File Ref.No.Ac.C1/Faculty of Science/2021

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

(Abstract)

Faculty of Science- Integrated M.Sc for Physics, Mathematics and Statistics - Outcome Based Syllabus (OBE) - Approved - Orders issued.

ACADEMIC C SECTION

No.CUSAT/AC(C).C1/3925/2021 Dated,KOCHI-22,04.11.2021

Read:-Item No.I (k) of the minutes of the meeting of the Academic Council held on 28.07.2021.

ORDER

The Academic Council at its meeting held on 28.07.2021, vide minutes item read above, considered along with the recommendation of the Standing Committee, the minutes of the online meeting of the Board of Studies in Physical and Mathematical Sciences and resolved to approve the Curriculum/Outcome Based Syllabus (OBE) of the Integrated M.Sc for Physics, Mathematics and Statistics, with effect from 2021 admission as in Appendices 1, 2 and 3 respectively.

Orders are issued accordingly.

Dr. Meera V *
Registrar

To:

1. Dr.K Girish Kumar, Dean of Faculty of Science & Professor, Department of Applied Chemistry, CUSAT, Kochi-22.
2. Dr. Titus K Mathew, Chairman, Board of Studies in Physical and Mathematical Sciences & Professor, Department of Physics, CUSAT, Kochi-22.
3. The Head, Department of Physics, CUSAT, Kochi-22.
4. The Head, Department of Mathematics, CUSAT, Kochi-22.
5. The Head, Department of Statistics, CUSAT, Kochi-22.
6. PS to V.C/PS to PVC/PA to Registrar.
7. The Controller of Examinations/ The Director, Academic Admissions/ JR (Exams)/ DR (Exams/Academic Admissions).
8. Exam B/D/E/P/Y sections/ Academic A/C sections.
9. Day File/Stock File/File Copy.

* This is a computer generated document. Hence no signature is required.

DEPARTMENT OF MATHEMATICS

Scheme of Examination and Syllabus for the
Five Year Integrated M.Sc. Mathematics Program
Approved by the Board of Studies in Physical and Mathematical Sciences
on 17/07/2021

(From 2021 admission onwards)

Cochin University of Science and Technology
Cochin – 682 022

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MAM 21-803-0201:Linear Algebra and Group Theory

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MAM 21-803-0302: Mathematical Methods I

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MAM 21-803-0501:Analysis I
MAM 21-803-0502: Linear Algebra and Geometry in R^n
MAM 21-803-0503: Algebra: Groups and Rings
MAM 21-803-0504: Introduction to Complex Analysis

Semester VI

MAM 21-803-0601: Analysis II
MAM 21-803-0602: Ordinary and Partial Differential Equations
MAM 21-803-0603: Complex Analysis and Number Theory

Semester VI - Electives

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MAM 21-803-0705: Linear Programming
MAM 21-803-0606: Elements of Applied Mathematics
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MAM 21-803-0609: Fuzzy Mathematics

Semester VII

MAM 21-803-0701: Linear Algebra
MAM 21-803-0702: Real Analysis
MAM 21-803-0703: Measurer and Integration
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MAM 21-803-0705: Computational Mathematics Laboratory

Semester VIII

MAM 21-803-0801: Fields and Modules
MAM 21-803-0802: Functional Analysis
MAM 21-803-0803: Complex Analysis
MAM 21-803-0804: Topology I
MAM 21-803-0805: Functions of Several Variables and Geometry

Semester IX

MAM 21-803-0901: Operator Theory
MAM 21-803-0902: Topology II
MAM 21-803-0903: Ordinary Differential Equations & Integral Equations
MAM 21-803-0904: Probability Theory

Semester X

MAM 21-803-1001: Partial Differential Equations & Variational Problems

LIST OF ELECTIVE COURSES

MAM 21-803-0905 : Topics in Applied Mathematics (Inter-departmental elective)
MAM 21-803-1002 : Wavelets
MAM 21-803-1003 : Optimization & Mathematical Methods For Deep Learning
MAM 21-803-1004 : Commutative Algebra
MAM 21-803-1005 : Graph Theory
MAM 21-803-1006 : Advanced Linear Algebra
MAM 21-803-1007 : Discrete Framelets
MAM 21-803-1008 : Harmonic Analysis
MAM 21-803-1009 : Integral Transforms
MAM 21-803-1010 : Functions Of Several Variables
MAM 21-803-1011 : Advanced Spectral Theory
MAM 21-803-1012 : Banach Algebras And Spectral Theory
MAM 21-803-1013 : Number Theory
MAM 21-803-1014 : Representation Theory Of Finite Groups
MAM 21-803-1015 : Algebraic Topology
MAM 21-803-1016 : Differential Geometry

Scheme

Semester–I

Course Code	Name	C/E	Marks Distribution			
			Cont.eval.	End semester	Total	Credit
ENG10101	English-I	C	50	50	100	2
MAL10101	Malayalam-I*	C	50	50	100	2
HIN10101	Hindi-I *	C	50	50	100	2
FLG10101	German - I*	C	50	50	100	2
PHY10101	Mechanics	C	50	50	100	3
CHE10101	Atomic Structure and Chemical Bonding	C	50	50	100	3
MAM 21-803-0101	Calculus-I	C	50	50	100	4
BIO10101	General	C	50	50	100	3
PHY10102	Biology	C	100	–	100	2
CHE10102	Physics Lab-I(Mechanics)	C	100	–	100	2
BIO10102	Inorganic Quantitative Analysis Lab General Biology Lab	C	100	–	100	2
	Total		600	300	900	23

* Either Malayalam-I or Hindi-I or Foreign Language-I is to be opted.

Semester–II

Course Code	Name	C/E	Marks Distribution			
			Cont.eval.	End semester	Total	Credit
ENG 10201	English-II	C	50	50	100	2
MAL10201	Malayalam-II*	C	50	50	100	2
HIN10201	Hindi-II *	C	50	50	100	2
FLG10201	German - II*	C	50	50	100	2
PHY10201	Waves & Optics	C	50	50	100	3
CHE10201	Periodicity, Nuclear Chemistry, Acid Base Chemistry and Metallurgy	C	50	50	100	3
MAM21-803-0201	Linear Algebra and Group Theory	C	50	50	100	4
BIO10201	Biochemistry Physics	C	50	50	100	3
PHY10202	Lab-II(Waves and Optics)	C	100	–	100	2
CHE10202	Inorganic Qualitative Analysis Lab	C	100	–	100	2
BIO10202	Biochemistry Lab	C	100	–	100	2
	Total		600	300	900	23

* Either Malayalam-II or Hindi-II or Foreign Language-II is to be opted.

Semester–III

Course Code	Name	C/E	Marks Distribution			
			Cont.eval.	End semester	Total	Credit
PHY10301	Electricity and Magnetism-I	C	50	50	100	3
CHE10301	Introductory Organic Chemistry	C	50	50	100	3
MAM 21-803-0301	Calculus-II	C	50	50	100	4
MAM 21-803-0302	Mathematical Methods-I	C	50	50	100	4
BIO10301	Cell Biology	C	50	50	100	3
EVS10301	Environmental Science	C	50	50	100	2
PHY10302	Physics Lab-(Electricity and Magnetism)	C	100	–	100	2
CHE10302	Organic Qualitative Analysis Lab	C	100	–	100	2
BIO10302	Cell Biology Lab	C	100	–	100	2
	Total		600	300	900	25

Semester–IV

Course Code	Name	C/E	Marks Distribution			
			Cont.eval.	End semester	Total	Credit
PHY10401	Quantum Physics and Relativity	C	50	50	100	3
CHE10401	Introductory Physical Chemistry	C	50	50	100	3
MAM 21-803-0401	Mathematical Methods-II	C	50	50	100	4
STA10401	Probability and Statistics	C	50	50	100	3
BIO10401	Molecular Biology and Genetics	C	50	50	100	3
COM10401	Basic Computer Science	C	50	50	100	2
PHY10402	Physics Lab-IV (Modern Physics)	C	100	–	100	2
CHE10402	Physical Chemistry Lab	C	100	–	100	2
BIO10402	Molecular Biology and Genetics Lab	C	100	–	100	2
	Total		600	300	900	24

Semester–V

Course Code	Name	C/E	Marks Distribution			
			Cont.eval.	End semester	Total	Credit
MAM 21-803-0501	Analysis I	C	50	50	100	4
MAM 21-803-0502	Linear Algebra & Geometry in R^n	C	50	50	100	4
MAM 21-803-0503	Algebra: Groups and Rings	C	50	50	100	4
MAM 21-803-0504	Introduction to Complex Analysis	C	50	50	100	4
STA10501	Statistics and Probability II	C	50	50	100	4
	Total		250	250	500	20

Semester–VI

Course Code	Name	C/E	Marks Distribution			
			Cont.eval.	End semester	Total	Credit
MAM 21-803-0601	Analysis II	C	50	50	100	4
MAM 21-803-0602	ODE and PDE	C	50	50	100	4
MAM 21-803-0603	Complex Analysis & Number Theory	C	50	50	100	4
MAM****	Elective I	E	50	50	100	4
MAM****	Elective II	E	50	50	100	4
	Total		250	250	500	20

Course Structure of MSc Mathematics 2021 admissions onwards

Semester VII

Course Code	Name of the Course	Credits
MAM 21-803-0701	Linear Algebra	4
MAM 21-803-0702	Real Analysis	4
MAM 21-803-0703	Measure and Integration	4
MAM 21-803-0704	Groups and Rings	4
MAM 21-803-0705	Computational Mathematical Laboratory	4
	VIVA VOCE	
Total Credits		20

Semester VIII

Course Code	Name of the Course	Credits
MAM 21-803-0801	Fields and Modules	4
MAM 21-803-0802	Functional Analysis	4
MAM 21-803-0803	Complex Analysis	4
MAM 21-803-0804	Topology I	4
MAM 21-803-0805	Functions of Several variables & Geometry	4
	VIVA VOCE	
Total Credits		20

Semester IX

Course Code	Name of the Course	Credits
MAM 21-803-0901	Operator Theory	4
MAM 21-803-0902	Topology II	4
MAM 21-803-0903	Ordinary Differential Equations & Integral Equations	4
MAM 21-803-0904	Probability Theory	4
MAM*****	Elective I	3
	VIVA VOCE	
Total Credits		19

SEMESTER X

Course Code	Name of the Course	Credits
MAM 21-803-1001	Partial Differential Equations & Variational Calculus	4
MAM*****	Elective II	4
MAM*****	Elective III	4
MAM*****	Elective IV	4
MAM*****	Elective V	4
	VIVA VOCE	1
	*Project (Optional)	8*
Total Minimum Credits		21

*Project is optional to the students. The students opt for project shall start the work immediately after the eighth semester. The project is equivalent to two Electives in the fourth semester.

LIST OF ELECTIVE COURSES

(1) MAM 21-803-0905 : TOPICS IN APPLIED MATHEMATICS (Inter-departmental elective)
(2) MAM 21-803-1002 : WAVELETS
(3) MAM 21-803-1003 : OPTIMIZATION & MATHEMATICAL METHODS FOR DEEP LEARNING
(4) MAM 21-803-1004 : COMMUTATIVE ALGEBRA
(5) MAM 21-803-1005 : GRAPH THEORY
(6) MAM 21-803-1006 : ADVANCED LINEAR ALGEBRA
(7) MAM 21-803-1007 : DISCRETE FRAMELETS
(8) MAM 21-803-1008 : HARMONIC ANALYSIS
(9) MAM 21-803-1009 : INTEGRAL TRANSFORMS
(10) MAM 21-803-1010 : FUNCTIONS OF SEVERAL VARIABLES
(11) MAM 21-803-1011 : ADVANCED SPECTRAL THEORY
(12) MAM 21-803-1012 : BANACH ALGEBRAS AND SPECTRAL THEORY
(13) MAM 21-803-1013 : NUMBER THEORY
(14) MAM 21-803-1014 : REPRESENTATION THEORY OF FINITE GROUPS
(15) MAM 21-803-1015 : ALGEBRAIC TOPOLOGY
(16) MAM 21-803-1016 : DIFFERENTIAL GEOMETRY

5 Year Integrated M.Sc. Program in Science
Mathematics Course Syllabus
(First 6 Semesters)
Admission from 2021 Batch Onwards

Semester I: Calculus I

Course Code: MAM 21-803-0101
Course is to be taught in: I Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 hours

Objective: This course introduces the basic concepts from calculus that are required both in the applied and pure branches of science.

Outcome: After completing the course, the student is expected to become familiar with the fundamental concepts and applications of calculus.

Prerequisites : Set theory, Operations on sets, functions, The set of natural numbers, Set of integers, Set of rational numbers, Set of real numbers and the set of Complex numbers.

Text books:

1. George B. Thomas and Ross L. Finney: *Calculus and Analytic Geometry*. Pearson Education India; 9th edition, (2010).

References:

1. Anton, Bivens and Davis, John: *Calculus single variable* 10th edition, Wiley and sons, Inc. (2012).
2. Tom M. Apostol: *Calculus, Vol I* (Second Edition), Wiley Student Edition, (2006).
3. N. Piskunov, M.I.R. Publisher, *Differential and Integral Calculus*, (Vol: I), (1977).
4. A Course in Calculus and Real Analysis, Ghorpade Sudhir, Limaye Balmohan V., Springer International Edition, (2006).

Syllabus

Module 1: Real Numbers and the Real Line, Coordinates, Lines, and Increments, Functions, Shifting Graphs, Trigonometric Functions, Rates of Change and Limits, Rules for Finding Limits, Target Values and Formal Definitions of Limits, Extensions of the Limit Concept, Continuity and Tangent Lines. (Sections: Preliminaries 1, 2, 3, 4, 5 and 1.1, 1.2, 1.3, 1.4, 1.5 and 1.6 of Text book 1).

Module 2: The Derivative of a Function, Differentiation Rules, Derivatives of Trigonometric Functions, The Chain Rule. Extreme Values of Functions, The Mean Value Theorem, The First Derivative Test for Local Extreme Values and Graphing with y' and y''. (Sections 2.1, 2.2, 2.4, 2.5, 3.1, 3.2, 3.3 and 3.4 of Text book 1).

Module 3: Indefinite Integrals, Differential Equations, Integration by Substitution-Running the Chain Rule Backward, Riemann Sums and Definite Integrals, Properties, Area, and the Mean Value Theorem, The Fundamental Theorem and Substitution in Definite Integrals. (Section 4.1, 4.2, 4.3, 4.5, 4.6, 4.7 and 4.8 of Text book 1).

Module 4: Areas Between Curves, Finding Volumes by Slicing, Lengths of Plane Curves, L Hopital's Rule, Limits of Sequences of Numbers and Theorems for Calculating Limits of Sequences. (Sections: 5.1, 5.2, 5.5, 6.6, 8.1 and 8.2 of Text book 1).

Module 5: Infinite series, The integral test for series of non negative terms, Comparison tests for series of non negative terms, Ratio and root test for series of non negative terms, Alternating Series, Absolute and Conditional Convergence. (Sections 8.3, 8.4, 8.5, 8.6 and 8.7 of text book 1).

Semester II: Linear Algebra and Group Theory

Course Code: MAM 21-803-0201
Course is to be taught in: II Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 hours

Objective: This course introduces the basic concepts from linear algebra and Group Theory that are required both in the applied and pure branches of science.

Outcome: After completing the course, the student is expected to become familiar with the fundamental concepts and applications of linear algebra and Group Theory .

Text books:

1 Ron Larson: *Elementary linear algebra*, 8e, Cengage Learning, 2016.

2 Joseph A. Gallian: *Contemporary Abstract Algebra*, Nineth Edition, Cengage Learning, 2017.

Reference books:

1 S. Kumaresan: *Linear Algebra: A Geometric Approach*, PHI Learning, 2009.

2 Sheldon Axler: *Linear Algebra Done Right*, 3rd edition. Undergraduate Texts in Mathematics, Springer, Cham, 2015.

3 Howard Anton and Chris Rorres: *Elementary Linear Algebra* with Supplemental Applications, 11th Edition, John Wiley, 2015.

4 Michael Artin: *Algebra*, Prentice Hall, Inc., Englewood Cliffs, NJ, 1991.

5 Gilbert Strang: *Introduction to Linear Algebra*, 4th Edition, Wellesley Cambridge Press; 2009.

6 John B. Fraleigh: *A First Course in Abstract Algebra*, 7th Edition, Pearson Education, 2006.

Syllabus

Module 1: Introduction to Systems of linear equations, Gaussian elimination and Gauss Jordan Elimination, Applications of systems of Linear Equations, Matrices: Operations with Matrices, Properties of Matrix operations, Inverse of a Matrix, Elementary Matrices, More Applications of Matrix operations. (Chapters 1, 2 of Text book 1).

Module 2: Determinants: Determinants and Elementary operations, properties of Determinants, Applications of Determinants, Vector spaces, Subspaces of Vector Spaces, Spanning Sets and Linear Independence, Basis and Dimension, Rank of a Matrix and Systems of Linear Equations, Coordinates and Change of basis, Applications of Vector Spaces. (Chapters 3, 4 of Text book 1).

Module 3: Length and Dot Product in $\mathbb{R}^n$, Inner Product Spaces, Introduction to Linear Transformations, The Kernel and Range of a Linear Transformation, Matrices for Linear Transformations, Eigenvalues and Eigenvectors, Diagonalization. (Sections 5.1, 5.2, 6.1, 6.2, 6.3, 7.1, 7.2 of Text book 1).

Module 4: Introduction to groups, Definitions and examples of groups, Elementary properties of groups, Subgroups, Examples of subgroups, Cyclic groups, Classification of subgroups of cyclic groups. (Chapters 1,2,3,4 of Text book 2).

Module 5. Permutation groups, Isomorphisms, Cayley's theorem, Properties of isomorphisms, automorphisms, Cosets, Lagrange's theorem and consequences, Application of cosets to permutation groups, Rotation group of a cube. (Chapters 5,6,7 of Text book 2).

Semester III: Calculus II

Course Code: MAM 21-803-0301
Course is to be taught in: III Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 hours

Objective: This course introduces the concepts of calculus of functions of more than one variable and the calculus on vector valued functions, which are essential in all branches of science.

Outcome: After completing the course, the student is expected to become familiar with the rules of partial differentiation, its applications calculus of vector valued functions and its applications.

Prerequisites: Basic theory, formulas and techniques of differential and integral calculus of one variable, Algebra of three dimensional vectors

Text books:

1. George B. Thomas and Ross L. Finney: *Calculus and Analytic Geometry*. Pearson Education India; 9th edition, (2010).

Reference books:

1. A course in Multivariable Calculus and Analysis, Ghorpade, Sudhir. R, Limaye, Balmohan V, Springer, (2010).
2. Advanced Engineering Mathematics, Erwin Kreyszig, 8th Edition. John Wiley and Sons, Inc., New York, (1999).
3. Calculus, Vol II (Second Edition), Tom M. Apostol, Wiley Student Edition, (1967).
4. Vector Calculus, P.C.Mathews, Springer, (2005).

Syllabus

Module 1. Polar coordinates, Cylindrical and Spherical coordinates, Vector valued functions and space curves, Arc length and the unit tangent vector, Curvature, torsion and the TNB frame. (Sections 9.6, 10.7, 11.1, 11.3 and 11.4 of the text book 1).

Module 2. Functions of several variables, Limits and continuity, Partial derivatives, Differentiability, Linearizion and Differentials, The chain rule, Partial derivatives with constrained variables, Directional derivatives, Gradient and tangent planes. (Sections 12.1, 12.2, 12.3, 12.4, 12.5, 12.6 and 12.7 of the text book 1).

Module 3. Extreme values and saddle points, Lagrange multipliers, Taylor's formula, Double integrals, Areas, Double integral in polar form, Triple integrals in Rectangular coordinates, Masses, moments in three dimension. (Sections 12.8, 12.9, 12.10, 13.1, 13.2, 13.3, 13.4 and 13.5 of the text book).

Module 4. Triple integral in cylindrical and spherical coordinates, Substitution in Multiple integrals, Line integral, Vector fields, work, circulation and flux, Path independence, Potential functions and conservative fields. (Sections 13.6, 13.7, 14.1, 14.2 and 14.3 of the text book 1).

Module 5. Green's theorem in the plane, Surface area Surface integral, parametrized surface, Stoke's theorem and Divergence theorem. (Sections 14.4, 14.5, 14.6, 14.7 and 14.8 of the text book 1).

Semester III: Mathematical Methods I

Course Code: MAM 21-803-0302
Course is to be taught in: III Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 hours

Objective: This course introduces basic Complex analysis and Differential equations techniques which are important tools in all branches of science.

Outcome: After completing the course, the student is expected to become familiar with basic Complex analysis and Differential equations techniques.

Prerequisites: Basic theory, formulas and techniques of differential and integral calculus of one variable.

Text book:

1. Advanced Engineering Mathematics, Erwin Kreyszig, 8th Edition. John Wiley and Sons, Inc., New York, (1999).

Reference books:

1. Calculus, Vol I (Second Edition), Tom M. Apostol, Wiley Student Edition, (2006).
2. Calculus and Analytic Geometry (Ninth Edition), George.B.Thomas and Ross.L.Finney, Pearson Education, Inc, (2006)
3. Complex variables and Applications (5th Edition) , J. W. Brown, R.V. Churchill, McGrawHill Higher Education, (1990).
4. Complex Analysis (3rd edition), L.V. Ahlfors, McGrawHill Book Company, (1979).

Syllabus

Module 1: Basic concepts and ideas, Geometric meaning, Exact equations, Linear differential equations, Applications Homogeneous Linear differential equations of second order.(Chapter 1, Section 2.1 of the Text book).

Module 2: Homogeneous Linear differential equations of second order with constant coefficients, Euler Cauchy equations, Existence and uniqueness theory, Wronskian, Non homogeneous equations, Solutions by undetermined coefficients and by variation of parameters. (Sections 2.2-2.3, Sections 2.6-2.10 of Text book).

Module 3. Complex Numbers, Polar form, Analytic Function, Cauchy-Riemann Equations, Elementary Functions, logarithm. (Section 12.1-12.4, 12.6-12.8 of the Text Book).

Module 4. Complex Integration, Cauchy's Integral Theorem and Integral Formula (without proof), Higher Derivatives (without proof). (Section 13.1-13.4 of the Text Book).

Module 5. Power Series, Power series representation of Analytic functions,Taylor series and Maclaurin series, Practical methods for power series. Laurent Series (without proof), Singularities and Zeros, Residue integration Method, Evaluation of Real Integrals. (Section 14.2-14.5, 15.1-15.4 of the Text Book).

Semester IV: Mathematical Methods II

Course Code: MAM 21-803-0401
Course is to be taught in: IV Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours 72 hours

Objective: This course introduces Laplace Transform and Fourier series which are important tools in all branches of science. Also, Numerical Methods in General, Numerical Methods in Linear Algebra and Numerical Methods for Differential Equations are introduced.

Outcome: After completing the course, the student is expected to become familiar with Laplace Transform and Fourier series and their applications to various branches. It is also expected that the student will get basic ideas about numerical methods.

Prerequisites: Basic theory, formulas and techniques of differential and integral calculus of one variable.

Text book:

1. Advanced Engineering Mathematics, Erwin Kreyszig, 8th Edition. John Wiley and Sons, Inc., New York, (1999).

Reference books:

1. Calculus, Vol I (Second Edition), Tom M. Apostol, Wiley Student Edition, (2006).
2. Calculus and Analytic Geometry (Ninth Edition), George.B.Thomas and Ross.L.Finney, Pearson Education, Inc, (2006)
3. Complex variables and Applications (5th Edition) , J. W. Brown, R.V. Churchill, McGrawHill Higher Education, (1990).
4. Complex Analysis (3rd edition), L.V. Ahlfors, McGrawHill Book Company, (1979).

Syllabus

Module 1. Laplace Transform, Transforms of Derivatives and integrals, Second Shifting theorem. Periodic functions, Fourier Series, Functions of any period, Half-Range Expansion. (Section 5.1-5.3, 10.1-10.2, 10.3-10.5 of the Text Book).

Module 2. Fourier Series (Contd.): Complex Fourier Series, Forced Oscillations, Fourier Transform. (Section 10.6-10.10 of the Text Book).

Module 3. Introduction, Solution of Equations by Iteration, Interpolation, Spline Interpolation, Numeric Integration and Differentiation, Linear Systems: Gauss Elimination (Tutorials: using sage,scilab). (Section 17.1-17.5 of the Text Book).

Module 4. Linear Systems: LU-Factorization, Matrix Inversion, Linear Systems: Solution by Iteration (Tutorials: using sage,scilab). (Section 18.1-18.3 of the Text Book).

Module 5. Matrix Eigenvalue Problems: Introduction Inclusion of Matrix Eigenvalues, Eigenvalues by Iteration(Power Method), Methods for First-Order Ordinary Differential Equations (Tutorials: using sage,scilab). (Section 18.6-18.8, 19.1 of the Text Book).

Semester V: Analysis I

Course Code: MAM 21-803-0501
Course is to be taught in: V Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 hours

Objective: This course aims to provide the fundamentals of mathematical analysis such as axiomati introduction to the real number system, convergence of sequences and series, notion of continuous functions on metric spaces motivated from the real number system.

Outcome: Creative skills to better understand abstract concepts, skill to construct proofs.
Text book:

1 R.G. Bartle and D.N. Sherbert, *Introduction to Real Analysis*, Thired Edition, John Wiley & Sons (2000).

Reference books:

1 G.B folland : *A Guide to Advanced Real Analysis* Mathematical Association of America Publishing.
2 Elias M. Stein, Rami Shakarchi: *REAL ANALYSIS Measure Theory, Integration, and Hilbert Spaces* Princeton University press.
3 Kenneth A. Ross *Elementary Analysis The Theory of Calculus* Springer-Verlag, New York, 2013.
4 Andrew M. Bruckner, Judith B. Bruckner, Brian S. Thomson *Real analysis* Prentice-Hall, 2001.
5 Sterling K. Berberian *Fundamentals of Real Analysis* Springer-Verlag, New York 1999.
6 Walter Rudin: *Principles of Mathematical Analysis*, third edition, McGrawHill Publishing (1964).

Syllabus

Module 1. Sets and Functions, Mathematicle Induction, Finte and Infinite Sets, The Algebraic and Order Properties of $\mathbb{R}$, Absolute Value and Real Line and The completeness Property of $\mathbb{R}$. (Sections 1.1, 1.2, 1.3, 2.1, 2.2 and 2.3 of Text book 1).

Module 2. Applications of the Supremum Property, Intervals, Open and Closed Sets in $\mathbb{R}$, Compact Sets, Continuous Functions and Metric Spaces. (Sections 2.4, 2.5, 11.1, 11.2, 11.3 and 11.4 of Text book 1).

Module 3. Sequences and Their Limits, Limit Theorems, Monotone Sequences, Subsequences and the Bolzano-Weierstrass Theorem, The Cauchy Criterion and Properly Divergent Sequences. (Sections 3.1, 3.2, 3.3, 3.4, 3.5, 3.6 of Text book 1).

Module 4. Introduction to Series, Limits of Functions, Limits Theorems and Some Extensions of Limit Concept. (Sections 3.7, 4.1, 4.2 and 4.3 of Text book 1).

Module 5. Continuous Functions, Combinations of Continuous Functions, Continuous Functions on Intervals, Uniform Continuity, Continuity and Gauges, Monotone and Inverse functions. (Sections 5.1, 5.2, 5.3, 5.4, 5.5 and 5.6 of Text book 1).

Semester V : Linear Algebra and Geometry in $\mathbb{R}^n$

Course Code: MAM 21-803-0502
Course is to be taught in: V Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 hours

Objective: This course is a continuation of the course on vector spaces with major focus on concepts in geometry in $\mathbb{R}^n$. Multi-variable differentiation in $\mathbb{R}^n$ is a major foundation course in geometry. In the last two modules basic topics on curves and surfaces are introduced.

Outcome: After completing the course, the student is expected to become familiar with the fundamental concepts and applications of linear algebra and geometry

Prerequisites Set theory, Operations on sets, functions, The set of natural numbers, Set of integers, Set of rational numbers, Set of real numbers and the set of Complex numbers. A basic course in Analysis that includes differentiation in single variable.
Text books:

1 S. Kumaresan, *Linear Algebra: A Geometric Approach*, PHI Learning, 2009.
2 Terrence Tao, *Analysis II*, Hindustan Book Agency, Third Edition, Reprint 2017.
3 Theodore Shifrin: *Differential Geometry: A first course in curves and surfaces*, 2016.

Reference books:

1 Andrew Pressley: *Elementary Differential Geometry*, Springer, 2000.
2 Sheldon Axler, *Linear Algebra Done Right*, 3rd edition. Undergraduate Texts in Mathematics,
3 Michael Artin, *Algebra*, Prentice Hall, Inc., Englewood Cliffs, NJ, 1991.
4 Michael Spivak, *Calculus on Manifolds: A mordern approach to classical theorems of advanced calculus*
5 Manfredo Do Carmo, *Differential Geometry of curves and surfaces*

Syllabus

Module 1. Inner Product Spaces, Orthogonality, Some Geometric Applications, Orthogonal Projection Onto A Line, Orthonormal Basis. (Chapter 5, Sections 5.1, 5.2, 5.3, 5.4, 5.5 of Textbook 1)

Module 2. Orthogonal Complements and Projections, Linear Functionals and Hyperplanes, Orthogonal Transformations, Reflections and Orthogonal Maps of the Plane. (Chapter 5, Sections 5.6, 5.7, 5.8, 5.9 of Textbook 1)

Module 3. Linear Transformations, Derivatives in several variable calculus, Partial and Directional Derivatives, The several variable calculus chain rule. (Chapter 6, Sections 6.1, 6.2, 6.3, 6.4 of Textbook 2)

Module 4. Curves, Examples, Arclength Parametrization, Local Theory: Frenet Frame. (Chapter 1, section 1,2 of Text book 3).

Module 5. Some Global Results, Surfaces:Local Theory, Parametrized Surfaces and the First Fundamental Form. (Chapter 1, section 3, Chapter 2, section 1 of Text book 3).

Semester V: Algebra: Groups and Rings

Course Code: MAM 21-803-0503
Course is to be taught in: V Semester Integrated M. Sc.

Number of credits:4

Total No. of Hours: 72 hours

Objective: Since groups are of great importance for the whole of mathematics, there is a highly developed theory of outstanding beauty. It takes just three simple axioms to define a group, and it is fascinating how much can be deduced from so little. The course is devoted to some of the basic concepts and results of Group Theory. This course aims to introduce students to some more sophisticated concepts and results of group theory as an essential part of general mathematical culture and as a basis for further study of more advanced mathematics.

Outcome: On successful completion of this course students will have acquired

- a sound understanding of the classification of finitely generated abelian groups.
- knowledge of some fundamental results and techniques from the theory of finite groups.
- an understanding of the symmetries in the Euclidean plane.

Prerequisites Set theory and numbers, the concept of groups, subgroups and various examples as given in an earlier semester
Text books:

1 John B. Fraleigh: *A First Course in Abstract Algebra*, 7th Edition, Pearson Education, 2006.

2 Michael Artin: *Algebra*, Prentice-Hall India, New Delhi, 1994.

Reference books:

1 Thomas.W.Hungerford: *Algebra* , Springer, 1974.
2 I S Luther and I B S Passi: *Algebra Vol I*, Narosa Publishing House, 2013.
3 I S Luther and I B S Passi: *Algebra Vol II*, Narosa Publishing House, 2012.
4 Joseph A. Gallian: *Contemporary Abstract Algebra*, Nineth Edition, Cengage Learning, 2017.
5 M.A. Amstrong: *Groups and Symmetry*, Springer, 1988.
6 I.N.Herstein: *Topics in Algebra*, 2nd Edition, John Wiley & Sons,
7 N. S. Gopalakrishnan: *University Algebra*, 2nd Edition), New Age International, 1986.

Syllabus

Module 1. Review of group theory: Groups, Subgroups, Cyclic groups, Generating sets. (Section 4,5,6,7 of of Text Book 1). Groups of Permutations, Orbits, Cycles, Alternating Groups, Cosets and Theorem of Lagrange. (Section 8,9,10 of Text Book 1).

Module 2. Direct Products and Finitely Generated Abelian Groups, Homomorphisms, Factor Groups, Factor-Group Computations and Simple Groups (Section 11,13,14,15 of Text Book 1).

Module 3. Symmetry: Symmetry of plane figures, The group of motions of the Plane, Finite group of motions (Section 5.1, Section 5.2, and Section 5.3 of Text Book 2).

Module 4. Introduction to Rings and Fields,Integral Domains, Fermat's and Euler theorems, The field of quotients of an integral domain. (Section 18, 19, 20, 21 of Text Book 1).

Module 5. Rings of Polynomials, Factorization of polynomials over a field, Homomorphisms and factor rings, Prime and Maximal ideals. (Section 22, 23, 26, 27 of Text Book 1).

Semester V: Introduction to Complex Analysis

Course Code: MAM 21-803-0504
Course is to be taught in: V Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 hours

Objective: This course introduces the concepts and results from complex variable theory that are required for further study of advanced mathematics.

Outcome: After completing the course, students will be equipped with the understanding of the fundamental concepts of complex variable theory and its application

Prerequisites Basic familiarity with formulas and techniques of differential and integral calculus
Text books:

1 J. W. Brown and R. V. Churchill, Complex Variables and Applications (8th Edition), Mcgraw-Hill,(2009).

Reference books:

1 L. V. Ahlfors, Complex Analysis, Mcgraw-Hill, 1980.
2 J. B. Conway, Functions of One Complex Variable (2nd Edition), Springer-Verlag, 1978.
3 R. Greene and S. G. Krantz, Function Theory of One Complex Variable, 3rd Edition, GSM, Vol. 40, AMS, 2006
4 T. W. Gamelin, Complex Analysis, Springer-Verlag, 2001.

Syllabus

Module 1. Review of Complex numbers Chapter - I, Functions of Complex Variable, Mappings, Mappings by the Exponential Function, Limits, Theorems of Limits, Limits Involving the Point at Infinity, Continuity, Derivatives and Differentiation Formulas. (Sections 12, 13, 14, 15, 16, 17, 18, 19, and 20 of the Text book 1).

Module 2. Cauchy-Riemann Equations, Sufficient Conditions for Differentiability, Polar Coordinates, Analytic Functions, Examples and Harmonic Functions. (Sections 21, 22, 23, 24, 25, and 26 of the text book 1).

Module 3. The Exponential Function, The Logarithmic Function, Branches and Derivatives of Logarithms, Some Identities Involving Logarithms, Complex Exponents, Trigonometric Functions Hyperbolic Functions, Inverse Trigonometric and Hyperbolic Functions. (Sections 29, 30, 31, 32, 33, 34, 35, and 36. of the text book 1).

Module 4. Derivatives of Functions w(t), Definite Integrals of Functions w(t), Contours, Contour Integrals, Some Examples. Upper Bounds for Moduli of Contour Integrals, Antiderivatives and Cauchy–Goursat Theorem. (Sections 37, 38, 39, 40, 41 43, 44, and 46 of the text book 1).

Module 5. Cauchy Integral Formula, An Extension of the Cauchy Integral Formula, Some Consequences of the Extension, Liouville's Theorem and the Fundamental Theorem of Algebra, Maximum Modulus Principle. Convergence of Sequences, Convergence of Series, Taylor Series, Examples, Laurent Series, and Examples. (Sections 50, 51, 52, 53 and 54 55, 56, 57, 59, 60 and 62 of the text book 1).

Semester VI: Analysis II

Course Code: MAM 21-803-0601
Course is to be taught in: VI Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 hours

Objective: This course aims to provide the fundamentals of mathematical analysis: notion of differentiability, The Riemann Integral, sequences and series of functions, uniformconvergence, and the interchange of limit operations and an invitation to the calculus of several real variables.

Outcome: After the completion of this course, student should be aware of doing calculus on the real line, capable of understanding the calculus on the n-dimensional Euclidean space and the integration
Text book:

1 R.G. Bartle and D.N. Sherbert, *Introduction to Real Analysis*, Thired Edition, John Wiley & Sons (2000).

Reference books:

1 G.B folland : *A Guide to Advanced Real Analysis* Mathematical Association of America Publishing.
2 Elias M. Stein, Rami Shakarchi: *REAL ANALYSIS Measure Theory, Integration, and Hilbert Spaces* Princeton University press.
3 Kenneth A. Ross *Elementary Analysis The Theory of Calculus* Springer-Verlag, New York, 2013.
4 Andrew M. Bruckner, Judith B. Bruckner, Brian S. Thomson *Real analysis* Prentice-Hall, 2001.
5 Sterling K. Berberian *Fundamentals of Real Analysis* Springer-Verlag, New York 1999.
6 Walter Rudin: *Principles of Mathematical Analysis*, third edition, McGrawHill Publishing (1964).

Syllabus

Module 1. The Derivatie, The Mean Value Theorem , L'Hospital Rules and Taylors Theorem. (Sections 6.1, 6.2, 6.3 and 6.4 of Text book 1).

Module 2. The Riemann Integral, Riemann Integrable Functions, The Fundamental Theorem and Approximate Integration. (Sections 7.1, 7.2, 7.3 and 7.4 of Text book 1).

Module 3. Pointwise and Uniform Convergence, Interchange of Limits, The Exponential and Logarithmic Functions and Trigonometric Functions. (Sections 8.1, 8.2, 8.3 and 8.4 of Text book 1).

Module 4. Absolute Convergence, Test for Absolute Convergence, Test for Nonabsolute Convergence and Series of Functions. (Sections 9.1, 9.2, 9.3 and 9.4 of Text book 1).

Module 5. Definition and main properties of Generalized Riemann Integral, Improper and Lebesuge Integrals, Infinite Intervals. (Sections 10.1, 10.2 and 10.3 of Text book 1).

Semester VI: Ordinary and Partial Differential Equations

Course Code: MAM 21-803-0602
Course is to be taught in: VI Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 hours

Objective: This course introduces the developments of ordinary and partial differential equations.

Outcome: After completing the course, the student is expected to become familiar with the fundamental concepts and applications of ordinary and partial differential equations

Prerequisites Basic Calculus and linear algebra.
Text books:

1 George F. Simmons, Differential Equations with Applications and Historical Notes, Tata McGraw-Hill Second Editon 2003.
2 Walter A. Strauss, Partial Differential Equations an Introduction, John Wiley, 1992.

Reference books:

1 S. L Ross, Differential Equations, Wiley.
2 W.E Boyce and R. C. DiPrima, Elementary Differential equations and Boundary Value Problems, John Wiley & Sons, 2001.
2 E. A. Coddington, An Introduction to Ordinary Differential Equations, Dover, 1989.

Syllabus

Module 1. Oscillations and the Sturm Separation Theorem, The Sturm Comparison Theorem, Series solutions of First order equations. (Chapter 4 and sections 25, 26 of chapter 5 (Text book 1)).

Module 2. Legendre Polynomials, Properties of Legendre Polynomials, Bessel functions. The Gamma Function, Properties of Bessel functions. (Chapter 6 of text book 1).

Module 3. The method of Successive Approximations, Picard's Theorem, Systems. (Chapter 11 of text book 1).

Module 4. What Is a Partial Differential Equation?, First-Order Linear Equations, Flows, Vibrations, and Diffusions, Initial and Boundary Conditions, Well-Posed Problems. (Sections 1.1, 1.2, 1.3, 1.4 and 1.5 of text book 2).

Module 5. The Wave Equation, Causality and Energy, The Diffusion Equation, Diffusion on the Whole Line, Comparison of Waves and Diffusions. (Sections 2.1, 2.2, 2.3, 2.4 and 2.5 of text book 2).

Semester VI: Complex Analysis and Number Theory

Course Code: MAM 21-803-0603
Course is to be taught in: VI Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 hours

Objective: This course introduces the concepts and results from complex variable theory and Number theory that are required for further study of advanced mathematics. Number theory is one of the oldest and most mysterious parts of mathematics. This course will give an introduction to the area of Number Theory.

Outcome: After completing the course, students will be equipped with the understanding of the fundamental concepts of complex variable theory, Number theory and its application.

Prerequisites: Basic familiarity with formulas, techniques of differential and integral calculus, Natural Numbers and Integers.

Text books:

1 J. W. Brown and R. V. Churchill, Complex Variables and Applications (8th Edition), Mcgraw-Hill,(2009).

2 G. A. Jones and J. M. Jones, Elementary Number Theory, Springer-Verlag (1998).

Reference books:

1 L. V. Ahlfors, Complex Analysis, Mcgraw-Hill, 1980.

2 J. B. Conway, Functions of One Complex Variable (2nd Edition), Springer-Verlag, 1978.

3 R. Greene and S. G. Krantz, Function Theory of One Complex Variable, 3rd Edition, GSM, Vol. 40, AMS, 2006.

4 T. W. Gamelin, Complex Analysis, Springer-Verlag, 2001.

5 Ivan Niven, Herbert S. Zuckerman, and Huge L. Montgomery: An Introduction to the Theory of Numbers, 5th Edition., John Wiley & Sons, Inc., New York, (1991).

Syllabus

Module 1. Absolute and Uniform Convergence of Power Series, Continuity of Sums of Power Series, Integration and Differentiation of Power Series, Uniqueness of Series Representations, Multiplication and Division of Power Series, Isolated Singular Points and Residues (Sections 63, 64, 65, 66, 67, 68 and 69 of Text book 1).

Module 2. Cauchy's Residue Theorem, Residue at Infinity, The Three Types of Isolated Singular Points, Residues at Poles, Examples, Zeros of Analytic Functions, Zeros and Poles, Behavior of Functions Near Isolated Singular Points. (Sections: 71, 72, 73, 74, 75, 76 and 77 of Text book 1).

Module 3. Evaluation of Improper Integrals, Example, Improper Integrals from Fourier Analysis, Jordan's Lemma, Indented Paths, An Indentation Around a Branch Point, Integration Along a Branch

Cut, Definite Integrals Involving Sines and Cosines, Argument Principle, Rouche's Theorem, Inverse Laplace Transforms and Examples. (Sections: 78, 79, 80, 81, 82, 83, 84, 85, 86, 87 and 88 of Text book 1).

Module 4. Divisors, Bezout's identity, Least common multiples, Linear Diophantine equations, Prime Numbers, Prime numbers and prime-power factorisations, Distribution of primes, Fermat and Mersenne primes, Primality-testing and factorisation. (Chapter 1 and 2 of Text book 2).

Module 5. Modular arithmetic, Linear congruences, Simultaneous linear congruences, Simultaneous non-linear congruences, An extension of the Chinese Remainder Theorem. (Chapter 3 of Text book 2).

Semester VI: Discrete Mathematics (Elective - I)

Course Code: MAM 21-803-0604
Course is to be taught in: VI Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 hours

Objective: This course gives a thorough introduction to Discrete Mathematics with rigorous mathematics and serves as the basis for further studies in this area.

Outcome: After completing the course, the student will achieve a basic foundation in Discrete Mathematics.

Text books:

1. John Clark Derek Allen Holton - A first look at graph theory, Allied Publishers, 1991.
2. Seymour Lipschutz - Discrete Mathematics, Tata McGraw Hill, 1997.

Module 1: Introduction to Graph Theory
Graph Theory. An introduction to graph. Definition of a Graph, More definitions, Vertex Degrees, Sub graphs, Paths and cycles, the matrix representation of graphs.
Text 1: Chapter 1 (Sections 1.1, 1.3 to 1.7)

Module 2: Trees and connectivity
Trees. Definitions and Simple properties, Bridges, Spanning trees. Cut vertices and Connectivity. Euler's Tours, the Chinese postman problem. Hamiltonian graphs and the travelling salesman problem.
Text 1: Chapter 2 (Sections 2.1, 2.2, 2.3, 2.6); Chapter 3 (Sections 3.1 (algorithm deleted), 3.2 (algorithm deleted), 3.3, and 3.4 (algorithm deleted))

Module 3: Counting
Counting, Basic counting principles, Permutations, Combinations, Pigeon-hole principle, Inclusion-exclusion principle, Ordered-unordered partitions.
Text 2: Chapter 6 (Sections 6.1-6.8)

Module 4: Language, Grammars and Machine - Lattices and Ordered Sets
Languages, Grammars, Machines languages, Regular languages, Finite state automata, Finite state machines, ordered sets, Lattices distributive lattices.
Text 2: Chapters 13 and 14 (Sections 13.1-13.7; 14.1-14.11)

Module 5: Boolean Algebra
Boolean algebra, Representation theorem, Minimal boolean expressions, Logic gates, boolean functions.
Text 2: Chapter 15 (Sections 15.1-15.11)

Semester VI: Linear Programming (Elective - II)

Course Code: MAM 21-803-0605
Course is to be taught in: VI Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 hours

Objective: Linear Programming is perhaps the most recognized and widely used optimization tool in the world today. It has its origins in planning and operations models from World War II through the seminal work of George Dantzig and his development of the simplex method. In this course, the student will learn how to model real world problems as linear programs, and will learn various methods to solve them.

Learning Outcomes: After the completion of this course, the student should be able to:
1. Solve LP problems geometrically and more effectively using Simplex algorithm.
2. Understand duality theory, a theory that establishes relationships between linear programming problems of maximization and minimization.
3. Solve transportation and assignment.
4. Determine the shortest path, critical path and maximal flow in a network.

Pre-Requisite : Elementary Linear Algebra and basic Calculus.

Text books:

1. K.V. Mital; C. Mohan: Optimization methods in operations, Research and systems analysis (3rd Edn.), New age international (P) Ltd., 1996.

References:-

(1) A. Ravindran, D.T. Philips and J.J. Solberg: Operations Research-Principles and Practices (2nd Edn.); John Wiley & Sons, 2000
(2) G. Hadley: Linear Programming; Addison-Wesley Pub Co Reading, 1975.
(3) Hamdy A. Taha: Operations Research-An Introduction, Prentice Hall of India, 2000.
(4) H.S. Kasana and K.D. Kumar: Introductory Operations Research-Theory and Applications, Springer-Verlag, 2003.
(5) James K. Strayer: Linear Programming and Its Applications,Under graduate Texts in Mathematics Springer (1989), Springer-Verlag, 2003.
(6) R. Panneerselvam: Operations Research, PHI, New Delhi (Fifth printing), 2004.

Module 1: Mathematical Preliminaries
Euclidean Space, Linear Algebraic functions, Convex Sets. (Chapter 1 (1.1-1.19) of the text).

Module 2: : Linear Programming
Introduction – Degeneracy. (Chapter 3 (3.1-3.14) of the text).

Module 3: Linear Programming (continued)
Simplex multipliers – Dual simplex method. (Chapter 3 (3.15-3.20) of the text).

Module 4:
Transportation and Assignment problems. (Chapter 4 (4.1 – 4.15) of the text).

Module 5:
Flow and potential in networks. (Chapter 5 (5.1 – 5.9) of the text).

Semester VI: Elements of Applied Mathematics (Elective - III)

Course Code: MAM 21-803-0606
Course is to be taught in: VI Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 hours

Objective: This course starts with the structure of $\mathbb{C}^n$ and it is planned to introduce the Discrete Fourier Transformation in a Linear algebraic perpsective. Towards the end Differece calculus and solution of Linear and Non Linear difference equations will be discussed.

Learning Outcomes: After the completion of this course, the student should be able to be familiar with the necessary tools in applied mathematics in a signal processing perspective.

Pre-Requisite : Review of sections $1.1, 1.2, 1.3$ of the text 1.

Text Book:

(1) Michael W. Frazier, An Introduction to Wavelets Through Linear Algebra, Springer-Verlag New York, (1999).
(2) Walter G. Kelley & Allan C. Peterson Difference Equations An Introduction with Applications, Second Edition, Academic Press 2001.

References:-

(1) Stephane Mallat, *A Wavelet Tour Of Signal Processing*, Academic Press (1999).
(2) Don Hong, Jianzhong Wang, Robert Gardner, *Real Analysis with an Introduction to Wavelets*, Elsevier Academic Press (2005).
(3) Ronald. E.Mickens, Difference Equations: Theory, Applications and Advanced Topics, Third Edition, Chapman and Hall, 2015.

UNIT 1: Diagonalization of Linear Transformations and Matrices, Inner products, Orthonormal Bases and Unitary Matrices. (Chapter 1, Sections 1.5, 1.6 of the text 1.)

UNIT 2: The Discrete Fourier Transform, Translation-Invariant Linear Transformations (Chapter 2, Sections 2.1, 2.2 of the text 1.)

UNIT 3: The Fast Fourier Transform, Introduction, The Difference Operator, Summation, Generating Functions and Approximate summation. (Section 2.3 of text 1, Chapters 1, 2 of the text 2.)

UNIT 4: Linear Difference Equations, First Order Equations, General Results for Linear Equations, Solving Linear Equations, Applications. (Chapter 3, Sections 3.1, 3.2, 3.3, 3.4 of the text 2.)

UNIT 5: Equations with Variable Coefficients, Nonlinear Equations That Can Be Linearized, The z-Transform. (Chapter 3 sections 3.5, 3.6, 3.7 of text 1.)

Semester VI: Introduction to Optimization Techniques (Elective - IV)

Course Code: MAM 21-803-0607
Course is to be taught in: VI Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 hours

Objective: The objective of this course is to introduce different classes of optimization problems following some classical methods to solve them. Starting with methods to solve Linear Programming problem, different direct and indirect methods to solve Non-linear Programming problems are also discussed in this course. This course also includes solution methods for constrained and unconstrained optimization problems.

Learning Outcomes: After the completion of this course, the student should be able to
1. Classify optimization problems based on objective function, constraints.
2. Use the knowledge of different optimization methods to solve an optimization problem efficiently.

Pre-Requisite : Calculus and Linear Algebra.

Text books:

1. "Engineering Optimization: Theory and Practice" by Singiresu S. Rao (Fourth Edition).

References:-

(1) "Optimization for Engineering Design Algorithms and Examples" by Kalyanmoy Deb.

Module 1: Introduction to Optimization
Introduction, Statement of an Optimization Problem, Classification of Optimization Problems. (Sec 1.1,1.4,1.5).

Module 2: : Classical Optimization Techniques
Single-Variable Optimization, Multivariable Optimization with No Constraints, Multivariable Optimization with Equality Constraints, Multivariable Optimization with Inequality Constraints, Convex Programming Problem. (Sec 2.1-2.6).

Module 3: Linear Programming
Standard Form of a Linear Programming Problem, Simplex Algorithm, Duality in Linear Programming, Transportation Problem, Karmarkar's Interior Method, Quadratic Programming. (Sec 3.3, 3.8, 3.9, 4.3, 4.6, 4.7, 4.8).

Module 4: Nonlinear Programming: Unconstrained Optimization Techniques
Random Search Methods, Grid Search Method, Univariate Method, Pattern Directions, Powell's

Method, Steepest Descent (Cauchy) Method, Conjugate Gradient (Fletcher–Reeves) Method, Newton's Method, Marquardt Method, Quasi-Newton Methods, DFP Method, BFGS Method. (Sec 6.2-6.6, 6.8-6.15).

Module 5: Nonlinear Programming: Constrained Optimization Techniques
Random Search Methods, Complex Method, Sequential Linear Programming, Basic Approach in the Methods of Feasible Directions, Zoutendijk's Method of Feasible Directions, Rosen's Gradient Projection Method, Sequential Quadratic Programming, Penalty Function Method, Convex Programming. Problem. (Sec 7.9-7.8, 7.10-7.15).

Semester VI : Metric Topology (Elective - V)

Course Code: MAM 21-803-0608
Course is to be taught in: VI Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 hours

Objective: The aim is to give a very streamlined development of a course in metric space topology emphasizing only the most useful concepts, concrete spaces and geometric ideas. To encourage the geometric thinking. In this course there are large number of examples which allow us to draw pictures and develop our intuition and draw conclusions, generate ideas for proofs. To this end, this course boasts of a lot of pictures. A secondary aim is to treat this as a preparatory ground for a general topology course and arm the reader with a repertory of examples.

Outcome: After completing the course, the student is expected to become familiar with metric topology, so that it will become easy for the students to learn general topology course in forthcoming semesters.

Prerequisites: Introductory course in real analysis.
Text books:

1 S. Kumaresan, *Topology of Metric Spaces*, Alpha Science International Ltd, 2005.

Reference books:

1 G.B. Folland : *A Guide to Advanced Real Analysis* Mathematical Association of America Publishing.
2 Andrew M. Bruckner, Judith B. Bruckner, Brian S. Thomson *Real analysis* Prentice-Hall, 2001.
3 Sterling K. Berberian *Fundamentals of Real Analysis* Springer-Verlag, New York 1999.
4 Walter Rudin: *Principles of Mathematical Analysis*, third edition, McGrawHill Publishing (1964).

Syllabus

Module 1: Review of Definition and Examples of Open Balls and Open Sets, Convergent Sequences, Limit and Cluster Points, Cauchy Sequences and Completeness, Bounded Sets, Dense Sets, Basis and Boundary of a Set. (Chapter 2 of Text book 1).

Module 2: Continuous Functions, Equivalent Definitions of Continuity, Topological Property, Uniform Continuity, Limit of a Function, Open and closed maps. (Chapter 3 of Text book 1).

Module 3: Compact Spaces and their Properties, Continuous Functions on Compact Spaces, Characterization of Compact Metric Spaces and Arzela-Ascoli Theorem. (Chapter 4 of Text book 1).

Module 4: Connected Spaces, Path Connected spaces. (Chapter 5 of Text book 1).

Module 5: Examples of Complete Metric Spaces, Completion of a Metric Space, Baire Category Theorem and Banach's Contraction Principle. (Chapter 6 of Text book 1).

Semester VI : Fuzzy Mathematics (Elective - VI)

Course Code: MAM 21-803-0609
Course is to be taught in: VI Semester Integrated M. Sc.

Number of credits: 4

Total No. of Hours: 72 hours

Objective: This course gives a thorough introduction to Fuzzy Mathematics with an extension to how crisp concepts can be fuzzified through introducing the concept of Fuzzy Graphs.

Outcome: The student will achieve a basic foundation in Fuzzy Mathematics which is one of the best tools to create mathematical models, as real life examples are more fuzzy in nature than being crisp.

Text books:

1 George J. Klir and BoYuan, Fuzzy Sets and Fuzzy Logic Theory and Applications, Prentice Hall of India Private Limited New Delhi, 2000.
2 Sunil Mathew, John N Mordeson, Davender S Malik, Fuzzy Graph Theory, Springer, 2018.

Reference books:

1 Klir, G. J and T. Folger, Fuzzy Sets, Uncertainty and Information, Prentice Hall of India Private Limited New Delhi, 1988.
2 H.J Zimmermann, Fuzzy Set Theory- and its Applications, Allied Publishers, 1996.
3 Dubois, D and H. Prade , Fuzzy Sets and System: Theory and Applications, Academic Press, New York, 1988.
4 Abraham Kandel, Fuzzy Mathematical Techniques with Applications, Addison Wesley Publishing Company 1986.

Syllabus

Module 1: Crisp sets to Fuzzy sets
Introduction , Crisp Sets: An Overview ,Fuzzy Sets: Basic Types ,Fuzzy Sets: Basic concepts. Additional properties ofalpha cuts, Representation of fuzzy sets.
(Chapter 1: 1.1, 1.2, 1.3 and 1.4 and Chapter 2: 2.1 , 2.2 of Text 1).

Module 2: Operations on Fuzzy Sets
Types of Operations, Fuzzy complements, Fuzzy intersections: t-norms, Fuzzy Union, t-conorms, Combinations of operations.
(Theorems 3.7, 3.8,3.11,3.13, 3.16 and 3.18 statement only)
(Chapter 3: 3.1, 3.2, 3.3, 3.4, 3.5 of Text 1).

Module 3: Fuzzy Arithmetic
Compact Fuzzy numbers, Arithmetic operations on Intervals, Arithmetic operations on Fuzzy numbers. (Exclude the proof of Theorem 4.2), Fuzzy equations.
(Chapter 4: 4.1, 4.3, 4.4 and 4.6 of Text 1).

Module 4: Fuzzy Logic
Classical Logic: An Overview, Multivalued Logics, Fuzzy propositions, Fuzzy quantifiers, Linguistic Hedges, Inference from Conditional Fuzzy propositions.
(Chapter 8: 8.1, 8.2, 8.3, 8.4, 8.5 and 8.6 only of Text 1).

Module 5: Fuzzy Graphs
Fuzzy Graphs: Definitions and Basic Properties, Connectivity in Fuzzy Graphs, Forests and Trees, Fuzzy Cut Sets.
(Chapter 2: 2.1, 2.2, 2.3, 2.4 of Text 2).

5 Year Integrated M.Sc. Program in Science
Mathematics Course Syllabus
(Last 4 Semesters)
Admission from 2021 Batch Onwards

Syllabus for MSC 2021 Admissions Onwards
MAM 21-803-0701 LINEAR ALGEBRA

Credits: 4

Total No. of Hours: 72

Objective: This course starts with the notion of vector spaces. Finite-dimensional vector spaces and maps between them preserving the structure are objects of study. The dual of a vector space also forms a major part of the study, especially with the study of the adjoint map. Studying the important multi-linear maps, like the Determinant map, form an important part of the course. Finally, the important primary decompositions of the vector space concerning a linear transformation is studied. This also helps to understand the extra symmetry in the representation of the matrices.
Learning Outcomes: After the completion of this course, the student should be able to

(1) have a clear understanding of vector spaces, linear transformations, coordinates and the representation of transformation by matrices.
(2) have a knowledge of the dual space of a vector space and importantly we also introduce the notion of the adjoint of a linear map which acts between the dual spaces.
(3) understand the important generalization of the notion of linear maps to more than one variable. In particular the multi-linear Determinant map and its important properties are studied in details.
(4) achieve ideas on the advanced topics like annihilating polynomials, simultaneous triangulation and diagonalization and direct sum decomposition.
(5) have knowledge on primary decompositions associated with subspaces or with respect to a given operator.

UNIT 1: Review of system of linear equations and their solution set, Vector spaces, Subspaces, Bases and dimensions, Coordinates, Summary of row equivalence, Linear Transformations, The Algebra of Linear transformations, Isomorphism, Representation of Transformations by matrices.
UNIT 2: Linear functionals, The double Dual, The Transpose of a Linear Transformation, Inner product spaces, Linear functionals and Adjoints. (Sections 3.1, 3.2, 3.3 and Sections 8.1, 8.2, 8.3 from Hoffman and Kunze)
UNIT 3: Bilinear forms, Symmetric forms: Orthogonality, The geometry associated to a positive form, Hermitian forms (Chapter 7 Sections 1, 2, 3, 4 from Artin), Determinants-Commutative rings, Determinant functions, Permutations and the Uniqueness of determinants. (Sections 5.1, 5.2, 5.3 from Hoffman and Kunze)
UNIT 4: Characteristic Values, Annihilating polynomials, Invariant subspaces, Simultaneous Triangulation, Simultaneous Diagonalization, Direct-Sum Decompositions, Invariant Direct Sums, The Primary Decomposition Theorem. (Chapter 6 of Hoffman and Kunze)
UNIT 5: The Rational and Jordan Forms- Cyclic Subspaces and Annihilators, Cyclic Decompositions and the Rational Form, The Jordan Form. (Sections 7.1, 7.2, 7.3 from Hoffman and Kunze)
Text Books:

(1) Kenneth Hoffman and Ray Kunze *Linear Algebra*, Second Edition, PHI (1975).
(2) M. Artin, Algebra, Prentice-Hall, (1991)

References:-

(1) M. Artin, *Algebra*, Prentice-Hall, (1991).
(2) Serge Lang, *Introduction to Linear Algebra*, Second Editon, Springer (1997).
(3) K.T Leung, *Linear Algebra and Geometry*, Hong Kong University Press, (1974).
(4) S.Kumaresan, *Linear Algebra: A Geometric Approach*, Fist Edition PHI Learning (2009).
(5) Sheldon Axler, *Linear Algebra Done Right*, Second Edition, Springer, (1997).
(6) Richard Kaye and Robert Wilson, *Linear Algebra*, Oxford University Press, (1998).

Syllabus for MSC 2021 Admissions Onwards

MAM 21-803-0702 REAL ANALYSIS

Credits: 4

Total No. of Hours: 72

Objective: This course starts with the structure of Real Numbers. This course is planned to introduce the notions Metric Spaces, Continuity, Uniform continuity, Differentiation, Riemann-Steiltjes integration, Fundamental theorem of Calculus, Convergence of sequence of functions, Uniform convergence, Stone-Weierstrass Theorem and Power series.

Learning Outcomes: This course is planned to build up calculus and other important notions on the set of real numbers. After the completion of this course, the student should able to be familiar with Metric Spaces, Continuity, Uniform continuity, Differentiation, Riemann-Steiltjes integration, Fundamental theorem of Calculus, Convergence of sequence of functions, Uniform convergence, Stone-Weierstrass Theorem and Power series.

UNIT 1: Metric Spaces; Definition and examples, open and closed sets in metric space, compactness, Connectedness, Continuity, Uniform continuity, discontinuity.(Chapter 2 and 4)

UNIT 2: Derivative: Derivatives and continuity, L' Hospital Rules, Mean-Value theorem, Derivatives of vector-valued functions.(Chapter 5)

UNIT 3: The Riemann-Steiltjes integrals, Fundamental theorem of Calculus, Differentiation under integral signs, integration under vector valued function, rectifiable curves. (Chapter 6)

UNIT 4: Sequences and series of functions: Uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation. (Chapter 7, sections upto 7.18)

UNIT 5: Equicontinuous families of functions, Stone-Weierstrass Theorem, Power series. (Chapter 7; sections upto 7.18-7.33, Chapter 8; sections up to 8.5)

Text Book: Walter Rudin, Principles of Mathematical analysis, 3rd edition, McGraw-Hill Higher Education (1976).

References:-

(1) Terence Tao, Analysis I and II, Third Edition, Springer 2016.
(2) N.L Carothers, Real Analysis, Wiley 2000.
(3) Halsey L. Royden, Real Analysis, Prentice Hall, Upper Saddle River, NJ, (1988).
(4) Tom M. Apostol, Mathematical Analysis, Addison-Wesley, Reading, MA, (1974).
(5) A. K. Sharma, Real Analysis, Discovery publishing house Pvt. Lts., New Delhi, (2008).
(6) D Somasundaram and B. Choudhary, A first course in mathematical analysis, Narosa, Oxford, London,(1996).
(7) S Kumaresan, Topology of Metric Space, Alpha Science international Ltd, Harrow, UK, (2005)
(8) K. A. Ross, Elementary Analysis; Theory of Calculus, Springer-Verlag,(2013).

Syllabus for MSC 2021 Admissions Onwards
MAM 21-803-0703 MEASURE AND INTEGRATION

Credits: 4

Total No. of Hours: 72

Objective: One of the objectives of measure theory is to make platform for developing tools for a new method of integration of functions that are not Riemann integrable. Apart from studying the Lebesgue measure and integration, this course introduces the concept of general measure spaces and the integration in this setting also.

Learning Outcomes: After the completion of this course, the student should be able to

(1) be familiar with Lebesgue measure, General measure spaces.
(2) be familiar with the new tools of integration of measurable functions.

Pre-requisites: Familiarity with complex numbers and basic calculus, Geometric ideas of school level.

UNIT 1: The Axiom of Choice, Zorn's Lemma, Lebesgue Outer measure, Measurable sets and Lebesgue measure, Non measurable sets (Chapter 2 and relevant sections of Preliminaries of the text)

UNIT 2: Lebesgue measurable functions: Litlewood's Three Principles, The Riemann Integral, The Lebesgue Integral (Chapters 3 and 4 of the text, upto section 4.3)

UNIT 3: The General Lebesgue Integral, Continuity of Integration, Convergence in Measure, Characterizations of Riemann and Lebesgue integrability, Differentiation of monotone functions, Lebesgue's theorem, Functions of bounded variations: Jordan's Theorem (avoid proofs of Vitali Covering lemma and Lebesgue's theorem). (Section 4.4-4.5, 5.2-5.3 and 6.1-6.3 of the text)

UNIT 4: Differentiation of an integral, Absolute continuity, Convex Functions, The L^p spaces, Minkowski and Hölder inequalities, (Section 6.4-6.6 and 7.1-7.2 of the text)

UNIT 5: Completeness of L^p spaces, Approximation and Separability, The Riesz Representation for the Dual of L^p spaces (Section 7.3-7.4 and 8.1 of the text)

Text Book: H L Royden, P. M. Fitzpatrick, Real Analysis, Fourth Edition (2009), PHI

References:-

(1) I K Rana, An Introduction to Measure and Integration, Narosa Publishing Company.
(2) P R Halmos, Measure Theory, GTM , Springer Verlag.
(3) T.W. Gamelin, Complex Analysis, Springer.
(4) R.G. Bartle, The elements of Integration (1966) John Wiley & Sons, Delhi,(2006)
(5) K B. Athreya and S N Lahiri:,Measure theory, Hindustan Book Agency, New Delhi.
(6) Thamban Nair, Measure and Integration: A First Course, CRC Press, 2019.
(7) Terence Tao: An Introduction to Measure Theory,Graduate Studies in Mathematics,Vol 126 AMS.
(8) S. Kesavan Measure and Integration, Hindustan Book Agency, Springer (TRIM 77).

Syllabus for MSC 2021 Admissions Onwards

MAM 21-803-0704 - GROUPS AND RINGS

Credits: 4

Total No. of Hours: 72

Objective: This course starts with the basic algebraic structure Group, and studies various aspects of groups. It also covers another mathematical structure Rings and various types of rings.
Learning Outcomes: After the completion of this course, the student should be able to

(1) have a working knowledge of the concepts such as definition of a group, order of a finite group and order of an element.
(2) have a clear understanding of different types of subgroups such as normal subgroups, cyclic subgroups, and understand the structure of the structure of these subgroups
(3) will be able to understand the mathematical concepts such as permutation groups, factor groups, group homomorphisms etc.
(4) will have knowledge on advanced topics such as Sylow's theorem and should be able to apply this result.
(5) will be able to understand other mathematical structures such as rings and various classes of rings, their sub structures ideals, and their homomorphisms.

UNIT 1: Introduction to Groups: Basic Axioms and Examples, Dihedral Groups, Symmetric Groups, Matrix Groups, The Quaternion Group, Homomorphisms and Isomorphisms, Subgroups: Definitions and Examples, Centralizers and Normalizers, Stabilizers and Kernels, Cyclic groups, Groups generated by subsets of a Group.
UNIT 2: Quotient Groups and Homomorphisms: Quotient Groups, homomorphisms, Langange's Theorem, The Isomorphism Theorems, Composition Series and Holder Program, Transpositions and Alternating Group
UNIT 3: Group Actions: Group actions and permutation representations, Cayley's Theorem, Orbits, Counting Lemma, Class Equation, Automorphisms, Sylow Theorems, Simplicity of A_n.
UNIT 4: Rings : Definition, Examples, Rings of Continuous Functions, Matrix Rings, Polynomial Rings, Power series rings, Laurent Rings, Boolean Rings, Direct Products, Several Variables, Characteristic of a ring.
Ideals: Definitions, Maximal ideals, generators, basic properties of ideals, algebra of ideals, quotient rings, ideals in quotient rings, local rings.
UNIT 5: Homomorphisms of rings: Definitions and basic properties, fundamental theorems, endomorphism rings, field of fractions, prime fields.
Factorisation in domains: Division in domains, Euclidean domain, Principal ideal domains, factorisation domains, Unique factorisation domains, Eisenstein's criterion.

Text Books:

(1) Abstract Algebra - D.S. Dummit and R.M. Foote, 3rd Edition, Publisher: Wiley.
(2) Rings and Modules - C. Musili, Second revised edition, Narosa Publishing House.

References:-

(1) A First Course in Abstract Algebra - J.B. Fraleigh, 7th Edition, Publisher - Pearson
(2) Algebra - M. Artin, Second Edition, Publisher - Pearson
(3) Contemporary Abstract Algebra - J. A. Gallian, 4th Edition, Publisher - Narosa
(4) Topics in Algebra - I.N. Herstein, Second Edition, Publisher - Wiley Student Edition.

Syllabus for MSC 2021 Admissions Onwards

MAM 21-803-0705 COMPUTATIONAL MATHEMATICAL LABORATORY

Credits: 4

Total No. of Hours: 72

Objective: This course starts with the review of Numerical methods for differentiation and integration, and simple models of Partial differential equations. This course is planned to introduce the basics of mathematical documention setting using LaTeX. Introduction of programming using Python for solving Mathematical problems arising in various fields, that are covered in the Msc curriculum.

Learning Outcomes: After the completion of this course, the student should be able to Be familiar with the skill to prepare mathematical documnets in LaTeX and python programming techniques which are focused to be applied in mathematical problems.

UNIT 1: Introduction to LaTeX Documentation setting, Standard document classes, Bibtex, standard environments, Macros, Table of contents, Bibliography styles, tables, Pstricks, Multiline math displays (Texts 1, 2)

UNIT 2: Introduction to programming with Python, Fundamentals, Data types, Functions, Pointers and string handling, Class, File handling, Programming Excercises from Linear Algebra, Number Theory, Numerical Approximations, Differential Equations. (Texts 3, 4, 5 , 6)

UNIT 3: Matplotlib, Numpy, and Scipy Exercises. (Texts 7, 3)

UNIT 4: Introduction to SageMath, Symbolic Calculus, Linear Algebra using SageMath, SageTex Package, Graphics, Combinatorics, Graph Theory (Text 8).

UNIT 5: Coding Theory using SageMath, Standard Rings and Fields (Text 8)

References:-

(1) George *Grätzer*, *Math into LaTeX an Introduction to LaTeX and AMS-LaTeX*, Birkhauser Boston, (1996).

(2) Donald. E. Knuth, *Computers & Type setting*, Addison-Wesley, (1986).

(3) Hans Petter Langtangen, *A Primer on Scientific Programming with Python*, Third Edition, Springer (2012).

(4) John M. Zelle, *Python Programming: An Introduction to Computer Science*, (2002).

(5) Steven Lott, *Functional Python Programming*, Packt Publishing Ltd, (2015).

(6) Jody. S. Ginther Start here: Python programming made simple for the Beginner.

(7) John Hunter, Darren Dale, Eric Firing, Michael Droettboom, *Matplotlib Release 1.4.3*.

(8) William Stein, *SAGE Reference Manual Release 2007.10.29*.

NB: A Lab Report type-setted in LaTeX by the student has to be submitted at the end of the semester.

Syllabus for MSC 2021 Admissions Onwards
MAM 21-803-0801 FIELDS AND MODULES

Credits: 4

Total No. of Hours: 72

Objective: This course starts with the advanced topics in Group theory. It also covers other mathematical structures Modules and Fields.

Learning Outcomes: After the completion of this course, the student should be able to

(1) have a working knowledge of the advanced concepts of group theory such as direct products, semi-direct products.
(2) should be able to classify the groups of small orders using the advanced concepts such as semi-direct products and direct products.
(3) understand the concept of algebraic structures called modules and recognize various types of modules.
(4) use the terminology and concepts of Field theory and apply those in a problem-solving approach.
(5) to apply the group-theoretic information to deduce results about fields and polynomials.

UNIT 1: Direct and Semi-direct Products and Abelian Groups: Direct products, Fundamental theorem of finitely generated abelian groups, Groups of small order, Recognizing direct products, Semi-direct Products.

UNIT 2: $p-$groups, nilpotent groups, solvable groups, applications in groups of medium order, free groups.

UNIT 3: Modules: Definitions and Examples, direct sums, free modules, vector spaces, quotient modules, homomorphisms, simple modules, modules over PID's.

UNIT 4: Fields: Irreducible polynomials, Classical Formulas, Splitting Fields, Finite fields, The Galois group, roots of unity, solvability by radicals.

UNIT 5: Fields: Independence of characters, Galois extensions, The fundamental theorem of Galois theory, Applications.

Text Books:

(1) Abstract Algebra - D.S. Dummit and R.M. Foote, 3rd Edition, Publisher: Wiley.
(2) Rings and Modules - C. Musili, Second revised edition, Narosa Publishing House.
(3) Galois Theory - J. Rotman, Second Edition, Springer International Edition.

References:-

(1) A First Course in Abstract Algebra - J.B. Fraleigh, 7th Edition, Publisher - Pearson
(2) Algebra - M. Artin, Second Edition, Publisher - Pearson
(3) Contemporary Abstract Algebra - J. A. Gallian, 4th Edition, Publisher - Narosa Publishing
(4) Topics in Algebra - I.N. Herstein, Second Edition, Publisher - Wiley Student Edition

Syllabus for MSC 2021 Admissions Onwards
MAM 21-803-0802 FUNCTIONAL ANALYSIS

Credits: 4

Total No. of Hours: 72

Objective: This is the first part of the series of 2 courses taught in the second and third semester on Functional Analysis. In the first part, we cover important structures used in analysis like Banach spaces, Hilbert spaces and operators acting on them. The foundation results are discussed in this part.
Learning Outcomes: After the completion of this course, the student should be able to be familiar with the concepts of Banach spaces, Hilbert spaces and operators acting on them.
Pre-requisites:

(1) A first course in linear algebra
(2) Basic real analysis and topology

UNIT 1: Review of Linear Spaces and Linear Maps, Metric Spaces and Continuous Functions, Lebesgue Measure and integration on R. (Chapter I, Section 2, 3, and 4; excluding the proofs of 2.1, 2.3, 3.4, 3.5, 3.9 and 3.10).
UNIT 2: Normed Spaces, Continuity of Linear Maps, Hahn-Banach Theorems (Chapter II, Section 5, 6, 7; upto Theorem 7.11).
UNIT 3: Banach Spaces., Uniform Boundedness Principle, Closed Graph and Open Mapping Theorem, Bounded Inverse Theorem. (Chapter III, Section 8, 9 upto Theorem 9.4, Section 10).
UNIT 4: Bounded Inverse Theorem, Inner Product Spaces, Orthonormal Sets. (Chapter III: Section 11, Chapter VI: Section 21, 22)
UNIT 5: Duals and Transpose. Duals of $L^p([a,b])$ and $C([a,b])$. (Chapter IV, Section 13, 14; upto Theorem 14.5).
Text Book: Balmohan V. Limaye, *Functional Analysis*, Revised Second Edition, New Age International Publishers, 1996 (Reprint 2013)

References:-

(1) Courant, R. and D. Hilbert, Methods of Mathematical Physics, vol. I, Interscience, Newyork (1953).
(2) Dunford N. and T. Schwartz, Linear Operators, Part I, Interscience, Newyork (1958).
(3) E. Kreyzig, Introduction to Function Analysis with Applications, Addison – Wesley.
(4) Rudin W., Real and Complex Analysis, 3rd edition, McGraw-Hill, Newyork (1986).
(5) Rudin W., Functional Analysis, 2nd edition, McGraw-Hill, Newyork (1991).
(6) Reed, M. and B. Simon, Methods of Mathematical Physics, vol. II, Academic Press, Newyork (1975).
(7) Rajendra Bhatia, Notes on Functional Analysis, Texts and Readings in Mathematics, Hindusthan Book Agency, New Delhi(2009).
(8) G. F. Simmons, Introduction to Topology and Modern Analysi,s TMH.
(9) M. Thamban Nair, Functional Analysis; A first course, PHI Learning Pvt. Ltd (2001).

Syllabus for MSC 2021 Admissions Onwards
MAM 21-803-0803 COMPLEX ANALYSIS

Credits: 4

Total No. of Hours: 72

Objective: This course starts with the review of complex functions which will be followed by the Classical theory of analytic functions. This will involve some of the classical theorems in the subject such as Cauchy's integral formula and its' general forms.

Learning Outcomes: After the completion of this course, the student should be able to

(1) be familiar with the Conformal mapping, Linear transformations, Analytic functions and the classical results in this regard.
(2) use the results like residue theorems to compute integrals and apply to various fields.

Pre-requisites: Familiarity with complex numbers and basic calculus, Geometric ideas of school level.

UNIT 1: The field of complex numbers, The complex plane, Polar representations and roots of complex numbers, Lines and half planes in complex plane, The extended plane and its spherical representations, Power series, Analytic functions and Analytic functions as mapping and Mobius transformations. [Chapter - I (Sections - 2,3,4,5,6), Chapter - III (Sections - 1,2,3)]

UNIT 2: Riemann-Stieltjes integrals, Power series representation of analytic functions, Zeros of an analytic function and The index of a closed curve [Chapter - IV (Sections - 1,2,3,4)].

UNIT 3: Cauchy's Theorem and Integral Formula, The homotopic version of Cauchy's Theorem and simple connectivity, Counting zeros; the Open Mapping Theorem and Goursat's Theorem [Chapter - IV (Sections - 5,6,7,8)].

UNIT 4: Classification of singularities, Residues and The Argument Principle [Chapter - V (Sections - 1,2,3)].

UNIT 5: The Maximum Principle, Schwarz's Lemma, Convex functions and Hadamard's Three Circles Theorem and Phragmen-Lindelof Theorem [Chapter - VI (Sections - 1,2,3,4)].

Text Book: J.B. Conway, Functions of One Complex Variable (2^{nd} Edition), Springer 1973.

References:-

(1) L.V. Ahlfors, Complex Analysis (Third Edition) Mc-Graw Hill International (1979)
(2) Milnor, Dynamics in One Complex Variable (3rd ed.), Princeton U. Press.
(3) T.W. Gamelin, Complex Analysis, Springer
(4) H. A. Priestley: Introduction to Complex Analysis, Oxford University Press.
(5) J.H. Mathews and R.W. Howell: Complex Analysis for Mathematics and Engineering, Jones & Bartlett Learning.

Syllabus for MSC 2021 Admissions Onwards
MAM 21-803-0804 TOPOLOGY I

Credits: 4

Total No. of Hours: 72

Objective: Topology is essentially the study of surfaces in which normally non geometric properties are studied. This course introduces the basic concepts of topology and standard properties such as compactness connectedness, separation axioms.

Learning Outcomes: On completion of this course, the student should be able to

(1) understand topological properties
(2) understand the connection of topology with other branches of mathematics
(3) apply topological properties to prove theorems.

Pre-requisites: Basic ideas of Set Theory, Basic concepts of Real Analysis and Metric Spaces.

UNIT 1: Topological Spaces: Logical warm up, Motivation for topology, Definition of topological spaces, examples, Bases and Sub bases, Subspaces. (Chapter 3 & 4 of Text 1)

UNIT 2: Basic Concepts: Closed sets and Closure, Neighbourhoods, Interior and Accumulation Points, Continuity and Related Concepts, Making functions continuous and Quotient Spaces (Chapter 5 of Text 1)

UNIT 3: Spaces with special properties: Smallness conditions on a space, Connectedness, Locally connectedness and paths. (Chapter 6 of Text 1)

UNIT 4: Separation axioms: Hierarchy of separation axioms, Compactness and separation axioms, Urysohn's characterization of normality, Tietze extension Theorem. (Chapter 7 of Text 1)

UNIT 5: Product and Coproducts: The Cartesian product of family of sets, product topology, productive properties, Embedding Lemma, Embedding theorem and Urysohn's Metrization Theorem. (Relevant sections of Chapter 8 & 9 of Text 1)

Text Book: K.D. Joshi: Introduction to General Topology (Revised Edn.), New Age International (P) Ltd., New Delhi, Revised printing in 1984.

References:-

(1) G.F. Simmons: Introduction to Topology and Modern Analysis; McGraw-Hill International Student Edn.; 1963
(2) J. Dugundji: Topology; Prentice Hall of India; 1975
(3) J. R. Munkers; Topology (Second Edition) PHI, 2009.
(4) M. Gemignani: Elementary Topology; Addison Wesley Pub Co Reading Mass; 1971
(5) M.A. Armstrong: Basic Topology; Springer- Verlag New York; 1983
(6) M.G. Murdeshwar: General Topology (2nd Edn.); Wiley Eastern Ltd; 1990
(7) S. Willard: General Topology; Addison Wesley Pub Co., Reading Mass; 1976
(8) John Gilbert Hocking and Gail S. Young, Topology (Revised Edition), Dover Publications, (1988).

Syllabus for MSC 2021 Admissions Onwards

MAM 21-803-0805 FUNCTIONS OF SEVERAL VARIABLES AND GEOMETRY

Credits: 4

Total No. of Hours: 72

Objective: In the first module, the students will be introduced to multivariable functions in Euclidean spaces and the notion of differentiation. The second module is aimed to apply the notions of multivariable differentiation and associated local properties to regular curves and surfaces. Differentiable manifolds are introduced in the third module. In the fourth module the notions of geometry are introduced. The Riemannian metric structure on a differentiable manifold is introduced for conceptual clarity. The first fundamental form on regular surfaces is introduced first, after which comes orientation and the Gauss map. The Gauss map for regular surfaces is studied in details culminating in the concept of Gaussian curvature along with applications of the Gauss-Bonnet theorem. Finally the standard concepts in geometry of parallel transport, geodesics and the exponential map are also studied.

Learning Outcomes: After completion of this course, the students shall learn

(1) Have a clear understanding about continuity and differentiability of functions of several variables and their applications.
(2) Application of these concepts to regular curves and surfaces in Euclidean spaces.
(3) Develop understanding of tangent planes to regular surfaces and then differentiable manifolds are introduced.
(4) Different examples of manifolds, the concept of orientation and vector fields on such manifolds are studied.
(5) Riemannian structure on a differentiable manifold is introduced which makes the study of geometry on regular surfaces in $\mathbb{R}^3$ more clear conceptually.
(6) Special emphasis is laid on the study of the Gauss map culminating with the Gaussian curvature for regular surfaces in $\mathbb{R}^3$. Gauss-Bonnet theorem and its applications are studied in details.
(7) Other important geometric concepts that are studied include the first fundamental form, parallel transport, geodesics and the exponential map.

Pre-requisites:

(1) Basic real analysis and Linear Algebra

UNIT 1: Norm and inner product, subsets of Euclidean spaces, functions and continuity, (Differentiation in several variables), Basic definitions, basic theorems, partial derivatives, derivatives. (Relevant sections from chapters 1, 2 of textbook 1)

UNIT 2: Inverse functions, Implicit functions (Chapter 2 of textbook 1), Regular curves, The local theory of curves parametrised by arc length, The local canonical form, Regular surfaces, Change of parameters, The tangent plane (Sections 1.3, 1.5, 1.6, 2.2, 2.3, 2.4 of textbook 2).

UNIT 3: Introduction to differentiable manifolds, tangent space of differentiable manifolds, Immersions and embeddings, other examples, Orientation, vector fields, brackets, topology of manifolds (Chapter 0 of textbook 3).

UNIT 4: Introduction to Riemannian metrics, Riemannian metrics (Chapter 1 of textbook 3), The first fundamental form (Area), Orientation of Surfaces, The definition of the Gauss map and its fundamental properties, The Gauss map in local coordinates. (Sections 2.5, 2.6, 3.2, 3.3 of textbook 2).
UNIT 5: The Gauss theorem and the equations of compatibility, Parallel transport, Geodesics, The Gauss-Bonnet theorem and its applications, The exponential map, Geodesic polar coordinates. (Sections 4.3, 4.4, 4.5, 4.6 of textbook 2).

Text Book:

(1) Michael Spivak: *Calculus on Manifolds A modern approach to classical theorems of advanced calculus*, Addison-Wesley Publishing house, 1965.
(2) Manfredo P. Do Carmo: *Differential geometry of curves and surfaces*, Dover Publications, Second edition, 2016.
(3) Manfredo P. Do Carmo: *Riemannian Geometry*, Birkhauser, 1993.

References:-

(1) Andrew Pressley: Elementary Differential Geometry, Springer, 2000.
(2) Theodore Shifrin: Differential Geometry: A first course in curves and surfaces, 2016.

Syllabus for MSC 2021 Admissions Onwards

MAM 21-803-0901 OPERATOR THEORY

Credits: 4

Total No. of Hours: 72

Objective: This is the second part of the series of 2 courses taught in the second and third semester on Functional Analysis. In the second part, we focus on compact operators on Banach spaces, Hilbert spaces and their spectral properties.

Learning Outcomes: After the completion of this course, the student should be able to be familiar with the spectral theory of compact self-adjoint operators and its applications.

Pre-requisites:

(1) A first course in functional analysis
(2) Basic real analysis and topology

UNIT 1: Spectrum of a Bounded Operator, Weak and Weak* Convergence, Reflexivity. (Chapter III, Section 12, Chapter IV, Section 15, upto Theorem 15.5, Chapter IV: Section 16 excluding the proof of Theorem 16.5).

UNIT 2: Compact Linear Maps, Spectrum of a Compact Linear Map. (Chapter V, Section 17, 18).

UNIT 3: Fredholm Alternative, Approximate Solutions, Normal, Unitary and Self-Adjoint Operators (Chapter V, Section 19, 20, upto Theorem 20.4, Chapter VII: Section 26).

UNIT 4: Approximation and Optimization, Projection and Riesz Representation Theorems. Bounded Operators and Adjoints. (Chapter VI: Section 23, 24, 25)

UNIT 5: Spectrum and Numerical Range, Compact Self-adjoint Operators, Sturm-Liouville Problems. (Chapter VII, Section 28, Appendix C).

Text Book: Balmohan V. Limaye, *Functional Analysis*, Revised Second Edition, New Age International Publishers, 1996 (Reprint 2013)

References:-

(1) Courant, R. and D. Hilbert, Methods of Mathematical Physics, vol. I, Interscience, Newyork (1953).
(2) Dunford N. and T. Schwartz, Linear Operators, Part I, Interscience, Newyork (1958).
(3) E. Kreyzig, Introduction to Function Analysis with Applications, Addison – Wesley.
(4) Rudin W., Real and Complex Analysis, 3rd edition, McGraw-Hill, Newyork (1986).
(5) Rudin W., Functional Analysis, 2nd edition, McGraw-Hill, Newyork (1991).
(6) Reed, M. and B. Simon, Methods of Mathematical Physics, vol. II, Academic Press, Newyork (1975).
(7) Rajendra Bhatia, Notes on Functional Analysis, Texts and Readings in Mathematics, Hindusthan Book Agency, New Delhi(2009).
(8) G. F. Simmons, Introduction to Topology and Modern Analysi,s TMH.
(9) M. Thamban Nair, Functional Analysis; A first course, PHI Learning Pvt. Ltd (2001).

Syllabus for MSC 2021 Admissions Onwards
MAM 21-803-0902 TOPOLOGY II

Credits: 4

Total No. of Hours: 72

Objective: With this course, the students will have a sound introductory knowledge of the topics in Algebraic topology. The first module is important to understand the topology of non-metric spaces. From second module onwards the student is gradually introduced to the important category of topological spaces and subsequently the algebraic machinery like simplicity homology and fundamental groups for their study. The course ends with a rigorous understanding of covering spaces.

Learning Outcomes: After completion of this course, the students shall learn

(1) About nets and filters, the generalisation of sequences for topologies that are no more defined by a metric.
(2) The important geometric objects like complexes and Polyhedra and different identification spaces whose topology is studied.
(3) The definition of simplicial homology groups and their application to compute the homology groups for certain important spaces.
(4) The fundamental group and the Van Kampen theorem with examples.
(5) Covering spaces their properties along with their classification.

UNIT 1: Nets and Filters: Definition and convergence of Nets, Topolgy and convergence of Nets, Filters and their convergence, Ultra filters (Tychnoff's theorem) (Relevant Sections from text 1)

UNIT 2: Geometric Complexes and Polyhedra: Introduction. Examples, Geometric Complexes and Polyhedra, Orientation of geometric complexes. **Simplicial Homology Groups:** Chains, cycles, Boundaries and homology groups, Examples of homology groups, The structure of homology groups, (Sections 1.1 to 1.4, Sections 2.1 to 2.3 from text 2)

UNIT 3: Simplicial Homology Groups (Contd.): The Euler Poincare's Theorem, Pseudo-manifolds and the homology groups of S_n. **Simplicial Approximation:** Introduction, Simplicial approximation, Induced homomorphisms on the Homology groups, The Brouwer fixed point theorem and related results (Sections 2.4, 2.5, and Sections 3.1 to 3.4 from text 2)

UNIT 4: The Fundamental Group: Introduction, Homotopic Paths and the Fundamental Group, The Covering Homotopy Property for S1, Examples of Fundamental Groups. (Sections 4.1 to 4.4 from text 2)

UNIT 5: Covering Spaces: The Definition and Some Examples, Basic Properties of Covering Spaces, Classification of Covering Spaces, Universal Covering Spaces, Applications (Sections 5.1 to 5.5 of text 2)

Text Books:

(1) K.D. Joshi: Introduction to General Topology (Revised Edn.),New Age International(P) Ltd., New Delhi, 1983.
(2) F.H. Croom: Basic Concepts of Algebraic Topology, Springer, 1978

References:-

(1) Allen Hatcher: Algebraic Topology, Cambridge University Press, 2002

(2) C.T.C. Wall: A Geometric Introduction to Topology, Addison-Wesley Pub. Co. Reading Mass, 1972
(3) Eilenberg S, Steenrod N.: Foundations of Algebraic Topology, Princeton Univ. Press, 1952.
(4) J. R. Munkers: Elements Of Algebraic Topology, Perseus Books, Reading Mass, 1993, CRC, 2018.
(5) J. R. Munkers: Topology (Second Edition) PHI, 2009.
(6) Massey W.S.: Algebraic Topology : An Introduction, Springer Verlag NY, 1977
(7) S.T. Hu: Homology Theory, Holden-Day, 1965

Syllabus for MSC 2021 Admissions Onwards

MAM 21-803-0903 Ordinary Differential Equations & Integral Equations

Credits: 4

Total No. of Hours: 72

Objective: This course starts with the review of Ordinary differential equations. Course aims to build an understanding of the classical models in terms of ordinary differential equations and pave the foundations for the study of Integral equations.

Learning Outcomes: Students will be able to understand the popular mathematical models of real life problems in terms of ordinary differential equations and Integral equations.

UNIT 1: Oscillations and the Sturm Separation Theorem, The Sturm Comparison Theorem, Series solutions of First order equations, Second order Linear Equations, Gauss's Hyper Geometric Equation. (Chapter 4, Section 24, 25. Chapter 5, sections 27, 28, 29, 30, 31.)

UNIT 2: Legendre Polynomials, Properties of Legendre Polynomials, Bessel Polynomials, Properties of Bessel Polynomials. (Chapter 8, sections 44, 45, 46, 47.)

UNIT 3: Systems, Nonlinear equations: Autonomous systems, The Phase Plane and its Phenomena, Types of Critical points. Stability, Critical points and Stability for Linear Systems. (Review Chapter 10, Chapter 11, Sections 58, 59,60)

UNIT 4: Method of successive approximations, Picard's Theorem, Integral Equations with separable kernels, Fredholm Integral Equations, Method of successive approximations. (Chapter 13, sections 68, 69 of text 1, Chapter 2 and 3 of the text 2.)

UNIT 5: The Fredholm Method of Solution, Fredholm's Theorems, Applications to Ordinary Differential Equations. (Chapters 4, 5 of the text 2)

Text Books:

(1) George F. Simmons, *Differential Equations with Applications and Historical Notes*, Tata McGraw-Hill, Third Editon 2003.

(2) Ram P. Kanwal, *Linear Integral Equations*, Second Edition, Springer Science+Business Media, LLC, (1997).

References:-

(1) Peter J. Collins, *Differential and Integral Equations*, Oxford University Press,(2006).

(2) Carmen Chicone, *Ordinary Differential Equations with Applications*, Springer (2006).

(3) Linear Integral Equations

(4) Michael D. Greenberg, *Ordinary Differential Equations*, Wiley (2012).

(5) Michael E. Taylor, *Introduction to Differential Equations*, AMS (2011).

(6) Vladimir I. Arnol'd, *Ordinary Differential Equations*, Springer (1992).

(7) Earl A. Coddington, *An Introduction to Ordinary Differential Equations*, Dover Publications, New york, (1961).

Syllabus for MSC 2021 Admissions Onwards

MAM 21-803-0904: Probability Theory

Credits: 4

Total No. of Hours: 72

Objective: This course starts with the introduction to probability theory following different probability distributions. The connection between probability theory and measures are also discussed in this course. This will involve some of the classical theorems in the subject such as central limit theorem and law of large numbers.

Learning Outcomes: After the completion of this course, the student should be able to

(1) be familiar with the concepts of probability theory and classical results.
(2) use the terminology and concepts of probability theory and apply those in a problem-solving approach.

Pre-requisites:

(1) A first course in measure theory.
(2) Basic real analysis and topology.

UNIT 1: Recalling Probability: Sample Space, events and probability, Independence and conditioning, Discrete random variables, The branching process, Borel's strong law of large numbers (Chapter 1)

UNIT 2: Integration: Measurability and measure, The Lebesgue integral, The other big theorems (Chapter 2)

UNIT 3: Probability and Expectation: From integral to expectation, Gaussian vectors, Conditional expectation (Chapter 3)

UNIT 4: Convergences Almost-sure convergences, Two other types of convergence, Zero-one laws (Chapter 4, section 4.1-4.3)

UNIT 5: Convergence continued: Convergence in distribution and in variation, Central Limit Theorem, The hierarchy of convergences (Chapter 4, section 4.4-4.6)

Text. Pierre Bremaud, Probability Theory and Stochastic Processes, Springer 2020.

References:-

1. S.R. Athreya, V.S. Sunder: Measure and Probability, University Press (India) Pvt. Ltd. (2008).
2. Sidney I Resnick: A Probability Path, Birkhauser 2005 Edition
3. A.K. Basu: Probability Theory, Prentice Hall, India, 2002.
4. W. Feller: An Introduction to Probability Theory and Its Applications.

Syllabus for MSC 2021 Admissions Onwards

MAM 21-803-1001 PARTIAL DIFFERENTIAL EQUATIONS & VARIATIONAL CALCULUS.

Credits: 4

Total No. of Hours: 72

Objective: This course starts with simple models of Partial differential equations which will be followed by the analytic and algebraic study of PDEs. This will involve some of the classical models in the subject: diffusion equations and wave equations. Towards the end of the course students will get an idea of variational calculus.

Learning Outcomes: After the completion of this course, the student should be able to be familiar with the concepts of classical models of diffusion and wave phenomena. Able to use the terminology and concepts of PDE's and apply those in a problem-solving approach.

UNIT 1: Classification of First-Order Equations, Construction of a First-Order Equation, Geometrical Interpretation of a First-Order Equation, Method of Characteristics and General Solutions, Canonical Forms of First-Order Linear Equations, Method of Separation of Variables (Chapter 2 of Text 1).

UNIT 2: The Vibrating String, The Vibrating Membrane, Waves in an Elastic Medium, Conduction of Heat in Solids, Second-Order Equations in Two Independent Variables, Canonical Forms, Equations with Constant Coefficients, The Cauchy Problem, Charpit's method. (Chapter 3, sections 3.2-3.5, Chapter 4 of Text 1, Sections 5.1-5.4.).

UNIT 3: Eigenvalue Problems and Special Functions, Sturm–Liouville Systems, Eigenfunction Expansions, Completeness and Parseval's Equality, Bessel's Equation and Bessel's Function (Sections 8.1-8.6 of the Text 1).

UNIT 4: Variation and its properties, Euler equation, Functionals involving higher order derivatives, Functionals involving partial derivatives, Variational problems with movable boundaries. (Chapter 1, 2 of text 2).

UNIT 5: Sufficiency condition for an extremum, Variational problems with constrained extrema, isoperimetric problems, Direct methods, Euler's method of finite differences, Ritz method. (Chapter 3, 4, 5 of text 2).

Text 1. Tyn Myint-U, Lokenath Debnath *Linear Partial Differential Equations for scientists and Engineers*, Fourth Edition, Birkhauser (2007).

Text 2. Lev D. Elsgolc, *Calculus of Variations*, Dover publications, Inc. (2007.)

References:-

(1) Walter A. Strauss, *Partial Differential Equations an Introduction*, John Wiley, (1992).

(2) Ravi P. Agarwal, Donal O'Regan, *Ordinary and Partial Differential Equations With Special Functions, Fourier Series, and Boundary Value Problems*, Springer-Verlag (2009).

(3) Fritz. John, *Partial Differential Equations*, Fourth Edition, Springer (2009).

(4) G. Evans, I. Blackedge and P.Yardley, *Analytic Methods for Partial Differential Equations*, Springer (1999).

(5) Ian N. Sneddon, *Elements of Partial Differential Equations*, McGraw Hill (1983).

Syllabus for MSC 2021 Admissions Onwards
MAM 21-803-0905 TOPICS IN APPLIED MATHEMATICS

Credits: 3

Total No. of Hours: 54

Objective: To Learn important Mathematical Tools applicable in Science and Technology.
Learning Outcomes: After the completion of this course, the student should able to be

(1) familiar with the necessary mathematical tools that are used in science and technology.
(2) failiar with the popular transforms of Laplace and Fourier and their applications to various fields.
(3) familiar with the popular mathematical models like vibating string, Heat conduction etc. and its solution using transforms.
(4) familiar with the necessary machinery in complex function theory.

UNIT 1: Second order Linear ODEs, Homogeneous Linear ODEs of Second Order, Homogeneous Linear ODEs with Constant Coefficients, Euler-Cauchy Equations.
UNIT 2: Laplace Transform, Linearity, First Shifting Theorem (s-Shifting), Transforms of Derivatives and Integrals ODEs, Unit Step Function (Heaviside Function), Second Shifting Theorem (t-Shifting)
UNIT 3: Fourier Series, Arbitrary Period, Even and Odd Functions, Half-Range Expansions, Forced Oscillations, Fourier Integral, Fourier Cosine and Sine Transforms, Fourier Transform.
UNIT 4: Basic Concepts of PDEs, Modeling: Vibrating String, Wave Equation, Modeling: Heat Flow from a Body in Space, Heat Equation
UNIT 5: Complex Numbers: Preliminary requirements, limits, Continuity, Cauchy-Reimann equations, Complex Integration, Line Integral in the complex plane, Cauchy's Integral Theorem, Cauchy's Integral formula, Derivatives of Analytic functions, Laurent Series, Singularities and zeros, Residue Integration method, Residue Integration of real Integrals.

Text Book: Advanced Engineering Mathematics, Erwin Kreyszig, 10^{th} edition, JOHN WILEY & SONS, INC.2011. (Chapter 2, Section 2.1-2.3, and 2.5, Chapter 6, Section 6.1-6.4, Chapter 11, Section 11.1-11.3, 11.7,11.8, Chapter 12, Section 12.1-12.6, Chapter 14, Section 14.1-14.4, Chapter 16, Section 16.1-16.4.)

References:-

(1) Advanced Engineering Mathematics, C.Ray Wylie, Louis. C. Barrett, 6th edition, McGraw Hill Publishing, 1998.
(2) Advanced Engineering Mathematics, K.A Stroud, 5th edition, Palgrave Macmillain, 2003.
(3) Advanced Engineering Mathematics, Michael Greenberg, 2nd edition, Prentice Hall, 1998.
(4) Advanced Engineering Mathematics, Dennis. G.Zill, Warren S.Wright, 4th edition, 2011.

Syllabus for MSC 2021 Admissions Onwards

MAM 21-803-1002 WAVELETS

Credits: 4

Total No. of Hours: 72

Objective: This course starts with the structure of $\mathbb{C}^n$. This course is planned to introduce the Wavelets as an extension to the idea of Fourier's method in Linear algebraic perpsective.

Learning Outcomes: After the completion of this course, the student should be able to be familiar with Multi-resolution analysis and its applications in different contexts like the space of periodic functions, non-periodic functions and on the space of square integrable functions on the real line.

UNIT 1: The Discrete Fourier Transform, Translation-Invariant Linear Transformations, First Stage Construction of Wavelets on $\mathbb{Z}_N$ (Chapter 2, Chapter 3, Sections 2.1, 2.2, 3.1)

UNIT 2: Construction of Wavelets on $\mathbb{Z}_N$: Iteration step, Examples and Applications, $l^2(\mathbb{Z})$ (Chapter 3, Sections 3.2, 3.3, Chapter 4, Section 4.1)

UNIT 3: Complete Orthonormal Sets in Hilbert Spaces, $L^2([-\pi,\pi))$ and Fourier Series, The Fourier Transform and Convolution on $l^2(\mathbb{Z})$ (Chapter 4, Sections 4.2, 4.3, 4.4, 4.5)

UNIT 4: First-Stage Wavelets on $\mathbb{Z}$, The Iteration step for Wavelets on $\mathbb{Z}$, Implementation and Examples. (Chapter 4, Sections 4.6, 4.7, Chapter 5, Section 5.1,)

UNIT 5: $L^2(\mathbb{R})$ and approximate Identities, The Fourier Transform on $\mathbb{R}$, Multiresolution Analysis and Wavelets, Construction of MRA (Chapter 5, Sections 5.2, 5.3, 5.4)

Text Book: Michael W. Frazier, An Introduction to Wavelets Through Linear Algebra, Springer-Verlag New York, (1999).

References:-

(1) Charles K. Chui, *An Introduction to Wavelets*, Academic (1992).

(2) Ingrid Daubechies, *Ten Lectures on Wavelets*, SIAM, (1992).

(3) K.R Unni, *Wavelets, Frames and Wavelet Bases in L^P Lecture notes*, Bhopal (1997).

(4) Stephane Mallat, *A Wavelet Tour Of Signal Processing*, Academic Press (1999).

(5) Don Hong, Jianzhong Wang, Robert Gardner, *Real Analysis with an Introduction to Wavelets*, Elsevier Academic Press (2005).

(6) Yves Meyer, *Wavelets and Operators*, Cambridge University Press (1992).

(7) John. J Beneditto, Michael W. Frazier *Wavelets-Mathematics and Applications*, CRC, (1994).

(8) Eugenio Hernandez, Guido L. Weiss, *First course on wavelets*, CRC, (1996).

Syllabus for MSC 2021 Admissions Onwards

MAM 21-803-1003 Optimization and Mathematical Methods for Deep Learning

Credits: 4

Total No. of Hours: 72

Objective: The objective of this course is

(1) to introduce optimization and discuss mathematical methods behind deep learning process.
(2) to give an insight on the mathematical tools and techniques required for modelling real life problems related to deep learning process.
(3) to provide the basis idea of convex analysis.

Learning Outcomes: After the completion of this course, the student will

(1) learn about the different types of optimization problems.
(2) acquire knowledge on mathematical models in Deep Learning process through linear algebra, Basic Probability theory, Optimization techniques, Neural Network and Fuzzy Logic and fuzzy systems.
(3) understand the basic concepts behind convex optimization such as convex sets, convex functions, differentiable and non-differentiable convex functions, optimum of convex function, necessary and sufficient optimality conditions for constrained and unconstrained optimization problem.

UNIT 1: (Different types of optimization) (Text 4) Discrete and Continuous Optimization, Constrained and Unconstrained Optimization, Deterministic and Stochastic Optimization, Optimization with none, one or many objectives. Some Illustrative Examples: Optimal Control Problems, Electrical Networks, Water Resources Management, Stochastic Resource Allocation, Location of Facilities. (Chapter 1)

UNIT 2: (Fuzzy Sets & Systems) (Text 3) Basic Definition and Terminology, Set-theoretic Operations, Member Function, Formulation and Parameterization, Fuzzy rules and fuzzy Reasoning, Extension Principal and Fuzzy Relations, Fuzzy if-then Rules, Fuzzy Inference Systems, Implementation using MATLAB.

UNIT 3: (Basics in Deep Learning) (Text 2) History of Deep Learning, Mc Culloch Pitts Neuron, Perceptron, Perceptron Learning Algorithm, MLP, Sigmoid Neurons, Gradient Descent, Feedforward Neural Networks, Back propagation Algorithm; Implementation using MATLAB.

UNIT 4: (Some Learning Strategies and Modern Trends in Deep Learning) (Text 1 & 2) Learning Theory, Supervised and Unsupervised Learning; Regression- Ordinary Least Squares, Polynomial Regression, Classification- Nearest Neighbour Model; Linear Discriminant Analysis, Quadratic Discriminant Analysis; Clustering- Dimensionality Reduction, K- Means Clustering. (Text 1) Convolution Neural Network (CNN), Recurrent Neural network (RNN), Auto encoders. (Text 2)

UNIT 5: (Basics of Convex Analysis) (Text 4) Convex sets, Convex hull, Closure and interior of a set, Weierstrass theorem, Separation and support of sets, Convex cones and polarity. (Chapter 2: 2.1-2.5) Convex functions and basic properties, Subgradients of convex functions, Differentiable convex functions, minima and maxima of convex functions. (Chapter 3: 3.1-3.4) The Fritz john and Karush-Kuhn-Tucker Optimality Conditions (without proofs). (Chapter 4: 4.1-4.3)

Text Books:

(1) T. M. Mitchell, “Machine Learning”, McGraw Hill, 2017.
(2) Deep Learning, Ian Goodfellow and YoshuaBengio and Aaron Courville, MIT Press, 2016.
(3) Bo Yuan, George J. Klir, “Fuzzy Sets and Fuzzy Logic: Theory and Applications”, Pearson Publishers, Second Edition 2015.
(4) M. S. Bazaraa, Hanif D. Sherali, C. M. Shetty; “Nonlinear Programming theory and algorithms”. John Wiley & Sons, Inc. Second Edition 2004.

References:-

(1) S.N. Shivnandam, “Principle of soft computing”, Wiley.
(2) Timothy J.Ross, “Fuzzy logic with Engineering Applications”, McGraw-Hills
(3) Jack M. Zurada, “Introduction to Artificial Neural Network System” JAico Publication.
(4) Simon Haykins, “Neural Network- A Comprehensive Foudation”.
(5) Hans-Jurgen Zimmermann,” Fuzzy Set Theory - and its Applications” Second -Revised Edition 2013, Springer Netherlands.
(6) Rao’s “Linear Statistical Inference and its Applications” published by Wiley ISBN: 978-0-471-21875-3.
(7) Press, Teukolsky, Vetterling, & Flannery “Numerical Recipes: the Art of Scientic Computing” published by Cambridge University Press, ISBN: 978-0-521-88068-8.
(8) Horn & Johnson’s “Matrix Analysis” published by Cambridge University Press, ISBN: 978-0-521-54823-6.
(9) Golub & Van Loan’s “Matrix Computations”, by Hopkins ISBN-13: 978-0801854149.
(10) Ross’ “A First Course in Probability”, published by Pearson, ISBN-13: 978-0321794772.
(11) Christopher Bishop’s “Pattern Recognition and Machine Learning” published by Springer, ISBN: 978-0-387-31073-2.
(12) R. T. Rockafellar “Convex Analysis” published by Princeton University Press, 1970.

Syllabus for MSC 2021 Admissions Onwards
MAM 21-803-1004 COMMUTATIVE ALGEBRA

Credits: 4

Total No. of Hours: 72

Objective: This course is an advanced course in algebra. This course discusses the theory of commutative rings. These rings are of fundamental significance in Mathematics because of its applications to other topics such as algebraic number theory, algebraic geometry and many other advanced topics in mathematics.

Learning Outcomes: After the completion of this course, the student should be able to

(1) understand the basic definitions concerning different classes of commutative rings, elements in commutative rings, and ideals in commutative rings.
(2) know the theory of modules, including the tensor product of modules and algebras, and localisation.
(3) know the theory of primary decomposition of ideals in a commutative rings.
(4) know the theory of integral dependance and integral extensions.
(5) know the definition and examples of Noetherian and Artinian rings.

UNIT 1: Rings and ideals: review of ideals in quotient rings; prime and maximal ideals, prime ideals under quotient, existence of maximal ideals; operations on ideals (sum, product, quotient and radical); Chinese Remainder theorem; nilradical and Jacobson radical; extension and contraction of ideals under ring homomorphisms; prime avoidance.

UNIT 2: Free modules; Projective Modules; Tensor Product of Modules and Algebras; Flat, Faithfully Flat and Finitely Presented Modules; Shanuels Lemma.

UNIT 3: Localisation and local rings, universal property of localisation, extended and contracted ideals and prime ideals under localisation, localisation and quotients, exactness property.

UNIT 4: Nagata's criterion for UFD and applications; equivalence of PID and one-dimensional UFD. Associated Primes and Primary Decomposition.

UNIT 5: Integral dependence, Going-up theorem, Integral Extensions: integral closure, Going-down theorem, Valuation rings, Chain Conditions. Definition and examples of Noetherian rings and Artinian rings.

Text Book: M.F. Atiyah and I.G. Macdonald, Introduction to commutative algebra, Addison-Wesley (1969).

References:-

(1) R.Y. Sharp: Steps in commutative algebra, LMS Student Texts (19), Cambridge Univ. Press (1995).
(2) D. Eisenbud: Commutative algebra with a view toward algebraic geometry GTM (150), Springer-Verlag (1995).
(3) H. Matsumura: Commutative ring theory, Cambridge Studies in Advanced Mathematics No. 8, Cambridge University Press (1980).
(4) N.S. Gopalakrishnan: Commutative Algebra (Second Edition), Universities Press (2016).
(5) Miles Reid: Undergraduate Commutative Algebra , Cambridge University Press (1995).

Syllabus for MSC 2021 Admissions Onwards

MAM 21-803-1005 - GRAPH THEORY

Credits: 4

Total No. of Hours: 72

Objective: The course introduce the concept of automorphism of simple graphs, graph operators, graph parameters and some interesting graph classes

Learning Outcomes: After the completion of this course, the student should be able to

(1) Understand the basic concepts of graph theory
(2) Have a clear picture of graph operators, graph parameters and graph classes
(3) Build graph models of real life problems
(4) Apply graph theoretic tools to solve problems.

UNIT 1: Basic Concepts, Degree of Vertices, Automorphism of a Simple Graph, Line Graphs, Operation on Graphs, Directed Graphs, Tournaments (Chapter 1: Sec. 1.1 - 1.12, Chapter 2: Sec. 2.1 - 2.3)

UNIT 2: Connectivity, Vertex Cuts and Edge Cuts, Connectivity and Edge Connectivity, Blocks, Trees, Definition, Characterization, Centers, Cayley's Formula, Applications (Chapter 3:Sec.3.1 – 3.4 (Theorem 3.4.3 omitted), Chapter 4: Sec. 4.1 - 4.5, 4.7)

UNIT 3: Independent sets, Vertex coverings, Edge Independent sets, Matchings, Factors, Matching in Bipartile Graphs, Eulerian Graphs, Hamiltonian Graphs, Hamilton Cycles in Line Graphs, 2-Factorable Graphs (Chapter 5: Sec. 5.1 - 5.5, Chapter 6: Sec. 6.1 - 6.3, 6.5 - 6.6)

UNIT 4: Graph Colorings, Critical Graphs, Brook's Theorem, Triangle Free Graphs, Edge Colorings, Chromatic Polynomials, Perfect Graphs, Triangulated Graphs, Interval Graphs (Chapter 7: Sec. 7.1 - 7.2, 7.3, 7.3.1, 7.5 – 7.6, 7.9, Chapter 9: Sec. 9.1 – 9.4)

UNIT 5: Planar and nonplanar graphs, Euler's Formula, Dual, Four Color Theorem and Five Color Theorem, Kuratowski's Theorem (without proof), Hamilton Plane graphs, Domination, Bounds, Independent Domination and Irredundance (Chapter8: Sec. 8.1 – 8.8, Chapter 10: Sec.10.1 – 10.3. 10.5)

Text Book: R. Balakrishnan, K. Ranganathan: A Text book of Graph Theory (Second Edition), Springer 2012.

References:-

1. D. B. West: Introduction to Graph Theory, 2nd ed. Prentice Hall, New Jersey (2011)
2. F. Harary: Graph Theory, Addison – Wesley Publishing Company, Inc. (1969).
3. M. C. Golumbic: Algorithmic Graph Theory and Perfect Graphs, Academic Press, New York (1980)
4. Teresa W. Haynes, S. T. Hedetneimi, P. J. Slater: Fundamentals of Domination in Graphs, Marcel Dekker, New York (1998)

Syllabus for MSC 2021 Admissions Onwards
MAM 21-803-1006 ADVANCED LINEAR ALGEBRA

Credits: 4

Total No. of Hours: 72

Objective: This course starts with the review of linear algebra, which will be followed by the factorisation and triangulation theorems. This will also discuss canonical forms and eigenvalue inequalities and inclusions for hermitian matrices. Some important results in linear algebra are discussed here which are not done in the core courses on this subject. This will benefit students wants to pursue research in the areas like Functional Analysis, Spectral theory, Stochastic models, Numerical linear algebra, etc.

Learning Outcomes: After the completion of this course, the students will be familiar with the advanced concepts of linear algebra and matrix analysis. It is expected to develop the skills to deal with advanced techniques in estimating eigenvalues, singular values, etc.

Pre-requisites:

(1) A basic course in linear algebra and matrix theory.
(2) Normed spaces and basic analysis.

UNIT 1: Review of Linear Algebra: Eigenvalues, Algebraic and geometric multiplicity, Special types of matrices, Change of basis, etc.

UNIT 2: Unitary matrices and QR factorization, Unitary similarity, Triangulation theorems and consequences, Singular Value Decomposition (SVD).

UNIT 3: Jordan canonical form and its consequences, minimal polynomial, Triangular factorization.

UNIT 4: Hermitian matrices, Eigenvalue inequalities, diagonalization.

UNIT 5: Matrix norms, Condition numbers, Gersgorin discs, Eigenvalue perturbation theorems.

Text Book: Roger A Horn, Charles R Johnson, Matrix Analysis, Second Edn., Cambridge University Press, 2013.

References:-

(1) M. Artin, Algebra, Prentice-Hall, (1991).
(2) Serge Lang, Introduction to Linear Algebra, Second Edition, Springer (1997).
(3) K.T Leung, Linear Algebra and Geometry, Hong Kong University Press, (1974).
(4) Kenneth Hoff man and Ray Kunze Linear Algebra, Second Edition, PHI (1975)
(5) Sheldon Axler, Linear Algebra Done Right, Second Edition, Springer, (1997).

Syllabus for MSC 2021 Admissions Onwards
MAM 21-803-1007 DISCRETE FRAMELETS

Credits: 4

Total No. of Hours: 72

Objective: Course is aimed to introduce the basic tools for applications using Discrete Framelets. Students will get knowlege in analysing signals and images using finite filters. This course will pave the necessary foundations to study numerical solutions of partial differential equations and some insights into computer aided geometric design.

Learning Outcomes: After the completion of this course, the student should be able to

(1) Understand the subject in a signal processing perspective with the help of finite filters.
(2) Be familiar with filterbank theory for signal analysis.
(3) Understand the multilevel framelet decomposition of signals in bounded intervals.

UNIT 1: Discrete Framelet Transform, Perfect reconstruction of discrete framelet transforms, One-Level Standard Discrete Framelet Transforms, Perfect Reconstruction of Discrete Framelet Transforms, Some Examples of Wavelet or Framelet Filter Banks. (Section 1.1 of text.)

UNIT 2: Sparsity of Discrete Framelet transforms, Convolution and Transition Operators on Polynomial Spaces, Subdivision Operator on Polynomial Spaces, Linear-Phase Moments and Symmetry Property of Filters, An Example. (Section 1.2 of text.)

UNIT 3: Multilevel Discrete Framelet Transforms and Stability, Multilevel Discrete Framelet Transforms, Stability of Multilevel Discrete Framelet Transforms, Discrete Affine Systems in $\ell^2(\mathbb{Z})$, Nonstationary and Undecimated Discrete Framelet Transforms (Section 1.3 of text.)

UNIT 4: Oblique extension principle, OEP-Based Tight Framelet Filter Banks, OEP-Based Filter Banks with One Pair of High-Pass Filters, OEP-Based Multilevel Discrete Framelet Transforms. (Section 1.4 of text.)

UNIT 5: Discrete Framelet Transforms for signals on bounded Intervals, Boundary Effect in a Standard Discrete Framelet Transform, Discrete Framelet Transforms Using Periodic Extension, Discrete Framelet Transforms Using Symmetric Extension, Symmetric Extension for Filter Banks Without Symmetry, Discrete Framelet Transforms Implemented in the Frequency Domain. (Section 1.5 and 1.6 of text.)

Text. Bin Han, Framelets and Wavelets Algorithms, Analysis and Applications, Birkhauser 2017.

References:-

1. Ole Christensen, Frames and Bases An Introductory Course, Birkhauser, 2008.
2. Ole Christensen, Frames and Riesz Bases, Birkhauser, 2008.
3. Christopher Heil, A Basis Theory Primer, Citeseer, 1998.
4. Yves Meyer, Wavelets and Operators, CUP, England, 1992.
5. Ingrid Daubechies, Ten Lectures on Wavelets, SIAM, Philadelphia, 1992.

Syllabus for MSC 2021 Admissions Onwards
MAM 21-803-1008 HARMONIC ANALYSIS

Credits: 4

Total No. of Hours: 72

Objective: This course starts with the review of Measure theory. This course is planned to introduce the basics of Topolgical groups and measure and Intergration on Locally compact groups.

Learning Outcomes: After the completion of this course, the student should be able to Be familiar with the formulation of Measure and integration on Locally comopact groups and representations of Compact groups.

UNIT 1: Topological groups, Haar Measure, Modular Functions, Convolutions (Sections 2.1, 2.2, 2.3, 2.4, 2.5)

UNIT 2: Homogeneous spaces, Unitary Representations, Representation of a group and its group algebra (Sections 2.6, 2.7, 2.8, 3.1, 3.2)

UNIT 3: Functions of positive type, The Dual group, The Fourier transform, The Pontrjagin Duality theorem (Sections 3.3, 3.4, 4.1, 4.2, 4.3)

UNIT 4: Representations of Locally Compact Abelian Groups, Closed ideals, Spectral synthesis, Bohr Compactification(Sections 4.4, 4.5, 4.6, 4.7, 4.8)

UNIT 5: Representations of Compact Groups, The Peter-Weyl Theorem, Fourier Analysis on Compact Groups. (Sections 5.1, 5.2, 5.3, 5.4, 5.5)

Text Book: Folland, G.B., *A Course in Abstract Harmonic Analysis*, CRC Press, (1995).

References:-

(1) Hewitt, E and Ross K., *Abstract Harmonic Analysis* Vol.1 Springer (1979).
(2) Gaal, S.A., *Linear Analysis and Representation Theory*, Dover (2010).
(3) Asim O. Barut and Ryszard Raczka, *Theory of Group Representations*, second revised edition, Polish scientific publishers (1980).
(4) Groenchenig, K., *Foundations of time frequency analysis*, Birkhauser Boston (2001).

Syllabus for MSC 2021 Admissions Onwards
MAM 21-803-1009 INTEGRAL TRANSFORMS

Credits: 4

Total No. of Hours: 72

Objective: This course starts with Fourier Transforms in detail. This course is planned to introduce the basics of Integral Transforms and its applications in various fields.
Learning Outcomes: After the completion of this course, the student should be able to be familiar with popular integral transforms and its applications.
UNIT 1: Integral Transforms, The Fourier Integral Formulas, Fourier Transforms of generalised functions, Basic Properties of Fourier Transforms, Z-transforms (Sections 1.1, 1.2, 2.1, 2.2, 2.3, 2.4, 2.5 and Chapter 12)
UNIT 2: Poisson's Summation formula, The Shannon Sampling Theorem, Gibbs Phenomenon, Heisenbergs' Uncertainty Principle, Applications of Fourier Transform to ODE, Laplace Transforms and their basic properties. (Sections 2.6, 2.7, 2.8, 2.9, 2.10, 3.1, 3.2, 3.3, 3.4)
UNIT 3: Convolution Theorem and the properties of convolution, Differentiation and Integration of Laplace transforms, The Inverse Laplace Transforms, Tauberian theorems and Watson's Lemma, Applications of Laplace transforms, Evaluation of Definite Integrals, Applications of Joint Laplace and Fourier Transform. (Sections 3.5, 3.6, 3.7, 3.8, 3.9, 4.1, 4.2, 4.3, 4.6, 4.8)
UNIT 4: Finite Fourier Sine and Cosine transforms, Basic properties and Applications, Finite Lapace Transforms, Tauberian Theorems. (Chapter 10, 11)
UNIT 5: Hilbert Transform and its basic properties, Hilbert transform in the complex plane, applications of Hilbert Transform, Asymptotic expansion of One sided Hilbert Transform. (Sections 9.1, 9.2, 9.3, 9.4, 9.5, 9.6)
Text Book: Lokenath Debnath, Dambaru Bhatta *Integral Transforms and their Applications*, second edition, Taylor and Francis, (2007).

References:-

(1) Frederick W. King, *Hilbert Transforms*, CRC (2009).
(2) Larry C. Andrews, Bhimsen K. Shivmaoggi *Integral Transforms for Engineers*, (1999).
(3) Ian N. Sneddon, *The Fourier Transforms*, Dover Publishers (1995).
(4) Joel L.Schiff, *Laplace Transforms: Theory and Applications*, second revised edition, Springer (1980).
(5) B.Davies, *The Integral Transforms and their applications*, Springer-Verlag (1978).
(6) Ian N. Sneddon, *The Use of Integral Transforms*, McGraw-Hill (1972).

Syllabus for MSC 2021 Admissions Onwards

MAM 21-803-1010 FUNCTIONS OF SEVERAL VARIABLES

Credits: 4

Total No. of Hours: 72

Objective: This course starts with the structure of $\mathbb{R}^n$. This course is planned to introduce the Differential calculus on the finite dimensional Euclidean Space and Integration on $\mathbb{R}^n$.
Learning Outcomes: After the completion of this course, the student should be able to be familiar with Differentiation and Intgration on $\mathbb{R}^n$.
UNIT 1: Multivariable Differential Calculus, Directional Derivatives and continuity, Total Derivative, The Jacobian matrix, Matrix form of the chain rule, Taylor formula for functions from $\mathbb{R}^n$ to $\mathbb{R}$ (Chapter 12)
UNIT 2: Implicit Functions and Extremum problems, functions with nonzero Jacobian determinant, Inverse function theorem, Implicit funtion theorem, Extrema of real-valued functions of several variables, Extremum problems with side conditions(Chapter 13)
UNIT 3: Multiple Riemann Integrals, The measure of a bounded interval in $\mathbb{R}^n$, Riemann Integral of a bounded funtion on a compact interval in $\mathbb{R}^n$, Lebesgue criterion for the existence of a multiple Riemann integral. (Chapter 14, Sections 14.1, 14.2, 14.3, 14.4, 14.5)
UNIT 4: Jordan Measurable sets in $\mathbb{R}^n$, Multiple Integration over Jordan-measurable sets, Step functions and their integrals, Fubini's reduction thorem for the double integral of a step function. (Chapter 14, 15 Sections 14.6, 14.7, 14.8, 14.9, 14.10, 15.1,15.2,15.3,15.4, 15.5)
UNIT 5: Multiple Lebesgue Integrals, Fubini's reduction theorem for double integrals ,Tonelli-Hobson test for integrability The transformation formula for multiple integrals(Chapter 15, Sections 15.6, 15.7, 15.7, 15.8, 15.9, 15.10, 15.11, 15.12, 15.13)
Text Book: Tom M. Apostol, *Mathematical Analysis*, Second Edition, Addison-Wesley 1974.

References:-

(1) Serge Lang, *Calculus Of Several Variables*, Addison-Wesley Publications, (1973).
(2) C.H. Edwards Jr.,*Advanced Calculus of Several Variables*, Academic Press New York, (1973).
(3) Rudin W., Real and Complex Analysis, 3rd edition, McGraw-Hill, New York (1986).
(4) Rudin W., Functional Analysis, 2nd edition, McGraw-Hill, New York (1991).
(5) D Somasundaram and B. Choudhary, A first course in mathematical analysis, Narosa, Oxford, London, (1996).
(6) K. A. Ross, Elementary Analysis; Theory of Calculus, Springer-Verlag, 2013.

Syllabus for MSC 2021 Admissions Onwards

MAM 21-803-1011 ADVANCED SPECTRAL THEORY

Credits: 4

Total No. of Hours: 72

Objective: This course starts with the review of Spectral Theory of Linear Operators in Normed Spaces. The idea of this course is to cover various classifications of spectrum and finally present the spectral theorem for bounded self-adjoint operators. Applications to quantum mechanics is also done.
Learning Outcomes: After the completion of this course, the student should be able to be familiar with the properties and applications of spectrum and spectral theorem.
Pre-requisites:

(1) Functional Analysis, Basic Analysis.
(2) Linear Algebra.

UNIT 1: Review of Spectral Theory of Linear Operators in Normed Spaces; Properties of Resolventa and Spectrum, Use of Complex Analysis in Spectral Theory. (Chapter 7)
UNIT 2: Spectral Properties of Bounded Self-adjoint Operators; Positive Operators, Spectral Family. (Chapter 9, Section 9.1 to 9.7)
UNIT 3: Spectral Theorem for Bounded Self-adjoint Operators, Properties of Spectral Family. (Chapter 9, Section 9.8 to 9.11)
UNIT 4: Unbounded Linear Operators in Hilbert Spaces; Spectral Representation of Unitary Operators, Spectral Representation of Self-Adjoint Operators (Unbounded). (Chapter 10)
UNIT 5: Unbounded Linear Operators in Quantum Mechanics. (Chapter 11)

Text Book: E. Kreyzig, Introduction to Functional Analysis with Applications, Addison – Wesley.

References:-

(1) Courant, R. and D. Hilbert, Methods of Mathematical Physics, vol. I, Interscience, Newyork (1953).
(2) Dunford N. and T. Schwartz, Linear Operators, Part I, Interscience, Newyork (1958).
(3) Rudin W., Real and Complex Analysis, 3rd edition, McGraw-Hill, Newyork (1986).
(4) Rudin W., Functional Analysis, 2nd edition, McGraw-Hill, Newyork (1991).
(5) Reed, M. and B. Simon, Methods of Mathematical Physics, vol. II, Academic Press, Newyork, (1975).
(6) Rajendra Bhatia, Notes on Functional Analysis, Texts and Readings in Mathematics, Hindusthan Book Agency, New Delhi (2009).
(7) G. F. Simmons, Introduction to Topology and Modern Analysi,s TMH.
(8) M. Thamban Nair, Functional Analysis; A first course, PHI Learning Pvt. Ltd. (2001).

Syllabus for MSC 2021 Admissions Onwards

MAM 21-803-1012 BANACH ALGEBRAS AND SPECTRAL THEORY

Credits: 4

Total No. of Hours: 72

Objective: This course introduces the notion of Banach Algebras. The theory of commutative Banach algebras are discussed in detail. Also, the spectral theory of bounded and unbounded operators on Hilbert spaces are discussed.

Learning Outcome: After completing the course, the student is expected to become familiar with the fundamental concepts and applications of Banach Algebras and Spectral Theory.

Prerequisites: A first course in Functional Analysis, Complex Analysis, Linear Algebra, Topology and Measure Theory is needed. The core courses taught in the first three semesters of the M.Sc. program will do the purpose.

UNIT 1: Banach Algebras: Introduction, Complex homomorphisms, Basic properties of Spectra, Symbolic Calculus, Invariant subspace theorem. (Chapter 10 of Text Book)

UNIT 2: Commutative Banach Algebras: Ideals and homomorphisms, Gelfand Transforms, Involutions, Positive functionals. (Chapter 11 of Text Book)

UNIT 3: Bounded Operators on a Hilbert Space: A commutativity theorem, Resolutions of the identity, The spectral theorem, Positive operators, An ergodic theorem. (Chapter 12 of Text Book)

UNIT 4: Unbounded Operators: Symmetric operators, The Cayley transform, Resolutions of the identity. (Chapter 13 of Text Book)

UNIT 5: Unbounded Operators (Contd.): The Spectral Theorem, Semigroup of Operators. (Chapter 13 of Text Book)

Text Book: Rudin, Walter. Functional Analysis. Second Edition. International Series in Pure and Applied Mathematics. McGraw-Hill, Inc., New York, 1991.

References:-

(1) Takesaki, M. Theory of Operator Algebras I. Reprint of the first (1979) edition. Encyclopaedia of Mathematical Sciences, 124. Operator Algebras and Non-commutative Geometry, 5. Springer- Verlag, Berlin, 2002.

(2) Arveson, William. An Invitation to C*-algebras. Graduate Texts in Mathematics, No. 39. Springer-Verlag, New York-Heidelberg, 1976.

(3) Douglas, Ronald G. Banach Algebras Techniques in Operator Theory. Second Edition. Graduate Texts in Mathematics, 179. Springer-Verlag, New York, 1998.

Syllabus for MSC 2021 Admissions Onwards

MAM 21-803-1013 NUMBER THEORY

Credits: 4

Total No. of Hours: 72

Objective: This course starts with the review of theory of numbers which will be followed by the divisibility and prime. This will involve some of the classical theory in the subject such as congruences, the Chinese remainder theorem, quadratic reciprocity law, Arithmetic functions and diophantine equations.

Learning Outcomes: After the completion of this course, the student should be able to be familiar with divisibility, primes, congruences, the Chinese remainder theorem, quadratic reciprocity law, Arithmetic functions and diophantine equations.

UNIT 1: Introduction to Numbers, Divisibility, Primes, [Chapter - 1 (Sections - 1.1,1.2,1.3)]

UNIT 2: Congruences, Solutions to congruences, The Chinese remainder theorem. [Chapter - 2 (Sections - 2.1,2.2,2.3)]

UNIT 3: Quadratic residues, Quadratic reciprocity, The Jacobi symbol. [Chapter - 3 (Sections - 3.1,3.2,3.3)]

UNIT 4: Greatest integer function, Arithmetic functions, The Mobius inversion formula. [Chapter - 4 (Sections 4.1, 4.2, 4.3)]

UNIT 5: The equation $ax + by = c$, Simultaneous equations, Pythagorean triangles, Assorted examples. [Chapter - 5 (Sections 5.1,5.2,5.3,5.4)]

Text Book: I. Niven, H.S. Zuckerman and H.L. Montgomery, An Introduction to the Theory of Numbers, 4th Ed., Wiley, New York, (1980).

References:-

(1) W.W. Adams and L.J. Goldstein, Introduction to the Theory of Numbers, 3rd ed., Wiley Eastern, (1972).

(2) A. Baker, A Concise Introduction to the Theory of Numbers, Cambridge University Press, Cambridge, (1984).

(3) K. Ireland and M. Rosen, A Classical Introduction to Modern Number Theory, 2nd ed., Springer-Verlag, Berlin, (1990).

(4) T.M. Apostol, An Introduction to Analytic Number Theory, Springer-Verlag, (1976).

Syllabus for MSC 2021 Admissions Onwards

MAM 21-803-1014 REPRESENTATION THEORY OF FINITE GROUPS

Credits: 4

Total No. of Hours: 72

Objective: To introduce the facinating theory of representations to the learner. Group representation theory will be discussed in detail through FG- Modules. To discuss the irreducible representations which are the building blocks of representations in detail. Chacter of a representation is a beautiful idea which is playing a vital role in the study of representations, here we discuss the character table of a group in detrail and construct the character table which will in fact replace the group itself.

Learning Outcome: The leaner must have gained a proper understanding of the idea of group representations such as permutation representation, linear representations. The leaner will be capable of constructing the character table of some interesting class of groups.

UNIT 1: Vector spaces, Modules, FG- modules, Group representations, Group algebras and homomorphisms. (Sections 1 to 7 of the text.)

UNIT 2: Maschke's theorem, Schur's lemma, Irreducibility (Sections 8 to 11 of the text.)

UNIT 3: Conjugacy classes, Character, Irreducibility, Inner product, Character table, Normal subgroups and lifted characters. (Sections 12 to 17 of the text.)

UNIT 4: Elementary charactertables, Tensor products, Restriction to subgroup, Induced modules and characters. (Sections 18 to 21 of the text.)

UNIT 5: Properties of character tables. Permutation chracters. (Sections 24 and 29 of the text.)

Text Book: Gordon James and Martin Liebeck, Representation and Characters of Groups, Cambridge University Press, Second Edition, 2001.

References:-

(1) Willim Fulton, Joe Harries, Representation theory, A first course, 191 Springer Verlag, ISBN 81-8128-134-9.

(2) David S Dummit, Richard M. Foot, Abstract Algebra , Third edition, John Wiley & Sons, Inc. 2004.

(3) Walter Ledermann, Introduction to group characters, Second edition, Cambridge University Press, 2008. ISBN 978-0-521-33781-6.

Syllabus for MSC 2021 Admissions Onwards
MAM 21-803-1015 ALGEBRAIC TOPOLOGY

Credits: 4

Total No. of Hours: 72

Objective: At the end of the course the students will have the necessary introduction to the subject of Algebraic topology. The algebraic notions of the fundamental group of a space and that of homology and even cohomology theories is covered in the course. All the important topological constructions and concepts conducive for the algebraic study are also studied with enough examples.

Learning Outcomes: At the completion of the course, students will be comfortable with the necessary topological concepts and constructions like attaching spaces, suspension, excision, homotopy and deformation retraction among others. Along with the study of the fundamental group and classification of covering spaces, the students will also work with the homology and cohomology theories, which will serve as an important application of their course in module theory.

UNIT 1: Homotopy and homotopy type, Cell complexes, Operations on spaces, Two criteria for homotopy equivalence, the homotopy extension property. (Chapter 0 of Hatcher)

UNIT 2: Applications of Van Kampen's theorem, Covering spaces, lifting properties, Universal cover and classification of covering spaces, Deck transformations and properly discontinuous actions. (chapter 1 of Hatcher)

UNIT 3: Delta-complexes and Simplicial homology, Singular homology, Homotopy Invariance, Exact sequences and excision, Equivalence of simplicial and singular homology. (Chapter 2 of Hatcher)

UNIT 4: Cellular homology (with special emphasis on CW-complexes), Mayer-Vietoris sequences, Homology with coefficients, the formal viewpoint of homology theories (briefly) (Chapter 2 of Hatcher)

UNIT 5: The definition of cohomology groups, The Universal Coefficient theorem, computation of cohomology of spaces, Relative groups and the long exact sequence of a pair of spaces (X, A), Cup product and the Cohomology ring structure, Kunneth formula for product of spaces, Poincare duality. (Chapter 3 of Hatcher)

Text Book: Algebraic Topology, Allen Hatcher.

References:-

(1) Lecture notes in Algebraic Topology, James F. Davis, Paul Kirk.

Syllabus for MSC 2021 Admissions Onwards
MAM 21-803-1016 DIFFERENTIAL GEOMETRY

Credits: 4

Total No. of Hours: 72

Objective: The course is aimed to introduce the popular tools to perform a study of geometry with the help of calculus on an n-dimensional surface. Develop the notion of curvature of parametric surfaces with the idea of, vector fields along a parametrized curve on the surface. Towards the end of the course, students will get all the necessary foundations to study Riemannian Geometry.

Learning Outcomes: After the completion of this course, the student should be able to

(1) be familiar with the concepts vector fields, tangent space, surfaces and its orientations.
(2) get introduced to the spherical image of surfaces, geodesics, Weingarten map, and curvature of surfaces.
(3) understand local equivalence of surfaces and parametrized surfaces.
(4) obtain sound knowledge in rigid motions, congruence, isometries and results related these.

Pre-requisites: Linear Algebra, Multivariate Calculus, and Differential Equations.

UNIT 1: Graphs and level sets, Vector fields, Tangent spaces, Surfaces, Vector Fields on Surfaces; Orientation, Gauss map.

UNIT 2: Geodesics, Parallel Transport, Weingarten Map, Curvature of Plane Curves.

UNIT 3: Arc lengths, Line integrals, Curvature of surfaces

UNIT 4: Parametrized surfaces, Local equivalence of surfaces and parametrized surfaces.

UNIT 5: Differentiable manifolds, Introduction, Tangent space, Immersions and embeddings; examples, Other Examples of manifolds, Orientation, Vector fields, brackets, Topology of manifolds. (Chapter 0 of the text 2)

Texts:

(1) J.A. Thorpe: Elementary Topics in Differential Geometry, Springer-Verlag [Chapters 1 -12, 14, 15, 22, 23]
(2) Manfredo Perdigao do Carmo, Riemannian Geometry, Birkhauser 1993.

References:-

(1) L. M. Woodward, J. Bolton, A First Course in Differential Geometry: Surfaces in Euclidean Space, Cambridge university press, 2019.
(2) Edouard Goursat, A Course in Mathematical Analysis, Vol. 1, Forgotten Books, 2012.
(3) Andrew Pressley, Elementary Differential Geometry, second edition, Springer 2010.
(4) Dirk J. Struik, Lectures on Classical Differential Geometry, Dover publications Inc. 1988.
(5) Kreyszig, Introduction to Differential Geometry and Reimannian Geometry, University of Toronto Press, 1968.

DEPARTMENT OF PHYSICS

Scheme of Examinations and Syllabus for
the Five Year Integrated M.Sc. Physics Degree Program

Approved by the Board of Studies in Physical and Mathematical Sciences
on 17th July 2021

(From 2021 admission onwards)

Cochin University of Science and Technology
Cochin - 682 022

Website: http://physics.cusat.ac.in

Preamble

Scientifically advanced people are a prerequisite for a society to become a developed one in every aspect. Becoming a developed nation depends upon creating a critical mass of researchers who work on some of the forefront areas of scientific knowledge. Building quality manpower in fundamental subjects such as physics is essential for a society to build a strong foundation in science and technology.

The Department of Physics of Cochin University envisions carrying out this mission by providing quality advanced training in Physics to students through its 5 year Integrated M.Sc. program and carrying out good scientific research. We strive to impart various skills to students, enabling them to take up scientific research and teaching as a career and engage in lifelong learning. We also acknowledge the diverse set of needs of students in a country like ours. We strive to impart to the students excellent analytical and computational skills, which are imperative for success in any field in today's world.

Our Integrated M.Sc. syllabus is designed with the view that a student completing the course will have mastery of several specialized fields in physics. This is achieved through providing advanced elective topics in both theoretical and experimental physics. An entire semester devoted to Project work and seminars complements the advanced courses to give the students a firsthand experience in scientific research. Integrated M.Sc. students can access various research labs of the department, which further enhance their experience. We believe in moving with time and incorporate the latest trends and technological advancements in education. An increased focus on learning and using various computational tools in the curriculum helps students progress in tune with the times.

Program specific outcomes: Integrated M.Sc. Physics

- Acquire mastery of several advanced topics in Physics according to the aptitude of students.
- Acquire excellent analytical and computational skills.
- Enable students to take up scientific research and teaching as a career and engage in lifelong learning.
- Acquire firsthand experience in scientific research by working on research problems at the forefront.
- Acquire excellent abilities in various aspects of scientific communication.

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Scheme

Semester – I

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
ENG 10101	English -I	C	50	50	100	2
MAL 10101	Malayalam - I*	C	50	50	100	2
HIN 10101	Hindi - I*	C	50	50	100	2
FLG 10101	German - I*	C	50	50	100	2
PHY 21-352-0101	Mechanics	C	50	50	100	3
CHE 10101	Atomic Structure and Chemical Bonding	C	50	50	100	3
MAM 10101	Calculus - I	C	50	50	100	4
BIO 10101	General Biology	C	50	50	100	3
PHY 21-352-0102	Physics Lab - I (Mechanics)	C	100	–	100	2
CHE 10102	Inorganic Quantitative Analysis Lab	C	100	–	100	2
BIO 10102	General Biology Lab	C	100	–	100	2
	Total		600	300	900	23

*Either Malayalam - I, Hindi - I or German - I is to be opted.

Semester – II

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
ENG 10201	English -II	C	50	50	100	2
MAL 10201	Malayalam - II*	C	50	50	100	2
HIN 10201	Hindi - II*	C	50	50	100	2
FLG 10201	German - II*	C	50	50	100	2
PHY 21-352-0201	Waves and Optics	C	50	50	100	3
CHE 10201	Periodicity, Nuclear Chemistry, Metallurgy and Acid Base Chemistry	C	50	50	100	3
MAM 10201	Linear Algebra and Graph Theory	C	50	50	100	4
BIO 10201	Biochemistry	C	50	50	100	3
PHY 21-352-0202	Physics Lab - II (Waves and Optics)	C	100	–	100	2
CHE 10202	Inorganic Qualitative Analysis Lab	C	100	–	100	2
BIO 10202	Biochemistry Lab	C	100	–	100	2
	Total		600	300	900	23

*Either Malayalam - II or Hindi - II or German - II is to be opted.

Semester – III

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
PHY 21-352-0301	Electricity and Magnetism - I	C	50	50	100	3
CHE 10301	Introductory Organic Chemistry	C	50	50	100	3
MAM 10301	Calculus - II	C	50	50	100	4
MAM 10302	Mathematical Methods - I	C	50	50	100	4
BIO 10301	Cell Biology	C	50	50	100	3
EVS 10301	Environmental Science	C	50	50	100	2
PHY 21-352-0302	Physics Lab - III (Electricity and Magnetism)	C	100	–	100	2
CHE 10302	Organic Qualitative analysis Lab	C	100	–	100	2
BIO 10302	Cell biology Lab	C	100	–	100	2
	Total		600	300	900	25

Semester – IV

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
PHY 21-352-0401	Quantum Physics and Relativity	C	50	50	100	3
CHE 10401	Introductory Physical Chemistry	C	50	50	100	3
MAM 10401	Mathematical Methods - II	C	50	50	100	4
STA 10401	Probability and Statistics	C	50	50	100	4
BIO 10401	Molecular Biology and Genetics	C	50	50	100	3
COM 10401	Basic Computer Science	C	50	50	100	2
PHY 21-352-0402	Physics Lab - IV (Modern Physics)	C	100	–	100	2
CHE 10402	Physical Chemistry Lab	C	100	–	100	2
BTG 10402	Molecular Biology and Genetics Lab	C	100	–	100	2
	Total		600	300	900	25

Semester – V

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
PHY 21-801-0501	Thermal Physics	C	50	50	100	4
PHY 21-801-0502	Electricity and Magnetism - II	C	50	50	100	4
PHY 21-801-0503	Basic Mathematical Physics	C	50	50	100	4
PHY 21-801-0504	Basic Solid State Physics	C	50	50	100	4
PHY 21-801-0505	Physics Lab - V (Computer Lab)	C	100	–	100	4
	Total		300	200	500	20

Semester – VI

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
PHY 21-801-0601	Modern Optics	C	50	50	100	4
PHY 21-801-0602	Electronics	C	50	50	100	4
PHY 21-801-0603	Basic Nuclear Physics	C	50	50	100	4
PHY 21-801-0604	Minor Project	C	50	50	100	4
PHY 21-801-0605	Physics Lab - VI	C	100	–	100	4
	Total		300	200	500	20

Semester – VII

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
PHY 21-801-0701	Mathematical Physics	C	50	50	100	4
PHY 21-801-0702	Classical Mechanics	C	50	50	100	4
PHY 21-801-0703	Electrodynamics	C	50	50	100	4
PHY 21-801-0704	Quantum Mechanics – I	C	50	50	100	4
PHY 21-801-0705	Advanced Experiments in Physics Lab-I	C	100	-	100	3
	Total		300	200	500	19

Semester –VIII

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
PHY 21-801-0801	Quantum Mechanics – II	C	50	50	100	4
PHY 21-801-0802	Statistical Mechanics	C	50	50	100	4
PHY 21-801-0803	Atomic and Molecular Spectroscopy	C	50	50	100	4
PHY 21-801-0804	Advanced Electronics	C	50	50	100	4
PHY 21-801-0805	Advanced Experiments in Physics Lab-II	C	100	-	100	4
	Total		300	200	500	20

Semester – IX

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
PHY 21-801-0901	Nuclear and Particle Physics	C	50	50	100	4
PHY 21-801-0902	Advanced Solid State Physics	C	50	50	100	4
PHY 21-801109xx	Elective – I *	E	50	50	100	4
PHY 21-801-09yy	Elective – II *	IE	50	50	100	4
PHY 21-801-0903	Advanced Experiments in Physics Lab-III	C	100	-	100	4
	Total		300	200	500	20

Semester – X

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
PHY 21-801-1001	Major Project@	C	200	200	400	16
PHY 21-801-1002	Online course **	E	50	-	50	2
PHY 21-801-10zz	Elective – III (Online Mode) *	E	50	50	100	4
	Total		300	250	550	22

Total credit requirement for the Program: 216

There will be no end semester examination for the practical or lab courses and they will have only continuous evaluation.
* Elective - I and Elective - III (Online mode) are Departmental elective courses. i.e offered by the faculty members of the Department. Elective – II is the interdepartmental elective (IE) course. Replace xx, yy and zz with selected elective course codes. Classes and continuous evaluation of Elective-III will be conducted fully in online mode so that students who do major project in other institutions have no difficulty attending it. The mode of end semester examination of Elective-III will be decided by the Department Council before the examination.

@**Regarding the Major Project the following directions may be followed:**

(a) The major project can be done within the department or in an external institution of National/International reputation. i.e. institutions like, IISc Bangalore, Various IIT's, IISERs, Central Universities, CSIR laboratories, NITs TIFR, Raman Research Institute, IIA, inter university centres like IUCAA, NPOL, ISRO, DRDO, IIEST, industrial organisation, etc and any other equivalent institution.

(b) If a student wants to do his/her project in an external institution he/she has to find the supervisor from a nationally/internationally reputed institution like as mentioned above. A consent letter from the external supervisor should be produced to the Department Head/Coordinator of the batch. The consent letter can be considered by the Department council/Department Head and approval can be given to the student to pursue the project with the supervisor concerned.

(c) An internal faculty in charge must be assigned by the Department Council/Department Head to each student who is doing the project in other institutions/departments.

(d) The internal faculty in charge will periodically monitor the progress of the students assigned to him/her.

(e) Continuous evaluation of the project must be done by the supervisor. In the case of projects done outside the department, this can be done either by the external supervisor alone or by internal faculty in charge (in cases where the external supervisor is not able produce an official evaluation statement) or by both the internal and external supervisors together.

(f) The department shall arrange a mid-term presentation for all students. This will form a part of the continuous evaluation.

(g) The students must submit a report at the end of the project, which is duly signed and recommended by the supervisor on or before the date stipulated by the Department. For projects done outside, the report must be duly signed by the external supervisor.

(h) The end semester evaluation in the form of a presentation followed by viva based on the project will be done in the Department by a committee appointed by the Department Council/Department Head.

** Online course PHY 21-801-1002 can be selected by the students from a set of courses approved by the Department Council. The Department can recommend courses from reputed platforms like Swayam (UGC), Coursera, CUSAT - MOOC etc. The following guidelines will be applicable for the online course.

(a) The credit given by the department for such a course will be two (2 only) regardless of its duration.

(b) A sub-committee appointed by the Department council can approve a set of courses that the students in the Department can take. This will be based on considerations such as the length of the course, the relevance of its content to the program, etc. The list of approved courses will be notified to the students before the beginning of the first semester. The students are allowed to choose a course from this approved set only.

(c) Students may register and complete the online course at their convenience during the two year period of the program but before the submission of the final project report.

(d) At the end of the course, the student should produce a valid document regarding the successful completion of the Course and stating his/her marks/grades. The Department Council will ascertain that the document produced is satisfactory and recommend awarding two (2 only) credits for the course along with the marks/grades obtained.

(e) If a student fails a course, he/she may take the same or another approved course after informing the council.

Syllabus

Semester I

PHY 21-352-0101: Mechanics

Credits: 3
Hours : 54 hours

Course Objective

This intends to develop the basics methods of analysing the mechanics of a system using the most fundamental rules of mechanics.

Course Outcome

1. Understand the, Newtons laws of motion, the most fundamental rule of Mechanics.
2. Enable the students to apply the Newtons law in order to analyse basic dynamics of physical systems.
3. Acquire the capacity to use the energy conservation principle to understand the dynamics of a system.
4. Familiarise the rules of understanding the different properties of the material world, like elasticity, surface tension, etc.

Module I General introduction. Vectors: Notation, addition and multiplication of vectors, scalar and vector products, vector derivatives, velocity and acceleration, form invariance. Laws of motion: Equations of motion, motion under gravitational force, law of universal gravitation, motion under electric and magnetic forces, momentum conservation, friction. Frames of reference: inertial and non-inertial frames, absolute and relative velocity, Galilean and transformation.

Module II Conservation laws: Conservation of energy, conservative forces, power, Conservation of linear and angular momentum, center of mass frame, systems with variable mass. Harmonic oscillator: Example systems, importance in physics, kinetic and potential energy, damped harmonic oscillator, driven harmonic oscillator, superposition principle.

Module III Rigid-body dynamics: Equation of motion, angular momentum and kinetic energy, moments of inertia, rotations about fixed axes, moments and products of inertia: Principal axes and Euler's equations, Motion under inverse-square-law force: circular orbit, Kepler 's laws, Two-body problem.

Module IV Properties of matter: Elasticity, Stress, strain, elastic constants, Poisson's ratio relation connecting various elastic constants, Hydrodynamics, Streamline and turbulent flows-tubes of flow and equation of continuity energy possessed by a liquid- Bernoulli's theorem-Torricelli's theorem, Viscosity, critical velocity-flow of liquid through a capillary tube (Poiseulle's formula)-Stokes formula, Surface tension, surface energy.

Text Books:

1. Mechanics, C. Kittel, W.D. Knight, M.A. Ruderman, C.A. Helmholz and B.J. Moyer, Berkeley Physics Course Vol 1, Tata McGraw-Hill Ltd (2008). (Chapters 1-9)

2. Elements of Properties of Matter, D. S. Mathur, S. Chand & Co (2008).

Reference Books:

1. University Physics, H.D Young and R.A. Freedman, 12-th Edition, Pearson (2009). (Chapters 1-14).

2. Mechanics, L.D. Landau and I.M. Lifshitz, 3rd edition, Elseviar (2007).

3. The Feynman Lectures on Physics Vol I, Narosa Publications (2003). (Chapters 1-25).

Semester II

PHY 21-352-0201: Waves and Optics

Credits: 3
Hours : 54 hours

Course Objective

To impart the basic properties of waves to understand different properties of light.

Course Outcome

:

1. Familiarise the terms wavelength, frequency, superposition of waves.
2. Familiarise the method of Fourier analysis to study the properties of wave
3. Familiarise the electromagnetic wave properties.
4. understand the methods reflection, refraction.

Module I Free oscillations of simple systems: Systems with one degree of freedom, linearity and the superposition principle, systems with two degrees of freedom, Beats.

Module II Review of periodic motion, Representations of periodic motion-Free oscillations of simple systems: Systems with one degree of freedom, linearity and the superposition principle, systems with two degrees of freedom, Matrix method of finding the normal co-ordinates, Beats, Lissajous figures, Comparison of parallel and perpendicular superposition.

Module III Electromagnetic theory, Photons and Light: Basic laws, electromagnetic waves, energy and momentum, light in bulk matter, electromagnetic-photon spectrum. Rayleigh scattering.

Module IV Reflection, refraction, Fermat's principle, total internal reflection, Fiber optics, optical properties of metals, Familiar aspects of interaction of light with matter, The Stokes treatment of reflection and refraction.

Text Book:

1. Waves, F.S. Crawford Jr, Berkeley Physics Course Volume 3, Tata McGraw-Hill Ltd (2008). (Chapters 1-2).
2. A First course in Vibration and Waves, Mohammed Samiullah, Oxford University Press (2015) (Chapters 1-4)
3. Physics of Waves and Oscillations, H. J. Pain, Wiley (2005) (Chapter 10).
4. Vibration and Waves, The M.I.T Introductory Physics Series, A.P.French, W.W. Norton & Company (1971)
5. Optics, E. Hecht, 4th Edition, Pearson education (2009) (Chapters 3-5).

Reference Books:

1. University Physics, H.D Young and R.A. Freedman, 12-th Edition, Pearson (2009). (Chapters 15-16).

2. The Feynman Lecture on Physics Vol. I, Narosa (2003). (Chapters 26-36).

Semester III

PHY 21-352-0301: Electricity and Magnetism I

Credits: 3
Hours : 54 hours

Course Objective

:
This course will help in understanding basic concepts of electricity and magnetism and their applications.
Basic course in electrostatics will equip the student with required prerequisites to understand electrodynamics phenomena.

Course Outcome

:

1. Demonstrate Coulomb's law for the electric field, and apply it to systems of point charges.
2. Apply Gauss?s law of electrostatics to solve a variety of problems.
3. Articulate knowledge of electric potential and electric potential energy and different electrical measuring instruments.
4. Demonstrate a working understanding of direct current circuits and characteristics of R- C and R-L circuits.
5. Describe the magnetic field produced by moving charge and various applications of motion of charged particles in the magnetic field.
6. Explain Faraday-Lenz laws to articulate the relationship between electric and magnetic fields.
7. Calculate the energy stored in a magnetic field

Module I Electrostatics - Charges and fields: Electric Charge, Conservation of Charge, Quantization of Charge, Coulomb?s Law, The Electric Field, and Electric forces, Electric field calculations, Electric field lines, electric dipoles, Charge and electric Flux, Gauss?s Law, Field of a Spherical Charge Distribution, Field of a uniform Line Charge, Field of an infinite plane sheet of charge

Module II The electric potential: Electric Potential Energy, Electric Potential Energy in a Uniform Field, Electric Potential Energy of Two Point Charges, Electric Potential Energy with Several Point Charges, Calculating Electric Potential, Finding Electric Potential from Electric Field, the electric potential of a charged conducting sphere, electric potential of an infinite line charge, potential of a ring of charge and line of charge, equipotential Surfaces, the potential gradient

Module III Electric currents: Electric Current and Current Density, Resistivity, Resistance, Electromotive Force, and Circuits, Energy and power in electric circuits, Electrical Conductivity and Ohm?s Law, The Physics of Electrical Conduction, Conduction in Metals, Semiconductors, Direct current circuits, Resistors in series and parallel, Kirchhoff?s rules, Electrical Measuring Instruments, R-C circuits The fields of moving charges: Magnetic Forces, Measurement of Charge in Motion, Invariance of Charge, Electric Field Measured in Different Frames of Reference, Field of a Point Charge Moving with Constant Velocity, Field of a Charge That Starts or Stops, Force on a Moving Charge, Interaction between a Moving Charge and Other Moving Charges.

Module IV Magnetic field and electromagnetic induction: Magnetic Field, the motion of charged particles in a magnetic field- applications, the magnetic force on a current-carrying conductor, Hall effect, magnetic field of a moving charge, magnetic field of a current element, magnetic field of a straight current-carrying conductor, magnetic field of a circular loop, Electromagnetic induction: Faraday?s law, Lenz?s law, Mutual Inductance, Self-inductance, Energy Stored in the Magnetic Field, R-L circuits.

Text Books:

1. Electricity and Magnetism, Purcell, Berkeley Physics Course Volume 2, Tata McGraw-Hill Ltd (2008). (Chapters 1-2, Chapters 4-7).

2. University Physics, H.D Young and R.A. Freedman, 12th Edition, Pearson (2009).(Ch 21- 23, 25-30)

Reference Books:

1. Introduction to Electrodynamics, D. J. Griffiths, Pearson Education India, 4th edition (2015).

2. The Feynman lectures Volume II, Narosa (2003).

3. Fundamentals of Physics, Halliday, Resnik and Walker, John Wiley and Sons Inc, 11th Edition.

Semester IV

PHY 21-352-0401: Quantum Physics and Relativity

Credits: 3
Hours : 54 hours

Course Objective

: The course aims to develop an understanding among the students about importance of Quantum Physics and Relativity. After completing this course, the students should be able to

1. Understand about special theory of relativity, doppler effect, time dilation, length contraction, relativistic energy and momentum.
2. Understand the importance of wave particle duality in blackbody radiation, photoelectric effect, Compton effect, pair production and particle in a box.
3. Describe the atomic structure and emission/absorption spectra.
4. Solve particle in a box, finite potential well, and harmonic oscillator problems using Schrödinger's equation.

Course Outcome

:

1. Solve standard problems in doppler effect, time dilation, and length contraction.
2. Define postulates of Special theory of relativity.
3. Understand the wave particle duality.
4. Understand the necessity of quantum physics for explaining blackbody radiation, photoelectric effect, Compton effect.
5. Differentiate phase and group velocity of de Broglie waves.
6. Understand Bohr atom model and energy levels.
7. Calculate excitation wavelength corresponding to different atomic transition.
8. Differentiate the importance of 3 and 4 level lasers with its energy level diagram.
9. Solve particle in a box, finite potential well, and harmonic oscillator problems using Schrödinger's equation.

Module I The speed of light as a fundamental constant of nature, measuring speed of light, speed of light in inertial frames in relative motion, Doppler effect. Special theory of relativity: basic assumptions, Lorentz transformation, time dilation and length contraction, relativistic energy and momentum, Transformation of momentum and energy, Transformation of the rate of change of momentum, constancy of charge, problems in relative dynamics.

Module II Particle properties of waves: electromagnetic waves, blackbody radiation, photoelectric effect, X-rays, Compton effect, pair production. Wave properties of particles: De Broglie waves, phase and group velocities, particle diffraction, particle in a box, uncertainty principle.

Module III Atomic structure: Electron orbits, atomic spectra, The Bohr atom, Energy levels and spectra, nuclear motion, atomic excitation, laser.

Module IV Quantum mechanics: The wave equation, Schrödinger's equation, linearity and superposition, expectation values, operators, steady state equation, particle in a box, finite potential well, tunnel effect, harmonic oscillator.

Text Books:

1. Concepts of Modern Physics, Arthur Beiser, Tata McGraw-Hill, 7th Edition, (2015).

2. Quantum Physics, H. C. Verma, Surya Publications, 2nd Edition (2009).

3. University Physics, H.D Young and R.A. Freedman, 12-th Edition, Pearson (2009). (Chapters 37-44).

Reference Books:

1. Quantum physics, E.H. Wichmann, Berkeley Physics Course Volume 4, Tata McGraw-Hill Ltd (2008).

2. Introduction to Quantum Mechanics, D. Griffiths, 2nd Edition, Cambridge University (2017).

Semester V

PHY 21-801-0501: Thermal Physics

Credits: 4
Hours : 72 hours

Course Objectives

This course introduces basics of thermal physics to the students. The course aims to make the students understand and apply various concepts of thermodynamics.

Course Outcomes

Upon completion of this course, a student should be able to -

1. Demonstrate an understanding of the terminology, concepts and principles of thermal physics.
2. Develop basics of Kinetic theory of gases.
3. Demonstrate an understanding of basics of thermal transport.
4. Demonstrate an understanding of laws of Thermodynamics.
5. Demonstrate an understanding of various thermodynamic potentials and their uses.

Module I Introductory material: Heat and heat capacity, basic probability, thermal equilibrium. Kinetic theory of gases: Maxwell-Boltzmann distribution, Pressure, Molecular effusion, mean free path and collisions.

Module II Transport and thermal diffusion: Transport properties in gases, The thermal diffusion equation. The first law of thermodynamics: Energy, Isothermal and adiabatic processes.

Module III The second law of thermodynamics: Heat engines and the second law, entropy and the second law.

Module IV Thermodynamic potentials: Internal energy, Enthalpy, Helmholtz function, Gibbs function, Maxwell's relations. Third law of thermodynamics.

Text Book:

1. Concepts in thermal physics, S.J. Blundell and K. M. Blundell, Oxford University Press (2008). (Chapters 1-16, Chapter-18)

Reference Books:

1. Statistical Physics, F. Reif, Berkeley Physics Course, Volume 3, Tata- McGraw-Hill (2008).
2. Heat and Thermodynamics, M. Zemansky and R. Dittman, 7th Edition, McGraw-Hill (1997).
3. University Physics, H.D Young and R.A. Freedman, 12-th Edition, Pearson (2009). (Chapters 17-20).

PHY 21-801-0502: Electricity and Magnetism II

Credits: 4
Hours : 72 hours

Course Objective

In paper I of this subject we have introduced the basic of electricity and magnetism. In this paper the main objective is to continue the effort in understanding further like properties of dipole etc and also understanding how these two fields have been united into a single object called electromagnetic field.

Course Outcome

1. Familiarise with the basics of electric field in conductors.
2. Familiarise with dielectric properties and allied phenomenon called electric polarisation.
3. Understanding mainly the alternating current and displacement current and their significance.
4. Understanding the magnetic properties of matter.

Module I Electric fields around conductors: Conductors and Insulators, Conductors in the Electrostatic Field, The General Electrostatic Problem, Uniqueness Theorem, Capacitance and Capacitors, Potentials and Charges on Several Conductors, Energy Stored in a Capacitor.

Module II Electric fields in matter: Dielectrics, The Moments of a Charge Distribution, The Potential and Field of a Dipole, The Torque and the Force on a Dipole in an External Field, Atomic and Molecular Dipoles, Induced Dipole Moments, Permanent Dipole Moments. The Electric Field Caused by Polarized Matter, The Field of a Polarized Sphere, A Dielectric Sphere in a Uniform Field, The Field of a Charge in a Dielectric Medium and Gauss's Law, A Microscopic View of the Dielectric Polarization in Changing Fields, The Bound-Charge Current, An Electromagnetic Wave in a Dielectric.

Module III Alternating current circuits: A Resonant Circuit, Alternating Current, Alternating-Current Networks, Admittance and Impedance, Power and Energy in Alternating-Current Circuits. Maxwell's equations and electromagnetic waves: The Displacement Current, Maxwell's Equations, An Electromagnetic Wave, Other Waveforms; Superposition of Waves, Energy Transport by Electromagnetic Waves, How a Wave Looks in a Different Frame.

Module IV Magnetic fields in matter: How Various Substances Respond to a Magnetic Field, The Absence of Magnetic "Charge", The Field of a Current Loop, The Force on a Dipole in an External Field, Electric Currents in Atoms, Electron Spin and Magnetic Moment, Magnetic Susceptibility, The Magnetic Field Caused by Magnetized Matter, The Field of a Permanent Magnet, Free Currents and the Field H, Ferromagnetism.

Text Books:

1. Electricity and Magnetism, Purcell, Berkeley Physics Course Volume 2, Tata McGraw-Hill Ltd (2008). (Chapter 3, Chapters 8-11).

Reference Books:

1. Introduction to Electrodynamics, D. J. Griffiths, 4th Edition, Cambridge University Press (2017).
2. The Feynman lectures on Physics Volume II, Narosa (2003).
3. University Physics, H.D Young and R.A. Freedman, 12-th Edition, Pearson (2009).

PHY 21-80-0503: Basic Mathematical Physics

Credits: 4
Hours : 72 hours

Module 1

Course Objectives

This course introduces basic mathematical tools used in physics to the students. The course aims to prepare the students for understanding and applying various mathematical formalisms used in physics. The course is a very relevant one for students as the mathematical techniques introduced find applications in every branch of physics and other quantitative sciences.

Course Outcomes

Upon completion of this course, a student should be able to -

1. Set up and solve problems involving matrices.
2. Diagonalize a matrix.
3. Solve basic problems in probability and understand Binomial and Poisson probability distributions.
4. Understand and solve basic problems in sample statistics.
5. Solve first order ordinary differential equation by different techniques.
6. Demonstrate an understanding of Heaviside unit step function and Dirac delta function.
7. Demonstrate an understanding of Fourier series and its applications.
8. Find Fourier transform of function.
9. Find Laplace transform of functions.
10. Use Laplace transform to solve an ordinary differential equations with constant coefficients.

Module I Matrices and vector spaces: Vector spaces, linear operators, matrices, basic matrix algebra, functions of matrices, transpose, Hermitian conjugate, trace, determinant, inverse and rank. Special types of square matrices, Eigenvectors and eigenvalues, Change of basis and similarity transformation, diagonalisation, simultaneous linear equations.

Module II Probability and statistics: Venn diagrams, probability, permutations and combinations, random variables and distributions, properties of distributions, important discrete distributions, Binomial, geometric and Poisson distributions. Experiments samples and populations, sample statistics, estimators and sampling distributions.

Module III First order ordinary differential equations: General form of solution. First degree first order equations. Separable- variable equations, exact equations, inexact equations, integrating factors, linear equations, homogeneous equations, isobaric equations, Bernoulli's equation, miscellaneous equations. Higher degree first order equations.

Module IV Heaviside unit step function, one dimensional Dirac delta function, properties and representations, three dimensional Dirac delta function. Fourier series–general properties, applications and properties of Fourier series. Integral transforms, Fourier transforms – inversion theorem, Fourier transform of derivatives, convolution theorem. Elementary Laplace transforms, Laplace transform of derivatives, inverse Laplace transforms, solution of ordinary differential equations with constant coefficients.

Text Books:

1. Tai L. Chow, Mathematical Methods for Physicists. A concise introduction, Cambridge University Press (2008).

2. George Arfken, Mathematical Methods for Physicists, Fourth (Prism Indian) 7th Edition, Elsevier (2012).

3. K. F. Riley, M. P. Hobson and S. J. Bence, Mathematical methods for physics and engineering, Cambridge Universality Press (2006).

PHY 21-801-0504: Basic Solid State Physics

Credits: 4
Hours : 72 hours

Course Objective

Introduce the most basic structure of solid state physics.

Course Outcome

1. Understanding the various types crystal structure and their properties.
2. Understanding the band structure in crystals.
3. Understanding the magnetic properties of solids and also the fundamentals of superconductivity.

Module I Crystal Structure Crystalline and amorphous solids, translational symmetry. Elementary ideas about crystal structure, lattice and bases, unit cell, reciprocal lattice, fundamental types of lattices, Miller indices, lattice planes, simple cubic, f.c.c. and b.c.c. lattices. Laue and Bragg equations. Determination of crystal structure with X-rays.

Module II Structure of solids Different types of bonding - ionic, covalent, metallic, van der Waals and hydrogen. Free electron theory of metals, effective mass, drift current, mobility and conductivity, Wiedemann-Franz law. Hall effect in metals. Band theory of solids, Periodic potential and Bloch theorem, Kronig-Penny model, energy band structure. Band structure in conductors, direct and indirect semiconductors and insulators (qualitative discussions).

Module III Magnetic properties of materials Dia, para and ferro-magnetic properties of solids. Langevin's theory of diamagnetism and paramagnetism. Quantum theory of paramagnetism, Curie's law. Ferromagnetism: spontaneous magnetization and domain structure; temperature dependence of spontaneous magnetisation; Curie-Weiss law, explanation of hysteresis. Superconductivity Introduction (Kamerlingh-Onnes experiment), effect of magnetic field, Type-I and type-II superconductors, Isotope effect. Meissner effect. Heat capacity. Energy gap. Ideas about High-Tc superconductors.

Module IV Lattice vibrations Elastic and atomic force constants; Dynamics of a chain of similar atoms and chain of two types of atoms; optical and acoustic modes; interaction of light with ionic crystals. Einstein's and Debye's theories of specific heats of solids. Dielectric properties of materials Electronic, ionic and dipolar polarizability, local fields, induced and oriented polarization – molecular field in a dielectric; Clausius-Mosotti relation.

Text Books:

1. Solid State Physics, Dekker, A. J., Macmillan (2000).
2. Introduction to Solid State Physics (8th Edition), Charles Kittel, Wiley (2004).
3. Solid state physics, Ashcroft, Neil W. and Mermin, N., Brooks/Cole (1976).

4. Elements of x-ray diffraction (3rd edition), Cullity, B. D. and Stock, Stuart H., Prentice Hall (2001).

5. Elementary Solid State Physics: Principles and Applications, Ali Omar, Pearson (1993).

6. The Oxford solid state basics, Simon, Steven, Oxford University Press (2004).

Semester VI

PHY 21-801-0601: Modern Optics

Credits: 4
Hours : 72 hours

Course Objective

Light and its various properties are important to understand to use them for suitable application. The objective of this course is to help the students in this regard in the basic level.

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Course Outcome

1. Understanding the modulation of light and its various significance.
2. Familiarise with the most important property of light, the polarisation and its significance.
3. Understanding Interference and diffraction of light.
4. Understanding the basics of Fourier optics.

Module 1 Modulation, pulses and wave packets: Group velocity, pulses, Fourier analysis of pulses and traveling wave packet.

Module 2 Nature of polarized light, polarizers, dichroism, birefringence, scattering and polarization, polarization by reflection, retarders, circular polarizers, polarization of polychromatic light, optical activity, induced optical effects-optical modulators, liquid crystals

Module 3 Interference: General considerations, conditions for interference, interferometers, types and localization of interference fringes, multiple-beam interference, applications of single and multi-layer films, applications of interferometry. Diffraction: Fraunhofer diffraction, Fresnel diffraction.

Module 4 Fourier optics: Introduction, fourier transforms, optical applications. Basics of coherence theory, mutual coherence function and the degree of coherence, Lasers: Lasers and laser light, Imagery, holography, nonlinear optics (basics)

Text Books:

1. Waves, F.S. Crawford Jr, Berkeley Physics Course Volume 3, Tata McGraw-Hill Ltd (2008). (Chapters 6).
2. Optics, E. Hecht, 4th Edition, Pearson education (2009) (Chapters 8-13).

Reference Books:

1. Introduction to modern optics, G.R Fowls, Second edition, Dover (1989).
2. Optics, Ajoy Ghatak, 5 edition, McGraw Hill Education (2012).

PHY 21-801-0602: Electronics

Credits: 4
Hours : 72 hours

Course Objective

To teach the basics of electronics

Course Outcome

1. Familiarise with the principles and characteristics of diodes and transistors
2. Understanding the operations of different types of amplifiers.
3. Understanding the basics of the digital circuits.
4. Understanding about the logical gates and their practical significance.

Module I Diode theory, forward and reverse-biased junctions, reverse-bias breakdown, load line analysis, diode applications - Limiters, clippers, clampers, voltage multipliers, half wave & full wave rectification, Special purpose diodes - Zener diode, Varactor, light emitting diodes, Laser diodes, Transistor fundamentals, Review of the characteristics of transistor in CE and CB configurations, Regions of operation (active, cut off and saturation), Current gains α and β. Relations between α and β, dc load line and Q point, Field-Effect Transistors (FET).

Module II Single and multi-stage transistor amplifiers, Concept of feedback, negative and positive feedback, Transistor oscillator circuits, Operational Amplifier basics, practical Op-Amp circuits, differential and Common mode operation, Inverting & Non Inverting Amplifier, differential and cascade amplifier, Op-Amp applications.

Module III Number System – Introduction to binary, octal, decimal & hexadecimal systems, representation of negative numbers, 1's, 2's, 9's, 10's complement and their arithmetic, Boolean algebra – Boolean theorems, minimization of Boolean function, K-Map, minimization using tabular method.

Module IV Basic logic gates, Boolean functions realization using logic gates, half & full adder, subtracter, Introduction to sequential logic, introduction to flip-flop, RS, D, T, JK flip-flops, race around condition, Master-slave JK flip-flops, flip-flop clocked sequential circuits.

Text Books:

1. Modern physics, Arthur Beiser, 6th Edition, Tata McGraw-Hill (2006). (Chapter-10).
2. A.S. Sedra & K.C.Smith, Microelectronics Circuits, Oxford University Press (1997).
3. Leach, Malvino, and Saha, Digital Principles and Applications, 5th Edition, McGraw Hill Education (1994).

Reference Books:

1. Robert L. Boylestad & Louis Nashelsky, Electronic Devices & Circuit Theory.
2. William Kleitz, Digital Electronics, Prentice Hall International Inc.
3. V. K. Metha, Rohit Metha, Principles of Electronics (S. Chand).
4. A. Anand Kumar, Fundamentals of Digital Circuits (3rd Edition), PHI Learning Pvt. Ltd., New Delhi (2014).
5. R. P. Jain, Thomas L. Floyd, Digital Fundamentals, Pearson Education (2005).

PHY 21-801-0603: Basic Nuclear Physics

Credits: 4
Hours : 72 hours

Course Objective

This paper intends to extend the student the basic knowledge in Nuclear Physics

Course Outcome

:

1. Understanding the basic properties of atomic nucleus, binding energy and elements of nuclear models
2. Familiarise the fundamental rules radioactivity and also nuclear reaction rate
3. Understanding the radiation-matter interaction
4. Familiarise the basic principles of nuclear reactors.

Module I Introduction and Basic concepts: The nucleus and its constituents, the N-Z chart, Nuclear mass, Radius, Density, Spin, Parity, Magnetic and electric moments, Stable Nuclei, Binding energy, Nuclear potential and energy levels, Semi empirical (liquid drop) model, Fermi-gas model, Nuclear shell model (with the harmonic oscillator potential), spin-orbit coupling and magic numbers.

Module II Radioactivity, Radioactive decay law, Half-life, Types of decays, Alpha emission, Beta emission and electron capture, Gamma emission and internal conversion, Natural Radioactivity, radioactive decay chains, Radioactive Dating, Nuclear Collisions, Cross section, differential cross section and reaction rate.

Module III Interaction of radiation with matter: Heavy charged particles interactions, Bethe-Bloch formula, Energy dependence, Bragg curve, Projectile dependence, Stopping medium dependence, Absorbed dose, equivalent dose, Gamma rays interactions, photoelectric effect, Compton scattering, Pair production, Attenuation.

Module IV Linear and circular accelerators, Nuclear reactors and energy production, Breeder reactors, Applications in tracing, material modification, sterilization, material modification, neutron activation analysis, Diagnostic Nuclear Medicine and Therapeutic Nuclear Medicines: CT, PET, SPECT, MRI.

Text Books:

1. J. S. Lilley, Nuclear Physics: Principles and Applications, John Wiley (2001).
2. Kenneth S. Krane, Introduction to Nuclear Physics, John Wiley (2008).

Reference Books:

1. Herald A. Engel, Introduction to Nuclear Physics, Addison Wesely (1967).
2. Cohen B. L., Concepts of Nuclear Physics, Tata McGraw Hill (2008).

Semester VII

PHY 21-801-0701: Mathematical Physics

Credits: 4
Hours : 72

Course Objectives

This course introduces different mathematical tools used in physics to the students. The course aims to prepare the students for understanding and applying various mathematical formalisms used in physics. The material covered in this course is very important for students as the mathematical techniques introduced find applications in every branch of physics and other quantitative sciences.

Course Outcomes

Upon completion of this course, a student should be able to -

1. Demonstrate an understanding of the meaning of gradient, divergence and curl. Work with them in different coordinate systems, and solve problems involving scalar and vector fields.
2. Demonstrate an understanding of basic tensor analysis.
3. Solve problems involving calculus of functions of a complex variable.
4. Solve a second order linear differential equation.
5. Solve important partial differential equations such as Laplace equation, wave equation and Poisson equation by the method of separation of variables.
6. Solve an equation numerically.
7. Solve differential equations numerically.
8. Calculate definite integrals numerically.
9. Solve basic problems in probability and demonstrate an understanding of the Binomial, Poisson and Gaussian probability distributions.

Module I

Review of vector calculus. Orthogonal curvilinear coordinates, cylindrical and spherical polar coordinates. Vector integration and integral theorems. Tensor analysis: Contravariant and covariant vectors, Basic operations with tensors, Quotient law, The line element and metric tensor.

Module II

Complex numbers, functions of a complex variable, mapping, branch lines and Riemann surface. Calculus of functions of a complex variable, elementary functions of z. Complex integration. Series representations of analytic functions. Integration by the method of residues, evaluation of real definite integrals.

Module III

Solution of linear second order differential equations. The Euler linear equation. Solutions in power series - Frobenius method, Bessel's equation. Simultaneous equations. Partial differential equations, Solutions of Laplace's and wave equation, solution Poisson's equation - Green's function method, Laplace and Fourier Transform methods.

Module IV

Numerical methods: Interpolation. finding roots of equations, graphical methods, method of linear interpolation, Newton's method. Numerical integration, the rectangular rule, The trapezoidal rule, Simpson's rule. Numerical solutions of differential equations, Euler's method, Runge-Kutta method, equations of higher order, system of equations. Least-squares fit.
Probability theory - definitions and sample space. Random variables and probability distributions. Calculating expectation and variance. The Binomial, Poisson and Gaussian distributions.

Text Books:

1. Mathematical methods for physics and engineering, K. F. Riley, M. P. Hobson and S. J. Bence, Cambridge Universality Press (2006).

2. Mathematical Methods for Physicists Paperback (7th Edition), Arfken, Elsevier (2012).

Reference Books:

1. Mathematical Methods for Physicists: A Concise Introduction, Tai L. Chow, Cambridge University Press (2001).

PHY 21-801-0702: Classical Mechanics

Credits: 4
Hours : 72 hours

Course Objectives

The course aims to develop an understanding of Lagrangian and Hamiltonian formulation which enable the students for simplified treatments of many complex problems in classical mechanics and provides the foundation for the modern understanding of dynamics. In a detailed way, since this course forms the foundation for the study of many areas of Physics, it apprises the students about Lagrangian and Hamiltonian formulations. The course aims:

- To define the concepts of Lagrangian Mechanics.
- To interpret the concepts of Hamiltonian Mechanics.
- To explain generating function, canonical transformation & Poisson brackets.
- To illustrate the dynamics of a rigid body and non-inertial frames of reference.
- To formulate the method of Hamilton-Jacobi and action-angle variable techniques.
- Understanding the basics of non-linear dynamics in physics and their applications

Course Outcomes

1. Understanding the drawback of Newtonian formulation of mechanics. Construct Lagrangian for different physical systems and Lagrange's equation of motion and solve it. (Module 1)
2. Understanding the Hamiltonian formalism in solving physics problems and understand Poisson bracket method in tackling physical problems. (Module 2)
3. Understanding the techniques for solving the problems of rigid body mechanics based on Lagrange's formulation (Module 3)
4. Understanding the Hamiltonian-Jacobi formulation and it's applications, solving simple problems based on action-angle variables. Understanding the basic features of non-linear dynamics (Module 4)

Module I - Lagrangian formulation

Mechanics of a system of particles(brief review)- Constraints - Generalized coordinates - D'Alembert's principle and Lagrange's equations -Calculus of variations and Derivation of Lagrange's equations form it. Symmetry properties and Noether's theorem. Application of Lagranges equation to Central force problem - equivalent one dimensional problem - classification of orbits - the differential equation for orbits - Kepler problem.

Module II - Hamiltonian Mechanics

Derivation of Hamilton's equation form variation of principle (Principle of least action with fixed end points), cyclic coordinates.Equations of canonical transformation - examples. Poisson Brackets-Equations of motion , angular momentum Poisson Bracket relations. Hamilton-Jacobi equation - harmonic oscillator problem - Hamilton's characteristic function.

Module III - Rotational dynamics

Independent co-ordinates of a rigid body. Orthogonal transformations - Euler angles - rigid body equations of motion- angular momentum and kinetic energy of motion about a point- inertia tensor-Solving rigid body problems and Euler equations of motion- torque free motion of a rigid body-symmetric top. Rate of change of a vector, centrifugal and Coriolis forces.

Module IV - Nonlinear dynamics and chaos

Chaotic trajectories and Liapunov exponents. Poincare maps. Logistic maps. Bifurcations, driven damped harmonic oscillator, parametric resonance. Logistic equation. Fractals and dimensionality : Cantor set, Sierpinski carpet.

Text Books:

1. H. Goldstein, C. Poole and J. Safko , Classical Mechanics, Third Edition, Pearson (2011).
2. N. C. Rana and P.S. Joag: Classical Mechanics, TMH, 1994
3. Michael Tabor, Chaos and Integrability in Nonlinear Dynamics, Wiley (1989).

Reference Books:

1. V. B. Bhatia , Classical Mechanics, Narosa (1997).
2. Landau and Lifshitz, Mechanics Vol. I, 3rd Edition, Butterworth-Heinemann (1976).

PHY 21-801-0703: Electrodynamics

Credits: 4
Hours : 72 hours

Course Objectives

The course aims to develop the fundamental concepts in classical electrodynamics. For students who are already familiar with the basics of electromagnetism, Maxwell's equations will be introduced and they will be equipped with advanced mathematical methods to tackle various boundary value problems in electrodynamics. By introducing the time dependent fields, the connection between magnetic and electric fields and the role of special theory of relativity in understanding the electromagnetic phenomena is also explained. The main objectives of the course are:

- To explain the various techniques for solving the boundary value problems.
- Investigate various consequences of Maxwell's equations. Viz. Gauge invariance, conservation laws and boundary conditions of electromagnetic fields at an interface.
- Application of Maxwell's equations for the study of propagation of electromagnetic waves in various media.
- To understand and develop the theory of wave guides and electromagnetic radiation phenomena.
- To look at the close relationship between electromagnetic phenomena and special theory of relativity.

Course Outcomes

1. Will get familiarized with the various boundary value problems and learn different techniques for its solutions (Module 1).
2. The introduction of conservation laws and investigation of the propagation of electromagnetic waves in various media leads to a clear understanding and applications Maxwell's equations (Module 2).
3. Will learn some of the other important consequences of Maxwell's equations by studying: 1. Electromagnetic wave propagation in wave guides and conducting media. 2. The electromagnetic radiation phenomena (Module 3).
4. Will understand the important concepts involved in special theory of relativity and its intimate connection to the electrodynamics phenomena (Module 4).

Module I

Review of vector calculus, Multipole expansion- electrostatic multipole moments - energy of a charge distribution in an external field. Boundary value problems, Introduction to Green's function, formal solution with Green's functions, electrostatic potential energy. Method of images- point charge near a grounded conducting sphere-point charge near a charged insulated conducting sphere - conducting sphere in an uniform electric field. Laplace equation in spherical polar coordinates- boundary value problem with azimuthal symmetry.

Module II

Maxwell's equations. Vector and scalar potentials - gauge transformations - Lorentz gauge, Coulomb gauge. Poynting's theorem and conservation of energy and momentum, complex Poynting vector. Boundary conditions for the electric and magnetic fields at an interface - Plane electromagnetic wave in a non-conducting medium, linear and circular polarization, reflection and refraction at a dielectric interface, polarization by reflection and total internal reflection.

Module III

Waves in conducting or dissipative medium-skin depth. Cylindrical cavities and wave guides, metallic wave guides, modes in a rectangular wave guide, resonant cavities. Green's function for wave equation. Simple radiating systems- fields and radiation of a localized oscillating source - electric dipole field and radiation, magnetic dipole and electric- quadrupole fields.

Module IV

Special theory of relativity - Postulates of relativity, Lorentz transformations, four vectors, addition of velocities, four velocity, relativistic momentum and energy, mathematical properties of space-time, matrix representation of Lorentz transformation. Dynamics of relativistic particles. Lagrangian and Hamiltonian of relativistic charged particle, motion in a uniform static electric and magnetic fields, magnetism as a relativistic phenomenon, transformation of the electromagnetic field, electromagnetic field tensor.

Text Books:

1. J. D. Jackson, Electrodynamics, 3rd Edition, Wiley (2009).
2. Introduction to Electrodynamics, D. J. Griffiths, 4th Edition, Cambridge University Press (2017).

Reference Books:

1. The Classical theory of fields - L D Landau and E M Lifshitz Pergamom Press Ltd (1971)
2. Electrodynamics - M. Chaichian, I. Merches, D Radu and A. Tureanu, Springer Verlag, (2016)
3. Classical Electrodynamics - W Greiner , Springer Verlag , New York (1998)

PHY 21-801-0704: Quantum Mechanics-I

Credits: 4
Hours : 72 hours

Course Objectives

The primary aim of the course is to provide an introduction to the mathematical formulation of Quantum Mechanics along with its physical principles. In addition, this course discusses some of the important time-independent 1D and 3D problems in Quantum Mechanics. The general objectives of course are:

- To formulate Quantum Mechanics using abstract mathematical structure of linear vector spaces.
- Describe the postulates of Quantum Mechanics and discuss the concepts of state, observables and time evolution in Quantum Mechanics.
- Discuss Schrodinger and Heisenberg formulations of Quantum Mechanics.
- Discuss various 1-dimensional and 3-dimensional time independent problems in quantum mechanics

Course Outcomes

1. Students will get an understanding of linear vector spaces which are fundamental to quantum mechanics . They will also learn concepts and properties of inner-product, basis, linear operators (in particular Hermitian operators) (Module I).
2. A thorough understanding of the postulates of quantum mechanics and other key concepts is obtained through the 2 nd module. The connection between classical and quantum physics is also elaborated in this module. (Module II).
3. Students will solve various 1-dimensional time independent problems in quantum physics. This will help them to formulate such problems and understand the general properties of solutions (Module III).
4. The student will learn to solve various 3-dimensional time independent problems in Quantum Mechanics. Study of angular momentum and atomic structure will be crucial to understand other subjects like spectroscopy (Module IV).

Module I - Linear Vector Spaces

de Broglie's hypothesis: matter waves and experimental confirmation, wave packets; Linear vector spaces: inner product, Hilbert space, Wave Functions; Linear operators: Hermitian operators, Projection operators, Commutator algebra, Unitary operators, Eigenvalues and Eigen vectors of a Hermitian operator; Basis: Representation in discrete bases, Matrix representation of kets, bras, and operators, Change of bases and unitary transformations, Matrix representation of the eigenvalue problem, Representation in position bases.

Module II - Postulates of Quantum Mechanics

Postulates of Quantum Mechanics: State of a System, Probability Density, Superposition Principle, Observables as Operators, Position and Momentum operators, Position and Momentum representation of state vector, Connecting the position and momentum representations, Measurement in quantum mechanics, Expectation values, Commuting operators and Uncertainty relations; Time evolution of the state: Time-independent potentials and Stationary States, Time evolution operator, infinitesimal and finite Unitary Transformations; Conservation of probability; Time evolution of expectation values: Ehrenfest theorem; Poisson's brackets and commutators; Matrix and Wave mechanics.

Module III - Time independent 1D problems

Discrete, continuous and mixed spectrum; symmetric potentials and parity; Infinite square well potential; Symmetric potential well; Finite square well potential: Scattering and bound state solutions; Free particle; Delta function potential; Harmonic oscillator.

Module IV - Time independent 3D problems

Free particle in 3-dimensions: spherically symmetric solution; Particle in a 3D box; Schrodinger equation in presence of central Potential; Orbital angular momentum: eigen values and eigen functions of of L^2 and L_z ; Hydrogen Atom; Scattering: Cross Section,Amplitude and Differential Cross Section, Scattering of Spin-less Particles, The Born Approximation, Validity of the Born Approximation.

Text Books:

1. Nourdine Zettili, Quantum Mechanics Concepts and Applications, 2nd edition, Wiley, 2009
2. David Griffiths, Introduction to Quantum Mechanics, 2nd edition, Prentice Hall, 2004

Reference Books:

1. J. J. Sakurai, Modern Quantum Mechanics, Revised edition, Addison-Wesley,1994
2. R. Shankar, Principle of Quantum Mechanics, 2nd edition, Kluwer Academic, 1994
3. Mathews and Venkatesan, Textbook of Quantum Mechanics, 2nd edition, Tata McGraw Hill, 2010
4. V.K. Thankappan, Quantum Mechanics, 4th edition, New Age International, 1985

Semester VIII

PHY 21-801-0801: Quantum Mechanics-II

Credits: 4
Hours : 72 hours

Course Objectives

The course aims to provide an introduction to advanced level topics in quantum mechanics. These include quantum theory of angular momentum, approximate methods for solving time dependent and time independent problems and an introduction to relativistic and multi-particle quantum mechanics. The general objectives are:

- To formulate a quantum theory of the total and the spin angular momentum of quantum particles.
- Formulate the time independent perturbation theory to find energy eigen values and eigen functions of problems that are not exactly solvable
- Introduce WKB approximation and variational method for time-independent potentials
- Introduce time-dependent perturbation theory to solve problems where potential is dependent on time.
- Formulate relativistic quantum mechanics
- Discuss indistinguishably in multi-particle quantum systems and their wave-functions.

Course Outcomes

1. Students will get a complete understanding of the total and the spin angular momenta of fundamental particles. They will also understand how angular momenta will add in a combined system. This is crucial to understand spectroscopy (Module I)
2. Students will be able to apply approximate methods like the perturbation theory, WKB method and variational method to solve time-independent problems that are not exactly solvable (Module II)
3. Perturbative approach to solve time-dependent problems will be understood. Various applications like Fermi's Golden rule, semi-classical theory of radiation will also be introduced (Module III)
4. Student will understand to formulate a relativistic theory of quantum mechanics and also multi particle quantum mechanics (Module IV)

Module I - Quantum Theory of Angular Momentum

Review of Orbital angular momentum; Total angular momentum: Commutation relations, eigenvalues, Matrix representation of angular momentum; Spin angular momentum: Pauli spin matrices and their properties, Two component wave function, Pauli's equation; Addition of Angular momentum and Clebsch-Gordan coefficients.

Module II - Time Independent Perturbation theory

Time-independent perturbation theory: Non degenerate perturbation theory, The Stark effect, Degenerate perturbation theory: Spin Orbit Coupling, Fine structure; Variational method; WKB method, Bound states for potential wells with no rigid walls, Tunnelling through a potential barrier.

Module III - Time Dependent Perturbation theory

Schrodinger and Heisenberg Pictures of Quantum Mechanics; The interaction Picture and Time- dependent perturbation theory: Transition probability; Constant perturbation; Harmonic perturbation; Adiabatic and sudden approximations; Interaction of atoms with radiation: Transition rates for absorption and stimulated emission of radiation, Dipole approximation, Electric dipole selection rules.

Module IV - Relativistic and Multi Particle Quantum Mechanics

Klein-Gordon equation: Free particle solutions, Probability density; Dirac equation: Dirac matrices, Probability density, Solution of free Dirac equation and positrons; Many-particle systems: Interchange symmetry; Systems of distinguishable non-interacting particle; Systems of identical particles: Exchange degeneracy, Symmetrization postulate; Constructing symmetric and anti-symmetric wave functions, Pauli's exclusion principle

Text Books:

1. Nourdine Zettili, Quantum Mechanics Concepts and Applications, 2nd edition, Wiley, 2009
2. J. J. Sakurai, Modern Quantum Mechanics, Revised edition, Addison-Wesley,1994
3. Walter Greiner, Relativistic Quantum Mechanics Wave Equations, 3rd Edition, Springer, 2000 (Module IV)

Reference Books:

1. R. Shankar, Principle of Quantum Mechanics, 2nd edition, Kluwer Academic, 1994
2. David Griffiths, Introduction to Quantum Mechanics, 2nd edition, Prentice Hall, 2004
3. Mathews and Venkatesan, Textbook of Quantum Mechanics, 2nd edition, Tata McGraw Hill, 2010
4. V.K. Thankappan, Quantum Mechanics, 4th edition, New Age International, 1985 (Module IV)

PHY 21-801-0802: Statistical Physics

Credits: 4
Hours : 72

Course Objectives

This course introduces students to the fundamental principles of equilibrium statistical physics. The focus is on developing a formalism to derive macroscopic or emergent quantities of various physical systems. The course is a very relevant one for students at a Master's level, as the formalism introduced underpins all of material science and other branches where one is interested in the collective behavior of a system.

Course Outcomes

Upon completion of this course, a student should be able to -

1. Differentiate between systems in equilibrium and out of equilibrium.
2. Demonstrate an understanding of the terminology, concepts and principles of describing equilibrium properties of physical systems.
3. For a given ideal system, derive various macroscopic quantities - either using a classical or a quantum setting - using the principles learned.
4. Derive the macroscopic properties of ideal quantum gases.
5. Develop a basic understanding of various aspects of the statistical physics of systems with interaction between its constituent components.

Module I

Features of macroscopic systems: Concept of equilibrium, Irreversibility and approach to equilibrium, Basic probability concepts: Statistical ensembles, Mean values and fluctuations, Statistical description of a system of particles, Micro and macro states, The microcanonical ensemble.

Module II

Thermal Interaction, Distribution of energy between macroscopic systems, Systems in contact with a heat reservoir, Canonical ensemble and the Boltzmann distribution, Partition function and Free energy, Paramagnetism, Ideal gas in canonical ensemble - mean energy and mean pressure, harmonic oscillator, Grand Canonical ensemble.

Module III

Canonical distribution in the classical approximation: Phase space of classical systems, Ideal gas, entropy of mixing and Gibbs paradox, Maxwell velocity distribution, harmonic oscillator, The equipartition theorem and its applications, Liouville's theorem.

Module IV

Statistical physics of ideal quantum gases: Ideal Fermi gas at zero and non-zero temperatures, Fermi-Dirac and Bose-Einstein integrals, Ideal Bose gas - Bose-Einstein condensation, Density operator. Interacting systems: 1D Ising model, Mean field approach, Phase transitions, Critical point and critical exponents, Universality, Renormalization group approach (Qualitative ideas).

Text Books:

1. Statistical Physics, Berkeley Physics Course, Volume 3, F. Reif, Tata- McGraw-Hill (2008).
2. Principles of equilibrium statistical mechanics, D. Chowdhury and D. Stauffer, Wiley (2000).

Reference Books:

1. An introduction to thermal physics, Daniel V Schroeder, Pearson Education (2007).
2. Statistical Mechanics, K. Huang, Wiley India (2008).
3. Statistical Physics, Landau and Lifshitz, Elsevier (2005).

PHY 21-801-0803: Atomic and Molecular Spectroscopy

Credits: 4
Hours : 72 hours

Course Objectives

Atomic and molecular spectroscopy has played an integral role in providing the necessary information leading to the development of quantum mechanics and to the understanding of the building blocks of matter. The objective of this course is to understand the origin of the quantized nature of atomic and molecular energy levels in a system and its application in molecular structure determination and medicine. This course also aims to give the detailed working principle of different laser systems, which has numerous applications in industry, material science, medicine, and telecommunications.

Course Outcomes

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

1. Describe the electronic state of atoms in terms of quantum numbers, the complexity of atomic spectra due to spin-orbit coupling, and the interpretation of term symbols. (Module 1)
2. Explain how atoms absorb and emit light and how this process can be affected by magnetic and electric fields. (Module 1)
3. Explain the contributions of transitions between rotational, vibrational and electronic states to the spectra of diatomic molecules. (Module 2)
4. Describe how IR and Raman spectroscopic techniques are used in molecular structure determination (Module 3)
5. Distinguish different spectroscopic techniques (absorption, fluorescence, Raman, NMR, and EPR) (Module 3)
6. Write the rate equations of three-level and four-level laser systems, and to describe the working principle of specific laser systems. (Module 4)

Module I

Quantum states of electrons in atoms - Pauli's exclusion principle, calculation of spin-orbit interaction energy in one electron systems, fine structure of spectral lines in hydrogen and alkali atoms. Equivalent and non-equivalent electrons, two electron systems, interaction energy in LS and j j couplings, spectra of helium and alkaline earth elements. Normal and anomalous Zeeman effects, Stark effect, Paschen-Back effect (all in one electron system only). Hyperfine structure of spectral lines - calculation in one electron systems. Line broadening mechanisms - line shape functions for Doppler and natural broadening

Module II

Types of molecules, rotational spectra of diatomic molecules as rigid rotor, intensity of rotational lines, The effect of isotopic substitution, energy levels and spectrum of non-rigid rotor, techniques and instrumentation for microwave spectroscopy. The vibrating diatomic molecule - simple harmonic oscillator, the anharmonic oscillator, the diatomic vibrating rotator - CO molecule. Interaction of rotation and vibrations, the vibrations of polyatomic molecules and their symmetry, the influence of rotation on the spectra of linear molecules - Electronic spectra of diatomic molecules - Born-Oppenheimer approximation, vibrational coarse structure - progressions. Intensity of vibrational transitions – the Franck-Condon principle. Dissociation energy and dissociation products. Rotational fine structure of electronic-vibrational transitions - the Fortrat diagram. Predissociation.

Module III

Raman effect - classical theory, elementary quantum theory, pure rotational Raman spectra - linear molecules, vibrational Raman spectra polarization of light and Raman effect, techniques and instrumentation of Raman and IR spectroscopy, structure determination by IR and Raman spectroscopy-simple examples, fundamentals of SERS. Nuclear and electron spin - interaction with applied magnetic field, population of energy levels Larmor procession, NMR: NMR of hydrogen nuclei - chemical shift, techniques and instrumentation for NMR spectroscopy, medical applications of NMR - ESR spectroscopy - g factor - fine and hyperfine structure, double resonance, Basic idea of Mossbauer Spectroscopy- Recoilless emission and absorption.

Module IV

Einstein's coefficients, Laser fundamentals and fabrication- active medium, pumping source, and the optical resonator, Phenomenon of population inversion, Characteristics of laser light, Three level laser - Four level laser - rate equations - pumping threshold, Specific laser systems - He-Ne laser -Argon ion laser - CO2 laser - excimer laser - ruby laser - dye laser - Nd:YAG laser - semiconductor diode lasers.

Text Books:

1. Introduction to Atomic Spectra, H. E. White, McGraw-Hill Inc., US (1934).
2. Fundamentals for Molecular Spectroscopy, 4th Ed., C. N. Banwell and E. M. McCash, McGraw Hill Education (2017).

Reference Books:

1. Laser fundamentals, 2nd Ed., William T Silfvast, Cambridge University Press (2008).
2. Lasers Theory and Applications, 2nd Ed., K. Thayagarajan and A.K Ghatak, Springer (2011).
3. Molecular structure and Spectroscopy (2nd Edition), G. Aruldhas, Prentice Hall of India (2007).
4. Spectroscopy Vol. I, II and III, B.P. Straughan and S.Walker, Chapman and Hall (1976).
5. Introduction to Molecular Spectroscopy, G. M. Barrow, McGraw-Hill Inc.,US (1962).
6. The Physics of Atoms and Quanta (4th ed.), H. Haken and Hans C. Wolf, Springer-Verlag (1994).
7. Laser Physics, Peter W. Milonni and Joseph H. Eberly, Wiley-Blackwell (2010).
8. Optical Electronics, A.K.Gahtak and K. Thayagarajan, Cambridge University press (1989).

PHY 21-801-0804: Advanced Electronics

Credits: 4
Hours : 72 hours

Course Objectives

Advanced level knowledge in Electronics is essential to understand the working of computers, telecommunication systems, sophisticated analytical instruments, and other electronic appliances in our everyday life. After completion of this course, the students will be able to design different digital and analog electronic circuits for specific applications like register, counter, analog to digital converter, integrator, differentiator, comparator, waveform generators etc. The students should also be able to understand the role of electronics in microprocessor architectures and analog and digital communication.

Course Outcomes

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

1. Explain the working of different combinational and sequential logic circuits and its design using universal-NAND gates. (Module 1)
2. Understand the primary applications of the operational amplifier as an adder, subtractor, differentiator, integrator, comparator, and waveform generator etc. (Module 2)
3. Design Op-amp circuits to find the solutions of differential equations. (Module 2)
4. Explain the architecture of 8085 Microprocessor, instructions, and its working. (Module 3)
5. Write assembly language program for 8085 Microprocessor (Module 3)
6. Demonstrate the working principle and instrumentation of analog and digital communications. (Module 4)

Module I

Combinational systems - Synthesis of Boolean functions, Boolean algebra, Universal gate - NAND, Integrated NAND circuit, Arithmetic circuits, Adder, Subtractor, BCD Addition, 2's complementary technique, Sequential systems - Flip flops-RS, JK, JK-MS, D-FF, Register, Buffer register, serial and parallel registers, Tristate switches, Tristate buffer registers, Bus organization in computers, Counters, Synchronous and Asynchronous counters, Ripple counters, Ring counter, Timing diagram, Fundamentals of D/A conversion,-Accuracy and resolution -ADC/DAC chips, Flash Converters.

Module II

Ideal amplifier - operational amplifier - the basic operational amplifier, differential amplifier and its transfer characteristics, frequency response of operational amplifiers, adder, subtractor, Op-amp as differentiators, integrators, applications of differentiators and integrators, Solution of differential equations – general ideas about analog computation and simulation – other applications of Op-amps, filters, comparators, sample and hold circuits, waveform generators.

Module III

Microprocessor architecture – memory – input/output – 8085 MPU – Instructions and timings – instruction classification – instruction format – instruction timing and operation status – Programming the 8085 – data transfer instructions – arithmetic operations – logic operations– branch operations – examples of assembly language programs.

Module IV

Amplitude Modulation – Double and Single sideband techniques – Frequency modulation and Demodulation techniques – Bandwidth requirements – Pulse communication – Pulse width, Pulse position and Pulse code modulation – Digital communication – error detection and correction – frequency and time division multiplexing.

Text Books:

1. John Ryder, Electronic Fundamentals and Applications (5th Edition), Prentice Hall, New Delhi, (1983).
2. Milman and Halkias, Integrated Electronics, Mc. Graw Hill, (1983).
3. Robert G. Irvine, Operational Amplifier – Characteristics and Applications, 2nd Edition, Prentice Hall, New Jersey (1987).
4. Gaonkar, Microprocessor Architecture, Programming and Applications, Wiley Eastern Limited, New Delhi (1992).

Reference Books:

1. John Wakerly, Digital Design: Principles and Practices (4th Ed.), Prentice Hall (2005).
2. D. C. Green, Digital Electronics (5th Ed.), Pearson Education Ltd., (2005).
3. Roddy and Coolen, Electronic Communications, Prentice Hall 4th Ed (1995).
4. B. P. Lathi, Modern Digital and Analog Communication Systems 3rd Ed, Oxford University press (1998).

Semester IX

PHY 21-801-0901: Nuclear and Particle Physics

Credits: 4
Hours : 72 hours

Course Objectives

The course aims to develop an understanding of advanced nuclear physics with the underlying quantum mechanical principles. Also, the students can get the idea of different types of nuclear radiation detectors and their properties. The course provides the details of different elementary particles an its properties. In short, the course provides a good platform to carry forward the studies to higher levels.

Course Outcomes

After completing this course the students should be able to

1. Describe the basic properties of the nuclear force. (Module 1)
2. Explain the nucleon-nucleon scattering and its underlying principles. (Module 1)
3. Review the different nuclear models and nuclear reactions. (Module 2)
4. Discuss nuclear fission and its applications. (Module 2)
5. Classify different nuclear radiations and radiation detectors. (Module 3)
6. Explain the properties of the nucleus.

Module I

Nuclear properties: Review of basic concepts, Nuclear radius, shape, spin, parity, Magnetic and electric moments, Nuclear binding energy. Nuclear two body problem, The deuteron, simple theory, spin dependence, tensor force, nucleon-nucleon scattering, partial wave analysis of n-p scattering, determination of phase shift, singlet and triplet potential, effective range theory, low energy p-p scattering.

Module II

Nuclear models, semi empirical mass formula, stability of nucleus, shell model, spin orbit potential, valance nucleons, Nilsson Model, Collective Model, Rotational and Vibration States.
Nuclear reactions, conservation laws, energetic, compound nuclear reactions, direct reaction, resonant reaction, nuclear fission, energy in fission, controlled fission reactions, fission reactors.

Module III

Nuclear decays: barrier penetration and alpha decay, beta decay, simple theory of beta decay, Kurie plot, parity violation in beta decay, gamma decay, multipole moments and selection rules.
Detection of nuclear radiation: Interaction of radiation with matters, gas-filled counters scintillation detectors, semiconductor detectors, energy and timing measurement.

Module IV

Meson Physics, properties of pi-mesons, decay modes, meson resonance, strange meson and baryons, CP violation in K decay.
Particle interaction and families, symmetries and conservation laws, quark model, coloured quarks and gluons, reactions and decays in the quark model, c, b and t quarks, quark dynamics.

Text Books:

1. Introductory Nuclear Physics (3rd Edition), Kenneth S. Krane, Wiley (1987).
2. The particle hunters (2nd Revised Edition), Yuval Ne'eman & Yoram Kirsh, Cambridge University Press (1996).

Reference Books:

1. Introduction to Nuclear Physics (1st Edition), Harald A. Enge, Addison Wesley (1996).
2. Concepts of Nuclear Physics, B. L. Cohen, McGraw-Hill Inc., US (1971).
3. Nuclear Physics: Theory and Experiment, R. R. Roy and B.P. Nigam, Newagepublishers (1996).
4. Theoretical Nuclear Physics, J. M. Blatt and V. F. Weisskopf, Springer-Verlag New York (1979).
5. An Introduction to Nuclear Physics (2nd Edition), S. B. Patel, New Age International (2011)
6. Introduction to Elementary Particles (2nd Revised Edition), David Griffiths, Wiley VCH (2008).

PHY 21-801-0902: Advanced Solid State Physics

Credits: 4
Hours : 72 hours

Course Objectives

The course aims to make the learner understand the physics of solids, which form the basic foundation for the study of other fields inside and outside the condensed matter physics. The course provides a clear picture about the development of the subject and how the knowledge about the solids and their properties used to change our society.

Course Outcomes

After completing this course the students should be able to:

1. Understand the underlying physics of solid-state materials. (Module 1 to module 5).
2. Understand the historic development of solid-state physics and how they explain specific heat of solids. (Module 1).
3. The details about the vibrations in the atomic chain and the applications of scattering experiments in solids. (Module 2)
4. Summarize the details of band theory and the developments of semiconductor physics and bandgap engineering. (Module 3).
5. The magnetic properties of solids, its microscopic details, and mean-field theories are covered.

Module I

Solids Without Considering Microscopic Structure: The Early Days of Solid State , Specific Heat of Solids - Einstein's Calculation-Debye's Calculation-Periodic (Born-von Karman) Boundary Conditions - Debye's Calculation Following Planck - Debye's "Interpolation" - Shortcomings of the Debye Theory - Electrons in Metals: Drude Theory - Electrons in an Electric Field - Electrons in Electric and Magnetic Fields - Thermal Transport - Sommerfeld (Free Electron) Theory - Basic Fermi-Dirac Statistics - Electronic Heat Capacity - Magnetic Spin Susceptibility (Pauli Paramagnetism) - Shortcomings of the Free Electron Model.

Module II

Vibrations of a One-Dimensional Mono-atomic Chain - Phonons-Crystal Momentum , Vibrations of a One-Dimensional Diatomic Chain - The Reciprocal Lattice in Three Dimensions - General Brillouin Zone Construction - Electronic and Vibrational Waves in Crystals in Three Dimensions - Wave Scattering by Crystals - Equivalence of Laue and Bragg conditions - Scattering Amplitudes - Systematic Absences - Geometric Interpretation of Selection Rules - Methods of Scattering Experiments - Powder Diffraction - Scattering in Liquids and Amorphous Solids.

Module III

Electrons in Solids - Electrons in a Periodic Potential - Kronig-Penny Model- Bloch's Theorem- Nearly Free Electron Model - Tight Binding Model - Energy Bands in One Dimension - Energy Bands in Two and Three Dimensions - Introduction to Electrons Filling Bands - Multiple Bands - Band-Structure Picture of Metals and Insulators - Optical Properties of Insulators and Semiconductors - Direct and Indirect Transitions - Optical Properties of Metals - Optical Effects of Impurities - Electrons and Holes - Doping - Impurity States - Statistical Mechanics of Semiconductors -Band Structure Engineering - Designing Band Gaps - Non-Homogeneous Band Gaps.

Module IV

Magnetism and Mean Field Theories - Hund's Rules - Coupling of Electrons in Atoms to an External Field - Free Spin (Curie or Langevin) Paramagnetism - Larmor Diamagnetism - (Spontaneous) Magnetic Order - Ferromagnets - Antiferromagnets - Ferrimagnets - Macroscopic Effects in Ferromagnets: Domains - Domain Wall Structure and the Bloch/ Neel Wall - Hysteresis in Ferromagnets.
Superconductors - Type-I and Type-II superconductors - Meissner effect - BCS theory (qualitative) - High temperature superconductors - applications - Josephson effect.

Text Books:

1. Solid state physics, Ashcroft, Neil W. and Mermin, N., Brooks/Cole (1976).
2. The Oxford solid state basics, Simon, Steven, Oxford University Press (2004).
3. Introduction to Solid State Physics (8th Edition), Charles Kittel, Wiley (2004).

Reference Books:

1. Solid State Physics, Dekker, A. J., Macmillan (2000).
2. Elementary Solid State Physics: Principles and Applications, Ali Omar, Pearson (1993).
3. Elements of x-ray diffraction (3rd edition), Cullity, B. D. and Stock, Stuart H., Prentice Hall (2001).

Elective Courses

06: 2D Materials

Course Code: 06
Credits: 4
Hours : 72

Course Objective

To introduce the field of 2D materials, different classes and their properties.

Course Outcome

1. To familiarise with low dimensional structures and their properties.
2. To learn about 2D material families (Graphene, 2D transition metal chalcogenides/carbides).
3. To familiarise with properties and applications of 2D materials.
4. To introduce 2D topological materials.

Module I

Schrodinger equation for an electron in a crystal- Concept of quasiparticles: electron, hole and exciton, Low dimensional structures: quantum wells, quantum wires and quantum dots. Graphene-Carbon and its allotropes-Dispersion Relation of Graphene - Dirac Points and Dirac Cones - Opening Gaps in Graphene - Electronic Properties of Graphene. Relationship between Dispersions of the 1-D and 2-D Systems, Metal contacts to graphene- Chemical bonding of metal with graphene-electrochemical equalization- orbital hybridization-characteristics of metal contact to graphene- applications of Graphene.

Module II

Introduction to 2D transition metal dichalcogenides (TMDC). Atomic and electronics Structure: Structure of individual triple layers – Bulk structure of polymorphs–Van der Waals Interlayers bonding-Electronic Structures. Raman and electronic spectra of TMDCs. Synthesis of Transition Metal Dichalcogenides – Top down Method:- Mechanical Exfoliation –Liquid Exfoliation-Electrochemical Exfoliation – Bottom up Method:-Chemical Vapour (CVD) – Pulsed Laser Deposition (PLD). Properties: Mechanical Properties-Thermal conductivity –Thermoelectric properties- optical properties-applications of TMDC.

Module III

Introduction to 2D transition metal carbides and nitrides, The M n+1 AX n phases- precursors for MXenes, Top down MXene synthesis (selective etching), Bottom up synthesis of 2D transition metal carbides and nitrides, Effect of synthesis methods on the structure and defects of two dimensional MXenes, MXene surface chemistry, Techniques of MXene delamination into single flakes, MXene films, coatings and bulk processing, Predicted electronic, magnetic, mechanical and optical properties of MXenes- applications of MXenes.

Module IV Two dimensional topological materials, Dirac/Weyl equation, topological insulators, Weyl semimetals, topological superconductors, electron transport in two dimensional topological materials, Weyl fermions in condensed matter systems, Fermi arcs, intrinsic anomalous Hall effect, magnetic breakdown and Klein tunnelling effect, Landau level collapse effect - applications of 2D topological materials.

Text Books :

1. Munarriz Arrieta, Modelling of Plasmonic and Graphene Nanodevices, Springer 2014.
2. S.V. Gaponenko, Optical properties of Semiconductor Nano crystals, Cambridge university press 1998.
3. Vasilios Georgakilas, Functinalization of Graphene, Wiley - VCH Verlag GmbH & Co. KGaA, 2014.
4. Two-DimensionalTransition-Metal Dichalcogenides, Alxander V Kolobov, Junji Tomenaga , https://www.springer.com/series/856.
5. Y. P. Venkata Subbaiah, K. J. Saji, and A. Tiwari, 'Atomically Thin MOS2: A Versatile Non-graphene 2D Material ,' Adv. Funct. Mater., vol. 26, no. 13, pp. 2046–2069, 2016, doi: 10.1002/adfm.201504202.
6. Advanced 2D materials , Editors : Ashutosh Tiwari,Mikeal Syvajarvi DOI:10.1002/9781119242635.
7. 2D Metal Carbides and Nitrides (MXenes), Structure, Properties and Applications, Editors: Anasori, Babak, Gogotsi, Yury (Eds.)
8. Transport in two-dimensional topological materials: recent developments in experiment and theory (Dimitrie Culcer et al 2020 2D Mater. 7 022007).
9. Weyl semi-metals : a short review Sumathi Rao Harish-Chandra Research Institute, Chhatnag Road, Jhusi, Allahabad 211 019, India.
10. Quasiparticle interference on type-I and type-II Weyl semimetal surfaces: a review Hao Zheng & M. Zahid Hasan.

07: Advanced Magnetism and Magnetic Materials

Course Code: 07
Credits: 4
Hours : 72 hours

Course Objectives

1. A postgraduate level course in Advanced Magnetism and Magnetic Materials will help in student having a thorough understanding of magnetism in condensed matter.
2. This course will equip the student with required prerequisites to proceed with a Ph.D. program in condensed matter physics or with a scientific position in magnetic materials industry.

Broad contents of the course

1. Review on fundamental magnetism
2. Diamagnetism and Paramagnetism
3. Ferromagnetism, Antiferromagnetism, and Ferrimagnetism
4. Magnetic anisotropy and Applications

Skills to be learned

1. This course will help in having a thorough understanding of magnetism in condensed matter.
2. A postgraduate level course in Advanced Magnetism and Magnetic Materials will equip the student with required prerequisites to proceed with a Ph.D. program in condensed matter physics or with a scientific position in a magnetic materials industry.

Course Outcomes

This course is a postgraduate level course in magnetic materials. The level of treatment presumes familiarity with differential calculus as well as introductory atomic physics, statistical mechanics, and quantum mechanics of solids. On successful completion of this course, students will be able to:

1. Explain paramagnetism based on both classical and quantum mechanical theory
2. Calculate the diamagnetic susceptibility of a solid.
3. Articulate knowledge of ferromagnetism in 3d transition metals.
4. Demonstrate a working understanding of permanent magnets, magnetic data storage, and magnetic refrigeration
5. Explain different types of interactions in a magnetic solid and ordered magnetic structures.
6. Understand the origins of magnetic anisotropy and correlate the technical magnetic properties with the underlying microstructure of the material

Module I

Review on basic magnetism: Magnetic poles - Magnetic flux - Circulating currents - Ampere's circuital law - Biot - Savart law- Field from a straight wire - Magnetic dipole - Magnet induction and magnetization - Flux density -Susceptibility and permeability - Hysteresis loops - Solution of the Schrodinger equation for a free atom- Extension to many-electron atoms - Normal Zeeman effect - Pauli exclusion principle - R-S coupling -Hund's rules - jj coupling - Anomalous Zeeman effect

Module II

Diamagnetism and Paramagnetism: Diamagnetism: Diamagnetic susceptibility - Diamagnetic substances & applications - Superconductivity-Paramagnetism: Langevin theory of paramagnetism - Curie - Weiss law - Quenching of orbital angular momentum - Pauli Paramagnetism - Paramagnetic oxygen - Applications of paramagnets

Module III

Ferromagnetism, Antiferromagnetism, and Ferrimagnetism: Interactions in ferromagnetic materials: Weiss molecular field theory - Origin of the Weiss molecular field - Collective-electron theory of ferromagnetism - Ferromagnetic domains - Observing domains - The occurrence of domains - Domain walls - Magnetization and hysteresis Antiferromagnetism: Neutron diffraction - Weiss theory of antiferromagnetism - Cause of negative molecular field - Applications Ferrimagnetism: Weiss theory of ferrimagnetism - Ferrites

Module IV

Magnetic anisotropy and Applications: Magnetocrystalline anisotropy - Shape anisotropy - Induced magnetic anisotropy, Applications of Magnetic Materials-Future of magnetic data storage-Permanent Magnets-Magnetocaloric effect (Elementary)

Text Books:

1. Magnetic Materials Fundamentals and Applications - Nicola A. Spaldin, Cambridge University Press, 2003 [Module 1,2,3 and 4]
2. Physics of Magnetism and Magnetic Materials - K.H.J Buschow and F.R De Boer, Kluver Academic Publishers, London, 2003 [Module 4]
3. Nanoscale Magnetic Materials and Applications - Editors: J.Ping Lu, Eric Fullerton, Oliver Gutfleish, David J. Sellmyer, Springer, 2009 [Module 4]

Reference Books:

1. Introduction to Magnetic Materials - B.D. Cullity and C.D. Graham. Addison-Wesley, 1972.
2. Introduction to Magnetism and Magnetic Materials - D. Jiles. Chapman & Hall, 1996.
3. Molecular Quantum Mechanics - P.W. Atkins. Oxford University Press, 1999.

08: Advanced mathematical physics

Course Code: 08
Credits: 4
Hours : 72

Course Objective

To equip the students to use some of the advance topics of mathematical physics.

Course Outcome

At the completion of this course,

1. The students will acquire an in-depth knowledge about ordinary and partial differential equations and various methods of finding their solutions.
2. Understand the concepts, terminology and principles of analysing groups.
3. Obtain an understanding of representation theory of groups, particularly symmetry groups, SO(n) group and SU(n) group.
4. Learn the terminology, concepts and principles of analysing tensors. Learn tensor algebra.
5. Learn Christoffel symbols and Reimann curvature tensor which are crucial to understand general relativity.
6. Understand basics of stochastic differential equations.

Module I

Review of solving first and second order ordinary differential equations. Review of solving first order partial differential equations. Sturm - Liouville theory: eigenvector expansions; Hilbert spaces; self-adjoint operators; eigenfunction expansions; existence of eigenvalues and completeness of eigenfunctions; spectral theory. Classification of second order PDE s hyperbolic, parabolic and elliptic equations. Green function methods for PDEs, Laplace transform and Fourier transform solutions.

Module II

Contravariant and covariant tensors - transformation rules - direct product, con-traction, quotient rule. Metric tensor - lowering and raising of indices - covariant derivatives -Christoffel symbols. Riemann curvature tensor.

Module III

Weiner process and white noise, Stochastic integrals, Ito calculus, stochastic differential equations, The Fokker-Plank equation, Brownian motion, numerical simulations.

Module IV

Definition of a group- Cyclic groups -Group multiplication table - Isomorphic groups - Group of permutations and Cayley's theorem - Subgroups and cosets - Conjugate classes and invariant subgroups - Group representations - symmetry group D2 and D3 - One-dimensional unitary group U(1) Orthogonal groups SO(2) and SO(3) - SU(n) groups.

Text Books :

1. Mathematical Methods for Physicists Paperback (7th Edition), Arfken, Elsevier (2012).
2. Mathematical methods for physics and engineering, K. F. Riley, M. P. Hobson and S. J. Bence, Cambridge Universality Press (2006).
3. Jon Mathews and Robert Walker,Mathematical Methods of Physics, Benjamin/Cummings Publishing Co. ISBN 0805370021.

Reference Books :

1. Mathematical Methods for Physicists: A Concise Introduction, Tai L. Chow, Cambridge University Press (2001).

09: Advanced Raman Spectroscopy

Course Code: 09
Credits: 4
Hours : 72
Prerequisites: None

Course Objectives

Raman spectroscopy is one of the important spectroscopic techniques which has wide variety of applications different fields of science and technology. The objective of this course is to understand the advanced applications of Raman spectroscopy including structure determination of micro and nano materials. This course also aims to give insights in to different Raman process which has applications in industry, material science, medicine and forensic science etc..

Course Outcomes

After completion of this course, the students will have good fundamental understanding, instrumental aspects, and analysis of materials using Raman spectroscopy.

Module I

Raman effect, classical theory of Raman effect, quantum mechanical treatment of Raman effect, Surface-Enhanced Raman Spectroscopy (SERS), Principle of SERS, Enhancement mechanism, Electromagnetic enhancement mechanism, Chemical enhancement, Surface selection rules, SERS substrates, metal films, metallic nanoparticles, Applications-biomolecules, in medicine, forensic science, Hyper Raman effect, Classical treatment of Hyper Raman effect, Experimental techniques for hyper Raman effect, Stimulated Raman scattering, inverse Raman scattering, CARS (Coherent antistokes Raman scattering)

Module II

Raman spectrometer, Major Components, Excitation Sources, Sample Illumination, Wavelength Selectors, Detection, FT Raman, Detection, Photon Counting, photodiode array, CCD, Instrument Calibration, Sampling Techniques, Fluorescence Problems, Raman Difference Spectroscopy, Miniature Raman Spectrometers, FT Raman spectrometer, Single crystal Raman spectra, Raman Microscopy, Fibre optical Raman spectrometer

Module III

Special techniques, High pressure Raman spectroscopy, Some examples of temperature and pressure induced phase transitions and its sample handling techniques. Raman microscopy, applications, Raman spectro-elctrochemistry- Applications, time resolved Raman Spectroscopy- applications, matrix isolation raman spectroscopy- applications, 2D correlation Raman Spectroscopy- applications, Raman Imaging Spectrometry- applications, Industrial Applications, Environmental applications.

Module IV

Analysis of Raman data, Compounds having inorganic functional groups, molecular symmetry, fundamental modes of vibration, Molecular symmetry, Molecules of type XY2, XY3, XY4, Sulphates, Phosphates, Carbonates, Iodates, Tungstates, Bromates etc. Analysis of Raman spectra of carbon rich compounds, carbon nano tubes, graphite, graphine, Analysis of oxide nano structures, Organic compounds, hydrogen bonds

Text Books:

1. Molecular Structure and Spectroscopy, G.Aruldhas, PHI Learning Private Limited New Delhi.
2. Introductory Raman spectroscopy Second Edition, J R Ferraro, K.Nakamoto, C.W.Brown, Academic press, Elsevier.

10: Advanced solid state physics-II

Course Code: 10
Credits: 4
Hours : 72 hours

Course Objectives

To make the students learn modern developments in the field of condensed matter physics particularly to those who wish to do research in this area.

Course Outcomes

1. To understand the different perspectives of the carrier absorption and its transport properties.
2. To familiarize with the theoretical tools like density of states etc.
3. To familiarize with the modern ideas like, quantum well and the associated properties.

Module I

Optical absorption: Free carrier absorption - optical transition between bands - direct and indirect - excitons - photoconductivity - general concepts - model of an ideal photoconductor - traps - space charge effects - crystal counters - experimental techniques - Transit time. Luminescence in crystal - excitation and emission - decay mechanism - Thallium activated alkali halides - model of luminescence in sulphide phosphors - electroluminescence.

Module II

Density of states - classification of solid into metals, semimetals, semiconductors and insulators - Calculation of number of carries in intrinsic semiconductor - Fermi level - carrier concentration in impurity semiconductors -electronic degeneracy in semiconductors. Equation of motion of electrons in a band - Effective mass and concept of holes - Boltzmann Transport equation. contact potential - metal-semiconductor contact - Schottky boundary layer - injecting contacts - surface states.

Module III

Quantum wells and low dimensional systems: Electron confinement in -infinitely deep square well and square well of finite depth - confinement in two and one dimensional well - ideas of quantum well structures, quantum dots and quantum wires - methods of preparation of nanomaterials: top down and bottom up approaches: wet chemical, self assembled vapour, phase condensation.

Module IV

Growth of single crystals - general ideas. Thin film preparation techniques - thermal and electron gun evaporation - dc and rf sputtering - amorphous solids : preparation techniques - applications. Classification of liquid crystals - applications of liquid crystals - ceramic processing techniques - electrical and mechanical properties - composite materials.

Text Books:

1. Introduction to Solid State Physics, 8th Ed., C. Kittel, Wiley, (2005)
2. Solid State Physics, A. J. Dekker, Macmillan (2000)
3. Electronic Properties of Crystalline Solids, R. H. Bube, Academic Press Inc (1974)

Reference Books:

1. Lectures on Solid State Physics, G. Busch and H. Schade, Pergamon Press (1976)
2. Theoretical Solid State Physics, A. Haug, Pergamon Press (1972)
3. Solid State Physics, N. W. Ashcroft, N. D. Mermin Holt, Rinehart and Winston, New York, 1976

11: Applied Vibrational Spectroscopy

Course Code: 11
Credits: 4
Hours : 72

Course Objectives

The course is designed so as to enable a student to understand the fundamentals and applications of vibrational spectroscopic techniques –Raman and infrared spectroscopic techniques. It also aims to familiarize the student about spectroscopic instruments and sample handling techniques.

Learning Outcomes

A student will be expected to know the techniques to measure Raman and IR spectra of the sample organic and inorganic compounds. The student will also get knowledge about the analysis of Raman and Infrared data of the samples.

Module I

Infrared spectroscopy- Fundamentals of Infrared spectroscopy- Infrared spectra preliminary- Infrared selection rules-Vibrations of polyatomic molecules-Normal vibrations of CO_2 and H_2O molecules-Dipole moment change in CO_2 molecule-Nomenclature of Internal modes- Fermi resonance-Hydrogen bonding-Normal modes of vibration in crystal-Solid state effects-Interpretation of vibrational spectra-group frequencies- Applications-Identification of molecular Constituents-Elucidation of molecular structure-Biological applications-Isotope effect.

Module II

Fundamentals of Raman spectroscopy-Classical and quantum theory-Molecular types-Planar molecules-pyramidal molecules-tetrahedral molecules-octahedral molecules-Rule of mutual exclusion principle-Internal modes of vibration-Polarization of Raman scattered light-Single crystal Raman spectra-Structure determination using Raman and IR spectroscopy- Raman investigations of phase transitions-Proton conduction in solids Raman study-Industrial applications-Resonance Raman scattering-Surface enhanced Raman scattering-Chemical enhancement –Electromagnetic enhancement-Substrates for SERS measurement.

Module III

Raman instrumentation-General idea on laser sources for Raman measurements-Components of Raman spectrometer-Modern spectrometers-Fibre coupled Raman spectrometer-FT Raman spectrometer-Raman microscopy- Raman sample handling techniques- High pressure Raman measurement system-Temperature dependent Raman measurement system- Raman measurement system with electric field IR instrumentation-IR sources-Components of IR spectrometer -FTIR spectroscopy-Interferometer arrangement- IR sample handling techniques.

Module IV

Analysis of Raman spectra and IR spectra-basic idea of factor group analysis-general idea on softwares for the computation of vibrational spectra- Vibrational spectral anaylysis of Inorganic compouds containing water- Sulphate- phosphate -bromate- carbonate- complexes of sulfate, carbonate, and related ligands-Organic compounds - Carbon nanotubes- graphite- Oxide nanomaterials- Identification of hydrogen bonded ssytem- Analysis of historical monuments-Forensic samples-cyano and nitrile complexes.

Text Books:

1. Molecular Structure and Spectroscopy, G.Aruldhas, PHI Learning Private Limited New Delhi.
2. Infrared and Raman Spectra of Inorganic and Coordination Compounds: Part A: Theory and Applications in Inorganic Chemistry, Sixth Edition; K.Nakamoto; 2009 John Wiley & Sons, Inc.
3. Infrared and Raman Spectra of Inorganic and Coordination Compounds: Part B Applications in Coordination, Organometallic, and Bioinorganic Chemistry, Sixth Edition; K.Nakamoto; 2009 John Wiley & Sons, Inc.

12: Astrophysics

Course Code: 12
Credits: 4
Hours : 72 hours

Course Objective

To study in detail the elements of Astrophysics, with an aim to develop the taste of research in the field.

Course Outcome

The learner will,

1. Acquire a thorough understanding of the basic concepts like magnitudes, color, H-R diagram etc.
2. Understand the theory of hydrostatic equilibrium in stars.
3. Get a clear idea about the energy production in stars.
4. Get a clear knowledge about the evolution of the main sequence stars.

Module I

Magnitudes: Apparent and Absolute stellar magnitudes, distance modulus, Bolometric and radiometric magnitudes, Color - index, Color temperature, effective temperature, Brightness temperature,luminosities of stars. Equatorial, ecliptic and galactic system of coordinates. Apparent and Mean solar time and their relations. Classification of stars, H-D classification, Hertzsprung-Russel (H-R) diagram.

Module II

Fundamental Equations: Equation of mass distribution. Equation of hydrostatic equilibrium. Equation of energy transport by radiative and convective processes. Equation of thermal equilibrium. Equation of state. Stellar opacity. Stellar energy sources.

Module III

Stellar Models : The overall problem and boundary conditions. Russell Voigt theorem. Dimensional discussions of mass luminosity law. Polytropic configurations. Homology transformations.

Module IV

Stellar Evolution: Jean's criterion for gravitational contraction and its difficulties. Pre-main sequence contraction under radiative and convective equilibrium. Evolution in the main sequence. Growth of isothermal core and subsequent development. Ages of galactic and globular clusters.

Text Books :

1. Textbook of astronomy an astrophysics with elements of cosmology, V.B.Bhatia, Narosa publishing house, 2001.

2. Astrophysics - Stars and Galaxies, K. D. Abhyankar, University Press, 2001.

Reference Books :

1. M.Schwarzschild:Stellar Evolution

2. S.Chandrasekhar:Stellar Structure

3. Theoritical Astrophysics (Vols.I,II,III) - T. Padmanabhan (CUP)

4. Menzel,Bhatnagar and Sen:Stellar Interiors.

5. Black Holes, White Dwarfs and Neutron Stars - S.L.Shapiro and S.A.Teukolsky (John Wiley, 1983)

6. Cox and Guili:Principles of Stellar Interiors - Vol.I and II.

7. R.Bowers and T. Deeming:Astrophysics (John and Barlett.Boston)

13: Biophysics

Course Code: 13
Credits: 4
Hours : 72

Course Objectives

The objective of this course is to introduce the interdisciplinary subject biophysics. This course also aims to give insights to the students on applications of physics in biosystems.

Course Outcomes

After completion of this course, the students will have good fundamental understanding of biophysics and its allied areas related to including structure determination of proteins.

Module I

Fundamental building blocks of biological systems-Molecules essential for life- Water-proteins- lipids-carbohydrates-cholestrol-Nucleic acid-living state interactions-forces and molecular bonds-electric and thermal interactions-polarisations and induced dipoles-Casimir interactions- (Qualitative treatment) heat transfer in biomaterials-heat transfer mechanisms-heat equation-heat transfer through a living cell-Joule heating tissue (Qualitative treatment).

Module II

Living state thermodynamics-thermodynamic equilibrium-First and second law of thermodynamics-measures of entropy-free expansion of gas-physics of many particle systems- Boltzmann factor in biology-DNA stretching- Brownian motion-Ficks laws of diffusion-Ficks law for growing bacterial cultures(Qualitative treatment)-Sedimentation of cell cultures.

Module III

Nerve impulses-Neurotransmitters and synapses-Passive and active transports in dendrites- Mechanical properties of biomaterials (Qualitative treatment)-Youngs, shear modulus and Poisson ratio-electrical stresses in bilological membranes-Mechanical effects of microgravity during space flight, fundamentals of biomagnetic field sources- fundamentals Passive electrical properties of living cells.

Module IV

Light absorption in biomolecules-Bioimpedence-Time harmonic current flow- Dielctric spectroscopy-Deybe relaxation model-Cole equation-Fundamentals of protein folding, basic techniques for protein folding, protein crystallization, Vapor diffusion- Sitting drop method- Hanging drop method- Basics of structure determination of proteins with X-ray crystallography- sample handling techniques.

Text Books:

1. Introductory biophysics perspectives on the living state J.Claycomb, J.Quoc P.Tran, Jones & Bartlet Publishers.
2. Biophysics; N. Arumugam, V. Kumaresan, Saras publication; SBN : 9789384826673.

3. Biological Physics; Philip Nelson; W. H. Freeman & Company ; 2013.
4. Protein Folding; Charis Ghelis; Academic Press;1982.
5. Preparation and Analysis of Protein Crystals; McPherson, A. 1982, John Wiley & Sons.
6. Terese M. Bergfor's, Protein Crystallization Techniques, Strategies and Tips, International University Line, 1999.

14: Complex networks

Course Code: 14
Credits: 4
Hours : 72
Prerequisites: None

Course Objectives

This course aims to introduce to the students the emerging area of complex networks. The course is a very relevant one in this era of complex systems and gives the students a flavor of interdisciplinary approaches to problem solving.

Course Outcomes

Upon completion of this course, a student should be able to

1. Demonstrate an understanding of the terminology, concepts and principles of the study of complex networks.
2. Identify problems that can be treated using the tools of complex networks.
3. Calculate various properties of a complex network related to its local structure.
4. Calculate various properties of a complex network related to its global structure.
5. Demonstrate an understanding of various models of complex networks and their properties and applications.

Module I

Introduction,Examples of networks, Mathematics of networks: Networks and their representation, The adjacency matrix, Networks: Weighted, Directed, Bipartite and Planar, Trees, Hypergraphs. Degree, Path, Components. Independent paths, connectivity, cut sets, The graph Laplacian, random walks.

Module II

Measures and Metrics: Degree centrality, Eigenvector centrality, Katz centrality, Page-rank, Hubs and authorities, Closeness centrality, Betweenness, Signed edges and structural balance, Similarity, Homophily and assortative mixing.

Module III

Large scale structure of networks: Components, Shortest paths and the small world effect, Degree distributions, Power-laws and scale free networks, Clustering coefficients.

Module IV

Network models, Erdos-Renyi random graph: Definition and properties. The configuration model: Definition and properties, Models of network formation.

Text Books:

1. Networks: An Introduction, M.E.J. Newman, Oxford University Press (2010).

Reference Books:

1. Network science, Albert Barabasi, Cambridge University Press (2016).

15: Computational Physics

Course Code: 15
Credits: 4
Hours : 72 hours

Course Objective

To introduce students to numerical methods and computational techniques for solving problems in various areas of Physics and Mathematics using Computers. This will prepare them for PhD level research or a career in the Industry, where scientific computing is widely used.

Course Outcome

Students will develop skills in solving problems in various areas of Physics using appropriate numerical methods and simulation techniques, on a Computer.

Main Prerequisite

Bachelor level understanding of Physics and Mathematics.

Module I

Introduction and Objectives of Computational Physics, Basic Programming techniques and data visualization. Machine representation, Numerical precision and stability, Errors. Review of Numerical Methods: Root finding, Numerical Differentiation, Numerical Integration, Interpolation Methods, Matrices and Linear Algebraic Equations, Ordinary Differential Equations. Data Fitting, Fourier Transforms, Optimization methods.

Module II

Simple harmonic motion, damped and driven oscillator. Nonlinear Dynamics and Chaos: Nonlinear oscillations, Phase Diagrams for Nonlinear systems. Chaos: Discrete and Continuous systems. Few-Body Problems.

Module III

Motion of classical electrons in crossed electric and magnetic fields. Partial differential equations: Laplace's equation, Poisson's equation, diffusion equation. Numerical solution of Schroedinger equation.

Module IV

Molecular dynamics: Theory, Integration methods, Measurement of static and dynamic properties. Langevin dynamics simulations for Brownian motion. The Monte Carlo method: Probability distribution functions, random number generation, Monte Carlo integration, importance sampling, Random walks and the Metropolis Algorithm, Application to model systems.

Text Books :

1. An Introduction to Computer Simulation Methods: Applications to Physical Systems - Gould, Tobochnik & Christian, 3rd Edition, Addison Wesley (2006).
2. Basic Concepts in Computational Physics - Stickler and Schachinger, Springer (2013).
3. Computational Physics: Problem Solving with Computers - Landau and Paez, 2nd Edition, John Wiley & Sons (2007).
4. Computational Physics - Nicholas J Giordano and Hisao Nakanishi, 2nd Edition, Pearson-Prentice Hall (2006).
5. Computational Physics - P. Scherer, Springer (2010).

Reference Books :

1. An Introduction to Numerical Analysis - K.E. Atkinson, 2nd Edition, John Wiley & Sons (1989).
2. An Introduction to Computational Physics - Tao Pang, 2nd Edition, Cambridge University Press (2006).

16: Crystal Growth

Course Code: 16
Credits: 4
Hours : 72 hours

Course Objectives

The objective of this course to provide information on the important aspects of crystals growth. This course also aims to give insights to the students on growing techniques crystals with different methods.

Course Outcomes

After completion of this course, the students will have good fundamental understanding on crystal growth.

Module I

Supersaturation and supercooling – nucleation concept – Kinds of nucleation - Homogeneous nucleation - Equilibrium stability and metastable state -Classical theory of nucleation - Gibbs-Thomson equation –Kinetic theory of nucleation - Statistical theory of nucleation - Free energy of formation of nucleus considering translation, vibration and rotation energies, Theories of crystal growth - Surface energy theory - Diffusion theory - Adsorption layer theory -Volmer theory -Bravais theory - Kossel theory.

Module II

Melt Growth Techniques -Crystal Pulling-Bridgman Method-Skull Melting Methods-Zone Melting-Verneuil Process -Kyropolous method - Czochralski method-Zone melting method - Growth of crystal from flux - Slow cooling method - Temperature difference method – High pressure method - Solvent evaporation method - Top seeded solution growth - Growth of crystals from vapour phase - Physical vapour deposition - Chemical vapour transport.

Module III

Solution Growth Techniques -General Aspects-Low-Temperature Methods-High- Temperature Methods-Growth of crystals from solutions - solvents and solutions - solubility - preparation of a solution -saturation and supersaturation - Measurement of supersaturation - Expression for supersaturation -Low temperature solution growth - Crystal growth by hydrothermal method– Crystal growth by solvo-hydrothermal method- Slow cooling method - Mason-jar method - Evaporation method -Temperature gradient method - Crystal growth in gels - Experimental methods -Chemical reaction method - Reduction method method - Growth of biologically important crystals.

Module IV

Crystallization of hydroxy apatite - Protein crystallization techniques - Hanging Drops-Sitting Drops-Sandwich Drops-Reverse Vapor Diffusion- pH Gradient Vapour Diffusion-Practical Tips for Vapuor Diffusion –Dialysis-Batch Techniques –Micro batch –Protein Samples- Precipitants- Buffers and pH –Temperature-Crystallization Strategies-A Flexible Sparse Matrix Screen-An Alternative to Sparse-Matrix Screens-Reverse Screen- Imperial College Grid Screen- Seeding-Macro seeding-bio-crystallization, protein crystallization and characterization of biological crystals.

Text Books:

1. J.C. Brice, Crystal growth processes, John Wiley and sons, New York, 1986.
2. P.Santhana Raghavan and P.Ramasamy, Crystal Growth Processes and Methods, KRU Publications, Kumbakonam (2000).
3. A. Laudise, The Growth of single crystals. Prentice Hall, 1970.
4. B.Pamplin, Crystal Growth. Volume 16, Pergamon Press.1973.
5. F.F. Abraham, Homogenous nucleation theory, Advances in Theoretical Chemistry, Academic Press, New York, 1974.
6. R.F. Strickland, Kinetics and Mechanism of Crystallization, Academic Press, New York, 1968.
7. Sujata V. Bhat, Biomaterials, Narosa Publising House, New Delhi,2002
8. A.Ducruix and R.Giege, Crystallization of Nucleic Acids and Proteins A Practical Approach, Oxford University Press, England, 1992
9. Terese M. Bergfor's, Protein Crystallization Techniques, Strategies and Tips, International University Line, 1999.

17: Elementary astronomy

Course Code: 17
Credits: 4
Hours : 72

Course Objective

This course enable the students learn the salient advancements in the field of Astronomy.

Course Outcome

1. Get knowledge about the celestial sphere and its various properties and uses.
2. Get good knowledge regarding the theories of solar system, planets - their formation and properties.
3. Get a reasonable knowledge about the formation of stars, and objects like white dwarf, black hole etc.

Module I

Celestial Sphere and Time : Constellations. The celestial sphere. Equatorial, ecliptic system of co-ordinates. Seasons, Sidereal, Apparent and Mean solar time. Calendar. Julian date. Stellar Distances and Magnitudes : Distance scale in astronomy. Determination of distances to planets and stars. Magnitude scale. Atmospheric extinction. Absolute magnitudes and distance modulus. Colour index.

Module II

Theories of formation of the Solar System, The Sun: Photosphere, chromosphere and corona of the Sun. Sun spots and magnetic fields on the sun. Solar activity, solar wind.
Planets and their Satellites : Surface features, atmospheres and magnetic fields of Earth, Moon and Planets. Satellites and rings of planets. Asteroids, Meteors, Meteorites and Comets.

Module III

Stars : Basics of Star formation & Evolution. The HR diagram. Pre-main sequence contraction, main sequence stage and formation of super dense objects - White dwarfs, Neutron stars & Pulsars. Black holes.

Module IV

The Milky Way Galaxy & Galaxies beyond : Structure of the Milky Way Galaxy Galactic and globular clusters. Inter Stellar Matter, Position of our Sun and its motion around the galactic centre. Rotation of the Galaxy and its mass.
Extragalactic Systems : Hubble's classification of galaxies and clusters of galaxies. Galaxy interactions, Elements of Astrobiology.
Introduction to Cosmology : The expanding universe. Big Bang and Steady State models of the universe. Dark matter.

Text books:

1. H. Karttunen, P Kroger, H Oja, M Poutanen & K. J. Donner editors. Fundamental Astronomy, 5^{th} Edition, Springer-Verlag (2007).
2. Baidyanath Basu: Introduction to Astrophysics, PHI, 2nd ed. (2013)

References :

1. W.M.Smart: Foundations of Astronomy, Longmans (1965)
2. Frank H. Shu: The Physical Universe-An Introduction to Astronomy, Univ Science Books (1981)
3. K D Abhyankar: Astrophysics of the Solar System, Universities Press (1999)
4. Horneck and Rettberg: Complete Course in Astrobiology, Wiley (2009)
5. Introduction to cosmology, J V Narlikar, Cambridge University Press; 3 edition (2002)

18: Fundamentals of Photovoltaics

Course Code: 18
Credits: 4
Hours : 72

Course Objectives

The objective of the course is to develop in-depth understanding of the physics of solar cells and various photovoltaic technologies (PV) and their applications to harness solar energy to electricity. The course will cover the basic semiconductor physics. The course will give an insight in the fabrication of the solar cells in laboratory and industrial scale, module fabrication and power generation using PV in off grid and grid connected systems.

Course Outcomes

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

1. Explain the working principle of solar cells
2. Understand PV based electricity generation
3. Differentiate the manufacturing and performance differences between different c- Si wafer technologies and between ?c-Si and thin film PV technologies
4. Identify the critical losses and loss mechanisms in c-Si solar cells
5. Calculate the power and energy produced by a solar module
6. Explain the differences and design aspects of off-grid and on-grid PV systems.

Module I

Basic Semiconductor Physics: Fundamental Properties of Semiconductors - Crystalline structure - Band model - Doping - Carrier concentration in equilibrium - Light absorption -Generation and recombination of electron and hole pairs: Band gap to band gap processes - Shockley-Read-Hall recombination - Auger recombination - Carrier transport - Minority carrier diffusion - Semiconductor junctions: p-n homojunctions - ideal diode equation - p-n heterojunctions - Metal-semiconductor junctions.

Module II

Solar Cell fundamentals: p-n junction under illumination - Solar Cell Parameters - Spectral response - the equivalent circuit - parasitic resistance effects -temperature effect - p-i-n solar cells - Losses and Efficiency Limits: The thermodynamic limit - the Schokley-Quiesser limit - other losses - design rules for solar cells - tandem solar cells First Generation technology: Crystalline Silicon Solar Cells - Physics of c-Si Solar cells - Sand to silicon - Silicon to wafer - wafer manufacturing - Design and manufacturing of Al-BSF solar cell - Passivation concepts

Module III

High efficiency concepts in c-Si Solar cells: PERL and PERC cells - interdigitated back contacts - TOPCon - Heterojunction solar cells Second generation technology: Thin film solar cells - merits and demerits -Transparent conducting oxides - the III-V PV technology - thin film Si technology - Chalcogenide solar cells - Organic photovoltaics - Hybrid organic-inorganic solar cells Third generation concepts: Multi junction solar cells - Spectral conversion - Multi- exciton generation - Intermediate band solar cells - Hot carrier solar cells.

Module IV

Module manufacturing: Interconnection of cells - series and parallel connections- silicon module production - PV systems: Standalone systems – grid connected systems - hybrid systems - micro grids - smart grids - specific applications- Solar cell and module measurement techniques.

Text Books:

1. K. Mertens, Photovoltaics: Fundamentals, Technology and Practice, John Wiley & Sons Ltd (2014)
2. A. Smets, K. Jager, O. Isabella, R. V. Swaaij, M. Zeman, Solar Energy: The physics and engineering of photovoltaic conversion, technologies and systems, UIT Cambridge Ltd. (2016).
3. D. A. Neamen and D. Biswas, Semiconductor Physics and Devices

Reference Books:

1. Handbook of Photovoltaic Science and Engineering 2nd Ed. , A. Luque, S. Hegedus (editors), John Wiley & Sons Ltd (2011)
2. S.R. Wenham, M. Green, M.E. Watt, R. Corkish, A. Sproul, Applied Photovoltaics, 2nd Edition (2009)
3. Chetan Singh Solanki, Solar Photovoltaics: Fundamentals, Technologies and applications, 3rd Edition, PHI Learning Pvt. Ltd. (2019).
4. Jenny Nelson, The Physics of Solar Cells, Imperial College Press (2003).
5. Peter Wurfel, Physics of solar cells: from principles to advanced concepts, 2nd Edition, Wiley-VCH (2009).
6. SM Sze and Kwok K Ng, Physics of semiconductor devices, third edition, John Wiley & Sons (2007)
7. R.F. Pierret, Semiconductor Device Fundamentals

19: Gravitation and Cosmology

Course Code: 19
Credits: 4
Hours : 72

Course Objectives

Provide a basic introduction to the general theory of relativity and its applications in astrophysics. Specific objectives are as follows.

- Introduce tensor algebra and Einstein's general theory of relativity.
- Apply the general theory of relativity to various astrophysical systems.
- Introduce the modern theory of cosmology as an application of general theory of relativity.

Course Outcomes

1. Students will learn tensor algebra and using it they will understand the general theory of relativity.
2. Students will apply general theory of relativity to various astrophysical systems like planetary motion, black holes and gravitational waves. They will find that new physics is emerging as a consequence of Einstein's theory compared to Newton's law of gravity.
3. Students will understand models of expanding Universe in connection with the general theory of relativity. They will be introduced to concepts of exotic components of matter in the Universe like dark matter and dark energy.

Module I

Tensor Analysis: Tensors ; Contravariant and covariant tensors; direct product; contraction; inner product; quotient rule; tensor densities, dual tensors. Metric tensor, Parallel transport; Christoffel symbol; Covariant derivative; Riemannian geometry, Riemann curvature tensor; Ricci tensor; Equation of geodesics.

Module II GTR: Drawback's of Newtonian theory of gravity, Mach's principle, Principle of equivalence; consequences of principle of equivalence (bending of light, redshift, time dilation); Gravity as curvature of space-time; Einstein equation; reduction to Newtonian form.

Module III

Astrophysical Applications of Einstein's equation: Schwarzschild solution: derivation, Schwarzschild singularity, gravitational redshift, particle orbits - precession of the perihelion of planet Mercury, light ray orbits - the deflection and time delay of light. Linearized gravitational waves.

Module IV

Cosmology: Cosmological Principle, Hubble's law, FRW model of the universe:- FRW metric, cosmological redshift, open, closed and flat universes, matter dominated and radiation dominated universes, Particle horizon and event horizon, primordial nucleosynthesis, CMBR, Flaws of the FRW model. Jean's mass in the expanding universe, evolution of the Jean's mass. Dark matter, recent acceleration of the universe, Dark energy. (only introductory ideas.)

Text Books:

1. Gravitaion and Cosmology, S. Weinberg, ,John Wiley & Sons (1972)
2. A First Course in General Relativity, Schutz, Bernard. New York, NY: Cambridge University Press, 1985. ISBN: 9780521277037.
3. Introduction to cosmology, J. V. Narlikar, Cambridge University Press, 3rd edition (2002)

Reference Books:

1. Gravity, J. B. Hartle, Pearson Education.(2003).
2. Gravitation, Charles W. Misner, Kip S. Thorne, and John Archibald Wheeler,(1973).
3. Gravitation - Foundations and Frontiers , T. Padmnabhan, cambridge University Press, New York (2010)

20: Laser and Nonlinear Optics

Course Code: 20
Credits: 4
Hours : 72

Course Objectives

The course aims at developing creative skills among students by understanding the principles of high-power lasers and applications. Topics include revising the basic principles of lasers, laser cavities, properties of Gaussian beams and imaging. The latter part of the course focuses on high power pulsed lasers from Q-switched nanosecond lasers to femto-second lasers and amplifiers.

Course Outcomes

At the end of the course, the student will be able to,

1. Analyse the propagation of Gaussian beams.
2. Apply the principles of phase contrast imaging.
3. Illustrate pulse shortening mechanisms and chirped pulse amplification.
4. Elaborate high power laser interaction with material.

Module I

Review of Radiation Laws (Stefan Boltzmann, Wien Displacement, Planks) and basics of lasers (Population Inversion - Stimulated emission - Einstein Coefficients) - Laser , Ruby Laser.

Module II

Optical Resonant Cavities , Longitudinal and Transverse modes , Properties of Gaussian laser beams , Spatial frequencies , Abbels theory of image formation , Spatial Filtering phase contrast Imaging.

Module III

Pulsed high power lasers , Q switching , Methods of producing Q switching , Mode locking , Methods of producing mode locking , Pulse shortening by self phase modulation, Group velocity dispersion, gratings or prisms , femto-second lasers , basic ideas of chirped pulse amplification and regenerative amplifiers.

Module IV

Nonlinear Optics , Nonlinear Wave equation , Optical rectification , Harmonic Generation , Phase matching , Third Harmonic generation , Parametric oscillator , B integral - self focusing , Two photon absorption.

Text Books:

1. Hecht, E and A R Ganesan, Optics 4th Ed., Pearson (2019).
2. Silfvast, W T, Laser Fundamentals 2nd Ed., Cambridge University Press (2008)
3. Boyd, R. W - Nonlinear Optics, Second Edition, Academic Press (2003).

References

1. Ajoy Ghatak, Optics 5th Ed., McGraw Hill.
2. Bahaa E . A. Saleh and Malvin Carl Teich , Fundamentals of Photonics 2nd Ed., Wiley (1991)
3. Laud, B.B. - Lasers and Nonlinear Optics, New Age International (P) Limited (1991)

21: Light Sources and Detectors

Course Code: 21
Credits: 4
Hours : 72

Course Objectives

This course aims to introduce students to the basic characteristics and working principle of various light sources and detectors in the UV-VIS-IR regimes.

Course Outcomes

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

1. Explain the difference between natural and artificial sources of light.
2. Explain the basic characteristics and working principle of various photon sources and detectors in ultraviolet-visible-infrared regions of the electromagnetic spectrum.
3. Demonstrate the safety procedures to be taken while setting up experiments with advanced optical sources and detectors.

Module I

Natural and Artificial Sources of Light, Characteristics of Light Sources, UV-VIS- IR Light Sources, Type of Optical Sources- Incandescent Lamp, Discharge Lamps-Low Pressure, High Pressure, and High Intensity Discharge Lamps, Semiconductor Diode-Light Emitting Diode (LED), Supercontinuum Sources.

Module II

Laser Fundamentals, Gas Lasers, Solid State Lasers, Semiconductor Laser Diodes, Safety Standards and Hazard Classifications, Laser Applications.

Module III

Detector Characteristics Quantum Efficiency, Response Time, Spectral Response. Types of Photoeffects-Photovoltaic Effect, Photoemissive Effect, and Photoconductive effect. Optical Detectors - UV, VIS, NIR, & IR Ranges.

Module IV

Types of Photon Detectors: Photodiodes, Photomultiplier Tube (PMT), Photodiode Array (PDA), Light Dependent Resistor (LDR), Charge-Coupled Device (CCD), Time Gated Detectors-Intensified Charged Coupled Device (ICCD).

Text Books:

1. Introduction to Solid-State Lighting - Zukauskas, Shur, Gaska, Wiley (2002)
2. Laser Fundamentals, 2nd Ed., William T Silfvast, Cambridge University Press (2008).
3. E. L. Dereniak, and D. G. Crowe, Optical Radiation Detectors, (Wiley Series in Pure and Applied Optics), Wiley, New York (1984).

References

1. Kingston, Robert H., Detection of Optical and Infrared Radiation, (Springer Series in Optical Sciences, Vol.10), Springer Verlag, New York (1978).
2. Chandra Roychoudhuri (Editor), Fundamentals of Photonics, SPIE (2008)
3. Bahaa E. A. Saleh Malvin Carl Teich, Fundamentals of Photonics, John Wiley & Sons, Inc. (1991)

22: Measurements and Optical Instrumentation

Course Code: 22
Credits: 4
Hours : 72 hours

Course Objectives

The course is designed so as to enable a student to understand different types of errors and noise occurred in Physical measurement system. It also aims to familiarize the student about optical detectors and spectroscopic instruments.

Course Outcomes

A student will be expected to be able to know the techniques to reduce errors in measurements and reduction of noises in experimental data. The student will also get knowledge about different types of optical detectors and the design concept of optical spectrometer.

Module I

Measurement, The Result of a Measurement, Sources of Uncertainty and Experimental Error, Systematic Error, Random Error, Definition of the Uncertainty, The Analysis of Repeated Measurements, The Mathematical Description of Data Distribution Functions, Derivation and properties of the Data Distribution Functions, Propagation of Error, Analysis of Data, Instrumentation and system design, experiment design, Multi-parameter Experiments.

Module II

Transducers, Transducer Characteristics, selection of an Instrumentation Transducer, The Transducer as an Electrical Element, Modeling External Circuit Components, Signal to noise considerations, Fluctuations and Noise in Measurement Systems, Noise in the Frequency Domain, Sources of Noise, Signal to Noise, a signal to Noise and Experimental Design, Frequency and Bandwidth Considerations, Boxcar integration.

Module III

Optical Measurements and the Electromagnetic Spectrum, Detectors, Thermal detectors, Photoconductive, piezoelectric and photo emissive detectors, photodiodes, Avalanche Photodiode phototransistors, applications, optical couplers, materials used to fabricate LEDs and lasers design of LED for optical communication, response times of LEDs, LED drive circuitry.

Module IV

Interferometry: Interference effect, radiometry, types of interference phenomenon and its application, Michelson's interferometer and its application refractometer, Rayleigh's interferometers, Spectroscopic instrumentation, Visible and Infrared Spectroscopy, Spectrometer Design, Refraction and Diffraction, Lenses and Refractive Optics, Dispersive Elements, spectrographs and monochromators, spectrophotometers, calorimeters Spectrometer Design.

Text Books:

1. Measurement, Instrumentation and experiment design in Physics and Engineering Michael Sayer and Abhai Mansingh prentice-Hall India.
2. J.Wilson & J F B Hawkes, Opto Electronics: An Introduction, Prentice Hall of India, (2011), 3rd ed.
3. Rajpal, S.Sirohi , Wave Optics and its Application, (2001), 1st ed.
4. A Yariv , Optical Electronics/C.B.S. Collage Publishing, New York, (1985).
5. Pollock ,Fundamentals of OPTOELECTRONICS, (1994).

23: Modern Optics

Course Code: 23
Credits: 4
Hours : 72

Course Objectives

The first part of the course (Modules 1 & 2) aims to expose learners to the concepts of polarization, coherence, interference, and diffraction and to apply these for the design of optical devices. Topics include polarization of light, coherence, and interference, Fraunhofer (far-filed) and Fresnel (near-field) diffraction, holography, and light modulators. The latter part of the course aims to develop creative skills among students by understanding the principles of high-power lasers and applications. Topics include revising the basic principles of lasers, laser cavities, properties of Gaussian beams and imaging. The course focuses also on high power pulsed lasers from Q-switched nanosecond lasers through to femto-second lasers and amplifiers.

Course Outcomes

At the end of the course, the student will be able to:

1. Illustrate and apply principles of optical systems.
2. Apply concepts for the design of high and anti-reflection coatings, interference filters etc.
3. Employ the theory of interference and diffraction for the development of devices like zone plates, holographic recording and re-construction.
4. Illustrate pulse shortening mechanisms and pulse amplification in modern lasers.
5. Explain linear to nonlinear transformation in laser material interactions.
6. Embrace lifelong learning and scientific research.

Module I

Polarisation: Nature of polarized light – linear, partial, elliptical and circular polarizations- Polarizers and Retarders - Jones Vectors of linearly, elliptically and circularly polarized light - Jones matrices for optical components. Induced optical effects – electro-optic modulators – Pockels effect - longitudinal and transverse electro optic modulators - Kerr effect - Magneto-optic effect, acousto-optic effect – Raman Nath and Bragg-type modulators.

Module II

Coherence: Spatial and temporal coherence-Visibility-Mutual coherence function - Degree of coherence – Temporal and spatial coherence. Interference: General considerations - Condition for interference - Wave front splitting- and Amplitude splitting interferometers – Fringes of equal inclination – Fringes of equal thickness – Michelson, Mach Zehnder and Sagnac interferometers - Fabry Perot interferometer – Fabry-perot spectroscopy - Applications of single and multilayer films - Anti-reflection coatings – Multilayer periodic systems - Interference filters.

Module III

Diffraction: Kirchhoff's theorem - Fresnel-Kirchhoff Formula – Babinets principle – Fraunhofer and Fresnel diffraction - Fraunhofer diffraction patterns for single, double slits, rectangular aperture, and circular aperture – Optical resolution – Diffraction gratings - Fresnel diffraction pattern – Fresnel Zones – Fourier analysis of Franhaufer diffraction - Zone plate – Applications of the Fourier transform to diffraction – Apodization and spatial filtering - Holography - Recording and reconstruction of wave fronts.

Module IV

Nonlinear Optics - Polarization response of materials to light – Nonlinear Wave equation – Optical rectification – second Harmonic Generation – Phase matching – Sum and difference Frequency generation – Third harmonic generation – Intensity dependent refractive index - self focusing - B integral – Optical Parametric oscillator –Two photon absorption.

Text Books:

1. G. R. Fowles, Introduction to modern optics 2nd Ed., Dover Publications (1975).
2. E Hecht and A R Ganesan, Optics 4th Ed., Pearson (2008).
3. Fibre optics and Optoelectronics, R.P. Khare, Oxford University Press, (2004).
4. W T Silfvast, Laser Fundamentals 2nd Ed., Cambridge University Press
5. Boyd, R. W - Nonlinear Optics, Second Edition, Academic Press, 2003.

Reference Books:

1. M. Born and E. Wolf, Principles of Optics 7 th Edition, Cambridge University Physics (2013).
2. Bahaa E . A. Saleh and Malvin Carl Teich , Fundamentals of Photonics 2 nd Ed., Wiley.
3. Optoelectronics: An Introduction, J. Wilson and J.F.B. Hawkes, PHI, (2000).

24: Molecular physics and laser spectroscopy

Course Code: 24
Credits: 4
Hours : 72

Course Objective

To impart the modern ideas and applications of Molecular Physics and spectroscopy.

Course Outcome

Students who completed this course will,

1. Have basic knowledge of the chemical bonding in molecules and also adequate knowledge in Valence theory
2. Posses the knowledge about the structure properties of polytropic molecules including water molecule.
3. Know the spectra of different molecules, which will enable to identify the molecule through a spectroscopic study.

Module I

Theory of chemical bonding in diatomic molecules Born-Oppenhemier approximation – Molecular orbital theory LCAO approximation. – H_2 molecule – Valence-Bond theory – H_2 molecule – Heitler and London treatment of H_2 molecule.
LCAO-MO treatment of general diatomic molecule – Valence-Bond treatment of diatomic molecules – Electronic states and Term symbols – Hund's coupling cases.

Module II

M.O. theory of simple polyatomics and application to water molecule, Huckel M.O. theory and its application to ethylene, allyl and butadiene systems.
Microwave spectroscopy – Rotational spectrum of non-rigid diatomic molecules – Stark effect in rotational spectra. Nuclear Quadrupole hyperfine interaction due to single nuclear spin. Zeeman effect in rotational spectra. Description of microwave spectrometer.

Module III

Electronic spectra of diatomic molecules – Rotational Structure of electronic bands – PQR branches – Bandhead formation and shading – Combination relations for evaluation of rotational constants.
Laser systems – three and four level schemes – solution of rate equations for three level systems – System description of semiconductor diode lasers – Ti-saphire lasers and Tunable Dye Lasers.

Module IV

Description of diode laser spectrometer – examples of diode laser spectra of diatomic molecules. Dunham representation of re-vibrational transitions. (basic ideas only)
CW dye laser spectrometers - basic ideas of intermodulated fluorescence spectroscopy – Microwave frequency - optical double resonance spectroscopy and infrared optical double resonance spectroscopy

Text Books:

1. R.K. Prasad, Quantum Chemistry, NEW AGE; Fourth edition (2010)
2. W. Gordy and E.L. Cook, Microwave Spectroscopy, John Wiley & Sons (1984)
3. G. Herzbera, Spectra of Diatomic Molecules, Van Nostrand Reinhold Company (1979)

Reference Books:

1. Qrazio Svelto, Principles of Lasers
2. Eizi Hirota, High Resolution Spectroscopy of Transient Molecules
3. A. Mooradian.T., Jaeger and P. Stockseth, Tunable Lasers and Applications
4. A.B. Budgor, L. Esterowitz and L.G. Deshazer, Tunable Solid State Lasers-II

25: Nondestructive measurement techniques and applications

Course Code: 25
Credits: 4
Hours : 72

Course Objective

To make the learner understand the modern trends in measurement techniques.

Course Outcome

To get a thorough knowledge in,

1. Magnetic techniques used for measurements.
2. Radiography and alleid techniques.
3. Ultrasound testing method and related phenomena.

Module I

Magnetism-Basic Definitions- Principle of MPT - Magnetizing Techniques -Magnetization using a magnet - Magnetization using an electromagnet - Contact current flow method. Eddy Current - Principles - Instrumentation for ECT -Techniques - High sensitivity techniques - Inspection of heat exchanger tubings by single frequency EC system - Multifrequency ECT - High frequency ECT - Pulsed ECT - 3D or phased array ECT - Inspection of ferromagnetic materials - Sensitivity - Applications - Limitations - Standards.

Module II

Radiography - Basic principle - Electromagnetic Radiation Sources -X-ray source - Production of X-rays - High energy X-ray source - Gamma ray sources - Properties of X- and gamma rays - Radiation Attenuation in the specimen - Effect of Radiation in film - Film ionization -Inherent unsharpness-Radiographic Imaging - Geometric factors - Radiographic film - Intensifying screens -Film density - Radiographic sensitivity - Penetrameter - Determining radiographic exposure -Inspection Techniques -Single wall single image technique - Double wall penetration technique .
Microwave methods-introduction, microwave radiation, microwave instrumentation, microwave measurements.

Module III

Ultrasonic Testing - Basic properties of Sound Beam - Sound waves - Velocity of ultrasonic waves - Acoustic pressure - Behaviour of ultrasonic waves - Ultrasonic Transducers - Characteristics of ultrasonic beam - Attenuation - Inspection methods - Normal incident pulse-echo inspection - Normal incident through transmission testing - Angle beam pulse-echo testing -Criteria for probe selection - Flaw sensitivity - Beam divergence - Penetration and resolution - Techniques for Normal beam inspection - Fatigue cracks -Inclusions, slag, porosity, and large grain structure - Thickness measurement-corrosion detection - Intergranular cracks-hydrogen attack-Techniques for Angle beam inspection- Flow characterization techniques - Ultrasonic flaw detection equipment - Modes of display - A-scan - B-scan - C-scan - Immersion testing - Applications of ultrasonic testing -Advantages - Limitations - Standards.

Module IV

Visual Examination Basic Principle - The Eye - Defects which can be detected by unaided visual inspection-Optical Aids Used for Visual Inspection-Microscope Borescope - Endoscope - Flexible fibre-optic Borescope (Flexiscope) - Telescope
The concept of Holographic imaging - The inline hologram- The off axis hologram-Fourier hologram-Nondestructive application of holography- Holographic interferometry-Real time holographic interferometry-Double-Exposure holographic interferometry- Sandwitch holograms- Holographic interferometry in an industrial environment- Holographic strain analysis Raman effect (Qualitative only), Raman spectroscopy as nondestructive tool. Instrumentation.

Text books

1. Practical Nondestructive Testing, Baldev Raj, T. Jayakumar, M. Thavasimuthu,Narosa Publishing House New Delhi
2. Optical Holography-Principles techniques and applications, P.Hariharan, Cambridge Studies in Modern Optics

Reference Books :

1. Electrical and Magnetic Methods of Non -Destructive Testing, Jack Blitz,Champan & Hall,2-6 Boundary Row,London SE1 8HN
2. Optical Electronics Ajoy Ghatak and K.Thygarajan,Cambridge University Press India Pvt.Ltd
3. Molecular Structure and Spectroscopy, G.Aruldhas, PHI Learning Private Limited New Delhi

26: Non-equilibrium statistical physics

Course Code: 26
Credits: 4
Hours : 72

Course Objectives

1. To introduce the important concepts in non-equilibrium physics.
2. To learn about natural systems and exact models that exhibit such processes.

Course Outcome

At the end of the course the learners will be able to:

1. Get a grasp on various theoretical methods useful in understanding non-equilibrium phenomena
2. Solve problems in stochastic processes and to predict the distributions of random variables.
3. To differentiate non-equilibrium systems from equilibrium systems wherever applicable.
4. To apply large deviation theory in physical systems.
5. Understand the technical terminology, and to follow the scientific literature of past and recent advances in the field.

Module I

Introduction to stochastic processes: basics of probability theory, Random numbers, Probability distributions, Moments, cumulants, generating functions Central limit theorem, Levy stable distributions.

Module II

Brownian motion, first passage properties, Markov processes, Master equation, Detailed balance condition, Langevin equations and Fokker-plank equation, Solutions to the Fokker plank equation for simple systems

Module III

Correlations, response, Fluctuation dissipation theorem, Linear response theory, Large deviation theory, Fluctuation relations.

Module IV

Non-equilibrium phenomena, Nucleation, Spinodal decomposition, Active and driven systems, Glassy systems, granular matter Exactly solvable systems

Text Books :

1. N G Van Kampen, Stochastic Processes in Physics and Chemistry (North-Holland Personal Library) North Holland; 3rd edition.
2. V Balakrishnan, Elements of Nonequilibrium statistical mechanics, Ane books, Delhi & CRC Press (2008)
3. R. Kubo, M Toda, N. Hashitsume, Statistical Physics II:Non-equilibrium statistical Mechanics, Springer-verlag, Berlin (1985)
4. A Kinetic view of statistical physics: Pavel L. Krapivsky, Sydney Redner, Eli Ben-Naim Cambridge University Press, (2013)

Reference Books :

1. Non-equilibrium Statistical Mechanics, Robert Zwanzig, OUP USA (2001)
2. Non-equilibrium Statistical Physics: Linear Irreversible Processes, Noelle Pottier OUP (Oxford Graduate Texts)
3. The mechanics and statistics of Active matter, Sriram Ramaswamy, Annual Review of Condensed Matter Physics 323-345 (2010).

27: Non-linear dynamics and chaos

Course Code: 27
Credits: 4
Hours : 72 hours

Course Objectives

To make the students understand the field of non-linear dynamics.

Course Outcomes

1. Understanding the basic of non-linearity in physical systems.
2. Understanding the discrete dynamical systems, logistic map and associated things.
3. To familiarise the concepts like Lyapunov exponents and its application in detecting chaos in systems.

Module I

Linear and nonlinear forces- Working definition of nonlinearity. Linear oscillators- free, damped and forced oscillators- Nonlinear oscillations and resonance.
Dynamical systems as systems of first order ordinary differential equations. Equilibrium points and their classification (two-dimension). Limit cycles, attractors, dissipative and conservative systems.

Module II

Simple bifurcations in dissipative systems. Discrete dynamical systems. Logistic map. Equilibrium points and stability. Periodic orbits. Period-doubling bifurcations. Onset of chaos. Lyapunov exponents. Bifurcation diagram. Strange attractors in Henon map. Quasiperiodic and intermittency route to chaos. Period-doubling bifurcations and chaos in Duffing oscillator and Lorenz equations.

Module III Canonical perturbation theory- problem of small divisors. Statement and discussion of KAM theorem. Surface of section. Henon-Heiles Hamiltonian(numerical results). Area-preserving maps. Poincare-Birkhoff theorem. Homoclinic points.

Module IV

Lyapunov exponents-numerical computation-one-dimensional maps and continuous time systems. Power spectrum. Autocorrelations.
Fractal sets-examples. Fractal dimension-box counting. Correlation dimension. Criteria for chaotic motion.

Text Books:

1. Nonlinear Dynamics, M.Lakshmanan and S.Rajasekar, Springer, (2003)
2. Chaos and Integrability in Nonlinear dynamics, M.Tabor, John Wiley, (1989)

Reference Books:

1. Chaos- an introduction to nonlinear dynamics, J. Alligood, T. Sauer and J.Yorke, Springer, (1997)
2. Chaos and Nonlinear Dynamics, R.C. Hilborn, Oxford University Press, (1994)
3. Deterministic Chaos, H.G.Schuster, Wiley-VCH, 3rd edition (1995)

28: Non-linear optics

Course Code: 28
Credits: 4
Hours : 72

Course Objective

Aquire the modern ideas on Non-linear optics.

Course Outcomes

1. Get a thorough knowledge of polarizability and wave propagation in dielectric material.
2. Get a clear knowledge of second harmonic generation, four wave mixing, phase-conjugation, etc.
3. Get good hand on the ideas of resonating oscillators.

Module I

Review of the concepts of polarizability and dielectric tensor of a medium. Frequency dependence of the dielectric tensor – wave vector dependence of the dielectric tensor – electromagnetic waves in an isotropic dielectrics.
Nonlinear dielectric response of matter – frequency variation of the nonlinear susceptibilities – wave vector dependence of the nonlinear susceptibilities.

Module II

Second harmonic generation – perturbation theory – phase matching evolution of SHW under phase matching conditions.
Four wave mixing spectroscopy – optical phase conjugation – nonlinear materials.

Module III

Scattering of light – Raman scattering – Quantum theory of Raman scattering – Brillouin scattering. Interaction of atoms with nearly resonant fields – wave function under near resonant conditions. Bloch equations – self induced transparency.

Module IV

Fibre optics – normal modes of optical fibres – nonlinear Schrödinger equations – linear theory.
Basic concepts of solitons and non-linear periodic structures. Effect of fibre loss – effect of wave guide property of a fibre – conditions of generation of a solitons in optical fibres.

Text Books:

1. D.L. Mills, Nonlinear Optics, Springer, 2nd,ed. (1998)

Reference Books:

1. F.Zernike and J.E. Midwinter, Applied Nonlinear Optics
2. G.C. Badwin, Nonlinear Optics
3. A. Hasegawa, Optical Solitons in Fibres

29: Phase transition and critical phenomena

Course Code: 29
Credits: 4
Hours : 72

Course Objectives

To understand how to develop the physics of a system in equilibrium with many interacting components.
Understand the physics of phase transitions and related critical phenomena.

Course Outcomes

1. Get an in-depth understanding of equilibrium statistical mechanics.
2. Acquire the ability to develop a quantitative theory of a system with many interacting degrees of freedom using exact and approximate methods.

Module I

Review of equilibrium statistical physics, statistical physics of Interacting systems: Cluster expansion for a classical gas. Virial expansion of the equation of state. Evaluation of the Virial coefficients. Van-Der-Walls equation of state and the liquid-vapor phase transition.

Module II

Ising models on lattices. Exact solution in 1D using transfer matrix, High and low temperature behavior of 2d model. Concepts related to phase transitions: Critical behavior, Order parameter, Peierls-Griffiths argument, Critical exponents.

Module III

Computer simulation methods, Metropolis algorithm. Mean field approach. Solution of d-dimensional Ising model. Evaluation of mean-field exponents. Landau theory of phase transition.

Module IV

Percolation phase transition. Exact solution in 1D and Bethe lattice. Cluster structure. Continuum percolation. Finite size scaling and the renormalization group approach (basic ideas).

Text Books :

1. R. K. Pathria, Statistical Mechanics, 2 nd edition, Elsevier (2005).
2. Principles of equilibrium statistical mechanics, D. Chowdhury and D. Stauffer, Wiley (2000).
3. D. Stauffer and A. Aharony, Introduction to percolation theory, Taylor & Francis (2003)

Reference Books :

1. K. Huang, Statistical Mechanics, 2 nd Edition, Wiley India (2008).
2. Landau and Lifshitz, Statistical Physics, Elsevier (2005).
3. Scaling and Renormalization in Statistical Physics, John Cardy, Cambridge University Press (2002).
4. Lectures On Phase Transitions And The Renormalization Group, Nigel Goldenfeld, CRC Press (2018).

30: Physics of Nanomaterials

Course Code: 30
Credits: 4
Hours : 72

Course Objectives

The course aims to develop an understanding of nanostructured materials and its various synthesis methods and characterization techniques. After completing the course, the students will be able to:

- Understand the fundamental differences between nanostructured materials and bulk materials.
- Classify 0D,1D,2D, and 3D materials and its optical, electrical, and magnetic properties.
- Differentiate Bottom-up and Top-down methods used for nanomaterials synthesis.
- Assess different characterization tools used for understanding the size and distribution of nanomaterials.

Course Outcomes

The student can explain

1. The primary difference between bulk material and nanomaterial
2. Classify the nanomaterials based on the dimension.
3. Understand weak and strong excitonic confinement.
4. Explain the blue shift in metals and semiconductors
5. Explain different methods for nanomaterial synthesis
6. Explain diverse characterization tools used in nanotechnology
7. Able to calculate particle size using Debye-Scherrer formula
8. Differentiate the purpose of using the characterization tools like SEM, TEM, XRD, and AFM.

Module I

Introduction to nanoscience and technology (brief ideas), concept of electrons, holes, and excitons, low dimensional structures, quantum well, quantum wire and quantum dots, fullerenes, carbon nanotubes, structure of CNT, vibrational, mechanical and optical properties of CNT, applications of carbon nanotube.

Module II

Size effects on the optical, electrical, mechanical and magnetic properties, weak excitonic confinement and strong excitonic confinement, blue shift, Giant magnetoresistance (GMR) and Colossal magnetoresistance (CMR).

Module III

Synthesis of nanostructured materials, Bottom-up and Top-down processes, method of making 1- D and 2-D nanomaterials, high energy ball milling, co-precipitation technique, sol gel synthesis, solvothermal methods-control of grain size chemical vapor deposition (CVD), physical vapor deposition (PVD), Lithography.

Module IV

Characterization of nanomaterials, preliminary ideas about the operation and characterization of nano materials using scanning electron microscope (SEM), transmission electron microscope (TEM), scanning tunneling microscope (STM), atomic force microscope (AFM) and x-ray diffraction (XRD).

Text Books:

1. Michael F. Ashby, Paulo J. Ferreira, Daniel L. Schodek, Nanomaterials, Nanotechnologies and design, an introduction for engineers and architects, Elsevier (2009).
2. S.V. Gaponenko, Optical properties of semiconducting nanocrystals, Cambridge University Press (1997).
3. Transmission Electron Microscopy: A textbook for materials science, David B. Williams, C. Barry Carter, second edition, Springer.
4. Elements of X-Ray diffraction, B. D. Cullity, S. R. Stock, Springer, (2001).

Reference Books:

1. A. K. Bandhyopadhyay, Nanomaterials, New Age International Publishers (2007).
2. Bieter K. Schroder, Semiconductor material and device characterization, Wiley - Inter-science publication (1993)
3. A I Gusev and A A Remphal, Nanocrystalline materials, Cambridge International Science Publishing
4. Hari Singh Nalwla, Nanostructured materials and nanotechnology Vol. I, II, III, IV, V, VI, VII,VIII, IX (2002)
5. K L Chopra and Inderjeet Kaur, Thin Film Device Applications, Plennum Press (1983)
6. J H Davis, Physics of low dimensional structures Cambridge (1998).

31: Principles of Biomedical instruments

Course Code: 31
Credits: 4
Hours : 72

Course Objectives

The objective of this course is to understand the underlying physics of the medical imaging systems and to give an overview of major modern diagnostic techniques.

Course Outcomes

After completion of this course, the students will have good understanding, on biomedical instruments

Module I

Flame photometers, Introduction to Spectro photometers,Beer lambert law,Colorimeters, Blood gas analyzers, Principles and techniques of sterilization–Autoclave, Sterrad. Chromatography – Gas and liquid Chromatographs – Principle and applications. Mass spectroscopy, flow cytometry–Principles and applications. Electrophoresis – Principles and applications.

Module II

X-rays:Principle and production of X-rays, Interaction of X rays with matters, Transfer characteristics of screen, Film and image intensifier systems, Properties of X-ray films and screens, Characteristics of Imaging system by image modulation transfer functions, Radiography:Various components of Radiography systems – Exposure switching and control of exposure time – Types of timer circuits, Filament circuit and KV– mA controls – HT units – X-ray tubes for various medical applications – fixed anode, rotating anode, X-ray tubes for specialized applications – collimators

Module III

Medical ultrasound: Physics of ultrasonic waves, Interactions with body matter, Generation and detection, Single element transducer, Linear and sector scanning Transducer arrays, Different modes of display, Modes of transmission of ultrasound, Colour Doppler, Ultrasonic diagnosis in abdomen, Breast, Heart, Chest, Eye, Kidney, Skull, Pulsatile motion, Pregnant and Non-Pregnant uterus. Ultrasound pulse echo imaging system, Design of scan converters, Design of frame grabbers, 2D scanners.

Module IV

Magnetic Resonance Imaging:Principles of image formation– MRI instrumentation-magnets Gradient system – RF coils receiver system, Pulse sequence– Image acquisition and reconstruction techniques, Application of MRI, Fundamentals of magnetocardiography and magnetoencephalography

Text Books:

Text Books :

1. Fundamental Physics of radiology,W.J. Meredith & J.B. Massey, Varghese Publishing House, Bombay, 1992.
2. The Physics of Diagnostic Ultrasound, Peter Fish, John Wiley & Sons, England, 1990. 4.
3. Ultrasound Physics & Instrumentation,D.L. Hykes, W.R. Hedrick & D.E. Starchman, Churchill Livingstone, Melbourne, 1985.

Reference Books :

1. Principles of Applied Biomedical Instrumentation,L.A.Geddes & L.E.Baker, Wiley
2. Handbook of Analytical Instruments, Khandpur R S, Tata McGraw Hill,1989
   India Pvt.Ltd, Third Edition, 1989.
3. Radiographic Imaging,D.N. & M.O. Chesney, CBS Publishers, 1990.
4. The Physics of Medical Imaging, S. Webb, IOP Publishing Ltd., 1988.

32: Quantum field theory

Course Code: 32
Credits: 4
Hours : 72

Course Objectives

To introduce the basic concepts and methods of classical and quantum field theory.

Course Outcomes

1. To understand the basics of classical field theory concepts and methods of calculation
2. To understand about the scalar field and Feymann propagator and it's usage.
3. To familiarize with the idea of quantization of the filed and allied facts.

Module I

Classical field theory, Euler Lagrange equations, Hamilton formalism, conservation laws. Canonical quantization of neutral and charged scalar filed, symmetry transformations.
(Sect. 2.1-2.2, 2.4, 4.1-4.3 of Ref. 1)

Module II

Scalar fields: The invariant commutation relations, scalar Feynman propagator. Dirac fields-- canonical quantization of Dirac fields-Feynman propagator.
(Sect. 4.4-4.5, 5.1-5.4 of Ref. 1)

Module III

Canonical quantization of Maxwell's field-Maxwell's equations-Lorentz and Coulomb gauges-Lagrangian density.
Canonical quantization in Lorentz and Coulomb gauges-Coulomb interaction and transverse delta functions.
(Sect. 6.1--6.2, 7.1--7.5, 7.7 of Ref. 1)

Module IV

Interacting fields, interaction picture, time evolution operator, scattering matrix, Wick's theorem(no proof), Feynman rules(no rigorous treatment) -Moller and Compton scattering.
(Sect. 8.1-8.7 of Ref. 1)
Spontaneous symmetry breaking, scalar theory, Goldston theorem(no proof), spontaneous breaking of gauge symmetries.
(Sect. 8.1-8.3 of Ref. 2)

Text Books:

1. Field Quantization, Greiner W and Reinhardt J, Springer, (2013)
2. Quantum Field Theory, Ryder L H, Cambridge University Press; 2 edition (1996)

Reference Books:

1. Quantum Field Theory, Itzykson C and Zuber J B, Dover Publications Inc., (2006)
2. Relativistic Quantum Fields I & II, Bjorken J D and Drell S D, McGraw Hills(1965)

33: Quantum Computation and Information

Course Code: 33
Credits: 4
Hours : 72

Prerequisites

Knowledge of basic quantum mechanics and Mathematical Physics.

Course Objectives

Course Outcomes

Students will get an overview of the emerging field of quantum computation and the techniques involved in that.

Module I

Introduction to classical computation. The Turing machine - the circuit model of computation - computational complexity (elementary ideas) - energy and information - reversible computation. Introduction to quantum mechanics - Linear vector space - Tensor products - Postulates of quantum mechanics - the EPR paradox and Bell's theorem. (relevant sections of Chapter 1 and 2 of Benenti et.al.)

Module II

The qubit - single qubit gates - controlled gates - universal quantum gates - Deutsch and Deutsch - Josza algorithms - the quantum Fourier transform - period finding and Schor's algorithm - quantum search - first experimental implementations (relevant sections of Chapter 3 of Benenti et.al.)

Module III

Classical cryptography-quantum no - cloning theorem - quantum cryptography - BB84 and E91 protocols - dense coding - quantum teleportation - experimental implementations. (relevant sections of Chapter 4 of Benenti et.al.)

Module IV

Classical information and Shannon entropy - data compression - density matrix in quantum mechanics - von Neumann etropy - quantum data compression - composite systems - Schmidt decomposition - entanglement concentration (relevant sections of Chapter 5 of Benenti et.al.)

Text Books:

1. G. Benenti, G. Casati and G. Strini, Principles of quantum computation and information (World Scientific)

Reference Books:

1. M. A. Nielson and I. L. Chuang, Quantum computation and quantum information (Cambridge University Press)

34: Quantum optics

Course Code: 34
Credits: 4
Hours : 72

Course Objective

To teach the students about the basics and sufficient advanced ideas of Quantum Optics.

Course Outcome

1. The students must acquire sufficient knowledge regarding the radiation-matter interaction
2. A thorough understanding of the black body radiation and laser theory
3. Get a clear idea about the modern concepts like, Doppler broadening, multimode field quantization, etc.

Module I

Interaction between electromagnetic waves and matter – linear dipole oscillator method – radiative damping – coherence.
Nonlinear dipole oscillator method. Coupled mode equations cubic nonlinearity – nonlinear susceptibilities.

Module II

Atom-field interaction for two level atoms – blackbody radiation – Rabi Flopping.
Introduction to laser theory – the laser self consistency equation – steady state amplitude and frequency – stability analysis – mode pulling.

Module III

Doppler – broadened lasers – Two mode operation and the ring laser – mode locking – single mode semiconductor theory – evaluation of laser gain and index formulas – transverse vibrations and Gaussian beams.
Field quantization - single mode field quantization – multimode field quantization – single mode in thermal equilibrium. Coherent states – coherence of Quantum fields p ( ) representations.

Module IV

Interaction between atoms and quantized fields – Dressed states – Jaynes-Cummings model – collapse and revival.
Squeezed state of light – squeezing the coherent states – two side mode master equation – two mode squeezing – squeezed vacuum.

Text Books:

1. P. Meystre and M. Sargent III, Elements of Quantum Optics (2$^{\text{nd}}$ Ed.)

Reference Books:

1. W.H. Louisell, Quantum Statistical Properties of Radiation
2. M. Sargent III, M.O. Scully and W.E. Lamb, Laser Physics

35: Solar Photovoltaic Technology

Course Code: 35
Credits: 4
Hours : 72

Course Objectives

The objective of the course is to develop a general understanding of the need for clean energy sources and the potential and application of photovoltaic (PV) technology to generate power. The course will give an insight in the fabrication of the solar cells in laboratory and industrial scale, module fabrication and power generation using PV in off grid and grid connected systems.

Course Outcomes

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

1. Understand PV based electricity generation
2. Differentiate the manufacturing and performance differences between different c- Si wafer technologies and between ?c-Si and thin film PV technologies
3. Calculate the power and energy produced by a solar module
4. Explain the differences and design aspects of off-grid and on-grid PV systems.
5. Basic knowledge to use PVSyst.
6. Explain various current and futuristic applications of PV.

Module I

Introduction: Energy scenario - Fossil fuel and Climate change - Renewable Energy sources - Integrating Renewable Energy - Renewable energy scenarios - Economic Analysis of Renewable Energy System - Photovoltaics - history of photovoltaics - status of Photovoltaics - Grid Parity - Challenges - trends in photovoltaic technology - Policy Impacts - PV market growth scenarios - Solar radiation: Solar constant - Solar Spectra - Air Mass - Global radiation -Position of the Sun - Solar Insolation Physics of Solar cells: Fundamental Properties of Semiconductors - Band model - Doping - Semiconductor types - absorption of light - recombination - p-n junction - Solar cells - Solar cell parameters - Spectral response - Upper limits of cell parameters - Thermodynamic limit-the Schokley-Quiesser limit - effect of temperature - effect of parasitic resistances

Module II

Solar PV technologies (qualitative)
First generation: Silicon wafer based technology: Design of c-Si solar cell - loss mechanism - silicon feed stock - production of silicon wafers - Manufacturing process of c-Si solar cells - high efficiency approaches - PERL and PERC cells - interdigitated back contacts - TOPCon - heterojunction solar cells - lab to industry requirements
Second generation: Thin film technologies: Merits and demerits of thin film technologies - Transparent conducting oxides - GaAs, amorphous-Si, CdTe and CIGS solar cells .
Third generation/emerging PV technologies: Organic PV - organic-inorganic hybrid solar cells - Quantum-dot - Hot-carrier - Up conversion and down conversion

Module III

Solar cell to modules: silicon feed stock - production of silicon wafers - Manufacturing process of c-Si solar cells – interconnection of cells - series and parallel connections - design and structure of PV module - production - measurement of modules - field performance- module reliability.

Module IV

PV systems: Standalone systems - grid-connected systems - hybrid systems - micro grids - smart grids - system components - system design Specific purpose PV application: introduction to PVSyst software, Lighting, agriculture, refrigeration, telecommunications, space, BIPV, fencing, water purification, navigation, solar cars, defense, etc.

Text Books:

1. S.R. Wenham, M. Green, M.E. Watt, R. Corkish, A. Sproul, Applied Photovoltaics ? 2nd Edition (2009)
2. K. Mertens, Photovoltaics: Fundamentals, Technology and Practice, John Wiley & Sons Ltd (2014)
3. Smets, K. Jager, O. Isabella, R. V. Swaaij, M. Zeman, Solar Energy: The physics and engineering of photovoltaic conversion, technologies and systems, UIT Cambridge Ltd. (2016).

Reference Books:

1. Handbook of Photovoltaic Science and Engineering - 2nd Ed. , A. Luque, S. Hegedus (editors), John Wiley & Sons Ltd (2011)
2. Chetan Singh Solanki, Solar Photovoltaics: Fundamentals, Technologies and applications, 3rd Edition, PHI Learning Pvt. Ltd. (2019).
3. Jenny Nelson, The Physics of Solar Cells, Imperial College Press (2003).
4. Godrfrey Boyle (Eds), Renewable Energy: Power for a sustainable future, Oxford University Pres (2012).
5. S.P. Sukhatme, J.K. Nayak, Solar Energy 4th Edn, McGraw-Hill Education (2017)
6. SM Sze and Kwok K Ng, Physics of semiconductor devices, third edition ,John Wiley & Sons (2007)
7. R.F. Pierret, Semiconductor Device Fundamentals
8. D. A. Neamen and D. Biswas ,Semiconductor Physics and Devices

36: Sophisticate Material Characterization Techniques

Course Code: 36
Credits: 4
Hours : 72

Course Objectives

To train the students on the fundamentals of structural characterization of materials and to understand the usefulness of different characterization techniques.

Course Outcomes

After completion of this course, the students will have good fundamental understanding, on different types of sophisticated material characterisation techniques.

Module I

X-ray diffraction - X-ray methods - Production of X-rays and X-ray Spectroscopy - Instrumental units - Detectors for the measurements of radiation - Semiconductor detectors - Direct X-ray methods - Powder method - rotating crystal method - specimen preparation - -Single crystal diffractometer – Electron diffraction-Neutron diffraction- Reflection high energy electron diffraction (RHEED), XPS-principle-Instrumentation and applications-X-ray topography(XRT)- Rutherford Back Scattering analysis(RBS)- XRF (X-ray fluorescence)- Synchrotron radiation- Applications (Qualitative) – XANES-XAFS.

Module II

Morphological studies Optical microscope, Electron matter interaction- Fundamental principle and instrumentation and applications of Scanning Electron Microscope (SEM)- Transmission Electron Microscope (TEM) - Scanning transmission electron microscopy (STEM)- Atomic Force Microscope- Elemental composition analysis-EDX-EELS- Auger electron spectroscopy (AES)- Optical measurements-UV-visible spectroscopy- Determination of band gap of semiconductors- Atomic emission spectrometry.

Module III

Absorption and Emission spectroscopy - Nature of electromagnetic radiation - Atomic energy level-Raman effect - Raman Spectroscopy- Instrumentation -Infrared spectroscopy - Near IR - Mid IR - Far IR Region - Correlation of infrared spectra with molecular structure - structural Analysis - Radiation sources - Detectors - Thermal Detectors -Spectrophotometers - Fourier Transform Interferometer Quantitative analysis- Sample handling. - Luminescence –Photoluminescence(PL) spectroscopy–Nuclear magnetic Resonance Spectroscopy - Basic principles - Quantitative analysis-Dyanamic Light scattering- Secondary ion mass spectroscopy (SIMS).

Module IV

Thermal analysis - Differential Thermal Analysis - Instrumentation – Differential Scanning calorimetry - Thermogravimetry - Instrumentation - Methodology of Differential Scanning Calorimetry and

Thermo Gravimetric Analysis - Conductance method – Electrical conductivity- Measurement of electrical conductance - Measurement of dielectric constant- Hall Mobility – Magnetic measurements-SQUID magnetometer- Fundamentals of cyclic voltammetry CV measurements.

Text Books:

1. B.D. Cullity, Element of X-ray Diffraction, Addison Wesley Publication, 1978.
2. X.F. Zong, Y.Y.Wang, J. Chen, Material and Process characterization for VLSI, World Scientific, New Jersey, 1988.
3. H.H.Willard, D.L.Merrti, Dean and Settle, Instrumental methods of analysis, CBS publishers.1992.
4. Yang Leng, Materials Characterization Introduction to Microscopic and Spectroscopic Methods; Wiley-VCH-Second Edition.
5. P.E. J. Flewitt and R K Wild Physical methods for Materials Characterization, IOP Publishing (2003).
6. P.Duke ; Synchratron radiation, Oxford university press 2000.
7. Molecular Structure and Spectroscopy, G.Aruldhas, PHI Learning Private Limited New Delhi.
8. Zoski, C. G., Ed. Handbook of Electrochemistry; Elsevier: Amsterdam, The Netherlands, 2006.
9. John Clarke , Alex I. Braginski; The SQUID Handbook: Fundamentals and Technology of SQUIDs and SQUID Systems- Wiley-VCH.
10. Banwell and E M McCash, Fundamentals of Molecular Spectroscopy; McGraw-Hill Education (India) Pvt Limited, 2001.

37: Thin film physics

Course Code: 37
Credits: 4
Hours : 72

Course Objective

To impart the modern ideas of thin film technologies used in various solid state physics and day today applications.

Course Outcome

1. To familiarise with the different thin film deposition methods.
2. To understand the nuclear theories of thin film formation.
3. To familiarise with the measurements techniques of the properties of thin films.
4. Awareness and knowledge of various application of thin films in semiconductor devices and in day today life.

Module I

Vacuum Technology: High vacuum production: Mechanical pumps – Diffusion pumps-Cryogenic pumps – Getter pumps – ion pumps- basics of ultra-high vacuum Measurement of Vacuum: McLeod gauge – Thermal conductivity gauges - Cold cathode and hot cathode ionisation gauges Designing a vacuum system- vacuum leak detection: helium leak detector, residual gas analyzer.

Module II

Thin film growth techniques: Physical Vapour Deposition: Vacuum evaporation - Evaporation theory - Rate of evaporation - Hertz-Kundsen equation - Free evaporation and effusion - Evaporation mechanisms - Directionality of evaporating molecules - vapour sources - wire and metal foils - Electron beam gun- sputtering - Glow discharge sputtering - Bias sputtering - Reactive sputtering - Magnetron sputtering - Ion beam sputtering - PLD- epitaxial films- MBE Chemical Vapour deposition: conventional CVD, Plasma enhance CVD, MOCVD, Atomic layer Deposition Film thickness measurements: Optical methods - basics of multilayer modelling- Ellipsometry -Other techniques: Electrical - Mechanical - Micro-balance - Quarts crystal monitor - X ray reflectivity.

Module III

Nucleation Theories: Condensation process - Theories of Nucleation – Capillarity theory – Atomistic theory – Comparison – stages of film growth – Incorporation of defects during growth.
Optical properties:Reflection and transmission at an interface – Reflection and transmission by a single film – Optical constants - Refractive index measurement techniques – Reflectivity variation with thickness Patterned films: lithography techniques – film etching methods.

Module IV

Electrical Properties: Electrical Properties: Sources of resistivity – sheet resistance – electron mobility- Hall Effect -TCR – Influence of thickness on resistance – Theories of size effect – Theories of conduction in discontinuous films – Electronic conduction in thin insulating films- MIS structure -Dielectric properties – D.C. conduction mechanisms – High and low field conduction – Temperature dependence – space charge limited conduction – A.C. conduction mechanisms Application of thin films: electrodes, transparent conducting oxides, thin film devices: LED, TFT, -Solar cells - optical and decorative coatings - dichroic coatings- biomedical coatings – tribological coatings.

Text Books:

1. Hand Book of Thin Film Technology, Maissel and Glang, McGraw Hill Higher Education (1970)
2. Materials science of thin films deposition and structures, Milton Ohring, Academic press, 2006.
3. Vacuum deposition of thin films, L. Holland, Chapman and Hall.
4. Glow discharge processes, B. Chapman, Wiley, New York.
5. Physics of Non-Metallic Thin Films, Dupy and Kachard, Plenum Press (1976).
6. Scientific Foundations of Vacuum Technology, S. Dushman and J.M. Lafferty, John Wiley & Sons, Inc.; 2nd Ed. (1962).
7. Thin Film Phenomena, K.L. Choppra, McGraw-Hill Inc.,US (1969).

Reference Books:

1. O. S. Heavens, Optical Properties of Thin Films, by, Dover Publications, Newyork 1991
2. Donald L. Smith ‘Thin Film deposition principle and Practice’s, McGraw Hill international Edition, 1995.
3. Various web resources and research papers

38: Ultrashort Pulse Lasers and Applications

Course Code: 38
Credits: 4
Hours : 72

Course Objectives

The course is on intense femto-second lasers and applications with emphasis on the current trends on the subject. Learning will be through lectures, books, journal articles and recent reviews on the subject.

Course Outcomes

At the end of the course, the student will be able to,

1. Illustrate process of generation, amplification, and measurement of ultrashort lasers.
2. Analyse high power relativistic and non-relativistic laser interaction with gaseous and condensed media.
3. Evaluate Research Opportunities and technology of intense field interaction physics.
4. Develop lifelong learning skills through research.

Module I: Femtosecond Lasers

Femtosecond laser oscillators - Mode locking - Kerr lens mode locking - Group velocity dispersion– Chirped Mirrors - Time bandwidth product - bandwidth limited pulses - Ti: Sapphire laser - chirped pulse amplification - regenerative amplifiers - multipass amplifiers –Ultrafast pulse measurements - intensity autocorrelation - cross correlation - FROG and SPIDER.

Module II: Laser Interaction with gas phase

Laser interaction with low density Gas - Ionization-Multiphoton ionization - Tunnel ionization - Keldysh Approximation - Over the barrier ionization - Laser interaction with Clusters - Generation of rare gas clusters - cluster diagnostics through Rayleigh scattering – Properties of clusters – cluster ionization – Nano plasma model – Expansion of clusters – Coulomb explosion – Hydrodynamic expansion.

Module III: Interaction with condensed media

Basics of a plasma – Plasma density, plasma temperature, Debye length plasma frequency, critical density - Laser interaction with solids above damage threshold - Inverse bremsstrahlung absorption – collisional absorption – resonance absorption (Brunel heating) – vacuum heating - Laser produced plasma – Free-free, free-bound and line radiations in a plasma.

Module IV: Applications of Intense Lasers

Transient absorption spectroscopy - THz radiation - Two photon polymerization and direct laser 3D printing - High harmonic generation (re-collision picture) – Attosecond pulses - X-ray sources from laser-solid and laser-cluster interactions – Water window radiation – Laser Wakefield acceleration (LWFA) of electrons – Inertial Confinement Fusion.

Text Books: Units I & II

1. Claude Rulliere, Femtosecond Laser Pulses – Principles & Experiments 2 nd Ed., Springer (2005).
2. Jean-Claude Diels and Wolfgang Rudolph Ultrashort Laser Pulse Phenomena, Elsevier (2006)

Unit III

1. W L Kruer, The Physics of Laser-plasma Interactions, Addison-Wesley (1988).
2. F F Chen Plasma Physics and Controlled Fusion, 2 nd Ed., Plenum Press (1984)

Unit IV

1. Jean-Claude Diels and Wolfgang Rudolph Ultrashort Laser Pulse Phenomena, Elsevier (2006).
2. Soft x-rays and Extreme Ultraviolet Radiation: Principles and Applications, David Atwood, Cambridge University Press, 1999.

Appendix-28

DEPARTMENT OF STATISTICS

Scheme of Examinations and Syllabus for the Five-Year Integrated M.Sc. Statistics Degree Program

(From 2021 admission onwards)

Cochin University of Science and Technology

Cochin - 682 022

Approved by the BOS in Physical and Mathematical Sciences 17-07-2021

Website: http://statistics.cusat.ac.in

SEMESTER – I

Course Code	Title of Paper	Core/ Elective	Credits	Continuous evaluation marks	End Semester Evaluation Marks	Total marks
ENG 10101	English I	C	2	50	50	100
MAL 10101	Malayalam- I	C	2	50	50	100
HIN 10101	Hindi- I	C	2	50	50	100
FLG 10101	Foreign Language - I*	C	2	50	50	100
PHY 10101	Mechanics	C	3	50	50	100
CHE 10101	Atomic Structure and Chemical Bonding.	C	3	50	50	100
MAM 10101	Calculus - I	C	4	50	50	100
BTG 10101	Basic Principles of Biology	C	3	50	50	100
PHY 10102	Physics Lab - I (Mechanics)	C	2	100	-	100
CHE 10102	Chemistry Lab-I (Quantitative Analysis-I)	C	2	100	-	100
BTG 10102	Biology Lab - I (Basic Principles of Biology)	C	2	100	-	100
	Total		23	600	300	900

*Either Malayalam - I or Hindi - I or Foreign Language -I is to be opted.

SEMESTER – II

Course Code	Title of Paper	Core/ Elective	Credits	Continuous evaluation marks	End Semester Evaluation Marks	Total marks
ENG 10201	English II	C	2	50	50	100
MAL 10201	Malayalam- II	C	2	50	50	100
HIN 10201	Hindi- II	C	2	50	50	100
FLG 10201	Foreign Language - II*	C	2	50	50	100
PHY 10201	Waves and Optics	C	3	50	50	100
CHE 10201	Periodicity, Nuclear Chemistry, Acid Base Chemistry and Metallurgy	C	3	50	50	100
MAM 10201	Linear Algebra and Group Theory	C	4	50	50	100
BTG 10201	Biomolecules of Life	C	3	50	50	100
PHY 10202	Physics Lab - II (Waves and Optics)	C	2	100	-	100
CHE 10202	Chemistry Lab-II (Qualitative Analysis I)	C	2	100	-	100

BTG 10102	Biology Lab - II (Biomolecules of life)	C	2	100	-	100
	Total		23	600	300	900

*Either Malayalam - II or Hindi - II or Foreign Language -II is to be opted.

SEMESTER – III

Course Code	Title of Paper	Core/ Elective	Credits	Continuous evaluation marks	End Semester Evaluation Marks	Total marks
PHY 10301	Electricity and Magnetism - I	C	3	50	50	100
CHE 10301	Introductory Organic Chemistry	C	3	50	50	100
MAM 10301	Calculus - II	C	4	50	50	100
MAM 10302	Mathematical Methods - I	C	4	50	50	100
BTG 10301	Introduction to cell biology and signaling	C	3	50	50	100
ENV 10301	Environmental Science	C	2	50	50	100
PHY 10302	Physics Lab - III (Electricity and Magnetism)	C	2	100	-	100
CHE 10302	Chemistry Lab-III (Qualitative analysis II)	C	2	100	-	100
BTG 10302	Biology Lab -	C	2	100	-	100

	III (Cell biology and signaling)					
	Total		25	600	300	900

SEMESTER – IV

Course Code	Title of Paper	Core/ Elective	Credits	Continuous evaluation marks	End Semester Evaluation Marks	Total marks
PHY 10401	Quantum Physics and Relativity	C	3	50	50	100
CHE 10401	Introductory Physical Chemistry	C	3	50	50	100
MAM 10401	Mathematical Methods - II	C	3	50	50	100
STA 10401	Statistics and Probability-I	C	3	50	50	100
BTG 10401	Fundamentals of molecular Biology and Genetics	C	3	50	50	100
COM 10401	Basic Computer Science	C	2	50	50	100
PHY 10402	Physics Lab - IV (Modern	C	2	100	-	100

	Physics)					
CHE 10402	Chemistry Lab-IV (Physical Chemistry)	C	2	100	-	100
BTG 10402	Biology Lab – IV (Molecular Biology and Genetics))	C	2	100	-	100
	Total		23	600	300	900

SEM V

Course Code	Title of Paper	Core/ Elective	Credits	Continuous evaluation marks	End Semester Evaluation Marks	Total marks
MAM 10501	Analysis I	C	4	50	50	100
MAM 10502	Linear Algebra and Geometry in R^n	C	4	50	50	100
MAM 10503	Algebra : Groups and Rings	C	4	50	50	100
MAM 10504	Introduction to Complex Analysis	C	4	50	50	100

STA10501	Statistics and Probability II	C	4	50	50	100
	Total		20	250	250	500

SEM VI

Course Code	Title of Paper	Core/ Elective	Credits	Continuous evaluation marks	End Semester Evaluation Marks	Total marks
MAM 10601	Analysis II	C	4	50	50	100
MAM 10602	Ordinary and Partial Differential Equations	C	4	50	50	100
MAM 10603	Complex Analysis and Number	C	4	50	50	100

	Theory					
STA10601	Design of Experiments and Sample Surveys (Elective I)	E	4	50	50	100
STA10602	Applied Statistics (Elective II)	E	4	50	50	100
	Total		20	250	250	500

Course Code		Title of Paper	Core/ Elective	Credits	Continuous evaluation marks	End Semester Evaluation Marks	Total marks
STA -10701		Mathematical Methods for Statistics	C	4	50	50	100
STA-10702		Probability Theory I	C	4	50	50	100
STA-10703		Probability Distributions	C	4	50	50	100
STA-10704		Sampling Theory &	C	4	50	50	100

		Methods					
	Elective - I (Choose any one)						
STA-10705		Elective – I: Data Analytics using R	E	3	50	50	100
STA-10706		Statistical Computing	E	3	50	50	100
		Total		19	250	250	500

SEMESTER – VII

SEMESTER – VIII

Course Code	Title of Paper	Core/ Elective	Credits	Continuous evaluation marks	End Semester Evaluation Marks	Total marks
STA-10801	Statistical Inference I	C	4	50	50	100
STA-10802	Probability Theory II	C	4	50	50	100
STA-10803	Stochastic Processes	C	4	50	50	100

STA-10804	Practical - I and Viva Voce	C	2	100	-	100
Elective – II (Choose any one)						
STA-10805	Statistics for National Development	E	3	50	50	100
STA-10806	Reliability Modeling and Analysis.	E	3	50	50	100
Elective - III						
STA-10807	** A suitable Online course	E	2	50	50	100
	Total		19	350	250	600

SEMESTER – IX

Course Code	Title of Paper	Core/ Elective	Credits	Continuous evaluation marks	End Semester Evaluation Marks	Total marks
STA-10901	Statistical Inference II	C	4	50	50	100
STA-10902	Multivariate Analysis	C	4	50	50	100
STA-10903	Applied	C	4	50	50	100

	Regression Analysis					
STA-10904	Practical - II using SPSS/ MATLAB	C	2	50 (practical) + 50 (viva)	-	100
Elective – IV (Choose any one of the following)						
STA-10905	Topics in Stochastic Finance	E	3	50	50	100
STA-10906	Operations Research-II	E	3	50	50	100
Elective V Either an inter-departmental course or an online course**						
STA-10907	STA 10907 Elected course	E	3	50	50	100
	Total		20	350	250	600

SEMESTER - X

Course Code	Title of Paper	Core/ Electiv e	Credits	Continuous evaluation marks	End Semester Evaluation Marks	Total marks
STA-11001	Design and Analysis of Experiments	C	4	50	50	100
STA-11002	Practical – III using SAS/R , and Viva Voce	C	4	50	50	100
STA-11003	Project***	C	5	100	--	100
Electives - VI, VII, VIII. (Choose any three)						
STA-11004	Statistical Quality	E	3	50	50	100

	Assurance					
STA-11005	Time Series Analysis	E	3	50	50	100
STA-11006	Lifetime data analysis.	E	3	50	50	100
STA-11007	Applied Multivariate Statistical Analysis.	E	3	50	50	100
STA-11008	Statistical Forecasting	E	3	50	50	100
STA-11009	Inference for Stochastic Processes	E	3	50	50	100
STA-11010	Online course**	E	3	50	50	100
	Total		22	350	250	600

* The Viva Voce examination in STA-11002 is to be conducted externally with at least one external examiner (50 marks). The project evaluation is based on a dissertation of STA-11003 shall be done in semester X internally with 100 marks.
** An online course from SWAYAM/NPTEL will be opted by students in consultation with the DC.
*** Project allotment and progress assessment will be done during the IX semester. Final evaluation will be done during the X semester.

Method of Evaluation : 50% weightage for Continuous evaluation and 50% for End semester examination.
Continuous evaluation based on internal tests, assignments, seminars and class attendance as per regulations of the University from time to time.

DETAILED SYLLABUS.

STA10401: Statistics and Probability I

This course is common for all branches and will be taught in fourth semester.

Hours per week – 4+1, Number of credits -4

Objective: This course introduces the basic concepts of Statistics.

Outcome: After completing the course, the students are expected to become familiar with the basic statistical tools needed for analysing scientific data.

Syllabus

Module I:

Descriptive statistics, graphical representation of data, measures of central tendency, dispersion, skewness, kurtosis, Probability, Conditional probability, Baye’s theorem, Independence of events.

Module II:

Random variables, Distribution functions, Expectation and moments, Joint and conditional distributions, functions of random variables

Module III:

Standard distributions (Continuous and discrete), Uniform, normal. Binomial, Poisson, Bivariate normal distribution, Sampling distributions (chi-square, t-, F).

Module IV: Method of point estimation, properties of good estimators (without proofs), Interval estimation, Examples and illustrations.

ModuleV:

Testing of hypothesis : small sample tests based on normal population, large sample tests. , Regression and correlation, curve fitting. Chi-square test for homogeneity and independence.

Text Book :

Ross, S. M (2014). Introduction to Probability and Statistics for Engineers and Scientists, 5th Edition, Academic Press,

Reference books:

1. Gupta S. C. and Kapoor V. K.(2002). Fundamentals of Mathematical Statistics, 11th edition, Sultan Chand and Sons.
2. Hogg R. V., Mckean J. W., and Craig A. T.(2014) Introduction to Mathematical Statistics, 6th edition, Pearson Education Inc.

STA10501: Statistics and Probability II

This course is meant for students opting Mathematics/Statistics for their M.Sc.

Hours per week – 4+1, Number of credits -4

Objective: This course introduces Probability and Statistics in a more rigorous manner.

Outcome: After completing the course, students are expected to equipped with useful tools and techniques in Probability and Statistics.

Syllabus

Module I: Review of classical and frequency approaches to probability. Fields, sigma fields and Random variables, Axioms of probability, distribution function and properties. Functions of random variables. Expectations and moments, Moment generating functions.

Module II: Properties of Standard discrete and continuous distributions: Uniform, Normal, exponential, gamma, Weibull, Bernoulli, Binomial, geometric, Poisson, negative binomial, hypergeometric (mean, variance, moment generating functions, inter-relationship among distributions).

ModuleIII:Modes of convergence: (only definitions, inter-relationships and examples).

Weak law and strong laws of large numbers (definitions, statements of standard limit theorems and examples for iid case only). Central limit theorem for independent and identically distributed random variables (statements of the theorems, examples and applications).

Module IV: Sampling distributions: Chi-square, t-, F and their properties such as genesis, moments and inter-relationships. Methods of estimation (moments, MLE), properties of good estimators, Statement of important theorems (eg: Rao Blackwell, Cramer Rao, ..),

Module V: Fundamentals of testing of hypothesis, Neyman-Pearson lemma with examples. Basic concepts of nonparametric tests. Sign test, signed rank test, Kolmogorov Smirnov test, Mann Whitney test.

Text Book:

Rohatgi, V. K. and Saleh, A.K.Md. Ehsanes (2001). An Introduction to Probability and Statistics, 2ndEdn. John Wiley and Sons.

Reference Books

1. Gupta S. C. and Kapoor V. K.(2002). Fundamentals of Mathematical Statistics, 11th edition, Sultan Chand and Sons.
2. Hogg R. V., Mckean J. W., and Craig A. T.(2014) Introduction to Mathematical Statistics, 6th edition, Pearson Education Inc.

STA10601: Design of Experiments and Sample Surveys

This course is meant for students opted for M.ScStatisitcs.

Hours per week : 4+1, Number of credits = 4

Objective: This course introduces basic tools in Sample survey and design of experiments.

Outcome: After completing the course, students are expected to know fundamental aspects of sample survey and analysis of variance.

Syllabus

Module I: Analysis of variance - introduction, One-way classification- fixed and random effect models.

Module II: Two-way classification (one observation per cell) – fixed and random effect models, Tukey's test.

Module III: Experimental design – basic principles, completely randomised design (CRD), randomized block design (RBD), Efficiency of RBD relative to CRD, Latin square design – concepts and applications.

Module IV: The principle steps in a sample survey, Sampling and non-sampling errors, Sample v/s complete enumeration, Types of sampling, Simple random sampling (SRS) - method of selection of SRS, Estimation of population mean and total, Sample size for a given margin of error.

Module V: Stratified random sampling - method of allocation and estimation of population mean, systematic sampling - method of allocation and estimation of population mean, Cluster and multistage sampling.

Text Books:

1. S.C.Gupta and V.K.Kapoor (2014) Fundamentals of Applied Statistics, Fourth thoroughly Revised Edition, Sultan Chand & Sons, New Delhi.

2. P.Mukhopadhyay (2016) Applied Statistics, Second edition (thoroughly revised), Books and Allied (P) Ltd., Kolkata.

Reference Books:

1. W.Cochran (2007) Sampling Techniques, Third Edition, Wiley India Private Ltd, New Delhi.

2. P.Mukhopadhyay (2016) Theory and Methods of Survey Sampling, Second Edition, PHI Learning Private Ltd, New Delhi.

3. D.C.Montgomery (2013) Design and Analysis of Experiments, Eighth Edition, Wiley India Private Ltd, New Delhi.

4. M.R.Spiegel, J.J.Schiller, R.A.Srinivasan and D.Goswami (2016) Probability and Statistics, Third Edition, Schaum's Outlines, McGraw Hill Education (India) Private Ltd, New Delhi.

STA10602: Applied Statistics

This course is meant for students opted for M.Sc. Statistics

Hours per week : 4+1, Number of credits = 4

Objective: This course introduces some of the statistical tools for data analysis.

Outcome: After completing the course, the students are expected to take decision on choosing a **suitable statistical tool for the given data set.**

Syllabus

Module I:Index Numbers - Introduction, construction of index numbers, criteria of a good index number, classification of index numbers, base shifting, splicing and deflating of index numbers, index of industrial production, index of agricultural production, uses and limitations of index numbers.

Module II: Regression Analysis – Simple and multiple regression, Basics of fitting and residual analysis, assumptions (such as, independent normal errors with mean zero and constant variance, exogeneity, linear independence of predictors etc.) and their violations

Module III: Time Series Analysis– Time series, components of time series, determination of trend, seasonal factors using parametric methods, forecasting, Holt-Winter method.

Module IV: Multivariate Data Analysis – Multivariate data, plotting multivariate data, matrix scatter plot, contour plot, tours, shadow matrix (for missing values), Andrew's curves, parallel coordinate plots, mean, variance-covariance matrix, median, data depth,

Module V:Data Mining – Concept of database, extraction of the data, Data warehousing, concept of ROC, specificity, sensitivity, accuracy of an algorithm method. Introduction to pattern discovery, Introduction to clustering

Text Books:

1. S.C.Gupta and V.K.Kapoor (2014) Fundamentals of Applied Statistics, Fourth thoroughly revised edition, Sultan Chand & Sons, New Delhi.
2. P.Mukhopadhyay (2016) Applied Statistics, Second Edition (thoroughly revised), Books and Allied (P) Ltd., Kolkata.
3. S.C.Gupta and V.K.Kapoor (2010) Fundamentals of Mathematical Statistics, Eleventh thoroughly revised edition, Sultan Chand & Sons, New Delhi.
4. H¨ardle, W. and Simar, L. (2003). Applied Multivariate Statistical Analysis
5. Han, J., Kamber, M., & Pei, J. (2011). Data mining: Concepts and techniques (3rd ed.). Waltham: Morgan Kaufmann.

Reference Books:

1. S.P.Gupta (1999) Statistical Methods, Sultan Chand & Sons, New Delhi.
2. D.C.Montgomery, E.A.Peck and G.G.Vining (2006) Introduction to linear regression analysis, Third Edition, Wiley India Private Ltd, New Delhi.
3. M.R.Spiegel, J.J.Schiller, R.A.Srinivasan and D.Goswami (2016) Probability and Statistics, Third Edition, Schaum's Outlines, McGraw Hill Education (India) Private Ltd, New Delhi.

SEMVII

STA 10701: MATHEMATICAL METHODS FOR STATISTICS

Course Outcome (CO)	Cognitive level
After completion of this course the student should be able to	
1. Demonstrate an understanding of limits and continuity of various functions.	Apply
2. Evaluate the Riemann-Stieltjes integral and verify the conditions for the existence of the integrals.	Evaluate
3. Distinguish between the concepts of sequence and series,	

	and determine limits of sequences and convergence and approximate sums of series.	Analysis
4.	Compute the partial and total derivatives and maxima and minima of multivariable function	Apply
5.	Solve systems of linear equations, diagonalize matrices and Characterize quadratic forms	Apply

Module-I

Riemann-Stieltjes Integral:- definition, linear properties, integration by parts, change of variable in a Riemann-Stieltjes integral, reduction to a Riemann integral, step functions as integrators, reduction of a Riemann-Stieltjes integral to a finite sum, Eulers summation formula, monotonically increasing integrators, Riemann's condition, comparison theorems, integrators of bounded variation, sufficient conditions for existence of Riemann-Stieltjes integrals, Mean value theorems of Riemann-Stieltjes integrals, integral as a function of the interval, second mean value theorem for Riemann-Stieltjes integrals.

Module-II

Sequences of functions:- Pointwise convergence of sequence of functions, Uniform convergence and continuity, Cauchy condition for uniform convergence, Uniform convergence of infinite series of functions, Uniform convergence and Riemann-Stieltjes Integration, Uniform convergence and differentiation, Multivariable Calculus:- limit and continuity of multivariable functions, Derivatives of a multivariable function - total derivative, directional derivatives, differentiation of composite functions, Taylor's Theorem for a multivariable function, inverse and implicit functions, optima of a multivariable function, method of Lagrange multipliers.

Module-III

Matrices:- Rank of a matrix, elementary transformations of a matrix, reduction to normal form, elementary matrices, elementary transformations and elementary matrices, employment of only row (column) transformations, rank of a product, a convenient method for computing the Inverse of a non-singular matrix, Generalized Inverse Matrices:- Definition and existence, an algorithm, Solving linear equations - consistent equations, obtaining solutions, properties of solutions, Penrose inverse, Symmetric matrices - properties of generalized inverse.

Module-IV

Quadratic forms:- definition, Quadratic forms in the real field:- reduction in the real field, canonical forms, classification of quadratic forms and its characteristic properties, necessary and sufficient conditions for a definite form, gram matrices, Characteristic roots and characteristic vectors of a matrix:- determination of characteristic roots and vectors, characteristic sup-spaces of a matrix, nature of characteristic roots of some special types of matrices, algebraic and geometric multiplicity of a characteristic roots, Cayley-Hamilton theorem, Orthogonal and unitary reductions of quadratic forms:- orthogonal reduction of real symmetric matrices, unitary reduction of Hermitian matrices, simultaneous reduction of a pair of quadratic forms, Spectral decomposition of a matrix.

Text Books:

1. Searle, S. R. and Khuri, A. I. (2017). Matrix Algebra Useful for Statistics. Wiley Series in Probability and Statistics, Second Edition.
2. Khuri, A.T. (1993). Advanced Calculus with Applications in Statistics, John Wiley & Sons, Inc., USA, Chapters - 3 and 7
3. Apostol, T.M. (1996). Mathematical Analysis, NarosaPublshing House, New Delhi, Second Edition, Chapters - 6, 7, 9.
4. Shanti Narayan (1991). A text of book of matrices, S. Chand & Company, New Delhi, Chapters - 3, 6, 7, 10, 11.
5. Searle, S.R. (1971). Linear models, John Wiley & Sons, Inc., Chapter - 1.

Reference Books:

1. Gupta, S.L. and Gupta, N.R. (2003) Principles of Real Analysis, Second edition, Pearson Education (Singapore) Pte. Ltd.
2. Widder, D.A. (1996) Advanced Calculus, Second Edition, Prentice Hall, Inc., New Delhi.
3. Nanda, S. and Saxena, V.P. (2000) Real Analysis, Allied Publishers Ltd.
4. Graybill, F.A. (1969) Introduction to matrices with applications in statistics, Wadsworth Publishing Company, USA.
5. Rao, C.R. (2002) Linear statistical inference and its applications, Second edition, Chapter 1b, 1c.

STA10702: PROBABILITY THEORY – I

Course Outcome (CO)	**Cognitive level**
After completion of this course the student should be able to	
1. Identify sigma fields and Compute limits of a sequence of random variables.	Apply
2. Describe properties of Probability Measure and distribution function	Remember
3. Define Expectation and moments	Understand
4. Compute Moment inequalities using Expectations	Apply
5. Concepts of Independence and its use in Multiplication properties, Zero-one laws.	Apply

Module-I

Random variables: Algebra of sets, Fields, Sigma fields, Inverse function, Measurable functions, Random variables, Induced sigma fields, Limits of random variables.

Module-II

Probability: General measure space, Lebesgue measure, Lebesgue-Stieltjes measure, Counting measure and their simple properties, Discrete probability space, General probability space as normed measure space, Induced probability space, Extension of probability measures. Distribution function of a random variable, Decomposition of distribution functions, Distribution function of random vectors.

Module-III

Integration with respect to measure (Introduction only), Expectation and moments: Definition and properties, Moment generating functions, Moment inequalities: C_r-, Holder, Jenson and basic inequalities, Product spaces and Fubini's theorem (idea and statement only), Independence: Definitions, Multiplication properties, Zero-one laws.

Module-IV

Convergence: Modes of convergence, Convergence in probability, in distribution, in rth mean, almost sure convergence and their inter-relationships, Convergence theorem for expectation such as Monotone convergence theorem, Fatou's lemma, Dominated convergence theorem (some remarks on the corresponding theorems for general integrals with respect to measure).

Text Books:

1. Billingsley, P. (1986) Probability and Measure, Second Edition, John Wiley.
2. Bhat, B.R. (2011) Modern Probability Theory, Second edition, Wiley Eastern,
   Chapters 1, 2, 3, 4, 5, 6, 9.

Reference Books:

1. Feller, W. (1966) An Introduction to Probability Theory and Its Applications, Volume II, Wiley Eastern.
2. Rao, C.R. (1973) Linear Statistical Inference and Its Applications, Wiley.
3. Rohatgi, V.K. and A.K.E. Salah (2001) Introduction to Probability and Statistics, John Wiley and Sons.
4. Basu, A.K. (1999) Measure Theory and Probability, Prentice-Hall.

STA10703: PROBABILITY DISTRIBUTIONS

Course outcome (CO)	Cognitive level
After completion of this course the student should be able to	
1. Describe and employ various statistical concepts to study the discrete distributions	Apply
2. Describe and employ various statistical concepts to	

study the discrete distributions — Apply

3. Describe properties of bivariate continuous exponential Distributions — Understand
4. Illustrate characterization properties of the bivariate exponential. — Apply

Module-I

Discrete Distributions : Modified power series family - properties, moment generating functions, recurrence relations for raw, central and factorial moments, recurrence relation for cumulants, Binomial, Negative binomial, Logarithmic series and Lagrangian distributions and their properties as special cases of the results from modified power series family, hypergeometric distribution and its properties.

Module-II

Continuous distribution: Pearson family – identifications of the different types, Beta, Gamma, Pareto and Normal Special cases of the Pearson family and their properties. Exponential family of distributions, Compound, truncated and mixture distributions.

Module-III

Sampling distributions: Sampling distributions of the mean and variance from normal population, independence of mean and variance, Chi-square, students t and F distribution and their non-central forms. Order statistics and their distributions, Conditional distribution of order statistics, distribution of sample range.

Module-IV

Bivariate distributions: Multinominal, bivariate normal, bivariate exponential distribution of Gumbel, Marshall and Olkin and Block and Basu, Dirichlet distribution.

Text Books:

1. Rohatgi V.K (1976) An introduction to Probability Theory and Mathematical Statistics, Wiley Eastern
2. Arnold B.C, Balakrishnan N and Nagaraja H.N (1992). A first course in order statistics
3. Galambos J, and Kotz's (1978): Characterization of Probability distributions, Springer -Verlag.
4. Ord J.K. (1972) Families of frequency distributions Griffin

Reference Books:

1. Johnson N.L, Kotz S and Kemp A.W (1992) Univariate discrete distributions, John Wiley.
2. Johnson N.L, Kotz S and Balakrishnan N (1991) Continuous univariate distributions I & II, John Wiley.
3. Johnson N.L, Kotz S and Balakrishnan N (1995) Multivariate Distribution, John Wiley.

STA10704: SAMPLING THEORY AND METHODS

Course Outcome (CO) — **Cognitive level**

After completing this course, the student should be able to

1. Apply various sampling procedures like SRS, Stratified, systematic, Cluster etc., and estimatethepopulationparametresfor attributes and variables	Apply
2. Estimate population ratio, population mean and population total using ratio, difference and regression estimators	Apply
3. Explain Midzuno-Sen- Lahiri, Murthy's, DesRaj's sampling strategies under varying probability without replacementsampling	Evaluate/ Apply
4 .Understand various types of errors in surveys, and procedures to rectify them	Apply
5 .Understand quota, networkand adaptive samplings; and evaluate estimator under adaptive sampling	Apply

Module-1

Basic concepts:- Population, sample, sampling design, interpenetrating subsampling; Simple Random Sampling (SRS):- SRS with replacement, SRS without replacement, confidence interval, estimation of population proportion, determination of sample size, comparison between SRSWR and SRSWOR; Stratified Random Sampling:- estimation of population mean and total, optimum allocation, other types of allocation, comparison with SRS.

Module-II

Estimation of gain due to stratification over SRS, construction of strata, number of strata, Ratio estimator:- Bias and mean square error, estimation of variance, confidence interval, comparison with mean per unit estimator, optimum property of ratio estimator, unbiased ratio type estimator, ratio estimator in stratified random sampling; Difference estimator and Regression estimator:- Difference estimator, regression estimator, comparison of regression estimator with mean per unit and ratio estimator, regression estimator in stratified random sampling.

Module-III

Systematic sampling:- estimation of population mean and variance, comparison of systematic sampling with SRS and stratified random sampling, circular systematic sampling; Cluster sampling:- estimation of population mean, estimation of efficiency by a cluster sample, variance function, determination of optimum cluster size, clusters of varying sizes; Probability proportional to size with replacement sampling:- estimation of population mean and total, selection of a ppswr sample; Varying probability without replacement sampling I:- properties of a sampling design, Horvitz-Thomson estimator.

Module-IV

Varying probability without replacement sampling II:-Midzuno-Sen-Lahiri sampling strategy, Desraj, Murthy's; Mutistage sampling:- estimation population total with SRS sampling at both stages, multiphase sampling (outline only); Errors in surveys:- effect of unit nonresponse in the estimate, procedures for unit nonresponse; quota sampling, network sampling; Adaptive sampling:- introduction and estimators under adaptive sampling

Text Books:

1. Mukhopadhay, P (2009) Theory and methods of survey sampling, Second edition, PHI Learning Pvt Ltd., New Delhi, Relevant sections of Chapters 1-16.
2. Sampath, S. (2001) Sampling theory and methods, Alpha Science International Ltd., India, Chapter 10.

Reference Books:

1. Cochran, W.G. (1999) Sampling Techniques, Third edition, John Wiley & Sons.
2. Des Raj (1976) Sampling Theory, McGraw Hill.
3. Murthy, M.N. (1977) Sampling Theory and Methods, Statistical Publishing Society, Calcutta.
4. Singh, D. and Chaudhary, F.S. (1986) Theory and Analysis of Sample Survey Designs, Wiley Eastern.

STA10705: ELECTIVE – I

SEMESTER VIII

STA10801: STATISTICAL INFERENCE - I

After completion of this course the students will be able to

CourseOutcome(CO) **Cognitive level**

1. Summarize the desirable properties of estimator of a parameter or parameters of any given distribution — Evaluate
2. Relate complete sufficient statistic, Rao-Blackwell theorem and Lehmann-Scheffe theorem. — Analyze
3. Relate Cramer-Rao, Chapmann-Robbin's and Bhattacharya bounds in connection with lower bound for the variance of an unbiased estimator — Analyze
4. Compute estimator of parameter or parameters of any given distribution using method of moments, method of maximum likelihood and method of minimum variance. — Apply
5. Judge MLE of parameter or parameters of any given distribution possess its invariance and large sample properties — Evaluate
6. Compare classical inference and Bayesian inference — Analyze
7. Evaluate Bayes and minimax estimator of parameter or parameters of any given distribution under given prior density and loss function — Evaluate
8. Illustrate Metropolis-Hasting algorithm, Gibbs sampler and MCMC method. — Analyze

Module-I

Point estimation: Sufficiency and minimal sufficiency, Exponential family of distributions, Pitman family, Factorization criterion, Likelihood equivalence, Unbiased estimation, Completeness, Ancillary statistics and Basu's Theorem, UMVUE estimators and their characterizations, Rao-Blackwell Theorem, Lehmann-Scheffe Theorem, UMVUE estimation of parametric functions from standard distributions.

Module-II

Fisher information measure and its properties, Fisher information matrix, Lower bound to the variance of an unbiased estimates, Cramer-Rao, Chapman-Robbin's and Bhattacharya bounds, BLUE of parametric functions, Efficiency, Consistency, Weak and strong consistency, Marginal and joint consistent estimators, Equivariance, Pitman estimators.

Module-III

Methods of estimation: Methods of moments, Maximum likelihood, Minimum chi square and its modification, Least square estimation, Properties of maximum likelihood estimators, Cramer-Huzurbazar Theorem, Likelihood equation - multiple roots, Iterative methods, E.M Algorithm.

Module-IV

Basic elements of Bayesian Inference, Loss function, Prior distribution, Bayes Theorem, Posterior distributions, Bayes risk, Bayes principle, Bayes estimators, Minimax estimators, Metropolis-Hastings algorithm, Gibbs sampler, MCMC method.

Text Books:

1. E.L.Lehmann (1998) Theory of Point Estimation, John Wiley and Sons.
2. V.K.Rohatgi and A.K.L. Saleh (2001) An Introduction to Probability and Mathematical Statistics, Wiley.
3. B.K. Kale (1999) A First Course in Parametric Inference, Narosa Publishing Company.
4. Robert C.P. and Casella, G (1999) Monte Carlo Statistical Methods, Springer Verlag.

Reference Books:

1. Rao, C.R. (1973) Linear Statistical Inference and its Applications, Wiley.
2. Casella, G and Berger, R.L (2002) Statistical Inference, Second Edition, Thompson-Duxbury Press.
3. Mukhopadhay, P. (1999) Mathematical Statistics, New Central Book Agency Pvt. Ltd.

STA10802: PROBABILITY THEORY – II

Course Outcome(CO)	Cognitive level
After completion of this course students will be able to	
1. Employ Inversion formula, Uniqueness theorem	Apply
2. Illustrate Convergence of distribution function characteristicfunctions,and moments.	Apply
3. Define Covergence of series of independent random variables	Understand
4. Describe different forms of Central limit theorems	Understand
5. Define Conditional expectation and conditional probability	Understand
6. Demonstrate Randon-Nikodym Theorem and its applications.	Apply
7.	

Module-I

Characteristic functions**:** Definition and simple properties, Inversion formula, Uniqueness theorem, Characteristic function and moments, Bochner's Theorem (Statement only), Convergence of distribution function: Weak convergence, Convergence of distribution functions and characteristic functions, Convergence of moments.

Module-II

Laws of Large Numbers**:** Covergence of series of independent random variables, Kolmogorov's inequality, Three series theorem, Weak law of large numbers (Kninchine's and Kolmogorov's), Kolmogorov's strong law of large numbers, Glivenko-Cantelli theorem, Kolmogorov's law of iterated logarithms (without proof).

Module-III

Limit Theorems**:** Central limit theorems for i.i.d random variables, Lindberg-Levy and Liaponov's CLT, Lindberg-Feller CLT, Infinitely divisible distributions--definition, elementary properties and examples, Canonical representation (without proof).

Module-IV

Conditioning: Conditional expectation and its properties, Conditional probabilities, Randon-Nikodym Theorem (Statement only) and its applications. Martingales, Submartingales,Martingale convergence theorem, Decomposition of submaritingales.

Text Books:

1. Bhat, B.R. (2011) Modern Probability Theory, Second edition, Wiley Eastern, Chapters 7, 8, 10, 11, 12.

2. Laha. R.G. and Rohatgi V.K. (1979) Probability Theory, John Wiley, Relevant sections of Chapters 2, 4, 6.

Reference Books:

1. Billingsley, P. (1986) Probability and Measure, Second edition, John Wiley
2. Feller, W. (1976) An Introduction to Probability Theory and its Applications, Volume II Wiley Eastern.
3. Hoffmann - Jorgensen J. (1994) Probability with a view towards Statistics, Chapman & Hall.
4. Loeve M. (1977) Probability Theory, Volume I, Fourth edition, Springer-Verlag
5. Loeve, M. (1978) Probability Theory, Volume II, Fourth edition, Springer-Verlag.
6. Rohatgi, V.K. and Saleh, A.K.E. (2001) An Introduction to Probability and Statistics, John Wiley & Sons.
7. Resnich, S. I. (2005). A Probability Path. Birhauser, Springer.

STA10803 : STOCHASTIC PROCESSES

Course Outcomes (CO)	**Cognitive level**
After completion of this course the students will be able to	
1. Understand the classifications of random processes and concepts such as strict stationarity, wide-sense stationary andergodicity.	Understand
2. Classify the states of a Markov chain and apply ergodic theorem for finding limiting distributions on states	Understand
3. Understand and apply Poisson, birth-death ,renewal Processes and Brownian motion	Apply
4. Describe and use the recurrence relation for generation sizes in a Branching Process and determine the probability of ultimate extinction	Evaluate

Module-I
Markov Chains: Definition, Examples and classification, Discrete renewal equation and basic limit theorem, Absorption probabilities, Criteria for recurrence.

Module-II
Continuous time Markov chains, Examples, General pure birth process, Poisson process, Birth and death process, Finite state continuous time Markov chains, Applications to queuing models.

Module-III
Galton-Watson branching processes, generating function, Extinction probabilities, Continuous time branching processes, Extinction probabilities, Branching processes with general variable life time.

Module-IV
Renewal equation, Renewal theorem, Applications, Generalizations and variations of renewal processes, Applications of renewal theory, Brownian motion.

Text Books:

1. Karlin..S. and Taylor, H.M. (1975) A First Course in Stochastic Processes, second edition, Academic Press, Relevant sections of Chapters 1, 2, 3, 4, 5 and 8.
2. Bhat, B.R. (2002) Stochastic Processes, second edition, New Age Publication.

Reference Books:

1. Feller, W. (1965, 1968), An Introduction to Probability Theory and its Applications, Volume I and II, Wiley Eastern.
2. Bhat, U.N. (1984) Elements of Applied Stochastic Processes, John Wiley.
3. Cinlar, E. (1975) Introduction to Stochastic Processes, Prentice Hall.
4. Cox, D.R. (1962) Renewal Theory, Methuen.
5. Ross, S. (1996) Stochastic Processes, Second edition, John Wiley
6. Medhi, J. (1994) Stochastic Processes, Second edition, Wiley Eastern.
7. Basu, A.K. (2002) Elements of Stochastic Processes, Narosa Publications.
8. Bhat, U.N. and Gregory Miller (2003) Elements of Applied Stochastic Process, John Wiley.
9. Hoel, P. G., Port, S. C and Stone, C. J. (1986). Introduction to Stochastic Processes. Waveland Press.

STA10804: PRACTICAL - I

Course Outcomes (CO) **Cognitive level**

After completion of this course the students will be able to

1. Apply the different sampling methods for designing and selecting a sample from a population Apply
2. Apply the methods of generating random numbers from different probability distributions and its goodness-of-fit using R software Apply
3. Formulate and solve problems which involve setting up stochastic models. Evaluate
4. Understand the notion of a parametric models, point and interval estimation of the parameters of those models using real data Understand
5. Apply topics related to the Elective in the Semester II using real data sets and interpretation of the results. Apply

Practicals based on topics covered in
STA10704 : Sampling Theory and Methods
STA10801 : Statistical Inference I
STA10803 : Stochastic Processes
STA10805 : Elective II

STA1080 -: ELECTIVE - II

STA1080 -: ELECTIVE – III

SEMESTER IX

STA10901: STATISTICAL INFERENCE – II

Course Outcome (C.O)	Cognitive level
After completion of this course the students will be able to	
1. Summarize the testing problem in statistical testing problem	Evaluate
2. Evaluate MP and UMP tests corresponding to any given testing problem	Evaluate.
3. Relate confidence interval estimation and testing of hypothesis	Analyze
4. Compute shortest confidence interval for parameter/s of any given distribution using different methods	Apply
5. Formulate LR test corresponding to any given testing problem	Evaluate
6. Construct SPRT corresponding to any given testing problem	Evaluate
7. Distinguish non-parametric confidence interval and bootstrap Confidence intervals	Analyze
8. Examine the non-parametric alternatives for each parametric tests.	Analyze

Module-I

Tests of hypotheses, Formulation of problem, Null and alternative hypotheses, Size of a test, Two kinds of errors, Simple and composite hypotheses, Randomized and non-randomized tests, Power of a test, Most powerful test, Neyman-Pearson lemma and its generalization, Monotone likelihood ratio property, UMP tests, Unbiased tests and UMPU tests with examples., Multiple hypothesis testing, False discovery rate.

Module-II

Confidence interval estimation, Relationship between confidence interval estimation and testing of hypothesis, UMA and UMAU confidence intervals, Shortest confidence intervals, Construction of confidence intervals using pivots, Large sample confidence interval based on maximum likelihood estimator, central limit theorem and Chebyshev's inequality, Bayesian credible regions.

Module-III

Likelihood ratio tests and their properties, Testing mean and variance of a normal population, Testing equality of means and variances of two normal populations, Sequential probability ratio tests, Construction of sequential probability ratio tests with examples.

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Module-IV

Non-parametric inference: Goodness of fit tests- Chi square test and Kolmogorov Smirnov test for one and two sample problems, Sign test, Signed rank test, Wald-Wolfowitz run test, Median test, Man-Whitney U-test, Non-parametric confidence intervals, Bootstrapping confidence intervals, P-P Plot and Q-Q plot, Kendall's tau, Tests for independence and homogeneity.

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Text Books:

1. Lehmann, E.L. (1998) Testing Statistical Hypothesis, John Wiley.

2. Wald, A. (1947) Sequential Analysis, Doves
3. Gibbons, J.K. (1971) Non-Parametric Statistical Inference, McGraw Hill
4. Rohatgi, V.K. and Saleh, A.K.E. (2001) An Introduction to Probability and Statistics, John Wiley and Sons.
5. Kale, B.K. (1999) A First Course in Parametric Inference, Narosa Publications.

Reference Books:

1. Rao, C.R. (1973) Linear Statistical Inference and its Applications, Wiley.
2. Casella, G and Berger, R.L (2002) Statistical Inference, Second Edition, Thompson-Duxbury Press.
3. Rajagopalan, M and Dhanavanthan, P. (2012). Statistical Inference.
4. Dixit, U. J. (2016). Examples in Parametric Inference with R, Springer.

STA10902: MULTIVARIATE ANALYSIS

Course Outcome (CO)	Cognitive level
After completion of this course the student should be able to	
1. Describe Multivariate data and its preliminary analysis	Understand
2. Interpret multivariate normal distribution (MVN)	Apply
3. Examine Wishart distribution and its properties	Analyze
4. Explain Hotelling's T^2 and Mahalanobis D^2 statistics	Understand
5. Outline various multivariate testing problems	Analyze
6. Evaluate the above testing problems	Apply
7. Explain classification problem	Understand
8. Describe Principal component analysis (PCA)	Understand

Module-I

Multivariate data, preliminary analysis, notion of multivariate distributions, multivariate normal distribution, marginal and conditional distributions, characteristic function, estimation of mean vector and covariance matrix.

Module-II

Distribution of rectangular co-ordinates, Wishart distribution and its properties, distribution of simple, partial and multiple correlations based on samples from normal population, Hotelling's T^2 and Mahalanobis D^2 statistics, properties of T^2 and D^2, multivariate Fisher-Behren's problem.

Module-III

Testing independence of sets of variates, testing equality of covariance matrices and means, Sphericity tests, testing the hypothesis that a covariance matrix equal to given matrix, Mean and covariance equal to a given vector and given matrix.

Module-IV

Classification problem - standards of good classification, procedures of classification into one of two populations with known probability distributions, classification into one of two known multivariate normal populations, classification into one of several populations; principal component analysis- definition, properties and ML estimation; canonical variables, canonical correlation.

Text Books:

1. Anderson, T.W. (1984) An Introduction to Multivariate Statistical Analysis, John Wiley.
2. Johnson, R.A. and Wichern, D.W. (1990) Applied Multivariate Statistical Analysis, Prentice Hall.

Reference Books:

1. Seber, G.A.F. (1977) Multivariate Observations, Wiley.
2. Giri, N., Multivariate Statistical Inference, Academic Publishers.
3. Morrison, D.F. (1976) Multivariate Statistical Methods, John Wiley.
4. Rao, C.R. (1973) Linear Statistical Inference and the Application, Wiley.
5. Rancher, A.C. (1995) Methods of Multivariate Analysis, John Wiley.

STA10903: APPLIED REGRESSION ANALYSIS

Course Outcome (CO)	Cognitive level
After completion of this unit the student should be able to	
1. Identify a linear and nonlinear regression problem	Apply
2. Model a data using an appropriate Regression model	Analyze
3. Identify and interpret a regression model.	Understand
4. Examine model diagnostics	Analyze
5. Identify a Non parametric Regression problem	Analyze
6. Apply Non Parametric Regression techniques	Apply

Module-I

Simple Linear Regression Model, Multiple linear regression model, Least squares estimation, Gauss Markov Theorem, Properties of the estimates, Distribution Theory, Maximum likelihood estimation, Hypothesis testing - likelihood ratio test, F-test; Confidence intervals.: Bonferroni-t-intervals, max modulus t intervals, Scheffes's method, Estimation with linear restrictions, Generalised least squares.(12+4+4hrs)

Module-II

Residual analysis, Departures from underlying assumptions, Effect of outliers, Collinearity, Non-constant variance and serial correlation, Departures from normality, Diagnostics and remedies.

Module-III

Polynomial regression in one and several variables, Orthogonal polynomials, Indicator variables, Subset selection of explanatory variables, stepwise regression and Mallows C_p-statistics, Introduction to non-parametric regression.

Module-IV

Introduction to nonlinear regression, Least squares in the nonlinear case and estimation of parameters, Models for binary response variables, estimation and diagnosis methods for logistic and Poisson regressions. Prediction and residual analysis, Generalized Linear Models – estimation and diagnostics.

Text Books:

1. Montgomery, D.C., Peck, E.A. and Vining, G.G. (2001) Introduction to Regression Analysis, Third edition. Wiley. Chapter 2, 3,
2. Seber, A.F. and Lee, A.J. (2003) Linear Regression Analysis, John Wiley, Relevant sections from chapters 3, 4, 5,

Reference Books:

1. Searle, S.R. (1971) Linear models, John Wiley & Sons, Inc.
2. N.Draper and H. Smith (1986) Applied Regression Analysis – John Wiley & Sons.
3. Fox, J. (1984) Linear Statistical Models and Related methods, John Wiley, Chapter 5.
4. Christensen, R. (2001) Advanced Linear Modeling, Chapter 7.
5. B.Abraham and Ledotter, J. (1983) Statistical Methods for Forecasting, John Wiley & Sons.

STA10904: PRACTICAL - II USING SPSS/MATLAB

Course Outcome (CO)	Cognitive level
After completion of this course the students will be able to	
1. Understand various tools in SPSS/Matlab	Understand
2. Apply different statistical testing problems using real data sets and interpretation of the results	Analyze
3. Apply different multivariate techniques using real data sets and interpretation of the results	Analyze
4. Apply different regression techniques using real data sets and interpretation of the results	Evaluate
5. Apply topics related to the Elective in the Semester III using real data sets and interpretation of the results.	Apply

Practicals based on topics covered in

STA10901 ;Statistical Inference II
STA10902 :Multivariate Analysis
STA10903 :Applied Regression Analysis
STA10905 : Elective IV

STA1090 - - : ELECTIVE – IV
STA1090 - - : ELECTIVE - V

SEMESTER X

STA11001: DESIGN AND ANALYSIS OF EXPERIMENTS

Course Outcome (CO)	Cognitive level
After completing the course, the student should be able to	
1. Understand the basic principles and guidelines of Design of experiments	Apply
2. Design and analyze CRD RBD,LSD and Greaco LSD	Apply
3. Apply incomplete block designs in designing experiments and analyze them	Analyze
4. Understand and apply the factorial designs and its various versions	Apply
5. Apply Response surface methodology understanding various aspects involved in it.	Apply

Module-I

Randomization, Replication and local control, One way and two way classifications with equal and unequal number of observations per cell with and without interaction, Fixed effects and Random effects model. Model adequacy checking, CRD, RBD and Latin Square designs, Analysis of co-variance for completely randomized and randomized block designs. Analysis of experiments with missing observations.

Module-II

Incomplete Block Designs: Balanced Incomplete Block designs, Construction of BIB Designs, Analysis with recovery of inter-block information and intra-block information. Partially balanced incomplete block designs, Analysis of partially balanced incomplete block designs with two associate classes, Lattice designs.

Module-III

2^n Factorial experiments. Analysis of 2^n factorial experiments. Total confounding of 2^n designs in 2^P blocks. Partial confounding in 2^P blocks. Fractional factorial designs, Resolution of a design, 3^n factorial designs. Split plot design and strip plot design (outline only).

Module-IV

Response surface designs - orthogonality, rotatability blocking and analysis - Method of Steepest accent, Models, properties and Analysis.

Text Books:

1. Montgomery, D.C. (2001)) Design and Analysis of Experiments, John Wiley.
2. Das M N and Giri N.C. (1979) Design and Analysis of Experiments, second edition, Wiley.
3. Hinkleman and Kempthrone, C. (1994) Design and Analysis of Experiments-I, John Wiley.

Reference Books:

1. Joshi D.D. (1987) Linear Estimation and Design of Experiments, Wiley Eastern.
2. Chakrabarti, M.C. (1964) Design of experiments, ISI, Calcutta.

STA1002: PRACTICALS - III USING SAS/R AND VIVA-VOCE

Course Outcome (CO)	Cognitive level
After completion of this course the students will be able to	
1. Understand the various computational techniques using R.	Understand
2. Develop programming skill tomeet the given Scientific objective.	Analyze
3. Apply different DoE techniques using real data sets and interpretation of the results :	Apply
4. Apply topics related to the Elective I in the Semester IV using real data sets and interpretation of the results	Apply
5. Apply topics related to the Elective II in the Semester IV using real data sets and interpretation of the results	Apply

Practical based on topics covered in

STA11001 : Design and Analysis of Experiments.

Elective IV, Elective V, Elective VI.

STA11003: Project

STA1100 - -: Elective VI

STA1100- -: Elective VII

STA1100- -: Elective VII

LIST OF ELECTIVES

Course Name-STA10705: Data Analytics using R

Course Outcome (CO)	**Cognitive level**
After completion of this course the students will be able to	
1. Develop a scientific computing environment using R	Evaluate
2. Identify the use of R software to meet the given scientific objective	Analyze
3. Identify the use of various packages in R	Analyze
4. Write an efficient programs using R to perform routine and specialized data manipulation /management and analysis tasks	Evaluate

Module-I

Introduction to statistical software R, Using R as a calculating environment, Arithmetic variables, Functions, Vectors, Expressions and assignments, Logical expressions, Manipulating vectors, matrices, importing of files.

Types of data, Scale of measurement, Data objects in R, Graphical summaries of data-Bar chart, Pie chart, Histogram, Box-plot, Stem and leaf plot, Frequency table, Plotting of probability distributions and sampling distributions, P-P plot, Q-Q Plot, Computations of descriptive statistics measures.

Inference from bivariate data-Scatter plot, Correlation and Regression.

Module-II

Basic programming, Branching with if, Looping with for, Looping with while, Vector-based programming, Program flow, Pseudo-code, Basic debugging, Programming with functions, Vectorized functions, Optional arguments and default values, Vector based programming using functions, Recursive programming, Debugging functions, Data frames, Lists, Use of apply group of functions.

Module-III

Simulation, Congruential generators, Seeding, Random Number Generation- Basic principles of Random number generation, Inversion method, Accept-reject method, Random number generation from Binomial, Poisson Uniform, Exponential, Cauchy and Normal, Rejection with exponential envelope, Box-Muller algorithm.

Module-IV

Statistical Inference Problems Using R-Estimation and confidence intervals-Point estimates of normal mean, confidence interval for normal mean with known and unknown standard deviation. Confidence interval for standard deviation. Confidence interval for proportion.
One sample t-test, two sample t-test, paired t-test, test on standard deviation (chi-square test).

Text Book:

1. Jones, O., Maillardet. R. and Robinson, A. (2014). Introduction to Scientific Programming and Simulation Using R. Chapman & Hall/CRC, The R Series.
2. Crawley, M, J. (2012). The R Book, 2nd Edition. John Wiley & Sons.

Reference Books:

1. Chambers, J. M. (2008). Software for Data Analysis-Programming with R. Springer-Verlag, New York.

2.Jammalamadaka, S. R. (2007). Essential Statistics with python and R.Kendal Hunt publishing.

STA10706: Statistical Computing

Course Outcome (C.O)	**Cognitive level**
After completion of this course the students will be able to	
1. Understand commonly used R codes for statistical work.	Understand
2. Identify the use of various packages in R.	Analyze
3. Apply R software to meet the given scientific objective.	Apply
4. Write an efficient R program to solve the given scientific problem.	Evaluate

Module-I

Introduction to statistical software R, Data objects in R, Vectors, manipulating vectors, matrices, importing of files. Input and outputs: Text - Input from a file - Input from the keyboard - Output to a file. Computations of descriptive statistics measures. Expressions and assignments, logical expressions. R-Graphics- lattice & 3D-plots. Histogram, Box-plot, Stem and leaf plot, Scatter plot, Plot options; Multiple plots in a single graphic window, frequency table, Plotting of probability distributions and sampling distributions, Controlling Loops- For, repeat, while, if , if else etc.

Module-II

Programming with functions: Functions - Scope and its consequences - Optional arguments and default values - Vector-based programming using functions - Recursive programming - Debugging functions - Sophisticated data structures - Factors -Dataframes -Lists - The apply family.
Graphics parameters: par -Graphical augmentation - Mathematical typesetting - Permanence -Grouped graphs: lattice - 3D-plots.

Module-III

Numerical methods- Root-finding - Fixed-point iteration -The Newton-Raphson method - The secant method - The bisection method - Numerical integration - Trapezoidal rule - Simpson's rule - Adaptive quadrature.

Module-IV

Simulation: Simulating iid uniform samples, Congruential generators, Seeding, Simulating discrete random variables, Inversion method for continuous random variables, Rejection method, generation of normal variates: Rejection with exponential envelope, Box-Muller algorithm.

Text Books:

1. Owen Jones, Robert Maillardet, Andrew Robinson, (2014) . Introduction to Scientific Programming and Simulation Using R, *Chapman & Hall/CRC The R Series*,
2. Alain F. Zuur, Elena N. Ieno, and Erik Meesters (2009) A Beginner's Guide to R, Springer, ISBN: 978-0-387-93836-3.
3. Phil Spector (2008) Data Manipulation with R, Springer, New York, ISBN 978-0-387-74730-9.
4. Christian Heumann, Michael Schomaker, Shalaf (2016). Introduction to statistics and data analysis. Springer.

Reference Books:

1. Gotifried, B.S. (2011) Programming with C, Schaum's Series,Third Edition, Tata McGraw Hill.
2. Mullishi Hank, Cooper, H.L. (1992) The spirit of C - An introduction to modern programming, Jaico Publishing House.
3. Kundu, D. and Basu, A. (2004) Statistical computing – existing methods and recent developments, Narosa publishing house, New Delhi.
4. Monahan, J.F. (2001) Numerical methods of statistics, Cambridge University Press.
5. Aitkinson, K.E. (1989) An introduction to numerical analysis, John Wiley & Sons, Singapore.

STA10805 :STATISTICS FOR NATIONAL DEVELOPMENT

Course Outcome (CO) **After completion of this course the students will be able to**	**Cognitive level**
1. Explain the concept of economic development, growth in per capita income and distributive justice	Understand
2. Define the indices of development like Human development index etc.	Understand
3. Estimate national income through income and expenditure approaches	Apply
4. Measure inequality in incomes, and measurepovertythrough measures of incidence and intensity combined.	Analyz
5. Define components of Time series	Remember
Determine the trend, analyze seasonal	
6. Fluctuations, construct seasonal indices Measure cyclical movement.	Analyze

Module-I

Demographic methods:- Sources of demographic data - census, register, adhoc survey, hospital records, demographic profiles of Indian census; Measurement of mortality and life tables - crude, death rates, infant mortality rates, death date by cause, standardized death rate; Complete life tables – its main features, mortality rate and probability of dying, use of survival tables; Measurement of fertility - crude birth rate, general fertility rate, total fertility rate, gross reproduction rate, net reproduction rate; Population growth in developing and developed countries; Population projection using Leslie metric; Labour force projection.

Module-II

Economic statistics:- Index number - its definition, price relatives and quantity or volume relatives, link and chain relatives, consumer price index; Demand analysis - static laws of demand and supply, price elasticity of demand, analysis of income and allied size distribution - Pareto distribution, graphical test, fitting of Pareto's law, log normal distribution and its properties, Lorenz curve and estimation of elasticity; Gini coefficient.

Module-III

Economic development, growth in per capita income and distributive justice, indices of development; Human Development Index, Estimation of national income - product approach, income approach and expenditure approach; Measuring inequality in incomes, poverty measurement - measures of incidence and intensity combined; Time Series:-components of time series, determination of trend, analysis of seasonal fluctuations, construction of seasonal indices, measurement of cyclic movement, random component in time series, smoothing methods.

Module-IV

Introduction to Indian and International Statistical System - role, function activities of Central and State Statistical Organizations; Organization of large scale sample surveys; Role of National sample survey organization; General and special data dissemination systems; Principal publications containing such statistics on the topics - population, agriculture industry, trade, price, labour and employment transport and communications, and finance; Educational and Psychological statistics:-Scaling individual test items, scaling of scores on a test, different types of scores and scaling, scaling of ranking and rating in terms of normal curve, Reliability of test scores, Rulon and Kuder Richardson methods, Reliability of a test, validity, comparison between reliability and validity, Intelligence coefficient.

Reference Books:

1. Basic Statistics Relating to Indian Economy (CSO), 1990 - Current Indian Statistics
2. Cox PR (1957) Demography, Cambridge University Press
3. Croxton F E and Crowder D J (1967) Applied General statistics, Prentice - Hall India.
4. Guide to current Indian Official Statistics CSO, Govt. of India, New Delhi
5. Guide to official Statistics (CSO) -1990
6. Kendall, M.G. and Stuart, A. (1966). The Advanced Theory of Statistics, Charles Griffin
7. Keyfitz, N. (1977) Applied Mathematical Demography - Springer Verlag
8. Mukhopadhyay, P Applied Statistics, Books and Allied (P) Ltd
9. Pollard, A H, Yusuf , F and Pollard, G.N. (1998) Demographic Techniques
10. Saluja M.P, Indian Official Statistical Systems, Statistics Publishing Society, Calcutta
11. Sen, A. (1997) : Poverty and inequality
12. Statistical System in Indian (CSO) 1995
13. UNESCO : Principles for Vital Statistics system, Series M-12

STA10806: RELIABILITY MODELING AND ANALYSIS

Course Outcome (CO)	Cognitive Level
After completing the course, the student should be able to	
1. Understand the various concepts and different notions of ageing used in Reliability analysis and their inter relations.	Describe
2. Identify the various aspects like monotonic failure rates , Bath tub and upside down bathtub shaped failure rates and other related measures for various life time distributions	Evaluate
3. Understand and discover the system reliability using the concept of structure functions	Understand
4. Understand the concepts like positive dependency and various measures of dependence viz - RCSI, LCSD, PF 2 , WPQD and their inter relations.	Evaluate
5. Estimate the reliability function for complete and censored samples through the maximum likelihood estimation,	Evaluate
6. Estimate the reliability function for complete and censored samples through Uniformly minimum variance unbiased estimation	Evaluate
7. Estimate the reliability function for complete and censored samplesthrough the Bayesian Estimation.	Evaluate

Module-I

Structure functions, Coherent Systems, Basic concepts in reliability: Failure rate, mean, variance and percentile residual life, identities connecting them; Notions of ageing - IFR, IFRA, NBU, NBUE, DMRL,HNBUE, NBUC etc and their mutual implications; TTT transforms and characterization of ageing classes.

Module-II

Non monotonic failure rates and mean residual life functions, Study of life time models viz. exponential,Weibull, lognormal, generalized Pareto, gamma with reference to basic concepts and ageing characteristics; Bath tub and upside down bath tub failure rate distributions.

Module-III

Reliability systems with dependent components:-Parallel and series systems, k out of n systems, ageing properties with dependent and independents components, concepts and measures of dependence in reliability - RCSI, LCSD, PF 2 , WPQD.

Module-IV

Reliability estimation using MLE - exponential, Weibull and gamma distributionsbased on censored and non censored samples; UMVUE estimation of reliability function; Bayesian reliability estimation of exponential and Weibull models.

Text Books:

1.Lai, C.D and Xie, M. (2006): Stochastic ageing and dependence in reliability (Relevanttopics) Springer.
2.Sinha S K (1986) Reliability and Life Testing, Wiley Eastern.
3.Barlow, R.E. and Proschan, F. (1975) Statistical Theory of Reliability and Life Testing, Holt, Reinhart and Winston.

Reference Books:

1. Marshall, A.W. and Olkin, I. (2007) Life Distributions, Springer
2. Galambos, J. and Kotz, S. (1978) Characterization of Probability distributions, Springer
3. Lawless, J.F. (2003) Statistical Models and Methods for Life Data, Wiley.

STA10905: TOPICS IN STOCHASTIC FINANCE

Course Outcome (CO)	**Cognitive level**
After completion of this course the students will be able to	
1. Define the terms: interest rate, options, pay-off, arbitrage, geometric Brownian motion, mean reversion, etc.	Remember
2. Describe and prove arbitrage theorem, Black Scholes theorem	Evaluate
3. Distinguish call and put options.	Understand
4. Analyze portfolios via utility functions.	Analyze
5. Apply CAPM.	Apply
6. Assess the value at risk.	Evaluate
7. Describe exotics by simulation.	Understand
8. Employ and fit AR models for log prices.	Apply

Module-I

Interest rate andPresent value analysis, rate of return, Continuously varying interest rate. Options, Pricing contracts via arbitrage, Arbitrage theorem, single and multi-period binomial model.

Module-II

Geometric Brownian motion, The Black-Scholes formula, Properties of the Black-Scholes option cost, the delta hedging arbitrage strategy, Derivatives, Call options on dividend-paying securities, Pricing American put options.

Module-III

Adding jumps to geometric Brownian motion, Estimating the volatility parameter, Valuing investments by expected utility, The portfolio selection problem, Value at risk and conditional value at risk, The Capital Assets Pricing Model.

Module-IV

Exotic Options, Barrier options, Asean and look back options, Pricing exotic options by simulation, Pricing with nonlinear payoffs, Approximation via multiperiod binomial models, Crude oil data, Autoregressive moving average models for returns, Mean reversion.

Text Book:

1.Sheldon M. Ross (2003).An Elementary Introduction to Mathematical Finance. Cambridge University Press.

Reference Books:

1. A.N. Shiryave (1999). Mathematical Finance, Theory and Practice, World Scientific.
2. David Ruper (2004). Statistics and Finance- An Introduction, Springer International Edition.
3. Fima C. Klebener (1997). Introduction to Mathematical Finance. World Scientific
4. John C. Hull (2008). Options, Futures and other derivatives. Pearson Education India.

STA10906: OPERATIONS RESEARCH II

Course Outcome (CO)	**Cognitive level**
After completion of this course the student should be able to	
1.Examine the properties of linear programming problem	Analyze
2.Solve different types of LPP	Apply
3.Solve LPP using duality	Apply
4. Employ transportation and assignment problems	Apply
5. Solve non-linear programming problems	Apply
6. Explain quadratic and convex programming problems	Understand
7. Examine deterministic and probabilistic inventory models	Analyze
8. Employ inventory models in real situations	Apply

Module-I

Linear programming:- convex sets and associated theorems, graphical method, definition of linear programming problem, properties of a solution to the linear programming problem, generating extreme-point solutions, simplex computational procedure, artificial variables technique - big M method, two phase method; Revised simplex method.

Module-II

Duality problems of linear programming:-unsymmetric primal-dual problems, symmetric primal-dual problems, Degeneracy and anticycling procedures:- perturbation techniques. Transportation problems:- general transportation problem, Finding initial basic feasible solution, test for optimality, degeneracy in transportation problem, unbalanced transportation problem, maximization transportation problem, Assignment problem:- mathematical formulation of the problem, the assignment method (Hungarian method).

Module-III

Non-linear programming problem (NLPP):- general non-linear programming problem, Constrained optimization with equality constraints - necessary conditions for a generalized NLPP, sufficient conditions for a general NLPP with one constraint, sufficient conditions for a general problem with $m(<n)$ constraints, Constrained optimization with inequality constraints - Kuhn-Tucker conditions for general NLPP with $m(<n)$ constraints, quadratic programming problem, convex programming problems.

Module-IV

Inventory models:- Deterministic inventory models - general inventory model, Static economic-order quantity (EOQ) models - classic EOQ model, EOQ with price breaks, multi-item EOQ with storage limitation, Probabilistic inventory models:- Continuous review models - “probabilitized” EOQ model, probabilistic EOQ model, Single-period models - No setup model (Newsvendor model), setup model (*s*-*S* policy).

Text Books:

1. Gass S.I. (1985) Linear Programming - methods and applications, Fifth edition, McGraw Hill, USA, Chapters 2-7.
2. KantiSwarup, Gupta, P.K. and Man Mohan (2001) Operations Research, Ninth edition, Sultan Chand & Sons, Chapters 3, 4, 10, 11 & 24.
3. Taha H.A. (2007) Operations Research - An introduction, Eighth edition, Prentice-Hall of India Ltd., Chapters 11, 14 & 15.

Reference Books:

1. Ravindran A, Philips D.T and Soleberg J.J. (1997) Operation Research - Principles and Practice, John Wiley & Sons.
2. Sinha, S.M. (2006) Mathematical programming theory and methods, Elsevier, a division of Reed Elsevier India Pvt. Ltd., New Delhi.
3. Paneerselvam, R. (2008) Operations Research, Second edition, Prentice Hall of India Pvt. Ltd., New Delhi.

STA11004: STATISTICAL QUALITY ASSURANCE

Course Outcome (CO)	**Cognitive level**
After completing the coursethe student should be able to	
1. Apply different statistical quality control techniques including various types sampling plans for attributes and measure the performance of these plans.	Apply
2. Explain and design various types of control charts, design control charts Distinguish between them.	Apply
3. .Explain acceptance sampling by variables , Sampling Plans for a single and double specification limits with known and unknown variance, Sampling plans with double specification limits.	Apply
4. Compare sampling plans by variables and attributes and Continuous sampling plans I, II & III.	Evaluate

Module-I

Quality and quality assurance, Methods of quality assurance, Introduction to TQM and ISO 9000 standards, statistical quality control: Acceptance sampling for attributes, Single sampling, Double sampling, Multiple and sequential sampling plans, Measuring the performance of these plans.

Module-II
Control charts, Basic ideas, designing of control charts for the number of non-conformities and fraction non-conformities, mean charts, Median charts, Extreme value charts, R-charts, and S-charts, ARL, Economic design of Shewarts control charts.

Module-III
Acceptance sampling by variables, Sampling plans for a single specification limit with known and unknown variance, Sampling plans with double specification limits, Comparison of sampling plans by variable and attributes, Continuous sampling plans I, II and III.

Module-IV
Process capability studies, Statistical aspect of six sigma philosophy, Lean concepts, Control charts with memory - CUSUM charts, EWMA-mean charts, OC and ARL for control charts, The Taguchi Method: The Taguchi philosophy of Quality, Loss functions, SN ratios, Performance measures, Experimental design in Taguchi Methods: Orthogonal arrays and linear graph, Estimation of effects, Parameter Design.

Text Books:

1. Montgomery, R.C. (1985). Introduction to Statistical Quality Control, Fourth edition,Wiley.
2. Mittag, H.J. & Rinne, H. (1993) Statistical Methods for Quality Assurance, Chapman &Hall, Chapters 1, 3 and 4,15
3. The ISO 9000 book, Second Edition, Rabbit, J T and Bergle, PA Quality resources,Chapter-I
4. Schilling, E.G. (1982) Acceptance Sampling in Quality Control, Marcel Dekker.
5. AmitavaMitra - Fundamentals of Quality Control and Improvement – PearsonEducation Asia 2001 – Chapter 12 (relevant parts)

Reference Books:

1. Duncan, A.J. (1986) Quality control and Industrial Statistics.
2. Grant E.L. and Leaven Worth, R.S. (1980) Statistical Quality Control, McGraw Hill.
3. Chin-Knei Cho (1987) Quality Programming, John Wiley.

STA11005: TIME SERIES ANALYSIS

Course Outcome (CO)	**Cognitive level**
After completion of this course the students will be able to	
1. Define time series in time and frequency domain.	Remember
2. Assess the stationarity of time series and its decomposition.	Evaluate
3. Identify suitable ARMA models for the stationary component of	Analyze

the given time series.

4. Estimate the parameters of the identified models.	Analyze
5. Discuss the validity of the model by residual analysis.	Understand
6. Prediction by MMSE methods.	Evaluate
7. Analyze Spectral density and periodogram.	Analyze
8. Analyze time series in a state space set up.	Analyze
9. Compute Smooth and filter by Kalman algorithm.	Apply
10. Identify a model for the given time series.	Analyze

Module-I

Characteristics of time series: Time series as a discrete parameter stochastic process, Auto-correlation (ACF) and cross correlations, Stationary time series, Estimation of autocorrelations. Classical regression in time series context, exploratory data analysis, smoothing methods for time series. Wold representation of linear stationary processes. (15 hours)

Module-II

Linear time series models :Autoregressive (AR), Moving Average (MA), Autoregressive Moving Average (ARMA) and Autoregressive Integrated Moving Average (ARIMA) models. Forecasting and estimation of ARMA models. Seasonal ARIMA models, Residual analysis and diagnostic checking. (20 hours)

Module-III

Spectral analysis: Time series in frequency domain, spectral density, periodogram and discrete Fourier transforms, estimation of spectral density, multiple series and cross spectra, linear filters. (15 hours)

Module-IV

State space models: Filtering, smoothing and forecasting using state space models, Kalman smoother, Maximum likelihood estimation, Missing data modifications. (15 hours).

Text Books:

1. Shumway, R. H and Stoffer, D. S. (2006). Time series Analysis and its Applications. Springer.
2. Box, G. E. P. Jenkins, G. M. and Reinsel, G. C. (1994). Time Series Analysis: Forecasting and Control, Pearson Education.
3. Brockwell, P.J and Davis R.A. (2006) Time Series: Theory and Methods, 2nd edn. Springer-Verlag.

Reference Books:

1. Abraham, B. and Ledolter, J.C. (1983) Statistical Methods for Forecasting, Wiley.
2. Anderson, T.W (1971) Statistical Analysis of Time Series, Wiley.
3. Fuller, W.A. (1978) Introduction to Statistical Time Series, John Wiley.
4. Kendall, M.G. (1978) Time Series, CharlerGraffin.
5. Tanaka, K. (1996) Time Series Analysis, Wiley Series.
6. Chatfield, C. (2004) The Analysis of Time Series - An Introduction, Sixth edition, Chapman and Hall.

STA11006: LIFETIME DATA ANALYSIS

Course Outcomes (CO)	**Cognitive level**
After completion of this course the student should be able to	
1. Understand the basic concepts and ideas of survival analysis.	Understand
2. Examine the properties and methods for standard survival time distributions.	Analysis
3. Estimate survival functions using parametric and non-parametric methods.	Evaluate
4. Apply and interpret semi-parametric and parametric regression models for survival data .	Apply

Module-I

Basic Quantities and Models - Survival function, Hazard function, Mean residual life function, Common Parametric Models for Survival Data; Censoring and Truncation - Right Censoring, Left or Interval Censoring, Truncation, Likelihood Construction for Censored and Truncated Data, Counting Processes.

Module-II

Nonparametric Estimation of Basic Quantities for Right Censored and Left Censored Data - Estimators of the Survival and Cumulative Hazard Functions for Right Censored Data, PointwiseConfidence Intervals for the Survival Function (without derivation), Estimators of the Survival Function for Left-Truncated and Right-Truncated Data; Estimation of the Survival Function for Left, Estimating the Hazard Function, Hypothesis Testing - One-Sample Tests, Tests for Two or More Samples.

Module-III

Semi-parametric Proportional Hazards Regression with Fixed Covariates - Coding Covariates, Partial Likelihoods for Distinct-Event Time Data, Partial Likelihoods when Ties are present, Model Building using the Proportional Hazards Model, Estimation for the Survival Function; Regression Diagnostics - Cox-Snell Residuals for assessing the fit of a Cox Model, Graphical Checks of the Proportional Hazards Assumption, Deviance Residuals.

Module-IV

Inference for Parametric Regression Models - Exponential, Weibull and Log Logistics; Multiple Modes of Failure – Basic Characteristics and Model Specification, Likelihood Function Formulation, Nonparametric Methods.

Text Books:

1. Klein J.P. and Moeschberger M.L. (2003) Survival Analysis - Techniques for censored and truncated data, Second Edition, Springer-Verlag , New York,
2. Lawless J.F (2003) Statistical Models and Methods for Lifetime Data, Second Editon, John Wiley & Sons, Relevant Sections of the Chapters 9.

Reference Books:

1. Kalbfleisch J.D and Prentice, R.L. (2002) The Statistical Analysis of Failure Time Data, Second Edition, John Wiley & Sons Inc.
2. Hosmer Jr. D.W and Lemeshow S (1999) Applied Survival Analysis - Regression Modelling of Time to event Data, John Wiley & Sons. Inc.
3. Nelson. W (2003) Applied Life Data Analysis.
4. Miller, R.G. (1981) Survival Analysis, John Wiley.
5. Deshpande, J .V. and Purohit, S. G. (2006). Lifetime Data: Statistical Models and Methods. World Scientific.

STA11007: APPLIED MULTIVARIATE STATISTICAL ANALYSIS

After completion of this course the student should be able to

Course Outcome (CO)	Cognitive level
1. Distinguish multivariate data and its preliminary analysis	Understand
2. Examine properties of principal component analysis	Analyze
3. Apply PCA and canonical variates to real data	Apply
4. Analyze factor model	Understand
5. Illustrate the factor analysis	Apply
6. Outline different clustering and similarity techniques	Understand
7. Apply various clustering and similarity techniques	Apply
8. Infer multivariate data using MANOVA	Apply

Module-I

Multivariate Data, Types and preliminary methods of analysis, Principal components Analysis: - population principal components, summarizing sample variation by principal components, graphing the principal components, large sample inference, monitoring quality with principal components; Canonical correlation analysis: - canonical variates and canonical correlations, interpreting the population canonical variables, the sample canonical variates and sample canonical correlations.

Module-II

Factor analysis: - orthogonal factor model; methods of estimation, factor rotation, factor scores, perspectives and a strategy for factor analysis.

Module-III

Cluster analysis: - similarity measures, hierarchical clustering methods, non-hierarchical clustering methods; Distance methods: - multidimensional scaling, correspondence analysis.

Module-IV

Comparison of several multivariate population means (one-way MANOVA), simultaneous confidence intervals for treatment effects, two-way multivariate analysis of variance; profile analysis; Repeated measures designs and growth curves, path analysis.

Text Books:

1. Johnson, R.A. and Wichern, D.W. (2007) Applied Multivariate Statistical Analysis, PHI Learning Private Ltd, New Delhi, Sixth edition, Relevant sections from Chapters 1, 6, 8, 9, 10 & 12.

2. Dillon, W.R. and Goldstein, M (1984) Multivariate Analysis, John Wiley, Relevant sections from Chapter 12.

Reference Books:

1. Seber G.A.F. (1983) Multivariate Observations, Wiley.
2. Tabachnick, B.G. and Fidell, L.S. (2018) Using multivariate statistics, Sixth edition, Pearson India Education Services Pvt Ltd, India.
3. Gnandesikan, R., Methods of Statistical Data Analysis of Multivariate Observations, Wiley.
4. Jambu, M and Lebeaux M.O., Cluster Analysis and Data Analysis.
5. Lebart, Lmorinean, A. and Warwick K.M., Multivariate Descriptive Statistical Analysis, John Wiley.
6. Davison, Multidimensional Scaling, John Wiley.
7. Morrison D.F., Multivariate Statistical Methods, McGraw Hill.
8. Rencher, A.C. (1995) Methods of Multivariate Analysis, John Wiley.

21-322-0408: STATISTICAL FORECASTING

Course Outcome(C.O)	**Cognitive level**
After completion of this course the students will be able to	
1. Define various types of forecasts and their performance measures.	Remember.
2. Compute forecasts based on regression models.	Apply
3. Compute forecast by simple and double exponential smoothing.	Apply
4. Understand algorithms of Holt-Winters methods for forecasting.	Understand
5. Estimate and forecast seasonal time series.	Evaluate
6. Describe explicit forms of stationary and non-stationary time series models and derive the forecasts.	Evaluate
7. Describe forecast formula for state-space models.	Evaluate
8. Smoothing and filtering by Kalman filters.	Analyze
9. Choose a model and construct forecast formula for a given time series.	Apply

Module-I

Review of linear regression and time series models. Forecasting in constant mean model, Locally constant mean model and simple exponential smoothing.Regression models with time as independent variable, Discounted least squares and general exponential smoothing. Locally constant linear trend model and double exponential smoothing, Prediction intervals.

Module-II

Seasonal time series, Globally constant seasonal models, Locally constant seasonal models, Winters' seasonal forecast procedures (additive and multiplicative), Seasonal adjustment procedures.

Module-III

Forecasts based on stationary ARMA and non-stationary ARIMA models. Transfer function models and forecasting.

Module-IV
State-space models- Filtering, smoothing and forecasting. Kalman filter. Vector ARMA models and Forecasting.

Text Books:

1. Abraham B and Ledolter, J (2005) Statistical Methods for Forecasting, John Wiley and Sons, New York.
2. Shumway, R. H and Stoffer, D. S. (2006). Time series Analysis and its Applications. Springer.
3. Montegomery, D. C., Jennings, C. L. and Kulachi, M. (2008). Introduction to Time series analysis and Forecasting.

Reference Books:

1. Pankratz, A. (1983) Forecasting with univariate Box-Jenkins models, John Wiley Sons, New York
2. Makridakis, S. and Wheelwright, S.C. (1998) Forecasting Methods and Applications, John Wiley and Sons
3. Box, G. E. P. Jenkins, G. M. and Reinsel, G. C. (1994). Time Series Analysis: Forecasting and Control, Pearson Education.
4. Brockwell, P.J. and Davis, R.A. (2013) Introduction to Time Series and Forecasting, second edition, Forth Edition, Springer.

21-322-0409: INFERENCE FOR STOCHASTIC PROCESSES

Course Outcome (CO) **Cognitive level**

After completion of this course the students will be able to

1. Define relevant optimality criteria for inference in Remember stochastic
processes.
2. Choose suitable method of estimation and test procedure for
given process. Evaluate
3. Compute estimates for relevant parametric functions for Markov
chains in discrete and continuous time space. Apply
4. Produce the asymptotic properties of the estimators for such processes. Apply
5. Compute the estimates and test statistics for continuous time Markov processes
such as Poisson processes, birth-death processes, etc. Apply
5. Give examples for processes satisfying the regularity conditions
under which estimators and test functions behave well. Understand
6. Identify a suitable stochastic model for the given situation. Analyze

Module-I
Brief review of basic principles of methods of statistical inference, Inference for the Galton-Watson process, The Markov branching process, Estimation and prediction in Auto regressive process.

Module-II
Inference in discrete Markov chains: Maximum likelihood estimation, Asymptotic properties of estimators, Asymptotic distribution of serial correlation, Tests of hypothesis tests of independence based

on serial correlation Bayesian analysis, Inference for an absorbing chain Inverse likelihood estimation of states, Macro model, grouped Markov chains, Estimation in countable state-space Markov chain.

Module-III

Inference in continuous time Markov chains: Inference in finite Markov chains, queuing models, pure birth and death process, Homogeneous and non-homogeneous Poisson processes, Inference for renewal process in relation to reliability applications.

Module-IV

Large sample theory for discrete parameter stochastic process, Estimation, Consistency, Asymptotic normality, Efficiency, Robustness, Maximum likelihood estimation for some optimal asymptotic tests.

Text Books:

1. Basava, I.V. and Prakasa Rao, B.L.S. (1980) Statistical Inference for Stochastic Processes Academic Press Chapters 1-7.

Reference Books:

1. Billingsley, P. (1961) Statistical Inference for Markov Processes, University of Chicago Press.
2. Chung K.L. (1967) Markov Chain with Stationary Transition Probabilities 2nd edition, Springer-Varlag
3. Karr, A.R. (1991) Point Processes and Their Statistical Inference, Marcel Dickker
4. Keiding, N. (1974) Estimation in the Birth Process, Biometrika, 61, 71-80.
5. Keiding, N.(1975) Maximum Likelihood Estimation in the Birth and Death Process, Annals of Statistics, 3, 363-372.
6. Rajarshi, M. B. (2013). Statistical Inference for Discrete time Stochastic Processes. Springer.