Indira Gandhi University, Meerpur (Rewari)
Scheme of Examination
Ph.D. Course Work (Mathematics)
Under Credit System w.e.f. 2020-21

Core Courses

Course Code	Title of the Course	Theory Marks	Internal Marks	Practical Marks	Max Marks	Credits
PHD MAT 101	Research Methodology	80	20	-	100	4
PHD MAT 102	Computer Applications	50	-	50	100	4

Course Code	Title of the Course	Max Marks	Credits
PHD MAT 103	Review of Literature and Seminar	50	2

Core Course provided by the University

Course Code	Title of the Course	Theory Marks	Practical and Viva Voce Marks	Max Marks	Credits
RPE-2020	Research and Publication Ethics	25	25	50	2

Subject Specific Courses (Any one)

Course Code	Title of the Course	Theory Marks	Internal Marks	Max Marks	Credits
PHD MAT 104	Algebraic Coding Theory	80	20	100	4
PHD MAT 105	Advanced Functional Analysis	80	20	100	4
PHD MAT 106	Fixed Point Theory	80	20	100	4
PHD MAT 107	Theory of Linear Operators	80	20	100	4
PHD MAT 108	Algebraic Number Theory	80	20	100	4
PHD MAT 109	Advanced Solid Mechanics	80	20	100	4
PHD MAT 110	Waves and Viscoelasticity	80	20	100	4
PHD MAT 111	Reliability Theory	80	20	100	4
PHD MAT 112	Inventory Management	80	20	100	4

Total Credits : 16

Note: 1. The internal assessment of 20 marks in each paper shall be based on two assignments of 5 marks each and one seminar of 10 marks presented by each candidate and their participation in seminar.

2. The syllabus of each theory course will be divided into three sections of two or three questions each. The question paper will consists of eight questions in all and students shall be asked to attempt five questions selecting at least one from each section.

3. Subject specific courses will be offered subject to availability of requisite resources/faculty.

PHD MAT 101: Research Methodology

Time : 3 hours **Max. Marks : 100**
Theory Marks : 80
Internal Marks : 20
Credits : 4

Note: The question paper will contain three sections and eight questions in all. The candidates are required to attempt five questions in all selecting at least one from each section. All questions carry equal marks.

Section-I(Three Questions)

Introduction: Meaning, objectives and types of research.
Research Process: Steps involved in research process, Problems encountered by researchers in India.
Research Design: Meaning and need for research design, Different research designs. Data collection through experimental techniques and theoretical calculations, Types of data and various methods of data collection and compilation.

Section-II(Three Questions)

Introduction to Computers: Functions, Operating systems, Windows- Working with files and folders, Internet Explorer, knowledge of Microsoft Word, Excel, Power Point. Basic knowledge of MATLAB.
Processing and analysis of data: Coding, editing, classification and tabulation of data, Elements of analysis, various kinds of charts and diagrams used in data analysis.

Section-III(Two Questions)

Use of Excel for analysing the data applying various statistical techniques.
Preparation of Dissertation: Types and layout of research, Precautions in preparing the research Dissertations. Bibliography and annexure, discussion of results, Drawing conclusions, giving suggestions and recommendations to the concerned persons.

Books recommended

1. Bill Taylor, Research Methodology: A Guide for Researchers in Management and Social Sciences, PHI.
2. R. P. Mishra, Research Methodology, Concept Publishing Company(P) Ltd., New Delhi.
3. G.V. Shenoy and Madan Pant, Statistical Methods in Business and Social Sciences, McMillan Indian Ltd., New Delhi.
4. Suresh C. Sinha and Anil K. Dhiman, Research Methodology, Ess Ess Publications, New Delhi, 2002
5. ITL Education Solutions Ltd., Introduction to Information Technology, Pearson Education.
6. C. R. Kothari, Research Methodology, New Age International Publishers, 2004.
7. S. J. Chapman, MATLAB Programming for Engineers, CL-Engineering.

PHD MAT 102: Computer Applications

Time : 3 hours

Max. Marks : 100
Theory Marks : 50
Practical Marks : 50
Credits : 4

Note: The question paper will contain three sections and eight questions in all. The candidates are required to attempt five questions in all selecting at least one from each section. All questions carry equal marks.

Section-I (Two Question)

LaTeX: Introduction of LaTex, Formatting Words, Lines and Paragraphs, Designing Pages, Creating List, Creating Tables and Inserting Pictures, Referencing, Typing Math Formulas, Developing Large Documents.
Mendeley: Introduction of Mendeley, Mendeley web importer, Mendeley Research Catalogue.

Section-II (Three Questions)

MATLAB: Basics of MATLAB, MATLAB Operators and Special Characters, Matrix and Array Operations, Character and strings, Command- Line Functions, Built-in Functions, Script Files, Function Files, Loops, branches, and control-flow, The Symbolic Math Toolbox, Simple Programs.

Section-III (Three Questions)

Applications of MATLAB: Linear Algebra, Curve Fitting and Interpolation, Data Analysis and Statistics, Numerical Integration, Ordinary Differential Equations, Plotting of Graphs (2-D, 3-D), Handle Graphics, Saving and Printing Graphs.

Books Recommended:

1. **S. Kottwitz**, *LaTeX beginners guide.* Packt Publishing Ltd, 2010.
2. **Datta, Dilip**, *LaTeX in 24 Hours: A Practical Guide for Scientific Writing.* Springer, 2017.
3. **R. Pratap**, *Getting started with MATLAB A quick introduction for Scientists and Engineers*, Vol. 8. 2002.
4. **T. Siauw and A. Bayen**, *An introduction to MATLAB programming and numerical methods for engineers.* 2014.
5. **MathWorks**, Inc. MATLAB: *The Language of Technical Computing. Getting started with MATLAB,* version 7. Vol. 1. MathWorks, Incorporated, 2005.

PHD MAT 103: Review of Literature and Seminar

Max. Marks : 50
Credits : 2

Note: Students shall review 15 to 20 research papers in the field of their interest. The evaluation shall be done by one internal examiner and one external examiner.

PHD MAT 104: Algebraic Coding Theory

Time : 3 hours

Max. Marks : 100
Theory Marks : 80
Internal Marks : 20
Credits : 4

Note: The question paper will contain three sections and eight questions in all. The candidates are required to attempt five questions in all selecting at least one from each section. All questions carry equal marks.

Section-I(Three Questions)

The Coding Problem. Block Codes, Group Codes, Error-Detecting and Error-Correcting Codes, Generator and parity check matrices, Polynomial codes, Hamming codes, Linear codes, Dual Codes, Weight distribution of dual codes. New codes obtained from the given codes.

Section-II(Two Questions)

Finite Fields, BCH Codes, Bounds on Minimum Distance for Block Codes: Plotkin bound, Hamming or Sphere-Packing Bound, Varshamov-Gilbert-Sacks Bound. Bounds for Burst Error-Detecting and Correcting Codes.

Section-III(Three Questions)

Hadamard matrices and Hadamard codes. Maximum Distance Separable(MDS) codes, Generator and parity check matrices of MDS codes, Weight distribution of MDS codes.

Books recommended

1. L.R. Vermani, Elements of Algebraic Coding Theory, Chapman and Hall Mathematics Series, 1996.
2. Raymond Hill, A First Course in Coding Theory, Oxford University Press, 1986.
3. W. Wesley Peterson and E.J. Weldon, Jr., Error-Correcting Codes. M.I.T. Press, Cambridge Massachuetts, 1972.
4. Elwyn R. Berlekamp, Algebraic Coding Theory, World Scientific Publishing Company, 2015.
5. F.J. MacWilliams and N.J.A. Sloane, The Theory of Error-Correcting Codes, North-Holland, 1983.
6. J.H. Van Lint, Introduction to Coding Theory, Graduate Texts in Mathematics, 86, Springer-Verlag Berlin Heidelberg, 1999
7. Man Young Rhee, Error-Correcting Coding Theory, McGraw Hill Inc. New York, 1989.

PHD MAT 105: Advanced Functional Analysis

Time : 3 hours

Max. Marks : 100
Theory Marks : 80
Internal Marks : 20
Credits : 4

Note: The question paper will contain three sections and eight questions in all. The candidates are required to attempt five questions in all selecting at least one from each section. All questions carry equal marks.

Section-I(Three Questions)

Contraction mapping theorem and its applications to differential equations, integral equations and system of linear equations. Equicontinuity, Arzla-Ascoli theorem and its application to differential equations. Weierstrass's approximation theorem, Stone-Weierstrass's approximation theorem, Semi-continuity and its applications to Arclength.

Section-II(Three Questions)

Analytic vector valued functions, Definition of normed and Banach algebras with identity. Regular points and spectrum. Compactness of spectrum. Resolvent function and its analyticity in the set of regular points. Gelfand's theorem about isomorphism between Banach algebras and complex numbers. Spectral radius and the spectral mapping theorem for polynomials. Ideals and Maximal ideals in commutative Banach algebras with identity. The set C(M) of complex functions on the set M of maximal ideals in a Banach algebra. Gelfand representation for algebras with identity.

Section-III(Two Questions)

Bilinear mappings, Bounded bilinear mappings, Sesquilinear mappings, Hermitian form, Bounded sesquilinear mappings, Bounded sesquilinear forms in Hilbert space.

Books recommended

1. Bachman, G. and Lawrerie Narici, Functional Analysis, Academic Press.
2. Goffman, C. and G. Pedrick, First Course in Functional Analysis .
3. Berberian, S.K., Introduction to Hilbert Spaces, (Chelsea Publishing Co. N.Y.).
4. Babu Ram, Metric Spaces, Vinayaka Publications, New Delhi.

PHD MAT 106: Fixed Point Theory

Time : 3 hours

Max. Marks : 100
Theory Marks : 80
Internal Marks : 20
Credits : 4

Note: The question paper will contain three sections and eight questions in all. The candidates are required to attempt five questions in all selecting at least one from each section. All questions carry equal marks.

Section-I(Three Questions)

Banach Contraction Principle (BCP) and some consequences of contraction principle, A converse of contraction principle, Some other extensions of BCP for single valued mappings as given in Section 2.4 of the Book at the Sr. No. 3., Retraction mappings, locally contractive maps, ϵ-chain, (ϵ-k) uniformly locally contractive maps, contractive and ϵ-contractive maps, Edelstein theorems for (ϵ-k) uniformly locally contractive, contractive and ϵ-contractive maps. Contractive mappings as defined by Boyd and Wong, fixed points of local power contraction mapping. Caristi fixed point theorem and its generalization.

Section-II(Three Questions)

Nonexpansive mappings, Some general properties of nonexpansive mappings. Approximation of fixed points of nonexpansive and generalized nonexpansive mappings.

Fixed point property, Brouwer's fixed point theorems and applications, Schauder's fixed point theorem and consequences of Schauder's theorem, Schauder Tychonoff and Krsnoselkii's fixed point theorems.

Section-III(Two Questions)

Some iterative methods for fixed points, The LE property and AF property for nonlinear operators, Demiclose principle, nearly Lipchitzian mappings. Asymptotically κ-strict Pseudocontractive in the intermediate sense, Picard iterative method, Mann iterative method, Ishikawa iterative method, Halpern iterative method, CQ iteration method and Browder iterative method for finding fixed points.

Books recommended

1. Istratescu, V.I., Fixed Point Theory: An Introduction, Mathematics and its applications, Springer, 2003.
2. Joshi, M.C. and Bose, R.K., Some Topics in Non-linear Functional Analysis, Wiley Eastern Limited, New Delhi (1985).
3. Saleh Almezel, Qamrul Hasan Ansari and Mohamed Amine Khamsi, Topics in Fixed Point Theory, Springer, 2014.
4. Ravi P. Agarwal, Maria Meehan and Donal O'Regan, Fixed Point Theory and Applications (Cambridge Tracts in Mathematics), Cambridge University Press, 2009.

PHD MAT 107: Theory of Linear Operators

Time : 3 hours

Max. Marks : 100
Theory Marks : 80
Internal Marks : 20
Credits : 4

Note: The question paper will contain three sections and eight questions in all. The candidates are required to attempt five questions in all selecting at least one from each section. All questions carry equal marks.

Section-I(Three Questions)

Spectral theory in normed spaces, resolvent set and spectrum, Spectral properties of bounded linear operators, Spectral radius of a bounded linear operator on a complex Banach space, Properties of resolvent and spectrum, Spectral mapping theorem for polynomials.

Compact linear operators on normed spaces. Separability of range and spectral properties of compact linear operators on normed spaces, Operator equations involving compact linear operators, Theorems of Fredholm type, Fredholm alternative theorem, Fredholm alternative for integral equations. (Scope as in Chapter 7 and 8 of Book at Sr.No.1).

Section-II(Three Questions)

Spectral properties of bounded self-adjoint linear operators on a complex Hilbert space, Positive Operators, Square roots of a Positive Operator, Projection Operators, Spectral family, Spectral family of a bounded self-adjoint Linear Operator, Spectral representation of bounded Self-adjoint Linear Operators, Extension of the Spectral theorem to continuous functions, Properties of the spectral family of a bounded self-adjoint linear operator.(Scope as in Chapter 9 of Book at Sr.No.1)

Section-III(Two Questions)

Unbounded linear operators and their Hilbert-Adjoint Operators, Hellinger-Toeplitz theorem, Symmetric and self-adjoint linear operators, Closed linear operators and closures, Spectral properties of self-adjoint linear operators, Spectral representation of Unitary operators, Wecken's lemma, Spectral theorem for Unitary operators, Spectral representation of self-adjoint linear operators, Cayley transform, Spectral theorem for self-adjoint linear operators, Multiplication operator and differentiation operator. (Scope as in Chapter 10 of Book at Sr.No.1).

Books recommended

1. E. Kreyszig, Introductory Functional Analysis with Applications, John Wiley and Sons, 1978
2. P. R. Halmos, Introduction to Hilbert Space and the Theory of Spectral Multiplicity, Second Edition, Chelsea Pub. Co., New York, 1957.
3. N. Dunford and J. T. Schwartz, Linear Operator 3 Parts, Interscience / Wiley, New York, 1958-71.
4. G. Bachman and L. Narici, Functional Analysis, Academic Press, New York, 1966.

5. Akhiezer, N. I and I. M. Glazmant : Theory of Linear Operators in Hilbert space, Freerick Ungar, Pub. Co., New York Vol.-I (1961) and Vol.-II (1963).

6. P. R. Halmos, A Hilbert Space Problem Book, Springer, 1982.

7. M. Schecter, Principles of Functional Analysis, Academic Press, Student's Edition, 1971.

PHD MAT 108: Algebraic Number Theory

Time : 3 hours

Max. Marks : 100
Theory Marks : 80
Internal Marks : 20
Credits : 4

Note: The question paper will contain three sections and eight questions in all. The candidates are required to attempt five questions in all selecting at least one from each section. All questions carry equal marks.

Section-I(Two Questions)

Algebraic numbers, algebraic integers, countability of set of algebraic numbers, Liouville's theorem and generalizations, transcendental numbers, algebraic number fields, Liouville's Theorem of Primitive elements, ring of algebraic integers, Theorem of Primitive Elements.
(Chapter 3 of book at Sr. No. 1).

Section-II(Three Questions)

Norm and trace of an algebraic number, non degeneracy of bilinear pairing, existence of an integral basis, Discriminant of an algebraic number field, Ideals in the ring of algebraic integers, explicit construction of integral basis, Sign of the discriminant, cyclotomic fields, calculation for quadratic and cubic cases.
(Chapter 4 of book at Sr. No. 1)

Section-III(Three Questions)

Integral closure, Noetherian ring, characterizing Dedekind domains, fractional ideals and unique factorization, g.c.d. and L.C.M. of Ideals, Chinese remainder theorem, Dedekind's theorem, ramified and unramified extensions. Different of an algebraic number field, factorization in the ring of algebraic integers.
(Chapter 5 of book at Sr. No. 1)

Books recommended

1. Esmonde and M Ram Murty, Problems in Algebraic Number Theory, GTM Vol. 190, Springer Verlag, 1999.
2. Leveque, W.J., Topics in Number Theory Vols. I, III Addition Wesley.
3. Narasimhan and others, Algebraic Number Theory, TIFR Pamphlet No. 4
4. Pollard, H., The Theory of Algebraic Number, Carus Monogrpah No. 9, Mathematical Association of America.
5. Riebenboim, P., Algebraic Numbers Wiley Inter-science.
6. Weiss, E., Algebraic Number Theory, McGraw Hill.

PHD MAT 109: Advanced Solid Mechanics

Time : 3 hours

Max. Marks : 100
Theory Marks : 80
Internal Marks : 20
Credits : 4

Note: The question paper will contain three sections and eight questions in all. The candidates are required to attempt five questions in all selecting at least one from each section. All questions carry equal marks.

Section-I(Three Questions)

Non-Linear Theory

Deformation gradient tensor. Decomposition of a deformation stretch and rotation. Strain tensors. Strain-displacement relations. Principal stretches. Strain invariants. Length and angle changes. Deformation of volume and surface elements.

Homogeneous deformation-dilation, simple extension, simple shear and plane strain.

Material derivative. Velocity and acceleration fields. Principle of conservation of mass-equation of continuity. Principles of balance of linear and angular momentum. Equations of motion in spatial coordinates. Principle of conservation of energy. Piola stresses. Equations of motion in material co-ordinates.

Section-II(Three Questions)

General Solution of the equilibrium equations

Papkovitch-Neuber solution. Lame's strain potential. Galerkin vector. Love's strain function. Applications to the solution of the Kelvin problem for an unbounded medium and the Boussinesq problem for a semi-infinite medium.

Exact solution of some linear elastic problems

Spherical shell subject to internal and external pressures. Gravitating elastic sphere.

Section-III(Two Questions)

Thermoelasticity

Generalized Hooke's law including the effects of thermal expansion, Thermoelastic Navier's equation, Thermal stresses in a long cylindrical shell and solid cylinder, Thermal stresses in a hollow spherical shell and solid spherical shell.

Books recommended

1. Mal. A.K. and Singh, S.J., Deformation of Elastic Solids, Prentice Hall, 1991
2. Fung, Y.C., Foundations of Solid Mechanics.
3. S. Valliappan, Continuum Mechanics - Fundamentals, Oxford and IBH Publishing Co., 1981
4. I.S. Sokolnikoff- Mathematical Theory and Elasticity, Tata McGraw Hill, New Delhi, 1977
5. S. Saada, A.S. Elasticity: Theory and Applications, Pergaman Press, 1973.

PHD MAT 110: Waves and Viscoelasticity

Time : 3 hours **Max. Marks : 100**
Theory Marks : 80
Internal Marks : 20
Credits : 4

Note: The question paper will contain three sections and eight questions in all. The candidates are required to attempt five questions in all selecting at least one from each section. All questions carry equal marks.

Section-I(Two Questions)

Waves on Strings

Free vibrations of an infinite string. Reflection at a change of density. Reflection at a concentrated load. Strings of finite length-normal modes. String plucked at its mid-point. String with load at its mid point. (Coulson: Waves, Secs. 13-23).

Lamb's Problem : A periodic line or normal point force acting on the surface of a semi-infinite elastic solid (formal solution only).

Section-II(Three Questions)

Liquid Waves

Types of liquid waves, Gravity waves, Particle path, Waves in deep water, Wave energy, Rate of transmission of energy for harmonic wave, Group velocity, Effect of surface tension, Stationary waves, Waves in a canal, rectangular tank, cylindrical tank. Complex potential for a simple harmonic progressive wave, Waves on the surface of a uniform stream, Waves at the interface between fluids and effect of surface tension, Circular waves.

Section-III(Three Questions)

Viscoelasticity

Spring and dashpot. Maxwell and Kelvin models. Three parameter solid. Constitutive equations for generalized Maxwell and Kelvin models. Creep compliance and relaxation modulus. Hereditary integrals. Vibrations-complex compliance, dissipation, application to specific materials, the simple spring-mass system, forced vibrations. Stress-strain relations for viscoelastic body. Correspondence principle and its application to the deformation of a viscoelastic thick-walled tube in plane strain. (Relevent Sections of Flugge's book "Viscoelasticity").

Books recommended

1. Atkin, R.J. and Fox, N. An Introduction to the Theory of Elasticity.
2. Bath, M., Mathematical Aspects of Seismology, Elsevier.
3. Ben-Menahem, A. and Singh, S.J. Seismic Waves and Sources, Springer
4. Bullen, K.E. and Bolt, A. An Introduction to the Theory of Seismology, Cambridge University Press.

5. Coulson, C.A., Waves, Longman.

6. Flugge, W., Viscoelasticity.

7. Fung, Y.C., Foundations of Solid Mechanics.

8. Besant, W. H. and Ramsey, A. S., A Treatise on Hydromechanics.

PHD MAT 111: Reliability Theory

Time : 3 hours

Max. Marks : 100
Theory Marks : 80
Internal Marks : 20
Credits : 4

Note: The question paper will contain three sections and eight questions in all. The candidates are required to attempt five questions in all selecting at least one from each section. All questions carry equal marks.

Section-I(Three Questions)

Reliability and Quality. Failure Data Analysis: Failure data, Failure density, Failure rate.
Some Important distributions: Exponential, Rayleigh, Weibull, Gamma and Lognormal distributions.
Laplace and Stieltjes transforms and convolutions.
Component Reliability and Hazard Models: Component reliability from test data, Mean time to failure (MTTF), Mean time between failures (MTBF), Time dependent hazard models, Bath-Tub Curve.

Section-II(Two Questions)

System Reliability Models: Systems with components in series, Systems with parallel components, k-out-of-m systems, Non-series parallel systems, Systems with mixed mode failures.
Standby redundancy: Simple standby system, k-out-of-n standby system.

Section-III(Three Questions)

Maintainability and Availability: Maintainability function, Availability function, Reliability and availability analysis of a two-unit parallel system with repair using Markov model, Reliability and availability analysis of single-unit and two- unit cold standby systems with constant failure and repair rates using regenerative point and supplementary variable techniques.

Economics of Reliability Engineering: Manufactures cost, Customers cost, Reliability achievement and utility cost models, Depreciation cost models and availability cost model for parallel system.

Books recommended

1. E. Balagurusami, Reliability Engineering, Tata McGraw Hill, New Delhi, 1984.
2. L. S. Srinath, Reliability Engineering, Affiliated East West Press, New Delhi, 1991.
3. Elsayed A. Elsayed, Reliability Engineering, Addison Wesley Longman. Inc. Publication
4. A. Birolini, Reliability Engineering: Theory and Practical, Springer-Verlag.
5. Jai Singh Gurjar, Reliability Technology, I.K. International Publishing House Pvt. Ltd.
6. Charles E Ebeling, An Introduction to Reliability and Maintainability Engineering, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2000.

PHD MAT 112: Inventory Management

Time : 3 hours **Max. Marks : 100**
Theory Marks : 80
Internal Marks : 20
Credits : 4

Note: The question paper will contain three sections and eight questions in all. The candidates are required to attempt five questions in all selecting at least one from each section. All questions carry equal marks.

Section-I(Two Questions)

Introduction: The Historical Development, Nature and Meaning of Operations Research and its Management Applications. Modelling in Operations Research and its Principles. Approximations and Main Characteristics of Operations Research. General Methods for solving Operations Research Models. Main Phases of Operations Research Study. Scope of Operations Research. Role of Operations Research in Decision-Making. Brief outlines of Operations Research-Models: Quantitative Techniques. Development of Operations Research in India. Role of Computers in Operations Research.

Section-II(Three Questions)

Inventory/Production Management-I (Deterministic Inventory Models): Inventory -Definition, Decisions. Types of Inventory Models and their Development. Costs involved and Variables in Inventory Problems. Deterministic Elementary Inventory Models: Static Demand Models, Dynamic or Fluctuating Demand Models and Deterministic Models with Price-Breaks.

Section-III(Three Questions)

Inventory/Production Management-II (Probabilistic Inventory Models and ABC Analysis): Probabilistic Inventory Models, Selective Inventory Management, Replacement and Reliability Models.

Books recommended

1. H. A. Taha, Operations Research-An Introduction, Prentice Hall, 2010.
2. P. K. Gupta and D.S. Hira, Operations Research, S. Chand and Co. Ltd., 2014.
3. S. D. Sharma, Operations Research, Kedar Nath Ram Nath Publications, 2012.
4. J. K. Sharma, Mathematical Models in Operations Research, Tata McGraw-Hill Publishing Company Ltd., 1989.
5. Kanti Swarup, P. K. Gupta and ManMohan, Operations Research, Sultan Chand and Sons, New Delhi, 2014.
6. Ravinderan, Philips and Soleberg, Operations Research-Principles and Practice, John Wiley & Sons, Pvt. Ltd., 2007.