracting surfaces, thin Lenses, Optical instrument. Interference: Coherence; double slit interference (analytical treatment); Interference from thin films, Newton's ring (analytical treatment); Michelson's interferometer; Fresnel's Biprism. Diffraction: Single slit diffraction; Intensity in single slit diffraction (analytical treatment); Double slit diffraction & interference combined; Diffraction at circular aperture; Diffraction from multiple slits; Diffraction grating; Dispersion and resolution power. Polarization: Polarization; polarization by polarizing sheet, by reflection, by double refraction and double scattering; Polarization states (linear, circular & elliptic polarization).

Book to be followed:

1. Physics Vol.1 (4^{th} edition), Halliday and Resnick, *John Wiley and Sons* (1992).
2. Physics Vol.1 (5^{th} edition), Halliday and Resnick, *John Wiley and Sons* (2002).
3. Fundamentals of Physics (5^{th} edition), Halliday & Resnick, *John Wiley and Sons* (1999).
4. Physics for Scientists and Engineers (extended version), P. M. Fishbane, *Prentice-Hall International Editions* (2016).
5. Classical Mechanics Simulations, Bruce Hawkins and Randall Jones, *John Wiley & Sons* (1995).

PHYS 1202: Thermal Physics & Bulk properties of matter
Cr. 3: Prerequisite: PHYS 1101

Course Objectives

1. Study bulk properties of matters.
2. Study the laws of thermodynamics and its applications to simple system.
3. Be able to solve relevant numerical problems.

Main Theme / Topic

Bulk Properties of Matter: Elastic properties of matter; Elasticity; Tension; Compression & Shearing; Elastic modulus; Elastic limit; Poisson's ratio; Relation b/w three types of elasticity.
Fluid Statics and Dynamics: Fluids; Pressure and density; Variation of pressure in a fluid at rest; Pascal and Archimedes principles, surface tension; Viscosity; Fluid flow, streamlines and equation of continuity, Bernoulli's equation and its applications. Entropy and Temperature: Thermal Equilibrium, temperature, entropy, Law of thermodynamics. Boltzmann distribution: Boltzmann factor, Pressure, Helmholtz free energy, Ideal gas. Chemical potential and Gibbs distribution: Definition of chemical potential, Gibbs factor and Gibbs sum; related examples and problems. Heat and work: Energy and entropy transfer, definitions of heat and work, heat and work at constant temperature and pressure; related examples and problems. Gibbs free energy and chemical reactions: Gibb free energy, Equilibrium in reactions, Equilibrium for ideal gas; related examples and problems. Phase transformation: Vapor pressure equation, Van der wall equation of states, Landau theory of phase transition.

Book to be followed:

1. Physics Vol.1 (4th edition), Halliday and Resnick, *John Wiley and Sons* (1992).
2. Physics Vol.1 (5th edition), Halliday and Resnick, *John Wiley and Sons* (2002).
3. Fundamentals of Physics (5th edition), Halliday & Resnick, *John Wiley and Sons* (1999).
4. Thermal Physics (2nd edition) Charles Kittle and Herbert Kroemer, *W. H. Freeman company* (2000)
5. Thermal and Statistical Physics Simulations, Bruce Hawkins and Randall Jones, *John Wiley & Sons* (1995).

PHYS 1203: Physics Lab II
Cr. 1: Prerequisite: PHYS 1201 & PHYS 1202

Course Objectives

The Lab will cover the experiment in Mechanics, Oscillations, Waves and Optics. After the completion of the Lab the students will be able to:

1. Verify the various laws of mechanics, wave and oscillation and optics.
2. Learns different techniques of analyzing and presenting scientific data.

Experiments on Mechanics, Oscillation, Waves and Optics.

1. Modulus of Rigidity by Static & Dynamics Methods (Maxwell's needle, Barton's Apparatus)
2. To study the damping features of an oscillating system using simple pendulum of variable mass.
3. Measurement of viscosity of liquid by Stoke's/Poiseuille's method.
4. Surface tension of water by capillary tube method.
5. To determine thermal emf and plot temperature diagram.
6. Determination of temperature coefficient of resistance of a given wire.
7. To determine Horizontal/Vertical distance by Sextant.
8. The determination of wavelength of Sodium lines by Newton's Rings.
9. The determination of wavelength of light/Laser by Diffraction grating.
10. Determination of wavelength of sodium light by Fresnel's bi-prism.
11. The determination of Resolving power of a diffraction grating.

PHYS 2301: Electricity and Magnetism
Cr. 3: Prerequisite PHYS 1201

Course Objectives

After the completion of the course the students will be able to:

1. Understand basic principle of electricity and magnetism and its applications.
2. Be able to solve relevant numerical problems.
3. Be able to use calculus in studying the electromagnetic systems.

Main Theme / Topics

Electrostatics: Electric Charge; Coulomb's law; Electric Field; Gauss's law; Application of Gauss's law; Electric filed due to surface and volume charge distribution; electric field due to dipole. Electric Potential: Electric potential; Potential due to point charge, due to collection of point charges; surface and volume charge distribution; due to dipole; Poisson's and Laplace equation (without solution). Capacitors & Dielectrics: Capacitance; Calculating capacitance; Energy storage in an electric field; Capacitor with dielectric; Dielectric (an atomic view); Dielectrics and Gauss's Law. Current and Resistance: Electric current & density; Ohm's law, microscopic view of Ohm's law; semiconductor and superconductivity. DC Circuits: Calculating current in a single loop & multiple loops; Voltage at various elements of a loop; Use of Kirchhoff's 1st and 2nd law; Thevenin theorem; Norton theorem and superposition theorems; Transient behavior of RC circuit. Magnetic Field: Magnetic Field; Definition of B; Magnetic Force on a current; Torque on a Current Loop; The Hall Effect; Circulation Charge; The Cyclotron; The Thomson Experiment. Ampere's Law: The Bio-Savart Law and its applications; Ampere's Law; Magnetic Lines of induction; Two Parallel Conductors; Solenoids and Toroids. Faraday's Law: Faraday's Law of Induction; Lenz's Law; Motional emf; Induced electric field; The Betatron; Induction; LR Circuit (transient behavior); Inductance and relative motion. Magnetic Properties of Matter: Gauss's law for magnetism; atomic and nuclear magnetism; Magnetization; Magnetic materials. AC Circuits: AC current; AC current in resistive, inductive and capacitive elements; RLC series and parallel circuits; Power in AC circuits. Maxwell's Equations: Displacement current; Maxwell's Equations; The wave equation; Energy Transport and Poynting Vector.

Book to be followed:

1. Physics Vol.1 (4th edition), Halliday and Resnick, *John Wiley and Sons* (1992).
2. Physics Vol.1 (5th edition), Halliday and Resnick, *John Wiley and Sons* (2002).
3. Fundamentals of Physics (5th edition), Halliday & Resnick, *John Wiley and Sons* (1999).
4. Physics for Scientists and Engineers (extended version), P. M. Fishbane, *Prentice-Hall International Editions* (2016).
5. Foundations of Electromagnetic Theory (3rd edition), J. R. Reitz, *Narosa Publishing House* (1997).

PHYS 2302: Physics Lab III
Cr. 1: Accompanying PHYS 2301

Course Objectives

The Lab will cover the experiments related to electricity, magnetism, and modern physics. After the completion of the Lab students will be able to:

1. Verify the laws which are basis of modern physics.
2. Learns different techniques of analyzing and presenting scientific data.

Experiments in electricity, magnetism, and modern physics.

1. Measurement of resistance using a Neon flash bulb and condenser.
2. Conversion of galvanometer into Voltmeter & an Ammeter.
3. Calibration of an Ammeter and a Voltmeter by potentiometer
4. Charge sensitivity of a ballistic galvanometer.
5. Comparison of capacitance by ballistic galvanometer
6. To study the BH curve & measuring the magnetic parameters.
7. Measurement of low resistance coil by a Carey Foster Bridge.
8. Resonance frequency of an acceptor circuit.
9. Study of the parameter of wave i.e. Amplitude, phase and time period of a complex signal by CRO.
10. Measurement of self/mutual inductance
11. Study of electric circuits by black box.
12. Determining resistances using a Wheatstone bridge

PHYS 2401: Modern Physics
Cr. 3: Prerequisite 2301

Course Objectives

The course will introduce modern physics and its applications. After the completion of the course students will be able to:

1. Understand basic principles of relativity.
2. Study the experiments and phenomena that lead to quantum physics.
3. Be able to solve relevant numerical problems.

Main Theme / Topics

Special Theory of Relativity: Inertial and non-inertial frame; Postulates of Relativity; Lorentz transformation and its consequences (time dilation and length contraction); Transformation of velocity; Variation of mass; relativistic momentum and energy; Energy mass relation. Origin of Quantum Theory: Black body radiation; Stefan, Boltzmann, Wien and Planck's law-consequences; Quantization of energy; Photoelectric effect; Einstein's photon theory; The Compton effect; Line spectra. Wave Nature of Matter: Wave behavior of particle; De Broglie's hypothesis; Wave packets and particles; Heisenberg's uncertainty principle; Wave function (its definition and probability interpretation); Trapped particles; The correspondence principle. Quantum Mechanic: Linear operators; Eigen values and functions; Postulates of QM; momentum and energy operators; Schrödinger equation and its application to free particle, potential well and step functions. Atomic Physics: Bohr's theory (Review); Frank. Hertz experiment; Atomic spectra; Angular momentum of electron; Orbital angular momentum; Spin quantization; Bohr's Magnetron; X-ray spectrum; Moseley's law; Pauli Exclusion Principle and its use in building periodic table. Nuclear Physics: Laws of radioactive decay; Half-life; Mean life; chain disintegration. Nuclear Reactions: Basic nuclear reactions; Q-Value; Nuclear fission; Liquid drop model; Nuclear fusion in stars.

Books to be followed:

1. Concepts of Modern Physics (6^{th} edition), Arthur Bieser, *McGraw-Hill Higher Education* (1994)
2. Physics Vol.1 (4^{th} edition), Halliday and Resnick, *John Wiley and Sons* (1992)
3. Physics Vol.1 (5^{th} edition), Halliday and Resnick, *John Wiley and Sons* (2002)
4. Modern Physics Simulation, R. Bigelow, J.R. Hiller and Moloney, *John Wiley and Sons* (1996)
5. Fundamentals of Physics (5^{th} edition), Halliday and Resnick, *John Wiley and Sons* (2002)
6. Physics for Scientists and Engineers (extended version), P. M. Fishbane, *Prentice-Hall International Editions* (2016)

PHYS 2402: Physics Lab IV
Cr. 1: Prerequisite 2301 and Accompanying PHYS 2401

Course Objectives

The Lab covers the advance experiments in modern physics and optics. After the completion of the Lab students will be able to:

1. Verify the various result in modern physics, optics, and nuclear physics.
2. Learns different techniques of analyzing and presenting scientific data.

Experiments in Modern Physics

1. Determination of e/m of an electron
2. Ionization potential of mercury.
3. To study the characteristic curves of a G.M. counter and use it to determine the absorption co-efficient of Beta particle in Aluminum.
4. Determination of range of Alpha particles.
5. Mass absorption coefficient of Pb for gamma using G.M. counter.

PHYS 2403: Electronics
Cr. 3: Prerequisite PHYS 2301

Course Objectives

The course will introduce basic principle of electronics. After the completion of the course students will be able to:

1. Understand basic principal of electronics.
2. Be able to solve relevant numerical problems.

Main Theme / Topics

Semiconductors: Classification of conductor, semiconductors and insulators by Band Theory; P-type & N-type; Doping; PN junction. Diode theory and Circuit: Characteristics of diode; Ideal Diode; Models of diode; The diode as rectifier; Surge current; The Zener diode; Optoelectronic devices; The Schottky diode. Bipolar Transistors: PNP and NPN transistors; Characteristics of transistors; Model of transistor; Transistor biasing. Transistor as amplifier: Transistor as voltage, current and power amplifier. Field-Effect transistors: The JFET; The biased JFET; Characteristics of JFET; FET circuits. Frequency effects: Frequency response of an amplifier; Miller's theorem; High Frequency FET analysis. OP-AMP: OP-AMP theory; OP-AMP negative feedback; Linear OP-AMP circuits; Non-linear OP-AMP circuits.

Book to be followed:

1. Electronic Principles (8^{th} edition), Paul Malvino, McGraw-Hill International (2015)
2. Electronics Circuits and Systems, J.D. Ryder, *Englewood Cliffs* (1976)
3. Electronics Devices, T.L. Floyd, *Prentice-Hall* (1996)
4. Electronic Devices and Circuit Theory, Boylestad and Nashhelsky, *Prentice-Hall* (1997)

PHYS 2404: Electronics Lab
Cr. 1: Accompanying PHYS 2403

Course Objective

The Lab covers experiments in electronics. After the completion of the course students will be able to:

1. Develop and study characteristics of different electronics circuits.
2. Be able to use different instrument in the study of electronic circuits.

Experiments in electronics:

1. Characteristics of a semiconductor Diode.
2. To construct a power supply and study the rectified wave form, ripple factor and regulation (without regulator).
3. To construct a voltage-regulated power supply with Zener diode.
4. Characteristics of Transistors.
5. To construct a single stage CE transistor voltage amplifier and study gain, input impedance, output impedance, half power points by sine/square wave testing and effect of bias on the output and measurement of distortion.
6. To construct a source follower FET voltage amplifier and study gain, input impedance, output impedance, half power points by sine/square wave testing.
7. To construct an R-C oscillator and compare it with a standard frequency.
8. To construct a Hartley or Colpitts oscillator and measure it frequency.
9. To construct and study the wave forms at the base and collector of the transistors of a free running a multivibrator.
10. To construct and study of the height, duration and time period of the output pulses in a monostable and bistable multivibrators with reference to the input trigger.
11. To construct from discrete components OR, AND, NOT, NAND, NOR, exclusive OR circuits and verify their truth tables.
12. Study of wave shaping circuits of diode, integrators and differentiators.
13. To construct the operational amplifier (741) by using discrete components and study its frequency response.

PHYS 3501: Classical Mechanics
Cr. 4: Prerequisite PHYS 1101, PHYS 1201

Course Objective

The course introduces Classical Mechanics at undergraduate level. After the completion of the course students will be able to:

1. Solve advance problems of mechanics.
2. Learn different formalism of classical mechanics.
3. Learn basic principles of non-linear dynamics

Main Theme / Topics

Mechanics of systems of particles: Degree of freedom; Degree of freedom of rigid body; Linear and angular momentum of many-body system; Energy law of many body system. Mechanics of Rigid Bodies: The Independent Coordinates of a Rigid Body; The Euler angles; Rate of Change of a Vector; Rotational Kinetic Energy and Angular Momentum; The Inertia Tensor; Euler's Equations of Motion; Motion of a Torque-free Symmetrical Top; The Motion of a Heavy Symmetrical Top with One Point Fixed; Stability of Rotational Motion. Lagrange Formalism: Constraints; Generalized coordinate; Quantities of mechanics in generalized coordinates; D'Almbert Principle and Derivation of Lagrange equations; Lagrange equations for nonholonomic constraints and Lagrange. Central Force Problem: Two body problem and its reduction to one body problem; equation of motion solution of one body problem; Planetary motion and derivation of Kepler's laws; Rutherford scattering formula. Hamilton's Formalism: Legendre transformation and Hamilton's equations of motion; Calculus of variation and Hamilton's principle; Derivation of Lagrange's equation from Hamilton's principle; Phase space and Liouville's theorem; Solution of some elementary problems by Hamilton's Formalism. Canonical Transformations: The canonical transformation and its examples; Lagrange's and Poisson bracket; Integrals of motion; Poisson's theorem. Hamilton Jacobi Theory: Hamilton-Jacobi theory; Solution of Hamilton-Jacobi DE for some elementary systems. Newtonian Mechanics in Moving Coordinate system: Introduction to operator D; Newton's equation in rotating coordinate system and in system with arbitrary relative motion; Free Fall on the rotating earth; perturbation calculation; Method of successive approximation; Exact solution; Foucault's pendulum; Solution of its DEs and discussion of solution. Non-linear Dynamics: Dynamics systems; Stability of Time-Dependent Path; Bifurcation; Lyapunov exponents and Chaos; Systems with Chaotic dynamics.

Books to be followed:

1. Classical Mechanics (2nd edition), T. L. Chow, *John Wiley* (1995).
2. Classical Mechanics (2nd edition), Greiner, *Springer* (2003).
3. Classical Mechanics Simulations, Bruce Hawkins and Randall Jones, *John Wiley & Sons* (1995).
4. Classical Mechanics (3rd edition), H. Goldstein, *Addison-Wesley* (1950).
5. Classical Mechanics, V.D. Barger and M. G. Olsson, *McGraw-Hill,* (1995).
6. Classical Mechanics (2nd edition), Atam and P. Arya, *Prentice Hall Int. Inc.* (1998).

PHYS 3502: Physics Lab V
Cr. 2: Prerequisite PHYS 2401

Course Objectives

The Lab covers the advance experiments in modern physics and optics. After the completion of the Lab students will be able to:

1. Verify the various laws in modern physics and optics.
2. Learns different techniques of analyzing and presenting scientific data.

Experiments in Optics and Modern Physics:

1. Measurement of wavelengths of sodium light, difference of wave lengths and thickness of thin film e.g., mica using Michelson interferometer
2. The study of spectra using Fabry-Perot interferometers
3. The determination of Cauchy's constants using spectrometer
4. To study some aspects of Ferromagnetism by drawing B-H curve.
5. Measurement of speed of light using laser source rotating mirror method.
6. To measure the wave length of light by Fresnel biprism
7. Study of sound with help of Noise-Level meter.
8. To determine e/m of an electron using a fine beam tube
9. To study the Hall effect in an n-type/p-type semiconductor or a metal

PHYS 3503: Digital Electronics
Cr. 3: Prerequisite PHYS 2403

Course Objective

The course will introduce basic principles of digital electronics. After the completion of the course students will be able to:

1. Fundamental principles of digital electronics
2. Basic components of combinational and sequential logic.
3. Understand the components and functioning of processors

Main Theme / Topics

Digital electronics: Binary and other number systems; Logic gates; Boolean algebra; combinational logic; sequential logic; Registers; counters and memory units; Register transfer logic. Processor logic design: Processor organization; Arithmetic logic unit; Status register; Shifter; Accumulator. Control logic design: Control organization; Hard-Wired Control; Control of processor unit. LabView: Introduction to LabView, Virtual Instruments, Block Diagrams, Controls and indicators, Data Acquisition, Debugging.

Book to be followed:

1. Digital Logic and Computer Design, M. M. Mano, *Prentice-Hall Inc* (1995).
2. Digital Fundamental (11^{th} Edition) , T. L. Floyd, *Prentice-Hall* (2015).
3. Digital Electronics: Principles and Applications, R. Tokheim, *McGraw-Hill* (2013).
4. Digital Electronics, R. Dueck and K. Reid, *Cengage Learning* (2011).

PHYS 3601: Electromagnetic Theory
Cr. 4: Prerequisite PHYS 2301

Course Objectives

The course introduces electromagnetic theory at undergraduate level. After the completion of the course students will be able to:

1. Solve advance problems of electromagnetism.
2. Apply Maxwell's equation to explain various wave phenomena.
3. Solve simple problems of electrodynamics.
4. Introduce covariant form of Maxwell's equations.

Main Theme / Topic

Fundamental Concept: Recapitulation of the fundamental concepts. Electrostatics: Poisson's and Laplace's equations; Properties of solution of Laplace's equation; Solution of Laplace's equation in spherical, cylindrical and Cartesian coordinates; Conducting sphere in a uniform electric field; Electrostatic images; Point charge and conducting sphere; Line charge and line images; system of conducting spheres. Electrostatic Field in Dielectric Media: Polarization; Field outside a dielectric medium; Electric field inside a dielectric; Gauss's law in a dielectric; Electric susceptibility and dielectric constant; Point charge in a dielectric fluid; Boundary conditions on the field vector at the interface b/w different medium. Electrostatic energy: PE of a group of point charges; Electrostatic energy of a charge distribution; Energy density of an electrostatic field; Energy of system of charged conductors; Coefficients of capacitance. Magneto-static Field: Current & current density; equation of continuity; Ohm's law; steady current in a continuous media; Electrostatic equilibrium; Magnetic induction; Forces on a current carrying conductors; Biot and Savart law and its applications; Ampere's law; Magnetic vector potential; Magnetic field of a distant circuit. Magnetic properties of Matter: Magnetization; Magnetic field produced by magnetized material; magnetic scalar potential and magnetic pole density; Magnetic intensity; The field equations; Magnetic susceptibility and permeability; Hysteresis; Boundary conditions on the field vector at the interface b/w different medium. Electromagnetic Induction and Magnetic energy: Electromagnetic induction; Magnetic energy of coupled circuits; Energy density in the magnetic field. Maxwell's Equations and their Applications: Generalization of Ampere's law; Maxwell's equations; Electromagnetic energy; Boundary Conditions; The wave equations; The wave equation with sources; Plane wave solution in non-conducting media; Polarization; Plane waves in conducting media; Spherical waves; Reflection and refraction at the boundary of two non-conducting media (normal and oblique incidence); Brewster's angle; Reflection from a conducting plane; The radiation from an oscillating dipole; Covariant formulation Maxwell's equation; The field uniformly moving point charge.

Books to be followed:

1. Classical Electrodynamics, Jackson, *Wiley* (1975).
2. Foundations of Electromagnetic Theory (4^{rd} edition), Addison-Wesley (2008).
3. Introduction to Electrodynamics (2^{nd} edition), D. Griffiths, *Prentice Hall* (1989).
4. Electromagnetic Theory, S. J. Adams, *Adams Press* (2008).

PHYS 3602: Quantum Mechanics I
Cr. 3: Prerequisite PHYS 2401

Course Objectives

The course introduces Quantum Mechanics at undergraduate level. After the completion of the course students will be able to:

1. Understand the fundament principles of Quantum Mechanics.
2. Solve basic problems of quantum mechanics in 1D and 3D.
3. Learning theory of angular momentum in quantum mechanics.

Main Theme / Topics

Classical concepts inadequate for measurements; Double slit electron beam experiment. Formulation of QM: Plane waves and wave packets; Mathematical preliminaries (Dirac notation; operators; eigen values and vectors); Parity. Postulates of QM; position and momentum representation; Schrodinger equations; stationary states; expectation value; probability current. One Dimensional systems: The potential step; potential barrier; infinite square well and bound states; alpha decay; Harmonic oscillator and number representation. Atomic squid; Quantum Hall-effect. Angular Momentum: General angular momentum operators in QM, Matrix representation, Spin angular momentum, Addition of angular momentum.

Books to be followed:

1. Quantum Mechanics: Concepts and applications (2nd edition), Zettili, *John Wiley & Sons* (2009).
2. Introduction to Quantum Mechanics, Griffiths, David J., *Pearson Education, New Delhi* (2014).
3. Introductory Quantum Mechanics (4th edition), Liboff, Richard L., *Pearson Education, New Delhi* (2003).
4. A Text Book of Quantum Mechanics, Mathew, P. M. & Venketeson, K., *Tata McGraw Hill, New Delhi* (1991).
5. Quantum Mechanics, Gasiorowicz & Stephen, *John Wiley & Sons, New York* (1996).
6. Understanding Quantum Physics Vol. I & II, M. A Morison, *Prentice Hall Inc.* (1990).

PHYS 3603: Physics Lab VI
Cr. 2: Prerequisite PHYS 2401

Course Objectives

The Lab covers the advance experiments in modern physics and optics. After the completion of the Lab students will be able to:

1. Verify the various laws in modern physics and optics.
2. Learns different techniques of analyzing and presenting scientific data.

List of experiment in optics and modern physics:

1. To measure the critical potential of mercury by Frank-Hertz Method.
2. To measure the Planck's constant by studying photoelectric effect.
3. To measure work function of metal and verification of Richardson's equation.
4. Determination of dielectric constant of liquid and solid.
5. To determine the characteristic of G. M. tube and measure the range and maximum energy of beta particles.
6. Measurement of half-life of radioactive source.
7. Characteristics of G.M. counter and study of fluctuations in random process.
8. To determine the charge of an electron by Millikan's oil drop method.
9. To determine half-life of radiative element.
10. To study random fluctuations in decay rate of unstable nucleus.
11. To study inverse square law of radiation propagation.

PHYS 4701: Quantum Mechanics II
Cr. 3: Prerequisite PHYS 3602

Course Objectives

1. Solving the central potential problems.
2. Study of system of identical particles.
3. Work in approximation methods in quantum mechanics.

Main Theme / Topics

Central Potential: Solution of stationary states in central potential; Reducing two body problem into one body; Eigen functions of L^2 and L_z operators, Hydrogen atom. Identical Particles: Indistinguishability of identical particles; systems of identical particles; symmetric and anti-symmetric states functions; Pauli's exclusion principle. Approximation methods in QM: Time independent perturbation theory and its applications; WKB approximation, Variational method, Time dependent perturbation theory. Transition probability for constant perturbation.
Scattering theory in QM: Differential and total cross section; scattering amplitude and its relation to differential cross section; The Born approximation; Partial wave analysis for elastic and inelastic scattering.

Books to be followed:

1. Quantum Mechanics: Concepts and applications (2nd edition), Zettili, *John Wiley & Sons* (2009).
2. Introduction to Quantum Mechanics, Griffiths, David J., *Pearson Education, New Delhi* (2014).
3. Introductory Quantum Mechanics (4th edition), Liboff, Richard L., *Pearson Education, New Delhi* (2003).
4. A Text Book of Quantum Mechanics, Mathew, P. M. & Venketeson, K., *Tata McGraw Hill, New Delhi* (1991).
5. Quantum Mechanics, Gasiorowicz & Stephen, *John Wiley & Sons, New York* (1996).
6. Understanding Quantum Physics Vol. I & II, M. A Morison, *Prentice Hall Inc.* (1990).

PHYS 4702: Statistical Physics
Cr. 3: Prerequisite PHYS 1201, PHYS 3602

Course Objectives

The course introduces Thermal and Statistical Physics at undergraduate level. After the completion of the course students will be able to:

1. Basic principles of equilibrium thermodynamics.
2. Basic principles of statistical mechanics.
3. Study of partition function and different statistical systems

Main Theme / Topics

Equilibrium Thermodynamics: Thermodynamical quantities, The laws of thermodynamics, Equations of state of an ideal gas, Specific heats, Maxwell relations and their applications.
Elements of Probability Theory: Probabilities and its laws; Probability distributions; binomial distribution; Gaussian distribution. Formulation of Statistical Mechanics: Micro and macro states of system; counting the states of a system (harmonic oscillators, ideal gas); micro canonical system; Thermal and mechanical interactions in statistical physics; absolute temperature and equations of state. Derivation of laws of thermodynamics. System in contact with heat reservoir and canonical ensemble. Partition Function: Partition function and its relationship with thermodynamical variables; Examples ideal gas, collection of simple harmonic oscillators, Pauli and van vleck paramagnetization); Theorem of equipartition of energy. Statistical Systems: Maxwell-Boltzmann, Bose-Einstein, Fermi-Dirac and Planck statistical systems; Back body radiations, Bose-Einstein condensation, Gas of electrons in solids. Phase transitions and their types.

Books to be followed:

1. Fundamental of Statistical and Thermal Physics, R. Reif, *McGraw-Hill* (1988).
2. Elementary Statistical Physics, C. Kittle, *Dover Publications* (1958).
3. Statistical and Thermal Physics, H. Gould and I. Tobochnik, *Princeton University Press* (2010).
4. Statistical Physics, Gregory H. Wannier, *Dover Publications, Inc., New York* (1987).

PHYS 4703: Relativity
Cr. 2: Prerequisite MATH 2301, PHYS 2401, MATH 3501, PHYS 3601

Course Objectives

1. Study basic principles of special and general relativity.
2. Cover the related mathematical concepts.
3. Study some basic application of relativity to Black-hole physics and cosmology.

Main Theme / Topics

Space-Time Formalism of Special Relativity: Lorentz Transformation, Minkowski spacetime, The Light-Cone Line Element, Four-Vectors, Four Velocity and Momentum, Relativistic Kinematics, Force Equation in Relativity. Law of Conservation of 4-Momentum. Covariant Form of Maxwell's Equations: Four-Vector Potential; Field Stress Tensor. Maxwell's Equation in Covariant Form.
Curved Manifold: Contravariant and Covariant Vectors, the Metric, Geodesics and the Geodesic Equation, the Christoffel Symbols, Curvature, Covariant Derivative, Parallel Transport, the Riemann Curvature Tensor, Ricci Tensor. General Relativity: Principle of Equivalence, Tidal Gravitational (Newtonian) Forces, Newtonian Deviation Equation, Einstein's Field Equations, Introducing the Schwarzschild Metric (without fully deriving it as a Solution to the Einstein Field Equation).

Books to be followed:

1. Gravity, An Introduction to Einstein's General Relativity, James B. Hartle, *Addison-Wesley* (2003).
2. Introducing Einstein's Relativity, R. D'Inverno, *Oxford University Press* (1992)
3. Dynamics and Relativity, W. D. McComb, *Oxford University Press* (1999)
4. A First Course on General Relativity, Bernard Schutz, *Cambridge University Press* (2009).
5. Relativity Demystified, David McMahon, *McGraw-Hill,* (2006).

PHYS 4801: Solid State Physics
Cr. 4: Prerequisite PHYS 4701,

Course Objectives

The course introduces Solid State Physics at undergraduate level. After the completion of the course students will be able to:

1. Learn the theory of crystal structure.
2. Study the origin of thermal properties of solids.
3. Study the band theory and semiconductor physics.
4. Computation techniques in solid states physics.

Main Theme / Topics

Crystal Structure: Periodic arrays of atoms; Fundamental types of lattices; Index system for crystal planes; Simple crystal structure; Direct imaging of atomic structure; Nonideal crystal structure. Reciprocal Lattice: Diffraction of waves by crystal; Scattered wave amplitude; Brillouin zones; Fourier analysis of the basis. Crystal Binding and Elastic Constants: Crystal of inert gases; Ionic crystals; Covalent crystals; Metals; Hydrogen bonds; Analysis of elastic strains; Elastic compliance and stiffness constants; Elastic waves in cubic crystal. Crystal Vibrations: Vibrations of crystals with monatomic basis; Two atoms per primitive basis; Quantization of elastic waves; Phonon momentum; Inelastic scattering by phonons. Thermal Properties: Phonon heat capacity; Inharmonic crystal interactions; Thermal conductivity; electronic heat capacity. Free Electron Theory: Energy levels in 1D; Effect temperature on the Fermi-Dirac distribution; Free electron gas in 3D; Heat capacity of electron gas; Electrical conductivity and Ohm's law; Motion in magnetic field; Thermal conductivity of metals. Band Theory:Nearly free electron model; Bloch function; Krnig-Penney model; Wave equation of electron in a periodic potential. Number of orbital in a band. Semiconductors: Theory of semiconductors; Extrinsic semiconductors; Mobility of current carriers; Minority carriers; Lifetime; Surfaces; Contacts; Semiconductor devices. Computational Techniques: Density Functional Theory, Hartee-Fock Methods, LAPW method.

Books to be followed:

1. Introduction to Solid State Physics (7th Edition), C. Kittle, *John Wiley & Sons, Inc.* (1996).
2. Solid State Physics, J. S. Blakemore, *Cambridge University Press* (1991).
3. Solid State Physics Simulations, Steven Spicklemire, *John Wiley & Sons* (1996).
4. Solid State Physics, Neil W. Ashcroft, *Thomson Press (India)*, 2003).
5. Solid State Physics (2nd Edition), G. Grosso, G. P. Parravicini, Academic Press (2013).

PHYS 4802: Nuclear Physics
Cr. 4: Prerequisite: PHYS 4701

Course Objectives

The course introduces Nuclear and Particle Physics at undergraduate level. After the completion of the course students will be able to:

1. Learn different nuclear models and explain the nuclear properties.
2. Theory of nuclear forces and its application to different nuclear reactions.
3. Theories of radioactive decay
4. Study of different mechanics of particles acceleration and detections.
5. Introduction of reactor physics
6. Introduction of elementary particles and their interaction

Main Theme / Topics

Introduction: Scope of nuclear physics; differential and total cross sections; decay rates; Rutherford and Mott's formula; Nuclear form factor. Size and Shape of Nuclei: Study of size of nucleus through electron and neutron scattering experiments; The isotope shift method; X-ray spectroscopy of muonic atoms; The shape of nuclei. The Masses of Nuclei: The properties of stable nuclei; Characteristics of experiment curve of binding energy per nucleon; Liquid drop model; Comparison of experimental and theoretical curves of binding energy per nucleons. Unstable Nuclei: Decay modes of unstable nuclei; Q values analysis of alpha and beta decay; Energy level diagrams; Spontaneous fission. Spin, Magnetic moments, and Parity of nuclei: Total angular momentum of odd and even nuclei; Magnetic moment; nuclear magneton; Schmidt model; Parity of a nuclei.
Shell Model and Collective models: Nuclear magic numbers; energy level diagrams; spin-orbit coupling; spin and parities of nuclear ground states; Excited states in shell model; The collective model. Theories of Radioactive Decay: Alpha decay; Potential barrier; Gamow theory of alpha decay; Fermi theory of beta decay. Theory of gamma decay. Nuclear Reactions: Direct reactions; Reaction involving the formation of compound nucleus; Stripping reactions; Resonance reactions; Bohr's theory of compound nucleus and its limitations; Breit-Wigner formula. Nuclear Radiation Detection and Measurements: Interaction of nuclear radiation with matter; Photographic emulsions; Gas-filled detectors; Scintillation counters and solid-state detectors. Particle Accelerators:Van de Graff generator; Cyclotron; Synchrocyclotron; Betatron; Electron-Synchrotrons; Proton-Synchrotron; Alternating-Gradient Synchrotron; Linear Accelerator. Elementary Particles: Elementary particles classification; ; Strong, electromagnetic and weak interactions; Conservation laws; The quark model.

Books to be followed:

1. Nuclear and Particle Physics (2nd edition), Burcham, E. E. and Jobes, M., Longman, *John Wiley & Sons* (1995).
2. Introduction to Nuclear and Particle Physics, Das, A. and Ferbel, T., *John Wiley and Sons* (1994).
3. Nuclear and Particle Physics, Williams, W.S.C., *Oxford University Press* (1995).
4. Introduction to Elementary Particles by David Griffiths, *Wiley-VCH*; 2nd edition (2008).

5. Nuclear Physics: An introduction, by Brian R. Martin and Graham Shaw, *Wiley; 3rd edition* (2019).
6. Nuclear and Particle Physics Simulations, Michael J. Moloney & Roberta Bigelow, *John Wiley & Sons* (1996).

PHYS 4704: Particle Physics I
Cr. Hrs. 3

Course Objectives

The course introduces Particle Physics at undergraduate level. After the completion of the course students will be able to:

1. Learn properties of fundamental particles from historical perspective.
2. Studying the probes in high energy physics.
3. Symmetries and their applications.

Main Theme / Topics

Historical Introduction to Particle Physics: Elementary particles and fundamental forces, photon, antiparticles, mesons, neutrinos, lepton and baryon number, strange particles and strange quantum number, Eightfold way, quark model. Nature of the experimental data in particle physics: Decay rate, Differential and total cross-section. Natural system of units. Continuous and discrete symmetries: Space-time symmetries in quantum mechanics and the laws of conservation, consequences of symmetries, translational and rotation symmetries, parity and its violation in weak interaction, internal symmetries, charge conjugation and C parity, Isospin symmetry and its application, CP violation.

Recommended Books:

1. Introduction to Elementary Particles by David Griffiths, *Wiley-VCH*; 2nd edition (2008).
2. Quarks and leptons, F. Halzen and A. D. Martin, *John Wiley & Sons* (1984).
3. Special Relativity: Applications to Particle Physics and Classical Theory of Fields, M. Saleem and M. Rafique, *Ellis Horwood* (1992).
4. A Modern Introduction to Particle Physics, Riazuddin and Fayyuddin, *World Scientific* (1992).
5. Quantum Mechanics, Thankapan, *John Wiley India* (1993).
6. Introduction to High Energy Physics, D. H. Perkins, *Addison Wesley* (2000).

PHYS 4803: Particle Physics II
Cr. Hrs. 3: Prerequisite 4704

Course Objectives

1. Learn the concepts related to scattering theory in quantum mechanics.
2. Study the relativistic quantum mechanics and its applications to electromagnetic processes.

Main Theme / Topics

Partial wave analysis: Boundary conditions of scattering in quantum mechanics, relation between differential cross section and scattering amplitude, solution of free Schrodinger equation in cartesian and spherical coordinate, relation between plane and spherical waves. Scattering amplitude for scattering by spherically symmetry potential, partial phases and their dependent on energy and angular momentum, the optical theory, simple application of scattering theory, Breit-Wigner resonance formula, scattering by complex potential and absorption cross section. Relativistic quantum mechanics: KG and Dirac equations, conserve current, and their plane wave solutions. Effect of electromagnetic interaction. Scattering Theory: Scattering amplitude in non-relativistic and relativistic perturbation theory, Fermi golden rule, Feynman rules of quantum electrodynamics, scattering cross sections of electron-muon elastic scattering and electron-positron scattering.

Books to be followed:

1. Introduction to Elementary Particles by David Griffiths, *Wiley-VCH*; 2nd edition (2008).
2. Quarks and leptons, F. Halzen and A. D. Martin, *John Wiley & Sons* (1984).
3. A Modern Introduction to Particle Physics, Riazuddin and Fayyuddin, *World Scientific* (1992).
4. Quantum Mechanics, Thankapan, *John Wiley India* (1993).
5. Introduction to High Energy Physics, D. H. Perkins, *Addison Wesley* (2000).
6. Elementary Particles (3rd edition), I. S. Hughes, *Cambridge University Press* (1991).

PHYS 4705: Detector Physics
Cr. Hrs. 3

Course Objectives

1. Study the different of mechanism of energy loss of radiation in matter.
2. Study the working principle and applications of particles detector.

Main Theme / Topics

Interaction of Radiation with matter: Energy loss by ionization and excitations, Bethe-Bloch formula, interaction, Bremsstrahlung, Interactions of photons, Strong interaction of hadrons.
Radiation Detection: Ionization counter, proportional counters, Geiger counters, Scintillation counters, Photomultipliers and photodiodes, Cherenkov counters. Track detectors: Cloud chambers, Bubble chambers, Multiwire proportional chambers, drift chambers, Time-projection chambers, Semiconductor track detector. Calorimeters: Electromagnetic calorimeters, Electron-photon cascades, Homogeneous calorimeters, Sampling calorimeters, Hadron calorimeters. Particle identification: Charged-particle identification; time-of-flight counters, identification by ionization losses, Neutron detection, Momentum measurement and muon detection: Magnetic spectrometers for fixed-target experiments, Magnetic spectrometers for special applications.

Books to be followed:

1. Particle Detectors (2nd Edition), C. Grupen and B. Shwartz, *Cambridge Monographs on Particles Physics, Nuclear Physics and Cosmology* (2008).
2. Radiation Detection and Measurements (2nd edition), G. F. Knoll, *John Willey* (1989).
3. Introduction to High Energy Physics (3nd edition), D. Perkins, *Addison-Welsey* (1987).
4. Techniques for Nuclear and Particle Physics Experiments (2nd edition), W. R. Leo, *Springer-Verlag* (1994).
5. Instrumentation in High Energy Physics, Sauli, *World Scientific* (1993)
6. Review of Particle Properties, Phys. Rev. D **98**, 030001 (2018).

PHYS 4804: Accelerator Physics
Cr. Hrs. 3: Prerequisite 4706

Course Objectives

1. Study the physics of particle accelerator and related phenomena.
2. Learn the related electronics coupled with design of particle accelerators.

Main Theme / Topic

Introduction: Historical Developments, Layout and Components of Accelerators, Accelerator Applications. Transverse Motion: Hamiltonian for particle motion in accelerators, linear betatron motion, effect of linear magnet imperfections, Off-momentum Orbit, Chromatic aberration, linear coupling, nonlinear resonances, Collective instabilities and Landau Damping. Synchrotron Motion: Longitudinal equation of motion, adiabatic synchrotron motion, RF Phase and voltage Modulations, Non adiabatic and nonlinear synchrotron motion, beam manipulation in synchrotron phase space, fundamentals of RF systems, longitudinal collective instabilities, Introduction to linear accelerators.

Books to be followed:

1. Accelerator Physics (3rd edition), S. Y. Lee, *World Scientific Publishing* (2012).
2. An Introduction to the Physics of High Energy Accelerators, D. A. Edwards and M. J. Syphers, *John-Wiley & Sons* (2008).
3. Introduction to the Physics of Particle Accelerators, Mario Conte and William W Mackay, *World Scientific* (1991).
4. Particle Accelerator Physics, Helmut Wiedemann, Springer (1993).

5. COMPUTATIONAL COURSES OF BS COMPUTATIONAL PHYSICS

COMP 1101: Introduction to Computer Science
Cr. 2 Prerequisite: F.Sc/A-Level

Course Objective

The course introduces the subject of Computer Science. After the completion of the course students will be able to:

1. Studying the history of computer and its applications.
2. Studying the architects of computer and various operating systems.
3. Learn to use the word processor and graphics packages.
4. Learning the basic concepts of data base management systems.

Main Theme / Topics

Introduction: Brief History of Computer, Mainframe, Mini, Micro and supercomputer, Intel core-based technology. Architects of computer: Logical gates, Circuits of logical gates based on transistor, resistor, capacitor and inductor, Flip flop and Register, Adder (half & full), Subtractor (half & full) and ALU Manufacturing of hard disk, Storage and retrieval of information from Hard disk. Computer Hardware: CPU, Motherboard, RAM, ROM, Storage devices, IO devices. Networking: Introduction to computer networks, BUS Topology, RING Topology, STAR Topology, MESH Topology, TREE Topology, HYBRID Topology, Internet and data searching. Operating System: BIOS, Window, Directory and folders, file management in window OS, Linux/Unix, MacOS. Computer Software: Word processing, Spread Sheets, Power point.

Books to be followed:

1. Introduction to Computers (6^{th} edition), Peter Norton, *McGraw-Hill* (2006).
2. Mastering Office 2010, Microsoft Press.
3. Introduction to Computers, D. W. Hajek, *CreateSpace Independent Publishing Platform* (2017)
4. Introduction to Computing Systems: From Bits and Gates to C and Beyond (2^{nd} Edition), Y. N. Pat and S. J. Patel, *McGraw-Hill* (2003)

COMP 2401: Computer Programming
Cr. 4 (2 +2 Lab) Prerequisite: COMP 1101

Course Objective

The course introduces the subject of Computer Programming. After the completion of the course students will be able to:

1. Studying the basic concepts of computer programming.
2. Learning to develop algorithms and its translation into programs.
3. Get familiar with programming Languages like C, FORTRAN 90 etc.
4. Learning Debugging and testing programs and its documentation.

Main Theme / Topics

Introduction to Programming:Problem analysis, Algorithm, flow chart. Programming Language:Introduction to C, C++, C++ and C# strcture. Pre-processors, Editor, Compilor, Executor and Error handling. Data types:Primary data types, integer, float, double, character, boolean and string.
Variables and constants:Variable types, identifier, declaration, memory allocation, initialization, literal constant, defined constant, declared constant. Operators:Assignment operator, increment/decrement operator, Relational operators, Mathematical oprators, logical operators, Comma operator, ternery operator, precedence of operators. Control structure:Selection Statements, Iteration/loop. Array: One dimentional array, two dimentional array, Declaration/Initializing array. Functions:Introduction to functt-in function, user defined function, types of functions, Defining, declaration and calling a function, Passing array to function, function overloading. Strings:String handeling, string copying, string comparision. Pointers:Address oprator, pointer operator, declaring a pointer, initializing pointers, pointer arithmatics, pointers and arrays, pointers and functions.

Books to be followed:

1. C Programming Language (2nd Edition), B. W. Kernighan, *Prentice Hall* (1988).
2. C++ How to program (9th edition), Paul Dietel and Harvey Dietel, *Pearson Education, Inc.* (2013).
3. Object Oriented Programming Using C++ (4th edition), Robert Lafore, *Sams Publishing* (2004).
4. Programming with C (2nd edition) Schaum Outlines Series, B. S. Gottfried, *McGraw Hill Press* (1996).

COMP 3501: Advanced Computer Programming
Cr. 3 (2 + 1 Lab) Prerequisite: COMP 2401

Course Objective

The course introduces the subject of object-oriented programming. After the completion of the course students will be able to:

1. Learning the difference between structured and modular programming.
2. Learning the concepts of object-oriented programming.

Main Theme / Topics

Structured Programming: Data structure, user defined data type, static vs dynamic memory allocation, linked list, singly linked list, double link list. Object oriented programming: Classes, constructor, destructor, constructor/function overloading, inheritance. Combined concept of data structures, pointers and classes. File handling: Concept of file management, text files, binary files, IO streams. Visual studio: Visual C++ and MFC application. Algorithm Analysis: Space and time complexity of an algorithm. Bog O, Ω and Θ. Parallel Processing: Need of parallel programing in scientific computation. Introduction to parallel programming with MPI.

Books to be followed:

1. C++ How to program (9th edition), Paul Dietel and Harvey Dietel, *Pearson Education, Inc.* (2013).
2. Object Oriented Programming Using C++ (4th edition), Robert Lafore, *Sams Publishing* (2004).
3. Advanced Programming with C++ (6th edition), C.M Aslam, Majeed Sons , *Urdu Bazar Lahore* (2015).
4. Parallel Programming with MPI, Peter S. Pacheco, *Morgan Kaufmann Publishers, inc.* (2011).
5. MPI tutorial in C#, Douglas Gregor and Benjamin Martin, *Open Systems Laboratory, Indiana University* (2008).

COMP 3502: Numerical Linear Algebra:
Cr. 3: Prerequisite: COMP 2401

Course Objective

The course introduces the subject of numerical linear algebra. After the completion of the course students will be able to:

1. Studying the fundamental concepts of numerical methods.
2. Learning different numerical methods of solving non-linear equations.
3. Learning different methods of solving set of equations.
4. Learning methods of interpolation and curve fitting.
5. Get experience of developing computer programs to implement various numerical methods.

Main Theme / Topics

Fundamentals of Numerical Methods: Introduction; Basic; Recursion Formulas; Successive Approximation; Steps of Problem-to-Solution Process; Errors in Computations. Solution of Non-linear Equations (Algebraic and transcendental): Non-Linear equations; Bisection Method; Linear interpolation method; Newton's Method; Fixed Point Iteration Method; Newton's Method for Polynomials; Multiple roots; Error estimation and convergence rates of roots. Solution of Set of Equations:System equations; Matrix notation; Elimination method; Gauss and Gauss-Jordan Methods; Gauss-Jacobi, Gauss-Seidel and Successive Over Relaxation (SOR) methods; Pathology in Linear Systems; Determinants and matrix inversion; Norms; Condition Numbers and error in solutions; Eigenvalues and eigen vector by simple iterative and QR methods. Interpolation and Curve Fitting: Interpolation Problem; Lagrangian polynomials; Divided differences; Evenly spaced data; Interpolation with a Cubic Spline; Least-Squares Approximations.

Books to be followed:

1. Applied Numerical Analysis, Curtis F. Gerald, *Addison-Wesley* (1994).
2. Introduction to Numerical Methods and FORTRAN Programming, Thomas Richard McCalla, *John Wiley & Sons* (1964).
3. Elementary Numerical Analysis, An Algorithmic Approach (3^{rd} edition), Samuel D. Conte, *McGraw-Hill International Edition* (1981).
4. Numerical Analysis: Mathematics of Scientific Computing (3^{rd} Edition), David Kincaid, *American Mathematical Society* (2010).
5. Numerical Recipes in C: The Art of Scientific Computing (2^{nd} Edition), W. H. Press, B. P. Teukolsky, W. T. Vetterling, *Cambridge University Press* (1992).

Software to be used:

1. Fortran, C/C++, Mathematica
2. Fortran and C routines

COMP 3601: Scientific Computation:
Cr. 4: Prerequisite: COMP 2401

Course Objective

The course introduces the subject of scientific computing. After the completion of the course students will be able to:

1. Studying the concepts of computer arithmetic and approximations in computing.
2. Getting experience of working with different problem-solving environments.
3. Getting experience of working with different Scientific Libraries.

Main Theme / Topics

Building Blocks of Mathematica: Arithmetic; Variables; Expressions; Patterns; Replacement Rules; Programming; Functions; Creating Vectors and Matrices; Addition and Dot Products of Vector and Matrices. Visualization in Mathematica: Graphics; Plotting Functions; Plotting Data; Animating Graphics. Symbolic Calculations: Symbolic vs. Numerical Computations; Operation with polynomials; Rational Expressions; Differentiations; Integration; Power Series; Solutions of equations; Simplifying Algebraic Expressions using Patterns. Numerical Calculations: Types of Numbers; Precision and Accuracy; Numerical Functions; Root finding; Finding the Minimum of a Function; Numerical Integration; Sums and Products; Interpolations functions; Curve Fitting.
Computation with Vectors Matrices and Tensors: The Cross Product; Gradient; Divergence; Curl; Eigenvalues and Eigenvectors. Computation in Differential Equations: Symbolic Solutions; Series approximations; Numerical Solutions; Inhomogeneous Boundary Values Problem; Shooting Method. Input and Output Operations: Output formats; I/O of expressions; Reading and Writing files.

Books to be followed:

1. Scientific Computing: An Introductory Survey, M. Heath, *McGraw-Hill International Edition* (1997).
2. Mathematica for Scientists and Engineers, Thomas B. Bahder, *Addison-Wesley* (1995).
3. Introduction to Scientific Computing (1st edition), Brigitte Lucquin, *John Wiley & Sons* (1998).
4. Numerical Recipes in C: The Art of Scientific Computing (2nd Edition), W. H. Press, B. P. Teukolsky, W. T. Vetterling, *Cambridge University Press* (1992).

Software to be used:

Mathematica (including the virtual book in help), Scientific Libraries for C/C++ and FORTRAN.

COMP 3602: Numerical Analysis
Cr. 3: Prerequisite: COMP 3502

Course Objective

The course introduces the subject of numerical analysis. After the completion of the course students will be able to:

1. Studying different methods of numerical differentiation and integrations.
2. Learning different numerical methods of solving ordinary differential equations and partial differential equations
3. Numerical study of boundary and characteristic value problems
4. Get experience of developing computer programs to implement various numerical methods

Main Theme / Topics

Numerical Differentiation and Numerical Integration: Getting Derivatives and Integrals Numerically; Derivatives from difference tables; Higher-Order derivatives; Extrapolation techniques; Newton-Cotes Integration Formulas; The Trapezoidal; Simpson's; Gaussian Quadrature; Adaptive Integration; Multiple Integrals; Applications of Cubic Splines. Numerical Solution of Ordinary Differential Equations: Taylor-Series Method; Euler and Modified Euler Methods; The Runge-Kutta Methods; Multistep Method; Milne's Method; The Adams-Moulton Method; Multivalued Methods; Convergence Criteria; Errors and Error Propagations; Systems of Equations and Higher-Order Equations; Comparison of Methods. Boundary-Value Problems and Characteristic-Value Problems: Introduction; The 'Shooting Method'; Solution Through a Set of Equations; Derivative Boundary conditions; Rayleigh-Ritz method; The Finite-Element method; Characteristic-value problems. Numerical Solution of Partial-Differential Equations: Finite difference method; Representation as a difference equation; Finite-element method; Laplace's equation on a rectangular region; The Poisson Equation.

Books to be followed:

1. Applied Numerical Analysis, Curtis F. Gerald, *Addison-Wesley* (1994).
2. Introduction to Numerical Methods and FORTRAN Programming, Thomas Richard McCalla, *John Wiley & Sons* (1964).
3. Elementary Numerical Analysis, An Algorithmic Approach (3rd edition), Samuel D. Conte, *McGraw-Hill International Edition* (1981).
4. Numerical Analysis: Mathematics of Scientific Computing (3rd Edition), David Kincaid, *American Mathematical Society* (2010).
5. Numerical Recipes in C: The Art of Scientific Computing (2nd Edition), W. H. Press, B. P. Teukolsky, W. T. Vetterling, *Cambridge University Press* (1992).

Software to be used:

1. Fortran, C/C++
2. Fortran and C routines

COMP 4701: Computational Physics Simulations
Cr. 3: Prerequisite: COMP 3502, COMP 3602

Course Objective

The course introduces the subject of scientific computing. After the completion of the course students will be able to:

1. Learning different techniques of simulating physical systems.
2. Get experience of simulating complicated systems.

Main Theme / Topics

Realistic Projectile Motion: The Effect of Air Resistance; Projectile Motion; Motion of a Batted Ball; The Effects of Spin. Oscillatory Motion and Chaos: Simple Harmonic Motion; Chaos in the Driven Nonlinear Pendulum; Lorenz Model; The Billiard Problem; Bouncing Balls; Chaos and Noise. The Solar System: Kepler's Laws; The Inverse-Square Law and the Stability of Planetary Orbits; Precession of the Perihelion of Mercury; The Three-body Problem and the Effect of Jupiter on Earth; Resonances in the solar systems; Chaotic tumbling of Hyperion. Potentials and Fields: Electric potentials and fields; potentials and fields near electric charges; magnetic field produced by a current; Magnetic field of a solenoid. Waves and optics: Waves; Interference, diffraction and polarization, Frequency spectrum of waves on a string; Motion of realistic string; spectral methods. Molecular Dynamics: Properties of a Dilute Gas, The melting transition.
Random Systems: Introduction; Generation of random numbers; Monte Carlo methods; Random walks; Self-avoiding walks; diffusion, entropy and the arrow of time; Cluster growth models.

Books to be followed:

1. Computational Physics: Problem Solving with Computers (2nd edition), Rubin H. Landau, *John Wiley & Sons* (2000).
2. Computational Physics (2st edition), Nicholas J. Giordano, *Prentice Hall* (2005).
3. Computational Physics, Mark Newman, *CreateSpace Independent Publishing Platform* (2012).
4. Computational Physics, Jos Thijssen, *Cambridge University Press* (2007).
5. Applied Computational Physics, J. F. Boudreau and E. S. Swanson, *Oxford University Press* (2017).

Software to be used:

FORTRAN and C routines, Mathematica

COMP 4702: Computational Physics Simulations Lab
Cr. 2: Accompanying COMP 4702

Course Objectives:

1. Apply the techniques of computational physics learned in the accompanying course.
2. To numerically solve physics problems of realistic systems.

Following simulation are applied in the lab:

Simulation of moving object; Bicycle motion (Ideal & realistic)**,** Freely falling objects. Radioactive decay along with exercises.
Projectile Motion; Projectile motion [ideal & Realistic case], The effect of air resistance, The effect of spin, Batted ball, Basketball, Relevant exercises
Oscillatory Motion and Chaos; Simple harmonic motion, Simple pendulum, Nonlinear pendulum, Lorenz model, Billiard ball, Relevant exercise
Solar System, Kepler's laws. The invers square law and stability of planetary orbits, Precision of the perihelion of the mercury, Two body problem, Three body problem and effect of Jupiter on earth, Resonance in the solar system
Potential and fields; Electric potential and fields, Potential and fields near electric charges, Magnetic field produced by current carrying conductor, Magnetic field of solenoid. Waves; Frequency spectrum of waves on a string, Motion of realistic string, Spectral methods.

COMP 4801: Quantum Physics Simulations
Cr. 3: Prerequisite: COMP 4702

Course Objective

The course introduces the subject of simulations of physical systems on computers. After the completion of the course students will be able to:

1. Study different techniques of simulating quantum systems.
2. Getting experience of solving the problem of quantum mechanics using numerical methods.

Main Theme / Topics

Quantum Mechanics: 1D (Shooting and Matching methods); Variational approach; Basis diagonalization method; Spectral methods. Quantum Systems: Time-independent Schrödinger Equation bound state solutions; Time-dependent Schrödinger Equation (Direct solutions); Fourier Transformations and momentum space; Bound states in momentum space; Random walk solutions of Schrödinger Equation; Quantum mechanical scattering. Monte Carlo Method: Monte Carlo integration; Multidimensional Monte Carlo integration; Diffusion Monte Carlo (DMC); Path Integral monte Carlo (PIMC). Quantum Monte Carlo Methods: Introduction; Postulates of Quantum Mechanics, Mathematical Properties of the Wave Functions; The Variational Monte Carlo Method; Variational Monte Carlo for Quantum Mechanical Systems; Variational Monte Carlo for atoms; The Born-Oppenheimer Approximation; The Hydrogen Atom; Metropolis sampling for the hydrogen atom and the harmonic oscillator; The Helium Atom. Monte Carlo Simulation Applications: The Ising Model and Statistical Mechanics; Mean-Field theory; The Ising model and second-order phase transitions; First-order phase transitions. Accelerators: Cyclotron, Linear accelerator, synchrotron.

Books to be followed:

1. Computational Quantum Mechanic, J. Izaac and Jingbo Wang, *Springer* (2019).
2. Quantum Mechanics Simulations, J. R. Hiller, I. D. Johnston, and D. F. Styer, *Wiley* (1995).
3. Computational Physics: Problem Solving with Computers (2nd edition), Rubin H. Landau, *John Wiley & Sons* (2000).
4. Computational Physics (2st edition), Nicholas J. Giordano, *Prentice Hall* (2005).
5. Computational Physics, Jos Thijssen, *Cambridge University Press* (2007).
6. Applied Computational Physics, J. F. Boudreau and E. S. Swanson, *Oxford University Press* (2017).

COMP 4802: Quantum Physics Simulations Lab
Cr. 2: Accompanying COMP 4801

Course Objectives

1. Apply the techniques of computational physics learned in the accompanying course.
2. To numerically solve quantum physics problems.

Following simulations/models are built in the lab:

Random numbers generator; One dimensional random walk; Two- and three-dimensional random walk; Self-avoiding random walk, Diffusion, Diffusion and random walk; Cluster growth model; Diffusion (limited aggregation); Particles in a box (MC simulations), Integration by MC simulations, DLA algorithm, Radioactivity decay; Radio activity decay with unstable daughter nuclei, Rutherford scattering, The Ising Model: MC methods and Ising model. 2^{nd} order phase transition. 1^{st} order phase transition, Schrodinger equation (direct solutions), Shooting method and eigen values of Schrodinger equation; Variational approach.

6. HUMANITY COURSES OF BS COMPUTATIONAL PHYSICS

HUM 1101: Islamic Studies
Cr. Hrs. 2

Course Objective

1. Study fundamental principles of Islam
2. Study the life of Hazrat Muhammad Rasoolullah Khatam-un-Nabiyyeen Sallalaho Alaihy Wa Aalehy Wa Ashabehi Wassalam.

Main Theme / Topics

Fundaments of Islam: Basic Themes of Quran, Introduction to Sciences of Hadith, Introduction to Islamic Jurisprudence, Primary & Secondary Sources of Islamic Law. Life of the Prophet: Makken & Madnian life of the Prophet, Islamic Economic System, Political theories, Social System of Islam. Islamic Society: Islamic Economic System, Political theories, Social System of Islam.

Books to be followed

1. Introduction to Islam by Dr Hamidullah, *Papular Library Publishers Lahore*.
2. Principles of Islamic Jurisprudence by Ahmad Hassan, *Islamic Research Institute, IIUI*.
3. Muslim Jurisprudence and the Quranic Law of Crimes, By Mir Waliullah, *Islamic Books Services*.

HUM 2401: Pakistan Studies
Cr. Hrs. 2

Course Objective

1. Study the historical movements and incidents that lead to creation of Pakistan.
2. Study the ideology of Pakistan.
3. Study of modern state of Pakistan.

Main Theme / Topics

History of Pakistan: Historical background of Pakistan, Religious movements: (role of significant religious persons), educational movements, Sir Syed Ahmed Khan's contributions, Political and constitutional development (1858-1935), Political and constitutional development 1935-1947, Jinnah's 14 points and its significance, Two nations theory, Ideology of Pakistan, Aims and objectives of the establishments of Pakistan, Early difficulties after the creation of Pakistan, Islamization in Pakistan. Geography, Foreign Policy, Productions sectors, and culture of Pakistan: Geography of Pakistan, Pakistan and Muslim world, Determinants foreign policy, objectives of Pakistan's foreign policy, Industrial sector of Pakistan, Agricultural sector of Pakistan, Pakistan and international organizations, Pakistan and regional organizations, Pakistan's relations with neighbor countries education in Pakistan, Features of Pakistan's culture, Iqbal's poetry, Few selected verses of Iqbal.

Books to be followed

Text Books:

1. Pakistan Studies by *Qureshi Books*.
2. Pakistan Studies by *Dogger Books*.
3. Pakistan Studies by M. Ikram Rabbani, Latest Edition, *Published by Caravan*.
4. Pakistan Studies by M. D. Zafar, Latest Edition, *Published by Published by Aziz Book*.
5. Pakistan Studies by Dr. Muhammad Sarwar, Latest Edition, *Published by Ilmi Books*.

Reference Books:

1. Ideological Orientation of Pakistan, Sharif-Al-Mujahid,ed., Published by *National Book Foundation*.
2. Muslim Struggle for Independence from Sir Syed Ahmad Khan to Quaid-I-Azam Muhammad Ali Jinnah, 1857-1947, Dr. S. Qalb-I-Abid.
3. The Making of Pakistan, K. K. Aziz *Published in London*.
4. The Making of Pakistan, by Richard Symmonds, *Published in London*.
5. Pakistan: A Modern History, by Ian Talbot
6. Constitutional and Political History of Pakistan, by Hamid Khan.

HUM 1102: English Comprehension
Cr. Hrs. 2

Course Objective

1. Learn comprehension skills and related rules of grammar.
2. Learn the comprehension skills by their active use.

Main Theme / Topics

Contextual Use of Tenses: Introduction via reading, speaking, writing & listening activities; Introduction to main idea of a paragraph via reading activities; Writing and reading aloud (during contextual use of tenses, students will write and read aloud); short videos in English (for a discussion). Introduction of tense combinations in speaking and writing: Introduction to inference of a paragraph via reading activities; paragraph writing (brainstorming, making a topic sentence making, organizing supporting details and using conjunctions for links and flow); reading aloud the class write ups; movie screening (discussion on a movie). Use of conditionals: speed reading (skimming and scanning of information). Writing: a visit to a reading bookshop with class discussion. Types of questions; novel reading (quizzes based on inferential questions); Email writing: request emails and thanks emails. Use of modals.

Regular class activities: Individual work. Pair work. Group Discussions (only in English). Role play. Debate. PowerPoint presentations.

Books to be followed

1. Novel: 'The Secret Seven Win Through' by Enid Blyton.
   Harper Collins Publishers (2013).
2. 'Understanding and Using English Grammar' by Betty Schrampfer Azar
   Pearson Education ESL; 5th edition (2016).
3. Online Resources: Google & Youtube.

HUM 1202: Communication Skills
Cr. Hrs. 2

Course Objective

1. Learn basic rules of grammar related to formal communication.
2. Develop the related skills by their active use.

Main Theme / Topics
Reading blogs and commenting on them: summary writing; movie screening; expressing opinions on blog topics. Novel reading (inferential question quizzes): Movie Review Writing; Ted Talk and discussion; PowerPoint presentation. Resume Writing.

Regular class activities: Individual work. Pair work. Group discussions (only in English). Reading aloud. Debate. Short video screening for discussion. A movie screening: ROOM.

Books to be followed

1. Novel: "Five Had a Wonderful Time" (The Famous Five Series) by Enid Blyton.
   Publisher: Hodder and Stoughton (1997).

2. "How English Works?" by Swan and Walter.
   Publisher: Oxford University Press (1997).

3. "Focus on Writing" by Ragina L Smalley, Mary K Reutten, Joann Rishel Kozyrev.
   Available at Anees Book Corner, Main Market, Gulberg, Lahore.

4. Online Resources: Google & Youtube.

HUM 4801: Philosophy of Science
Cr. 2

Course Objective

Learn different philosophical terms and views related to the nature of science.

Main Theme / Topics

The Platonic theory of universals and the revolt against it: realism and nominalism; ontology and logic. Scientific Empiricism: Observation; Inductive reasoning; refutability; facts and theories; positivism; epistemology. Constrained Relativism: Contingency (freeness) of singular facts in scientific theories. Claimed origins of knowledge free with respect to science: chance, environment and free will. Paradigms, trust and revolutions in science. Experience and extended empiricism: the difference between unscientific (against science) and non-scientific (other than science). Conditions for the possibility of science: limited realism, the correspondence principle, objectivity and other moral values.

Books to be followed:

1. What is This Thing Called Science? by Chalmers, *A. F, UQP* (2012).
2. The Logic of Scientific Discovery by Popper, K., *Routledge* (2002).
3. The Structure of Scientific Revolutions by Kuhn, T. S., *The University of Chicago Press, Chicago* (1970).
4. The Quark and the Jaguar: Adventures in the Simple and the Complex by Mann, M., *W. H. Freeman* (1994).
5. The Marriage of Sense and Soul Integrating Science and Religion by Wilber, K., *Random House, New York* (1998).
6. Helgoland, making sense of the quantum revolution, by Carlo Rovelli, translated by E. Segre and S. Carnell, *Riverhead Books, New York* (2021).

7. COURSES FROM OTHER AREAS OF SCIENCE

CHEM 2301: Chemistry
Cr. 3

Course Objective

1. To learn basics of rules that govern the chemical reactions.
2. To study basic application related to environment and Earth atmosphere.

Main Theme / Topics

Classification of Matter and its properties: Pure substance, elements, compound, and mixtures; Physical and chemical changes, separation of mixtures. Atom, Molecules and Ions: Atomic structure, electron configuration and periodic table, molecules, and molecular compounds, Ions and ionic compounds, organic and inorganics compounds. Chemical reactions and reaction stoichiometry: Chemical equations and their balancing, combination and decomposition reactions, combustion reactions, empirical formula from analyses, reactions in aqueous solutions.
Thermochemistry: Chemical energy, Enthalpy of reactions, calorimetry, Hess's law. Basic concepts of chemical bonding: Lewis symbols, octet rule, Ionic bonding, covalent bonding, bond polarity and electronegativity, resonance structures. Chemistry of environment: Earth atmosphere, Entropy changes in chemical reactions, Gibbs free energy, Free energy and temperature.

Books to be followed:

1. Chemistry: the central science, by T. E. Brown et. al. Pearson, (2017)
2. Chemistry, by S. S. Zumdahl and S. A. Zumdahl, Cengage, (2017)
3. Chemistry: structure and properties, by N. J. Tro, Pearson, (2017)

BIO 2401: Biology
Cr. 2

Course Objective

1. To learn the biology of cells.
2. To learn the theory of evolution and its applications.

Main Theme / Topics

The Cellular foundation of life: Themes and concepts of biology; Chemistry of biology; The building blocks of molecules, biological molecules, the cell structure and functions; Comparing of Prokaryotic and Eukaryotic cells, The cell membrane, Passive transport and active transport; Metabolism of cells, cellular respiration, photosynthesis. The Cell division and Genetics: Reproduction at Cellular level, The Genome, The Cell cycle, Prokaryotic cell division; The cellular basis of inheritance, sexual reproduction, Meiosis, Patterns of inheritance; Mendel's experiments, law of inheritance. Molecular Biology: The structure of DNA, DNA replication; How genes are regulated; Cloning and genetic engineering, Biotechnology in medicine and agriculture, Genomics and Proteomics. Evolution of diversity of life: Mechanism of evolutions; Evidence of evolution; Speciation; Common misconception about Evolution; Organizing life on earth, Diversity of microbes, fungi, and Protists; Diversity of animals and plants.

Books to be followed:

1. Biology, by Neil A. Compbell, Jane B. Reece, *Pearson* (2016)
2. Biology: The Core, by Eric J. Simon, *Pearson* (2016)
3. Concepts of Biology, by Samantha Fowler, Rebecca Roush, James Wise, *OpenStax* (2013)