

# Syllabus for Ph.D Programme

Pre-Ph.D Course Work for the year 2015-16

Paper (i) – Research Methodology (Compulsory Paper)

Paper (ii) – Reading Courses (RC) (Two papers to be chosen)

## Research Methodology in Mathematics

Scientific research and literature survey. History of mathematics, finding and solving research problems, role of a supervisor, survey of a research topic, publishing a paper, reviewing a paper, research grant proposal writing, copyright issues, ethics and plagiarism.

Research tools. Searching google (query modifiers), MathSciNet, ZMATH, Scopus, ISI Web of Science, Impact factor, h-index, Google Scholar, ORCID, JStor, Online and open access journals, Virtual library of various countries

Scientific writing and presentation. Writing a research paper, survey article, thesis writing; LaTeX, PSTricks, Beamer, HTML and MathJaX

Software for Mathematics. Mathematica/Matlab/Scilab/GAP

Reference:

[1] J. Stillwell, Mathematics and its History, Springer International Edition, 4th Indian Reprint, 2005

[2] L. Lamport, LaTeX, a Document Preparation System, 2nd ed, Addison-Wesley, 1994.

[3] Norman E. Steenrod, Paul R. Halmos, Menahem M. Schiffer, Jean A. Dieudonne, How to Write Mathematics, American Mathematical Society, 1973.

[4] Nicholas J. Higham, Handbook of Writing for the Mathematical Sciences, Second Edition, SIAM, 1998.

[5] Donald E. Knuth, Tracy L. Larrabee, and Paul M. Roberts, Mathematical Writing, Mathematical Association of America Washington, D.C., 1989.

[6] Frank Mittelbach, Michel Goossens, Johannes Braams, David Carlisle, Chris Rowley, The LaTeX Companion, 2nd edition (TTCT series), Addison-Wesley, 2004.

[7] Michel Goossens, Frank Mittelbach, Sebastian Rahtz, Denis Roegel, Herbert Voss, The LaTeX Graphics Companion, 2nd edition (TTCT series), Addison-Wesley, 2004

[8] Mathtools documentation

(<http://mirrors.ctan.org/macros/latex/contrib/mathtools/mathtools.pdf>)

[9] Pstricks documentation (<http://tug.org/PSTricks/main.cgi?file=doc/docs>)

[10] MathJax documentation (<http://tug.org/PSTricks/main.cgi?file=doc/docs>)

## RC(i) - Lie Groups and Lie Algebras

**Unit -I** : Differential Manifolds Topological manifolds, Charts, Atlases and smooth structure, Smooth maps and diffeomorphism, Partitions of Unity, Tangent space, Tangent map, Vector fields and 1-forms.

**Unit -II** : Lie Groups Definition and examples, Linear Lie groups, Lie group homomorphism, Lie algebra and the exponential map, Adjoint representation, Homogeneous spaces, Baker-Campbell-Housdorff formula.

**Unit -III** : Lie Algebras Definition and examples, Classical Lie algebras, Solvable and nilpotent Lie algebras, Lie and Engel theorems, Semisimple and reductive algebras, Semisimplicity of Classical Lie algebras, Killing form and Cartan criterion, Cartan subalgebra, root decomposition and root systems, Weyl group and Weyl chambers, Dynkin diagrams, Classification of simple Lie algebras.

**Unit -IV** : Partial Differential Equations on Manifolds Partial differential operators and formal adjoints, Sobolev spaces in  $\mathbb{R}^n$ , Elliptic estimates in  $\mathbb{R}^n$ , Elliptic regularity, Fredholm theory and spectral theory of Laplacian.

Suggested Texts:

1. S. Kumaresan, Differential Geometry and Lie Groups, Hindustan Book Agency.
2. Alexander Kirillov Jr, An Introduction to Lie Groups and Lie Algebras, Cambridge University Press.
3. James Humphreys, Introduction to Lie Algebras and Representation Theory, Springer.
4. Brian Hall, Lie Groups, Lie Algebras, and Representations: An Elementary Introduction, Second Edition, Springer.
5. J. M. Lee, Manifolds and Differential Geometry, Graduate Studies in Mathematics vol 107, AMS.
6. Liviu I Nicolaescu, Lectures on Geometry of Manifolds, Second Edition, World Scientific.
7. A. C. Pipkin, A Course on Integral Equations, Text in Applied Mathematics Series, Springer.

## RC(ii) – Representation of Nilpotent Lie Group

Basic facts about Lie groups and Lie algebras, Nilpotent Lie groups, Coadjoint orbits and the dual of  $\mathfrak{g}$ , Some generalities on representations, Elements of Kirillov theory, Proof of basic theorems, subgroups of codimension 1 and representations.

### References

1. L.J. Corwin and F.D. Grenleaf, Representations of nilpotent Lie groups and their applications, Cambridge University Press, 1990
2. V.S. Varadarajan, Lie groups, Lie algebras and their representations, Prentice-Hall, 1974.

## RC(iii) - Univalent Functions

Univalent functions, area theorems, Bieberbach theorem and its applications, subclasses of starlike and convex functions and their generalizations, functions with positive real part, typically real functions.

Close-to-convex functions and the functions of bounded boundary rotation, bounded functions, radius problems and Koebe domains, combination and convolutions of univalent functions, Integrals and integral inequalities, meromorphic functions.

References.

[1] A. W. Goodman, Univalent Functions I & II, Mariner, Florida, 1983.

[2] P. Duren, Univalent Functions, Springer, New York, 1983

[3] Ch. Pommerenke, Univalent Functions, Van den Hoek and Ruprecht, Göttingen, 1975.

## RC(iv) - Theory of Differential Subordination

Jack-Miller-Mocanu Lemma, Admissible functions and fundamental theorems, open door lemma and integral existence theorem, first order differential subordination, Briot-Bouquet differential subordinations, and its generalizations and applications, integral operator, subordination preserving integral operators .

Second order differential subordinations, integral operators preserving functions with positive real part, bounded functions, averaging operators, Hypergeometric functions, Schwarzian derivative, applications to starlikeness and convexity.

### References

[1] S. S. Miller and P. T. Mocanu, Differential Subordinations. Theory and Applications, Marcel Dekker Inc., New York, Basel, 2000.

[2] T. Bulboacă, Differential Subordinations and Superordination: Recent Results, Cluj-Napoca, 2005.

## RC(v) - Harmonic Mappings in the Plane

Harmonic mappings, Argument principle, Dirichlet problem, critical points of harmonic mappings, Lewy's theorem, Heinz's theorem, Rado's theorem

The Rado-Kneser-Choquet theorem, Shear construction, structure of convex mappings, covering theorems and coefficient bounds

Harmonic self mappings of the disk, normalization and normality of harmonic univalent functions, Harmonic Koebe functions and coefficient conjectures, extremal problems, typically real and starlike functions, problems and conjectures in planar harmonic mappings.

Text:

[1] P.L. Duren, Harmonic Mappings in the Plane, Cambridge Univ. Press, Cambridge, 2004.

[2] D. Bshouty and A. Lyzzaik, Problems and Conjectures in Planar Harmonic Mappings, J. Analysis,

Volume 18 (2010), 69–81.

## RC (vi) - Operator Spaces

Operator Spaces (concrete and abstract), Completely bounded maps, subspaces, quotients, products, Dual spaces, conjugates, mapping spaces, opposite, representation theorem, The min and max quantizations, Arveson-Wittstock theorem, Column and Row Hilbert spaces. Projective tensor product, injective tensor product and Haagerup tensor product.

### References

1. Blecher, D. P. and Merdy, C. Le., Operator algebras and their modules-an operator space approach. London Mathematical Society Monographs, New series, vol. 30, The Clarendon Press, Oxford University Press, Oxford, 2004.
2. Effros, E. G. and Ruan, Z. J., Operator spaces, Clarendon Press-Oxford, 2000.
3. Pisier, G., Introduction to operator space theory, Cambridge University Press, 2003.



## RC(vii) - Advanced Operator Algebras

*Unitary representations of locally compact groups:* The involutive algebra  $L^1(G)$ , representations of  $G$  and  $L^1(G)$ , positive forms on  $L^1(G)$  and positive-definite functions, weak\*-convergence and compact convergence of continuous positive-definite functions, pure positive-definite functions, square integrable positive definite functions, the  $C^*$ -algebra of a locally compact group

*Group  $C^*$ -algebras:* Group representations, amenability, free group, reduced  $C^*$ -algebra of the free group

*Tensor Products:* Tensor products of Banach spaces, Tensor product of Hilbert spaces, Tensor products  $C^*$ -algebras, Tensor products of  $W^*$ -algebras

### References

1.  *$C^*$ -algebras by example*, K. R. Davidson, American Mathematical Society
2.  *$C^*$ -algebras*, J. Dixmier, North Holland Publishing Company, 1977.
3. *Theory of Operator Algebras I*, M. Takesaki, Springer.
4. *Introduction to Tensor Product of Banach Spaces*, R. Ryan, Springer.
5. *Fundamentals of the Theory of Operator Algebras*, Volume II, R. V. Kadison and J. R. Ringrose, Academic Press.

## RC(viii) - Symmetries and Differential Equations

**Lie Groups of Transformations:** Groups, Groups of Transformations, One-Parameter Lie Group of Transformations, Examples of One-Parameter Lie Groups of Transformations.

**Infinitesimal Transformations:** First Fundamental Theorem of Lie, Infinitesimal Generators, Invariant Functions, Canonical Coordinates, Examples of Sets of Canonical Coordinates, Invariant Surfaces, Invariant Curves, and Invariant Points.

**Extended Transformations (Prolongations):** Extended Group Transformations-One, Dependent and One Independent Variable, Extended Infinitesimal Transformations-One Dependent and One Independent Variable, Extended Transformations-One Dependent and n Independent Variables, Extended Infinitesimal Transformations-One, Dependent and n Independent Variables, Extended Transformations and Extended Infinitesimal Transformations-m Dependent and n Independent Variables.

**Ordinary Differential Equations:** Invariance of an Ordinary Differential Equation, First Order ODE's, Determining Equation for Infinitesimal Transformations of a First Order ODE, Determination of First Order ODE's Invariant Under a Given Group, Second and Higher Order ODE's, Reduction of Order by Differential Invariants, Examples of Reduction of Order, Determining Equations for Infinitesimal Transformations of an nth Order ODE, Determination of nth Order ODE's Invariant Under a Given Group, Applications to Boundary Value Problems for ODE's.

**Partial Differential Equations:** Invariance of a Partial Differential Equation, Invariant Solutions, Mapping of Solutions to Other Solutions from Group Invariance of a PDE, Determining Equations for Infinitesimal Transformations of a  $k^{\text{th}}$  Order PDE, Invariance for Systems of PDE's, Determining Equations for Infinitesimal Transformations of a System of PDE's, Applications to Boundary Value Problems for PDE's.

References:

- (1). George W. Bluman, J. D. Cole, Similarity methods for differential equations, Springer New York (Verlag), 1974.
- (2). George W. Bluman, Sukeyuki Kumei, Symmetries and Differential Equations, Springer New York, 1989.

## RC(ix)-Chaotic Dynamical Systems

Theory and Application of Chaos in Dynamical systems, One dimensional map, Examples of Dynamical Systems, Stability of fixed points, Orbits, Graphical Analysis, Fixed and Periodic points, Quadratic family, Transition to Chaos.

Bifurcations of Chaotic Systems, Dynamics of a quadratic map, Saddle node Bifurcation, Period Doubling Bifurcation, Transcritical Bifurcation, Pitchfork Bifurcation.

Lyapunov Exponents, chaotic orbits, conjugacy and logistic map, Transition graphs and fixed points, Basin of attraction. Lorenz equations, strange attractors, Lorenz map, Simple properties of Lorenz equations, Chaos in Hamiltonian Systems, and Control and Synchronism of chaos.

Equilibria in Nonlinear Systems, Nonlinear Sinks and Sources, Saddles, Stability, Closed orbit and Limit Sets, Poincare map, Applications in physics, engineering and biology.

### References:

- (1). R. L. Deveny, A First Course in Chaotic Dynamical Systems, 2<sup>nd</sup> Edition, Westview Press.
- (2). Steven H. Strogatz, Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Westview Press.
- (3). Kathleen T. Alligood, Tim D. Sauer, James A. Yorke, Chaos: An Introduction to Dynamical Systems, Springer-Verlag, New York.
- (4). L. Douglas Kiel and Euel W. Elliott, Chaos Theory in the Social Sciences, University of Michigan Press.
- (5). M.W. Hirsch and S. Smale, Differential Equations, Dynamical Systems and an Introduction to Chaos, 3<sup>rd</sup> Edition, Academic Press, USA.

## RC (x) - Recent Developments on Minimal Ring Extensions and APD's

**Contents:** Introduction to Minimal Ring extensions, Minimal Ring Homomorphisms, Overring, Finitely many intermediate rings property and related results, Finitely many subrings property and related results, Composites, Kaplansky Transform, Direct Products and  $\lambda$ -extensions,  $\mu$ -extensions, P-extensions, i-domains. Results on minimal field extension.

Commutative Perfect Rings and almost Perfect Rings, Properties of Almost perfect domains, Valuation overrings of APDs, connection of APDs with other classes of domains, examples of APDs.

### References:

1. Commutative Rings: New Research, John Lee, Nova Science Publication Inc., New York.
2. Multiplicative Ideal Theory in Commutative Algebra, J. W. Brewer, S. Glaz, W. J. Heinzer, B. M. Olberding, Springer, 2006
3. Commutative ring theory, H. Matsumura, Cambridge university press, 1989.
4. Basic commutative algebra, Balwant Singh, World scientific publishing co., 2011.

## RC(xi)-Advanced commutative algebra

Direct limit, Inverse limit, Graded rings and modules, Associated graded rings, I-adic completion, Krull's intersection theorem, Hensel's lemma, Hilbert function, Hilbert polynomial, Dimension theory of Noetherian local rings, Regular local rings, UFD property of regular local rings, Hom functor, Tensor functor, I-torsion functor, Flat modules, Projective and injective modules, Complexes, Projective and injective resolution, Derived functor, Tor and ext functor, Minimal resolution, Regular sequences, Cohen-Macaulay rings and modules.

### References:

1. H. Matsumura, Commutative ring theory, Cambridge university press, 1989.
2. Balwant Singh, Basic commutative algebra, World scientific publishing co., 2011.
3. D. Eisenbud, Commutative algebra with a view towards algebraic geometry, Springer verlag, 1995.
4. M.F. Atiyah & I.G. Macdonald, Introduction to commutative algebra, Addison Wesley, 1969.

## RC(xii) - Banach Spaces of Analytic Functions

Analytic and Harmonic Functions in the unit disc: Cauchy and Poisson kernels, boundary values, Fatou's Theorem,  $H^p$  spaces.

The space  $H^1$ : The Helson Lowdenslager Approach, Szego's theorem, Dirichlet Algebras.

Factorization of  $H^p$  Functions: Inner and outer functions, Blaschke products and singular functions, Factorisation theorem. The Shift operator : The shift operator on  $H^2$ . Invariant subspaces for  $H^2$  on the half plane, the shift on  $L^2$  the vector valued case, representations on  $H^\infty$ .

Text book: K. Hoffman, Banach Spaces of Analytic Functions, Dover Publications, 2007.

### **RC(xiii) - Banach Algebra Techniques in Operator Theory**

Revision of Banach spaces and Geometry of Hilbert Space. Basic theory of Banach Algebras, The Disk Algebra. Multiplication operators and maximal abelian algebras. The Bilateral shift operator.  $C^*$  algebras. The GelfandNaimark Theorem. Spectral Theorem. Functional Calculus. The Unilateral Shift Operator. Topelitz operators. The Spectrum of self-adjoint and analytic Toeplitz Operators.

R.G. Douglas, Banach Algebra Techniques in Operator Theory, Graduate Texts in Mathematics 179, Springer, 1998

## RC(xiv) - Conservation laws in Fluid Dynamics

Hyperbolic system of conservation laws, breakdown of smooth solution, genuine nonlinearity, weak solutions and jump condition, Riemann problem, entropy conditions, Convection, diffusion and heat transfer, two-phase flow, boundary layer flow, Free and Moving boundary problems.

### Reference

1. Hyperbolic system of conservation laws and mathematical theory of shock waves, Peter D. Lax, SIAM, 1973
2. Quasilinear Hyperbolic Systems, Compressible Flows and Waves, V.D.Sharma, Chapman and Hall/ CRC, 2010
3. Free and Moving Boundary Problems, J. Crank, Oxford university press, New York, 1984
4. Boundary Layer Theory, H.Schlichting, K. Gersten, Springer, 2000
5. Thermo-Fluid Dynamics of Two-Phase Flow, M. Ishii, T.Hibiki, Springer, 2011



## RC(xv) - Methods in Fluid Dynamics

Characteristics methods, Similarity methods, Self-similar solution and the method of Lie-group invariance, Perturbation methods, Homotopy perturbation methods, Homotopy analysis method, Adomian decomposition method, Variational method, Numerical method.

### References

1. Similarity and Dimensional Method in Mechanics, L.I.Sedov, Mir Publisher, 1982
2. Symmetries and Differential Equation, G.W. Bluman and S. Kumei, Springer, 1989
3. Beyond Perturbation: Introduction to the Homotopy Analysis Method, S. Liao, Chapman and Hall/ CRC, 2004
4. Partial Differential Equation and Soliton Wave Theory, Abdul-Majid Waswas, Springer, 2009
5. Numerical Approximation of Hyperbolic System of Conservation Laws, E. Godlweski, P.A. Raviart, Springer, 1996
6. Fundamental of finite element method in heat and fluid flow, R.W.Lewis, P. Nithiarasu, K.N. Seetharamu, John-Wiley and Sons, 2004

## RC(xvi) - Set-Valued Analysis

Order relations, Cone properties related to the topology and the order, Convexity notions for sets and set-valued maps, Solution concepts in vector optimization, Vector optimization problems with variable ordering structure, Solution concepts in set-valued optimization, Solution concepts based on vector approach, Solution concepts based on set approach, Solution concepts based on lattice structure, The embedding approach by Kuroiwa, Solution concepts with respect to abstract preference relations, Set-valued optimization problems with variable ordering structure, Approximate solutions of set-valued optimization problems, Relationships between solution concepts

Continuity notions for set-valued maps, Continuity properties of set-valued maps under convexity assumptions, Lipschitz properties for single-valued and set-valued maps, Clarke's normal cone and subdifferential, Limiting cones and generalized differentiability, Approximate cones and generalized differentiability

### References

1. Akhtar A. Khan, Christiane Tammer, Constantin Zălinescu, **Set-Valued Optimization: An Introduction with Applications**, Springer Verlag, 2015.
2. Regina S. Burachik and Alfredo N. Iusem, **Set-Valued Mappings and Enlargements of Monotone Operators**, Springer Verlag, 2008.
3. Guang-ya Chen, Xuexiang Huang and Xiaogi Yang, **Vector Optimization: Set-valued and Variational Analysis**, Springer Verlag, 2005.

## RC(xvii)- Scalarization in Multiobjective Optimization

Basics of multiobjective optimization, Minimality notion, Polyhedral ordering cones, Pascoletti-Serafini scalarization, Parameter set restriction for the Pascoletti-Serafini scalarization, Modified Pascoletti-Serafini scalarization,  $\varepsilon$ -constraint problem, Normal boundary intersection problem, Modified Polak problem, Weighted Chebyshev norm problem, Problem of Gourion and Luc, Generalized weighted sum problem, Weighted sum problem, Problem of Kaliszewski

Sensitivity results in partially ordered spaces, Sensitivity results in naturally ordered spaces, Sensitivity results for the  $\varepsilon$ -constraint problem

Adaptive parameter control, Quality criteria for approximations, Adaptive parameter control in the bicriteria case, Algorithm for the Pascoletti-Serafini scalarization, Algorithm for the  $\varepsilon$ -constraint scalarization, Algorithm for the normal boundary intersection scalarization, Algorithm for the modified Polak scalarization, Adaptive parameter control in the multicriteria case

### References

1. Gabriele Eichfelder, **Adaptive Scalarization Methods in Multiobjective Optimization**, Springer Verlag, 2008.
2. Johannes Jahn, **Vector Optimization Theory, Applications, and Extensions**, Springer Verlag, 2011.
3. Kayan Deb, **Multi-Objective Optimization using Evolutionary Algorithms**, John Wiley & Sons, Chichester, 2001.

## RC(xviii) - Fixed Point Theorems

Contractions, Banach Contraction Principle, Theorem of Edelstein, Picard–Lindelof Theorem.

Non expansive Maps, Schauder's Theorem for non–expansive maps, Continuation Methods for Contractive and non–expansive mappings.

Some Applications of The Banach Contraction Principle, Some Extensions of Banach Contraction Principle for Single – Valued Mappings, Generalized distances, Some Extensions of Banach Contraction Principle under Generalized Distances, Multivalued versions of Banach Contraction Principle.

### **References :**

- [1] S. Almezal, Q. H. Ansari and M. A. Khamsi; Topics in Fixed Point Theory, Springer 2014.
- [2] R. P. Agarwal, M. Meehan, D. O' Regan; Fixed Point Theory And Applications, Cambridge University Press 2004.

## **RC(xix) - Applications of Fixed Point Theorems in Economics and Game Theory**

Sperner's Lemma, The Knaster – Kuratowski –Mazurkiewicz Lemma, Brouwer's Fixed Point Theorem, The Fan – Browder Theorem, Kakutani's Theorem.

The maximum Theorem, Set with convex sections and a minimax Theorem, Variational inequalities, Price equilibrium and complementarity, Equilibrium of excess demand correspondences, Nash equilibrium of games and abstract economics, Walrasian equilibrium of an economy.

### **Reference :**

- [1] K.C.Border; Fixed Point Theorems with Applications to Economics and Game Theory; Cambridge University Press 1985.

## **RC (xx) - Mathematical- Biological Modeling**

Continuous and Discrete population models for single species, Models for interacting populations, Dynamics of infectious diseases, Reaction Diffusion, Chemotaxis, Spatial pattern formation with reaction diffusion systems, Animal coat patterns and other practical applications of reaction diffusion mechanisms.

### **References:**

1. J.D. Murray, Mathematical Biology I: An Introduction, Third Edition, Springer, 2002.
2. J.D. Murray, Mathematical Biology II: Spatial Models and Biomedical Applications, Third Edition, Springer, 2002.

## RC (xxi) - Parallel Iterative Methods for Partial Differential Equations

Speedup; efficiency; Amdahl's law; point and block parallel relaxation algorithms (Jacobi, Gauss-Seidel, SOR); triangular matrix decomposition; quadrant interlocking factorisation method; red-black ordering; application to elliptic BVPs; parallel ADI algorithms; parallel multi-grid and domain decomposition method.

The alternating group explicit (AGE) method for two point BVPs (natural, derivative, mixed, periodic) and their convergence analysis; the modified AGE and smart AGE methods; the computational complexity of the AGE method; the Newton-AGE method.

Parabolic equation: AGE algorithm for diffusion-convection equation and its convergence analysis; stability analysis of more general scheme; coupled reduced AGE method; AGE method for fourth order parabolic equation.

Hyperbolic equation: Group explicit method for first and second order hyperbolic equations; stability analysis of Group Explicit method; AGE iterative method for first and second order hyperbolic equations.

Elliptic equation: Douglas-Rachford algorithm; BLAGE iterative algorithm with different boundary conditions; parallel implementation.

### Books recommended:

1. Y. Saad, *Iterative Methods for Sparse Linear Systems*, SIAM, Philadelphia (2003).
2. L.A. Hageman and D.M. Young, *Applied Iterative Methods*, Dover publication, New York (2004).
3. Jianping Zhu, *Solving Partial Differential Equations on Parallel Computers*, World Scientific, New Jersey (1994).
4. D.J. Evans, *Group Explicit Methods for the Numerical Solution of Partial Differential Equations*, Gordon and Breach Science publisher, Amsterdam (1997).

## RC(xxii) - Hyperspaces

The general notion of a Hyperspace, Topological invariance, Specified Hyperspaces. Convergence in hyperspaces, L-convergence,  $T_v$ -convergence, relation between L-convergence and  $T_v$ -convergence,

### REFERENCES:

[1] Alejandro Wanes and Sam B. Nadler, Jr. Hyperspaces: Fundamentals and Recent Advances, Marcel Dekker, Inc. New York.



## **RC(xxiii) - Uniform Spaces**

Uniformities and the uniform topology, Uniform continuity, Product uniformities, Completeness.

### **REFERENCES:**

- [1] John L. Kelly, *General Topology*, Springer-Verlag New York Berlin Heideberg.
- [2] Stephen Willard, *General Topology*, Dover Publication, Inc, Mineola, New York.

## **RC(xxiv) – Introduction to Transformation Groups**

Definition and fundamental properties of topological Groups, Examples of topological groups, subgroups, Isotropy groups, Isomorphism, Semi-direct products and Direct products, the Classical groups, Characteristic functions on compact groups.

Transformation groups and its fundamental properties, Examples of transformation groups, Group actions, Fixed point sets, Orbits and orbit spaces. Homogeneous spaces and equivariant maps, Induced transformation groups.

### REFERENCES:

1. P.J. Hissins, Introduction to Topological Groups, L M S (Lecture Notes Series), Cambridge University Press, 1975.
2. M. L. Curtis, Matrix Groups, Springer, 1984.
3. G. E. Bredon, Introduction to Compact transformation Groups, Academic Press, 1972.
4. T. B. Singh, Elements of Topology, CRC Press (Taylor and Francis Group), 2013.