SIDDHARTH UNIVERSITY, KAPILVASTU

SIDDHARTH NAGAR

Pre-Ph.D. COURSE WORK

in

MATHEMATICS

Course Work for Ph. D. Mathematics Students

Every student admitted in Mathematics for the Ph. D. programme will be required to pass a course work of 16credits. The course work has been divided into three papers. Paper-I (4 credits) is*compulsory*for all Ph.D. students. Paper-II (6-credits) is*discipline-specific course*andPaper-III (6 credits) is*research theme- specific course*.

Course Nature	Course Code	Core Courses	Credit
Compulsory Course			
Compulsory Course	MTH 601	Research Methodology, Computer Applications, Research and Publication Ethics	04
			04 Credits
General Mathematics			
Discipline-Specific Course	MTH 602	Real Analysis, Complex Analysis, Abstract Algebra(Group Theory, Module Theory and Field Theory), Partial Differential Equations	04
		Typesetting Software: Latex	02
			06 Credits
	Open Elective Course (*Any one of the followings*)		
Research Theme-Specific Course	MTH 603	a. Dynamical Systems and Chaos b. Fuzzy Topology c. Advanced Fluid Dynamics d. Magnetohydrodynamics e. Structures on a differentiable Manifold f. Hypergeometric Functions & its applications g. Methods in Nonlinear Evolution Equations h. Sampling Theory	06
			06 Credits
		Total	**16 Credits**

Programme Outcomes:

PO1: The students have undergone relevant (taught) courses required for undertaking specialized research.

PO2: The students will be capable of identifying unsolved yet relevant problem in a specific field.

PO3: The students will be capable of articulating ideas and strategies for addressing a research problem.

PO4: The students will be able of undertake original research on a particular topic.

PO5: The students will be capable of effectively communicating research, through journal publications and conference presentations, to the mathematics community.

PO6: The students will be capable of disseminating research to a broader audience.

Programme Specific Outcomes:

PSO1: Generate publications in reputed mathematical journals.
PSO2: Provide scope for interaction with international researchers and developing collaborations.
PSO3: Demonstrate the highest standard of ethics in research.
PSO4: Produce next generation researchers in Mathematics.

Paper-I
Research Methodology, ComputerApplications, Research and Publication Ethics

Course Code: MTH601 **Credits: 04**

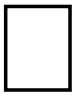
Course outcomes:

CO1: The students will have an understanding of the basic framework of research process.**CO2:**The students will have an understanding of various research design and techniques.**CO3:** The students will be able to identify various sources of information for literature review and data collection.

CO4: The students will be able to appreciate the components of scholarly writing and evaluate its quality.

Unit-I:Introduction to research methodology, Meaning, Objectives, Types, Significance of research,Identification, Selection of research problem, Formulation of research objectives, Researchdesign, Quantitative and qualitative methodology, h-index, impact factor, Immediacy index,acknowledgement and its index, copy rights, Research ethics, plagiarism,

Unit-II: Effective word selection in science writing, Common mathematical functions and theirabbreviations, symbols, operators commonly used in mathematics, Greek, roman letters used in Mathematics, Mathematics journals(science citation index, engineering indexed and Scopusindexed) and their abbreviations, Mathematics subject classifications, Mathematical review, MathSciNet, other E- resources.



Unit-III: **Scientific conduct**: Ethics with respect to science and research, Intellectual honesty and research integrity, scientific misconduct: Falsification, Fabrication and Plagiarism (FFP), Redundant publication: duplicate and overlapping publication, salami slicing, Selective reporting and misrepresentation of data.

Publication Ethics: Definition, introduction and importance, best practices/ standard setting initiatives and guidelines: COPE, WAME, etc, conflict of interest, publication misconduct, definition, concept, problems that lead to unethical behavior and vice-versa, types, Violation of publication Ethics, Authorship and contributorship, identification of publication misconduct, complain and appeals, Predatory publisher and journals.

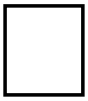
Unit-IV: Computer Fundamentals, Working of a Monitor,Keyboard,Mouse,Hard Disc,Compact Discand Printer. Working with the Control Panel, Customize Desk top, working with files and folders,Features of MS-Word, Working with MS-Word, Formatting documents and texts. Introduction to Excel and Power Point Presentation.Working on Internet and e-mail.

Practice: -

1. Open Access Publishing: open Access publication and initiatives, SHERPA/ RoMEO online resource to check publisher copyright and self-archiving policies, Software tool to identify predatory publication developed by SPPU, Journal finder/ journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester,etc.
2. Publication Misconduct: Group Discussion regarding subject specific Ethical Issues, FFP, Authorship, conflict of Interest, complaints and appeals: example and fraud from India andabroad.
3. Software tools: Use of plagiarism software like Turnitin, Urkund and other open-source softwaretools.
4. Databases and Research Metrics: Databases: Indexing databases, Citation database: web of Science, Scopus etc. Research Metrics: Impact factor of journal as per journal citation report, SNIP, SJR, IPP, Cite, Metrics: h-index, g-index, i10 index,altmetrics.

Suggested readings:

1. Garg, B.L.,Karadia, R., Agarwal, F. and Agarwal, U.K., 2002. An introduction to Research Methodology, RBSA Publishers.
2. Kothari, C.R., 1990. Research Methodology: Methods and Techniques. New Age International, 418p.
3. Day, R.A., 1992. How to write and publish a Scientific paper, Cambridge University Press.
4. Fink, A.,2009. Conducting Research Literature Reviews: From the internet to paper. Sage Publications.
5. Satarkar, S.V.,2000. Intellectual property rights and copyright. EssEss Publications.
6. Saxena, V.P.,2013. Lecture Notes on Research Methodology. Indra Publishing House.
7. P. Chaddah, (2018) Ethics in Competitive Research: Do not get scooped; do not get plagiarized, ISBN:978-9387480865



8. Resnik, D. B. (2011). What is ethics in research & why is it important. National Institute of Environmental Health Sciences, 1-10. Retrived from http://www.niehs.nih.gov/research/resources/bioethics/whatis/index.cfm
9. Indian National Science Academy (INSA), Ethics in Science Education, Reasearch and Governance(2019),ISBN:978-81-939482-1-7. http://www.insaindia.res.in/pdf/Ethics_Book.pdf
10. Bird, A. (2006)- Philosophy of Science.
11. Maclntyre, Alasdair (1967)- A short History of Ethics.
12. National Academy of Science, National Academy of Engineering and institute of Medicine (2009) On being a Scientist: A Guide of Responsible Conduct in Research.
13. Beall, J. (2012) – Predatory publishers are corrupting open access. Nature, 489(7415).
14. Introduction to Information Technology, ITL Education Solutions, Pearson Education.
15. Introduction to Computer Science, ITL Education Solutions, Pearson Education.
16. Sinha, P.K. &Sinha, Priti, Computer Fundamentals, BPB Publications.

Paper-II

GENERAL MATHEMATICS

Course Code: MTH 602 **Credits: 06**

Course Outcome:

CO1: The students will be able to define and recognize the limit, continuity and differentiability of real and complex-valued functions.

CO2: The students will be able to apply Sylow's theorem for finding subgroups of a finite group.

CO3: The students will be able to identify Noetherian and Artinian modules and find field extensions of a field.

CO4: The students will be able to solve real-world problems using partial differential equations.

CO5: The students will be able to type their research paper/ article/thesis using Latex.

Credits: 04

Real Analysis: Completeness of $\mathbb{R}$, Continuity, uniform continuity, differentiability, mean value theorems, Sequences and series of functions, uniform convergence, Monotonic functions, types of discontinuity, functions of bounded variation, Metric spaces, compactness, connectedness.

Complex Analysis: Analytic functions, singularities, complex integration, Riemann surfaces and properties, Power series, Analytic Continuation, Maximum Modulus Principle, Schwarz's lemma.

Groups: Finite groups, Nilpotent and solvable groups, Sylow's theorems, free groups, Representation theory of finite groups.

Modules: Modules, submodules, Cyclic modules, free modules, Noetherian and Artinian modules.

Field Theory: Algebraic and transcendental extensions, Splitting field, introduction to Galois theory.

Partial Differential Equations (PDEs): Method of characteristics, wave equation, weak solutions, system of PDE, Linear PDE: dimensional analysis and self-similarity, regular and singular perturbation, asymptotic and complete solution, Conversion of non-linear PDE into linear PDE.

Credits: 02

Typesetting Software-LaTex

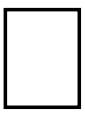
Sample Document, Type Style, Environments, Lists, Centering, Tables, Verbatim, Vertical and Horizontal Spacing, Equation Environments, Fonts, Hats, and Underlining, Braces, Arrays and Matrices, Customized Commands, Theorem-like Environments, Math Styles, Document Classes and the Overall Structure, Titles for Documents, Sectioning Commands, Packages, Inputting Files, Inputting Pictures, Making a Bibliography, Scientific article, Beamer

Practical:

(i) Prepare regular Documents such as letter, draft, etc. (ii) Prepare Curriculum Vitae using list and Tables, (iii). Prepare salary chart using lists and tables, (iv) Prepare documents containing mathematical expressions-equation, matrices, tensors, etc. (v) Prepare scientific research article (vi) Prepare presentation using Beamer.

Suggested readings:

1. AliprantisC.D.,Principle of Real Analysis(third Edition); Academic Press, 1998.
2. Conway J.B.,Functions of one Complex Variables, Springer/ Narosa, New Delhi.
3. Hewitt E. and Stromberg K., Real and Abstract Analysis, Springer, 1975.
4. Walter Rudin, 'Principles of Mathematical Analysis', Third Edition, Tata McGraw – Hill International book company.
5. M. Artin, Algebra,PHI Publ.
6. I.N. Herstein. Topics in Algebra. Willey Publ.
7. S. Lang. Algebra., PHI Publ.
9. A.H. Nayfeh, Introduction to Perturbation methods, John Wiley ,1981.
10. F. Verhulst, Non-linear Differential Equations and Dynamical Systems, Springer, 1990.
11. P.Prasad and R. Ravindran, Partial Differential Equations, Wiley Eastern, 1985.
12. W.E. Williams, Partial Differential Equations, Oxford Univ. Press, 1980.
13. R.R. Garabedian, Partial Differential Equations, Wiley, 1984.
14. J. Kevorkian, Partial Differential Equations: analytical solution techniques, Springer, 2000.
15. H. Levine, Partial differential Equations, Amer. Math. Soc. Intl. Press, 1997.
16. L. Debnath, Non-linear Partial Differential Equations for Scientists and engineers, Birkhauser, 1997.
17. George Grätzer, More Math intoLaTeX, 4th Edition, Springer (2016).
18. DilipDatta, LaTeX in 24 Hours: A Practical Guide for Scientific Writing, Springer (2017).
19. Laslie Lamport: LATEX, Addison Wesley Publications Company (1994).
20. David F. Griffiths, Desmond J.Higham: Learning LATEX, Society for Industrial and Applied Mathematics, Philadelphia (1997).



PAPER-III

RESEARCH THEME-SPECIFIC COURSE

Credits:06

Every student has to opt one of the following courses:

1. Course code-MTH 603(a)
Dynamical Systems and Chaos

Course Outcomes:

CO1: The students will be able to understand Lorenz system and Lorenz attractor.
CO2: The students will be able to describe discrete dynamical system.
CO3: The students will be able to explain homoclinic phenomena.

Differential Equations: Ordinary differential equations and their solutions, Linear differential equations and their solutions, system of linear differential equations and its solutions.

The Lorenz System: The Lorenz system and its elementary properties, the Lorenz Attractor and a model for it, the Chaotic Attractor, Exploration of the Rössler Attractor.

Discrete Dynamical System: Discrete dynamical systems, Bifurcations, the discrete logistic model, Chaos, Symbolic dynamics,The shift map, The Cantor Middle-Thirds set, Explorations of Cubic chaos and the Orbit diagram.

Homoclinic Phenomena: The Shil'nikov system, the horseshoe map, Double scroll atrractor, Homoclinic bifurcations, Exploration of the Chua circuit.

Suggested readings:

1. Morris W. Hirsch, Stephen Smale and Robert L. Devaney, Differential Equations, Dynamical Systems & An Introduction to Chaos, Second edition, Elsevier Academic Press.

2. Course code-MTH603(b)
Fuzzy Topology

Course Outcomes:

CO1: The students will be able to describe Boolean Algebra, Continuous lattice and complete Boolean Algebra.
CO2: The students will be able to know the difference between crisp set and fuzzy set and hence they will be able to generalize the definition of topology, i.e., fuzzy topology.
CO3: The students will be able to explain category- theoretic concepts in fuzzy topology.

Lattice Theory: Partial order relation, Lattices, bounded lattices, complemented and distributive lattices, Boolean Algebra, Atoms, Irreducible elements, Definitions of Continuous lattices and completely distributive lattices**.**

Fuzzy set theory: Basic definitions of fuzzy sets, various operations on it. Representation of fuzzy sets through α- cuts, Backward and forward operators related to functions between sets. Zadeh extension principle. Fuzzy points, belonging relations and quasi-coincidence, Some generalization of fuzzy sets including L-fuzzy sets and introductory accounts of intuitionistic fuzzy sets and rough sets.

Fuzzy topology: Definition of fuzzy topology and its various suggested modifications. Examples, particularly the fuzzy real line, the fuzzy unit interval and fuzzy Sierpinski space, Fuzzy continuity, Initial and final fuzzy topologies, Induced fuzzy topologies, Fuzzy product topology, Fuzzy separation axioms, connectedness and compactness, Fuzzy sobriety.

Categorical aspects of fuzzy topology: Basic concepts of category theory(categories, functors, special morphisms, adjoint functors and reflective & coreflective subcategories), The category FTS of fuzzy topological spaces and its being a topological category, The relation between FTS and the category TOP of topological spaces, Some coreflective subcategories of FTS and related categories.

Suggested readings:

1. J. Adamek, H.Herrlich and G.E. Strecker, Abstract and Concrete Categories: The Joy of Cats, John Wiley & Sons, 1990.
2. G. Gierz, K.H. Hofmann, K. Keimel, J.D. Lawson, M. Mislove and D.S. Scott, A Compendium of Continuous Lattices, Springer-Verlag, 1980.
3. Y.-M. Liu and M.-K.Luo, Fuzzy Topology, World Scientific, 1997.
4. S. Maclane, Categories for the Working Mathematician (2^{nd} edition) Springer, 1997.

3. Course code-MTH603(c)
Advanced Fluid Dynamics
Course Outcomes:

CO1: The students will be able tounderstand the concept of fluid and their classification, models and approaches to study the fluid flow.

CO2: The students will be able toformulate mass and momentum conservation principle and obtain solution for nonviscous flow.

CO3: The students will be able to know potential theorems, minimum energy theorem and circulation theorem.**CO4**: The students will be able to understand two-dimensional motion, circle theorem and Blasius theorem.**CO5:**The students will be able to understand three dimensional motions, Weiss's and Butler's sphere theorems and Kelvin's inversion theorem.

Classification of fluids, Continuum model, Eulerian and Lagrangian approach of description, Differentiation following the fluid motion, Irrotational flow, Vorticity vector, Equipotential surfaces, Streamlines, pathlines and streaklines of particles, Stream tube and stream surface, Mass flux density, Conservation of mass leading to equation of continuity (Euler's form), Boundary surface, Conservation of momentum and its mathematical formulation (Euler's form), Integration of Euler's equation under different conditions, Bernoulli's equation, steady motion under conservative body forces.

Theory of irrotational motion, Kelvin's minimum energy and circulation theorems, Potential theorems, Two-dimensional flows of irrotational, incompressible fluids, Complex potential, Sources, sinks, doublets and vortices, Milne–Thomson circle theorem, Images with respect to a plane and circles, Blasius theorem.

Three-dimensional flows, Sources, sinks, doublets, Axi-symmetric flow and Stokes stream function, Butler sphere theorem, Kelvin's inversion theorem, Weiss's sphere theorem, Images with respect to a plane and sphere, Axi-symmetric flows and stream function, Motion of cylinders and spheres.

Viscous flow, stress and strain analysis, Stokes hypothesis, Navier–Stokes equations of motion, Some exactly solvable problems in viscous flows, Steady flow between parallel plates, Poiseuille flow, Steady flow between concentric rotating cylinders.

Suggested readings:

1. F. Chorlton, Text Book of Fluid Dynamics, CBS Publisher, 2005.
2. R.W. Fox, P.J. Pritchard and A.T. McDonald, Introduction to Fluid Mechanics, Seventh Edition, John Wiley & Sons, 2009.
3. P.K. Kundu, I.M. Cohen, D.R. Dowling, Fluid Mechanics, Sixth Edition, Academic Press, 2016.

4. Course code-MTH603(d) Magnetohydrodynamics

Course Outcomes:

CO1: The students will be able tounderstand various laws of electromagnetism and their consequences.

CO2: The students will be able to examine the electromagnetic waves and its effects on the flowsystem.

CO3: The students will be able to explore the force field, magnetic field and its significances.

CO4: The students will be capable of modelling of modern MHD flow problems and consequences of magnetic field domain to the flow-field.

Fundamentals of Magnetohydrodynamics (MHD)

Basic concepts of Magnetohydrodynamics and its applications, MHD approximations, Maxwell's relations, Electrostatics: Coulombs law, Gauss law, Dielectric material, Electrodynamics: Faraday's law, Conservation of charges, Ampere's law, Solenoidal relation, Ohm's law.

Kinematic Aspect of MHD

Lorentz force, Magnetic Induction equation, Alfven theorem, Frozen-field-phenomenon, Analogue of Helmholtz vorticity equation in MHD, Bernoulli's equation in MHD, Ferraro's law of isorotation, Electromagnetic boundary conditions, non-dimensional numbers.

Magnetohydrodynamic Waves

Alfven waves, Alfven waves in incompressible fluids, Walen's equation, equipartition of energy, Alfven waves in compressible fluids, Transverse and Magneto-Acoustic Waves.

Magnetostatics
Force free magnetic field, Equations of force free magnetic field, Chandrasekhar's theorem, Applications of magnetostatics, Pinch effect, Instability of Bennett Pinch.

Magnetohydrodynamic flows
One dimensional MHD flow: Hartmann flow, MHD Couette flow, MHD Stokes flow, MHD Rayleigh's flow, Hartmann-Stokes boundary layer, Alfven's boundary layer, two dimensional MHD flow (a) Aligned flow (b) Stagnation point flow.

Suggested readings:

1. T.G.Cowling, Magnetohydrodynamics, Interscience Publishers, New York, 1957.
2. J.A. Shercliff, A Text Book of Magnetohydrodynamics, Pergamon Press, Oxford, 1965.
3. S.I. Pai, Magnetohydrodynamics and Plasma Dynamics, Springer Verlag, NewYork, 1962.
4. K. R. Cramer and S. I. Pai, Magnetofluid Dynamics for Engineers and Applied Physicists, McGraw Hill, New York, 1973.
5. G. W. Sutton and A. Sherman, "Engineering Magnetohydrodynamics", Dover Publication Inc., New York, (1965).
6. P. A. Davidson, "An Introduction to Magnetohydrodynamics", Cambridge University Press, New York, (2010).

5. Course code-MTH603(e)

Structures on a Differentiable Manifold

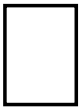
Course Outcomes:

CO1: The students will be able to describe tensor product of tensors.
CO2: The students will be able to understand concepts related to differentiable manifolds.**CO3:** The students will be able distinguish manifolds on even dimension and odd dimension.

Tensor Algebra: Tensor product of vector spaces, tensors, tensor product of tensors,Algebraic operations.
Differentiable manifolds: Differentiable manifolds, differentiable functions, tangent space, vector fields, maps, Submanifolds.

Linear Connections: Parallelism, Covariant derivative, Geodesic, Lie derivative, Riemannian manifold and curvature tensors on it, Submanifolds, Normals, induced Connections, Gauss formulae, Weingarten formulae, the equations of Gauss and Codazzi.

Manifolds on even dimension: Almost complex manifolds, Almost Hermite manifolds, K*ä*hler manifolds, Nearly K*ä*hler manifolds.
Manifolds on odd dimension: Almost contact manifolds, Almost Grayan manifolds, Sasakian manifolds, Nearly Sasakian manifolds.



Suggested readings:

1. B.B.Sinha: AnIntroductiontoModernDifferentialGeometry,Kalyani Publishers, New Delhi,1982
2. R.S. Mishra: Structures on differentiable manifold and their applications, Chandrama Prakashan, Allahabad,

6. Course code-MTH603(f)
Hypergeometric Functions & its applications

Course Outcomes:

CO1: The students will be able to understand how and when to use various special functions like Legendre, Bessel, Laguerre, Hermite and Hypergeometric functions.

CO2: The students will be able to learn how to find new results using various techniques

CO3: The students will be able to learn its applications in the other branches of Mathematics such as number theory, orthogonal polynomials, combinatorics, partition theory etc.

Power Series Solution of Differential Equations: Power Series Solutions and special functions, Review of power series, Series solutions of first order equations, Second order linear equations, Ordinary points, Regular singular point, Indicial equations, The point at infinity.

Special Functions: Legendre polynomials, properties of Legendre polynomials, Bessel Functions, Properties of Bessel Functions, Laguerre equation & its solution, Generating function for Laguerre polynomial, Hermite equation & its solution, Generating function for Hermite polynomial.

Hypergeometric Functions: The function F(a,b;c;z), A simple integral form, F(a,b;c;1) as a function of the parameters, Evaluation of F(a,b;c;1), The contiguous function relations, The Hypergeometric differential equations, Simple transformations, Relation between functions of z and 1-z, A theorem due to Kummer, Additional properties.

Generalized Hypergeometric Functions: The function ${}_pF_{q,,}$ The exponential and binomialfunctions, A differential equation, Other solutions of the differential equation, A simple integral, The function ${}_pF_q$ with unit argument, Saalschutz theorem,Whipple's theorem, Dixon's theorem, A useful integral.

Suggested readings:

1. E.D. Rainville:Special Functions,Chelsea Publishing Company,Bronx,New York.
2. H.M.Srivastava and H.L.Manocha: A Treatise on Generating Functions, John Wiley and Sons, New York.
3. R. P. Agarwal and R. C. Gupta: Essentials of Ordinary Differential Equations, McGraw Hill Book Co. Inc. New York.
4. W.W. Bell, Special functions for scientists and engineers, D Van Nostrand Co. Inc., New York.
5. G.Gasper,M.Rahman; Basic Hypergeometric Series, Cambridge University Press,1990.

6. L. J. Slater "Generalised hypergeometric series", Cambridge Univ. Press Cambridge (1966).

7. Course code-MTH603(g)
Methods in Nonlinear Evolution Equations

Course Outcomes:

CO1: The students will be able to understand one -dimensional, two-dimensional and three-dimensional heat flow.

CO2: The students will be able to describe homogeneous and inhomogeneous wave equations.

CO3: The students will be able to solve non-linear partial differential equations by Adomian method and Variational iteration method.

Adomian decomposition method (ADM) and Variational iteration method (VIM): One Dimensional Heat Flow, Homogeneous Heat Equations, Inhomogeneous Heat Equations. Higher Dimensional Heat Flow: Two-Dimensional Heat Flow, Three-Dimensional Heat Flow. One Dimensional Wave Equation: Homogeneous Wave Equations, Inhomogeneous Wave Equations, Wave Equation in an Infinite Domain.

Nonlinear Partial Differential Equations (NPDEs**):** Calculation of Adomian Polynomials, Alternative Algorithm for Calculating Adomian Polynomials, Nonlinear ordinary differential equations (ODEs) by Adomian Method, Nonlinear ODEs by VIM, Nonlinear PDEs by Adomian Method, Nonlinear PDEs by VIM, Nonlinear PDEs Systems by Adomian Method, Systems of Nonlinear PDEs by VIM.

Analysis of the Analytical Methods:

The Korteweg-deVries (KdV) and Burger Equation: Ansatz method: Using the Tanh-Coth Method, Using the Sine-cosine Method. He's Variational Approach, Perturbation methods, Homotopy analysis method.

Analysis of the Solitary Waves Solutions: Dispersion and Dissipation, Types of Travelling Wave Solutions.

Suggested readings:

1. Abdul-Majid Wazwaz, Partial Differential Equation and Soliton Wave Theory, Springer, 2009.

2. S. Liao, Beyond Perturbation: Introduction to the Homotopy Analysis Method, Chapman and Hall/ CRC, 2004.

8. Course code-MTH603(h)

Sampling Theory

Course Outcomes:

CO1: The students will be able to understand concepts of Fourier Analysis.

CO2: The students will be able to describe frames in Hilbert spaces.

CO3: The students will be able to explain sampling in shift-Invariant spaces.

Basic Fourier Analysis: Definition of Fourier Transform, fundamental operations(translation, modulation and convolution), Fourier Trasnsforms and derivatives, Inversion formula, The Poisson summation formula, Plancherel's Theorem, Zak Transform and its properties.

Frames in Hilbert Spaces: Frames and their properties, Frames and Riesz basis, dual frames, Sinc function, B-spline functions, frames of translates, The canonical dual frame.

Sampling in Shift-Invariant Spaces: Sampling problem, space of bandlimited functions, sampling in bandlimited space, shift-invariant space, Wiener amalgam space.

Reproducing kernel Hilbert space (RKHS), Relation between RKHS, Frames and Sampling, Frame reconstruction algorithm, Iterative A-P reconstruction algorithm.

Suggested readings:

1. Karlheinz Grochenig, *Foundations of Time-Frequency analysis,* Birkhauser, 2001.

2. Ole Christensen, *Frames and Bases: An Introductory Course,* Birkhauser, 2008.

3. Akram Aldroubi, Karlheinz Grochenig, *Nonuniform Sampling and Reconstruction in shift-Invariant Spaces,* SIAM Review, 2001.