Curriculum and Credit Framework

For

Ph.D. (Mathematics)

(To be effective from the Academic Session 2024-25)

Department of Mathematics

Gurugram University, Gurugram

(A State Govt. University Established Under Haryana Act 17 Of 2017)

Scheme of Programme

Ph.D. MATHEMATICS

Course Work Structure for Ph.D. Degree in Mathematics

Course Code	Course Title	Course ID	Teaching Hours per week	Credits	Marks (T.I.+ T.E.)
Core Course(s)					
CC-01	Research Methodology	24/MAT/CW/CC/01	4	04	30+70
CC-02	Research Publication and Ethics	24/MAT/CW/CC/02	2	02	15+35
Specific Elective Courses					
EC-01	Tensor and Background of Cosmology	24/MAT/CW/EC/01	4	04	30+70
EC-02	Robotics and Control Theory	24/MAT/CW/EC/02	4	04	30+70
EC-03	Mathematical Modeling in Seismology	24/MAT/CW/EC/03	4	04	30+70
EC-04	Fractional Calculus and its Application	24/MAT/CW/EC/04	4	04	30+70
EC-05	Fixed Point Theory	24/MAT/CW/EC/05	4	04	30+70
Term paper Courses					
TP-01	Seminar	24/MAT/CW/TP/01	Seminar Based	02	50
TP-02	Review of Literature	24/MAT/CW/TP/02	Assignment Based	02	50
Total Credits				14	350

Marks will be converted into letter grades and grade points as per the following table:

Marks	Letter Grade	Grade Point
85-100	O	10
75-84	A^+	9
65-74	A	8
55-64	B^+	7
50-54	B	6
41-49	C	5
40	P	4
Less than 40	F	0

Example to calculate the Grade Point Average (GPA)

Course	Credit	Letter Grade	Grade Point	Credit Point
Research Methodology	4	A	8	4x8=32
Research Publication and Ethics	2	A^+	9	2x9=18
Specific Elective Courses	4	A	8	4x8=32
Seminar in Thrust Area of Research	2	B	6	2x6=12
Review of Literature	2	A	8	2x8=16
Total	14			110

A candidate must obtain a minimum grade point of 7 on each paper and a minimum GPA of 7 to qualify for the coursework.

CORE COURSES

Name of Course	Research Methodology	
Credits: 04	**Total Max. Marks: 100** **Theory Internal: 30** **Theory External: 70**	**Theory Exam Duration:** 3 Hrs

COURSE SYLLABUS

Note: Eight questions will be set, two from each of the sections I, II, III & IV. The candidates are required to attempt five questions in all, selecting at least one question from each section. All questions shall carry equal marks.

Section	Contents	Contact Hrs
I	Meaning, objectives and motivations in research, Characteristics and limitations of research, Components of research work, Criteria of good research, Research process, Types of Research, Fundamental, Pure or Theoretical Research, Applied Research, Descriptive Research, Evaluation Research, Experimental Research, Survey Research, Qualitative Research, Quantitative Research, Historical Research; Research problem: Selecting and analyzing the research problem, problem statement formulation, formulation of hypothesis, Literature review: purpose, sources, and importance - literature review procedure. Objectives: Learning Objectives; Definitions; Formulation of the research objectives.	15
II	Variables in Research, Measurement and scaling, Different scales, Construction of instrument, Validity and Reliability of instrument. Data Collection methods: primary and secondary data, Construction of questionnaire and instrument, validation of instruments. Sample size determination, Sample design and sampling techniques. Processing of Data: Editing of Data, Coding of Data, Classification of Data, Statistical Series.	15
III	Qualitative vs Quantitative data analyses: Univariate, Bivariate and Multivariate statistical techniques, Introduction to Excel, Data handling and plotting in Excel, Plotting software (at least one), Measures of Central Tendency, Dispersion, correlation and Regression, Chi-square test: Applications, Steps, characteristics, limitations, Analysis of Variance and Covariance, Factor analysis, Discriminant analysis, cluster analysis, multiple regression and correlation, multidimensional scaling, Conjoint Analysis, Application of statistical software for data analysis.	15

IV	Research report: Different types, Contents of report, executive summary, contents of chapter, report writing, the role of audience, readability, comprehension, tone, final proof, report format, title of the report, Ethical issues in research: Code of Ethics in Research: Ethics and Research Process, Importance of Ethics in Research; Formal Methods: Formal Specification, Algorithm, and Complexity; Building Artefacts: Proof of Performance, Proof of Concept, and Proof of Existence; Process Methodology: Methods for Software Engineering and Human-Computer Interaction, Cognitive Processes, Interactive Games, Social Networks, and Web Analytics. Introduction to Latex, Elementary Latex syntax, Paper and thesis writing using Latex	15

Suggested Books

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. Suresh C. Sinha and Anil K. Dhiman, Research Methodology, Ess Publications, New Delhi, 2002
4. C. R. Kothari, Research Methodology, New Age International Publishers, 2004.

CORE COURSES

Name of Course	Research Publication and Ethics	
Credits: 02	**Total Max. Marks: 50** **Theory Internal: 15** **Theory External: 35**	**Theory Exam Duration:** 2 Hrs
COURSE SYLLABUS		
Note:		

Section	Contents	Contact Hrs
	Theory	
I	**Philosophy and Ethics:** 1. Introduction to philosophy: definition, nature and scope, concept, branches 2. Ethics: definition, moral philosophy, nature of moral judgment and reactions	3
II	**Scientific Conduct:** 1. Ethics with respect to science and research 2. Intellectual honesty and research integrity 3. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP) 4. Redundant publications: duplicate and overlapping publications, salami slicing 5. Selective reporting and misrepresentation of data	5
III	**Publication Ethics:** 1. Publication ethics: definition, introduction, and importance 2. Best practices/standards setting initiatives and guidance: COPE, WAME, etc. 3. Conflicts of interest 4. Publication misconduct: definition, concept, problems that lead to unethical behavior and vice versa, types 5. Violation of publication ethics, authorship, and contributorship 6. Identification of publication misconduct, complaints, and appeals 7. Predatory publishers and journals	7
	Practice	
IV	**Open Access Publishing:** 1. Open-access publications and initiatives 2. SHERPA/RoMEO online resource to check publisher copyright & self-archiving policies 3. A software tool to identify predatory publications developed by SPPU 4. Journal finder/journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer, Journal Suggester, etc.	4

V	**Publication Misconduct**: A. Group Discussion (2 hrs) 1. Subject-specific ethical issues, FFP, authorship 2. Conflicts of interest 3. Complaints and appeals: examples of fraud from India and abroad B. Software tools (2 hrs) 1. Use of plagiarism software like Turnitin, Urkund, and other open-source software tools	4
VI	**Databases and Research Metrics**: A. Databases (4 hrs) 1. Indexing databases Research Metrics 2. Citation databases: Web of Science, Scopus, etc. B. Research Metrics (3 hrs.) 1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IIP, Cite Score 2. Metrics: h index, g index, i10 index, altmetrics	7

Suggested Books

1. Bird, A. (2006). Philosophy of Science. Routledge
2. MacIntyre, Alasdair (1967) A Short History of Ethics. London
3. P. Chaddah, (2018) Ethics in Competitive Research: Do not get scooped; do not get plagiarized, ISBN:978-9387480865
4. National Academy of Sciences, National Academy of Engineering and Institute of
5. Medicine. (2009). On Being a Scientist: A Guide to Responsible Conduct in Research: Third Edition. National Academics Press.
6. Resnik, D. B. (2011). What is ethics in research and why is it important. National Institute of Environmental Health Sciences, 1-10. Retrieved from https://www.neihs.nih.gov/research/resources/bioethics/whatis/index.cfm
7. Beall, J. (2012). Predatory publishers are corrupting open access. Nature, 489 (7415), 179-179. https://doi.org/10.1038/489179a
8. Indian National Science Academy (INSA), Ethics in Science Education, Research and Governance (2019), ISBN:978-81-939482-1-7. 1956

Specific Elective Courses

Name of Course	Tensor and Background of Cosmology	
Credits: 04	**Total Max. Marks: 100** **Theory Internal: 30** **Theory External: 70**	**Theory Exam Duration:** 3 Hrs

COURSE SYLLABUS

Note: Eight questions will be set, two from each of the sections I, II, III & IV. The candidates are required to attempt five questions in all, selecting at least one question from each section. All questions shall carry equal marks.

Section	Contents	Contact Hrs
I	**Tensor and Mathematical Foundations** Introduction to Tensor: Types of tensor (covariant and contravariant tensors). Tensor transformations. Symmetric and skew-symmetric tensors. Covariant and contravariant differentiation of tensor. Christoffel symbols: Definitions, Ricci tensor and Ricci scalar, Covariant differentiation of the Riemann tensor.	15
II	**Special Theory of Relativity:** Inertial and non-inertial frames of reference, Galilean and Lorentz transformations, Transformation of physical quantities (Mathematical equations and physical implications only): Mass, density, momentum, force, and energy, Four-vectors and tensors in Minkowski space.	15
III	**General Theory of Relativity:** Principles of equivalence and general covariance. Mach's Principle and its cosmological implications. Space-time geometry (FLRW, Bianchi type, Plane symmetric, non-statics spacetime etc): Basics and significance. Christoffel symbols of first and second kind. Ricci tensors. Energy-momentum tensors and their role in gravitational theory. Gravitational equations and Einstein's field equations. Solutions to Einstein's equations. Expanding universe and cosmological redshift.	15
IV	**Background of Cosmology: Historical and theoretical foundations of the observed universe.** Principles of equivalence and general covariance. Theoretical Study of the Universe: The expansion (Hubble diagram) and Hubble's Law. Isotropy and homogeneity: Assumptions of large-scale structure. Age of the Universe: Insights from cosmological data. Static and Dynamic Cosmological Models: Models with non-zero cosmological constant. The Friedmann models and their implications. The early Universe and the inflationary phase. Singularities in Cosmological Models: Mathematical and physical implications. Astrophysical Phenomena: accelerating universe, dark energy, and dark matter. Alternative Cosmologies: Theoretical challenges to standard models.	15

Suggested Books

1. U.C. De, Absos Ali Shaikh, Joydeep Sengupta, Tensor Calculus, Narosa Publications, 2005.
2. Zafar Ahsan, Tensors: Mathematics of Differential Geometry & Relativity, PHI Learning Pvt. Ltd., 2015.
3. I.S. Sokolnikoff, Tensor Analysis: Theory and Applications to Geometry and Mechanics of Continua, Second Edition, John Wiley & Sons, Inc.
4. Farook Rahaman, The Special Theory of Relativity: A Mathematical Approach, Springer India, 2014.
5. S.K. Srivastava, General Relativity & Cosmology, PHI Learning Pvt. Ltd., 2008.
6. J.V. Narlikar, An Introduction to Relativity, Cambridge University Press, 2010.
7. S.M. Carroll, Spacetime and Geometry: An introduction to general relativity, Addison-Wesley Longman, 2004.
8. R.M. Wald, General Relativity, Overseas Press (India), 2006.
9. J.V. Narlikar, An introduction to Cosmology, Cambridge University Press, 2002.
10. S. Weinberg, Cosmology, Oxford University Press, 2008.

Name of Course	Robotics and Control Theory	
Credits: 04	**Total Max. Marks: 100** **Theory Internal: 30** **Theory External: 70**	**Theory Exam Duration:** 3 Hrs

COURSE SYLLABUS

Note: Eight questions will be set, two from each of the sections I, II, III & IV. The candidates are required to attempt five questions in all, selecting at least one question from each section. All questions shall carry equal marks.

Section	Contents	Contact Hrs
I	**Robotic Manipulation:** Robot Classification, Robot specification. **Direct Kinematics:** Dot and cross products, coordinate frames, rotation, homogenous coordinates, link coordinates, And arm equation. **Inverse Kinematics:** General properties of solutions, Tool configuration.	15
II	**Workspace and Trajectory Planning:** Workspace Analysis, Workspace Fixtures, The pick-and-place operation, Continuous-path Motion, Interpolated Motion, Straight-line motion. **Differential Motion and Statics:** The Tool-configuration Jacobian matrix, The joint-space singularities, The manipulator Jacobian, Induced joint torques and forces.	15
III	**Manipulator Dynamics:** Lagrange's Equation, Generalized Force, Lagrange-Euler Dynamic Model, Recursive Newton-Euler formulation, Direct and Inverse Dynamics, Problem.	15
IV	**Robot Control:** The Control Problem, State Equations, Constant solutions, PD-gravity Control, Computed-Torque Control, Variable-structure Control, Impedance Control.	15

Suggested Books

1. Robert J. Schilling, Fundamentals of Robotics: Analysis and Control, Pearson Education Inc, 1990.
2. Angeles, Jorge, ed. Fundamentals of robotic mechanical systems: theory, methods, and algorithms. New York, NY: Springer New York, 2003.
3. Herath D, St-Onge D. Foundations of robotics: a multidisciplinary approach with Python and ROS. Springer Nature; 2022.
4. Craig JJ. Introduction to robotics. Pearson Educacion; 2006.

Name of Course	Mathematical Modeling in Seismology	
Credits: 04	**Total Max. Marks: 100** **Theory Internal: 30** **Theory External: 70**	**Theory Exam Duration:** 3 Hrs

COURSE SYLLABUS

Note: Eight questions will be set, two from each of the sections I, II, III & IV. The candidates are required to attempt five questions in all, selecting at least one question from each section. All questions shall carry equal marks.

Section	Contents	Contact Hrs
I	**Introduction to Seismology:** Earthquakes, location of earthquakes, causes of earthquakes, observation of earthquakes, aftershocks and foreshocks, earthquake magnitude, seismic moment, energy released by earthquakes, interior structure of the Earth. **Waves:** General form of progressive waves, harmonic waves, plane waves, the wave equation, Principle of superposition, progressive and stationary type solutions of wave equation, solutions of the wave equation in Cartesian, Cylindrical, and Spherical coordinate systems, equation of telegraphy, exponential form of harmonic waves, D'Alembert's formula, inhomogeneous wave equation, Dispersion: Group velocity, relation between phase velocity and group velocity.	15
II	**Reduction of the Equation of Motion to Wave Equations:** Derivation of wave equations from the equations of motion, P-waves and S-waves, their characteristics and differences in propagation, polarization of plane P-waves and S-waves. **Snell's Law:** Reflection and refraction of seismic waves at boundaries, reflection of plane P-waves and SV-waves at a free surface, partition of reflected energy, reflection at critical angles.	15
III	**Spherical waves:** Expansion of a spherical wave into plane waves: Sommerfield's integral. Kirchoff's solution of the wave equation, Poissons's formula, Helmholtz's formula. **Heat Conduction in Seismology:** Heat conduction modeling and its relation to seismic wave propagation, thermal diffusion in the Earth's crust and its influence on seismic velocity and wave attenuation, the heat equation in 1D, 2D, and 3D, impact of thermal gradients on seismic waves, particularly in volcanic regions and subduction zones.	15
IV	**Reflection and Refraction at Material Interfaces:** Reflection and refraction of seismic waves at liquid-liquid, liquid-solid, and solid-solid interfaces, special cases of seismic wave interaction at various material boundaries. **Surface Waves:** Rayleigh waves, Love waves, and Stoneley waves, as well as their characteristics, propagation, and mathematical modeling.	15

Suggested Books

1. C.A. Coulson and A. Jefferey, *Waves*, Longman, New York, 1977.
2. M. Bath, *Mathematical Aspects of Seismology*, Elsevier Publishing Company, 1968.
3. W.M. Ewing, W.S. Jardetzky and F. Press, *Elastic Waves in Layered Media*, McGraw Hill Book Company, 1957.
4. T. L. Bergman, A S. Lavine, F.P. Incropera, & D.P. DeWitt, *Introduction to heat transfer*. John Wiley & Sons, 2011.
5. C.M.R. Fowler, *The Solid Earth*, Cambridge University Press, 1990
6. P.M. Shearer, *Introduction to Seismology*, Cambridge University Press,(UK) 1999.
7. K. E. Bullen, B. A. Bolt, *An Introduction to the theory of Seismology*, 4th Edi., 1985.

Name of Course	Fractional Calculus and its Application	
Credits: 04	**Total Max. Marks: 100** **Theory Internal: 30** **Theory External: 70**	**Theory Exam Duration:** 3 Hrs

COURSE SYLLABUS

Note: Eight questions will be set, two from each of the sections I, II, III & IV. The candidates are required to attempt five questions in all, selecting at least one question from each section. All questions shall carry equal marks.

Section	Contents	Contact Hrs
I	Brief review of Special Functions of the Fractional Calculus, Definition of Mittag-Leffler Functions of one and two parameters, Relations of Mittag-Leffler Function to some other functions, The Laplace transform of Mittag-Leffler Function in two parameters. Wright Function, Definition of Wright function, Integral relation and relation to other functions, Miller Ross function.	15
II	Fractional derivatives, Riemann-Liouville fractional derivatives, Riemann-Liouville left& right-sided derivative, Leibnitz's Formula of Fractional Derivatives. Laplace transform of fractional derivatives, Fourier transform of fractional derivatives and Mellin transform of fractional derivatives. Fractional derivatives of standard functions Left and right fractional derivatives.	15
III	Definition of Weyl Fractional Integral, Weyl Fractional Derivatives, A Leibniz Formula for Weyl Fractional Integral and simple applications. Definition Caputo Fractional Derivative, Leibnitz's formula for Caputo fractional derivative, Laplace transform of Caputo fractional derivative, Difference between Caputo fractional derivative and R-L fractional derivative.	15
IV	Caputo-Fabrizio fractional derivative. Fractional differential equation of a general form.existence and uniqueness theorem as a method of solution. Solutions of the homogeneous and nonhomogeneous fractional differential equations, Reduction of fractional partial differential equations to ordinary differential equations.	15

Suggested Books

1. Miller K.S. and Ross B., An Introduction to the Fractional Differential Equations, John Wiley and Sons, 1993.
2. Samko S.G., Kilbas A.A., Marichev O.I., Fractional Integrals and Derivatives, Gordon and Breach Science Publishers, 1987.
3. Oldham K.B. and Spanier J., The Fractional Calculus, Academic Press Inc., 1974.
4. Kilbas A.A., Srivastava H.M., Trujillo J.J., Theory and Applications of Fractional Differential Equations, Elsevier, 2006.
5. Podlubny I., Fractional Differential Equation, Academic Press Inc., 1999.

Name of Course	Fixed Point Theory	
Credits: 04	**Total Max. Marks: 100** **Theory Internal: 30** **Theory External: 70**	**Theory Exam Duration:** 3 Hrs

COURSE SYLLABUS

Note: Eight questions will be set, two from each of the sections I, II, III & IV. The candidates are required to attempt five questions in all, selecting at least one question from each section. All questions shall carry equal marks..

Section	Contents	Contact Hrs
I	Banach Contractions Principle and some consequences of Contraction Principle, A converse of contraction Principle. Retraction mappings, Computation of fixed points of locally Contractive, $\varepsilon -$ Contractive and Contractive mappings as defined by Boyd and Wong, Caristi Fixed Point Theorem.	15
II	Fixed points of local power Contraction, Local radial Contraction and Hardy Roger's type mappings in a Complete metric space, Convex Contraction of order n. Fixed Points and Set-Valued Mappings. Hyper convex Spaces. Non expansive mappings, Some general properties of non-expansive mappings. Approximation of Fixed Points of non-expansive and generalized non-expansive mappings.	15
III	Normal Structure, Some general properties of non-expansive mappings in Hilbert and Banach spaces, Fixed points of Pseudo Contractive, Quasi non-expansive and asymptotically non-expansive mappings. Fixed point Theorems for mappings on PM spaces, Contraction mappings in PM spaces.	15
IV	(ε, λ) Chainable mappings Probabilistic Measure of Non-Compactness, sequence of mappings and fixed points. 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.	15

Suggested Books

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.

Term Paper Courses

Name of Course	Seminar	
Credits: 02	**Total Max. Marks:** 50	**Seminar Duration:** 01 Hr
COURSE SYLLABUS		
Section	**Contents**	**Contact Hrs**
I	Each candidate will deliver a seminar on the chosen subject areas and a report before the departmental research committee.	**30**

Name of Course	Review of Literature	
Credits: 02	**Total Max. Marks:** 50	

COURSE SYLLABUS

Section	Contents	Contact Hrs
I	Each candidate shall submit three copies (hard bound) of a review article with at least 30 relevant up-to-date references on a topic assigned by the proposed supervisor based on published works. Candidates will ensure plagiarism by using plagiarism checker and will submit the similarity index (not more than 10%) report along with hard bound review.	30