Four Year Undergraduate Program (FYUGP), 2023-24
(Old Syllabus)

MATHEMATICS SYLLABUS

Minor Courses

SEM	Paper Code	Paper Level	Paper	Paper Description	Paper Type	Full Marks		Credit		Page No.
						TH	TU	L	T	
I	UMATMIN10001	100	MIN	Classical and Linear Algebra	TH	60	15	3	1	
II	UMATMIN10001	100	MIN	Classical and Linear Algebra	TH	60	15	3	1	
III	UMATMIN20002	200	MIN	Calculus, Geometry and Group Theory	TH	60	15	3	1	
IV	UMATMIN20002	200	MIN	Calculus, Geometry and Group Theory	TH	60	15	3	1	
V	UMATMIN30003	200	MIN	Differential Equations and Integral Transforms	TH	60	15	3	1	
VI	UMATMIN30003	200	MIN	Differential Equations and Integral Transforms	TH	60	15	3	1	
VIi	UMATMIN40004	300	MIN	Real Analysis and Vector Calculus	TH	60	15	3	1	
VII	UMATMIN40004	300	MIN	Real Analysis and Vector Calculus	TH	60	15	3	1	

Prof. Manoranjan Singha
Chairperson
UG-BOS in Mathematics, NBU

DETAILED SYLLABUS

of

MINOR COURSES

(semester wise)

Semester-1												
Paper Description	Classical And Linear Algebra		**Paper Code**				UMATMIN10001				
Paper (Type)	Minor Course (Theory)		**Credit**				**Marks**				
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**PRC**	**CE**	**ATT**	**Total**
100	4 Hours/week	2 Hr. 30 Min	3	1	--	4	60	---	10	5	75

CLASSICAL AND LINEAR ALGEBRA

Classical Algebra

Unit 1: **10 classes**

Complex numbers: Polar representation, De Moivre's theorem for rational indices and its applications. Trigonometric, logarithm, exponential and hyperbolic functions of complex variable.

Unit 2: **15 classes**

Theory of equations: Fundamental theorem of Classical Algebra (statement only), relation between roots and coefficients, symmetric functions of roots, transformation of equation, Descartes' rule of signs, Sturms' theorem, cubic equation (Cardan's method), biquadratic equation (Ferrari's method).

Unit 3: **5 classes**

Inequality: $AM \geq GM \geq HM$, theorem of weighted means and m-th power theorem (statement only), Cauchy-Schwartz inequality (statements only) and its application.

Linear Algebra

Unit 4: **15 classes**

Matrices: Inverse of a matrix, characterizations of invertible matrices, elementary operations and matrices, echelon matrix, row/column reduced echelon matrix, rank of matrix, normal forms, equivalency and congruency of matrices.

Unit 5: **10 classes**

Systems of linear equations: Consistency in equivalence system, Solution of homogeneous system AX=O, Solution of nonhomogeneous system AX=B using row reduced echelon form.

Unit 6: **5 classes**

Eigen values and eigen vectors of a square matrix, characteristic equation of a matrix, Cayley-Hamilton theorem, and its use in finding the inverse of a matrix.

Suggested Reading Books:

1. S. Lang, Introduction to Linear Algebra, *Springer.*
2. S.K. Mapa, Higher Algebra: Classical, *Levant.*
3. S.K. Mapa, Higher Algebra: Abstract & Linear, *Levant*.
4. W.S. Burnstine and A.W. Panton, Theory of equations, *Creative Media.*
5. S.H. Friedberg, A.J. Insel and L.E. Spence, Linear Algebra, *Pearson Edu. Pub. (Indian).*
6. K. Hoffman and R. Kunze, Linear algebra, *Prentice Hall India.*
7. T. Andreescu and D. Andrica, Complex Numbers from A to Z, *Birkhause.*
8. V. Sahai and V. Bist, Linear Algebra, *Narosa Pub. House.*

Semester-2												
Paper Description	Classical And Linear Algebra		**Paper Code**				UMATMIN10001				
Paper (Type)	Minor Course (Theory)		**Credit**				**Marks**				
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**PRC**	**CE**	**ATT**	**Total**
100	4 Hours/week	2 Hr. 30 Min	3	1	--	4	60	---	10	5	75

CLASSICAL AND LINEAR ALGEBRA

Classical Algebra

Unit 1: **10 classes**

Complex numbers: Polar representation, De Moivre's theorem for rational indices and its applications. Trigonometric, logarithm, exponential and hyperbolic functions of complex variable.

Unit 2: **15 classes**

Theory of equations: Fundamental theorem of Classical Algebra (statement only), relation between roots and coefficients, symmetric functions of roots, transformation of equation, Descartes' rule of signs, Sturms' theorem, cubic equation (Cardan's method), biquadratic equation (Ferrari's method).

Unit 3: **5 classes**

Inequality: $AM \geq GM \geq HM$, theorem of weighted means and m-th power theorem (statement only), Cauchy-Schwartz inequality (statements only) and its application.

Linear Algebra

Unit 4: **15 classes**

Matrices: Inverse of a matrix, characterizations of invertible matrices, elementary operations and matrices, echelon matrix, row/column reduced echelon matrix, rank of matrix, normal forms, equivalency and congruency of matrices.

Unit 5: **10 classes**

Systems of linear equations: Consistency in equivalence system, Solution of homogeneous system AX=O, Solution of nonhomogeneous system AX=B using row reduced echelon form.

Unit 6: **5 classes**

Eigen values and eigen vectors of a square matrix, characteristic equation of a matrix, Cayley-Hamilton theorem, and its use in finding the inverse of a matrix.

Suggested Reading Books:

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2. S.K. Mapa, Higher Algebra: Classical, *Levant.*
3. S.K. Mapa, Higher Algebra: Abstract & Linear, *Levant*.
4. W.S. Burnstine and A.W. Panton, Theory of equations, *Creative Media.*
5. S.H. Friedberg, A.J. Insel and L.E. Spence, Linear Algebra, *Pearson Edu. Pub. (Indian).*
6. K. Hoffman and R. Kunze, Linear algebra, *Prentice Hall India.*
7. T. Andreescu and D. Andrica, Complex Numbers from A to Z, *Birkhause.*
8. V. Sahai and V. Bist, Linear Algebra, *Narosa Pub. House.*

Semester-3											
Paper Description	Calculus, Geometry and Group Theory		**Paper Code**				UMATMIN20002				
Paper (Type)	Minor Course (Theory)		**Credit**				**Marks**				
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**PRC**	**CE**	**ATT**	**Total**
200	4 Hours/week	2 Hr. 30 Min	3	1	-- -	4	60	---	10	5	75

CALCULUS, GEOMETRY AND GROUP THEORY

Calculus:

Unit 1: **10 classes**

Reduction formulae, derivations and illustrations of reduction formulae of the type $\int sin^n x\, dx, \int \cos^n x\, dx, \int \sec^n x\, dx, \int \tan^n x\, dx,\ \int (logx)^n\, dx,\ \int \sin^n x \cos^m x\, dx$ etc. Successive derivatives, Leibnitz rule and its applications. Indeterminate forms, L'Hospital's rule and it's applications.

Unit 2: **13 classes**

Volume and surface areas of solids formed by revolution of known plane curves and areas (simple problems only). Concept of parameterizations of a curve. Envelopes, asymptotes, radius of curvature. Concavity, convexity, and inflection points.

Geometry:

Unit 3: **13 classes**

2D: Rotation of axes and second-degree equations, pair of straight lines, classification of conics using the discriminant, polar equations of conics.

Unit 4: **13 classes**

3D: Spheres, cylindrical surfaces, cones, ellipsoids, paraboloids, hyperboloids, classification of quadrics.

Group Theory:

Unit 5: **11 classes**

Equivalence relations, functions, permutations, even and odd permutations. Definitions and examples of Groups, finite and infinite groups, commutative groups. Elementary properties of groups. Some well-known groups: $\mathbb{Z}_n$, U_n, $M_n(R)$, Klein's 4-group, multiplicative group of n-th roots of unity, symmetric group S_n etc. Definition and examples of subgroup. Statement of necessary and sufficient condition for a subset of a group to be a subgroup and its simple applications.

Suggested Reading Books:

1. G.B. Thomas and R.L. Finney, Calculus, Pearson Education, Delhi.
2. M.J. Strauss, G. L. Bradley, and K. J. Smith, Calculus, Pearson Education, Delhi.
3. H. Anton, I. Bivens and S. Davis, Calculus, John Wiley and Sons (Asia) P. Ltd., Singapore.
4. R. Courant and F. John, Introduction to Calculus and Analysis (Volumes I & II), Springer Verlag.
5. S.K. Mapa, Introduction to Real Analysis, *Levant.*
6. S.C. Malik and S. Arora, Mathematical Analysis, *New Age International.*
7. R.K. Ghosh and K.C. Maity, Integral Calculus, *New Central Book Agency.*
8. J.G.Chakravorty and P.R. Ghosh, Advanced Mathemetical Geometry, Dhar & Sons.

Semester-4												
Paper Description	Calculus, Geometry and Group Theory		**Paper Code**				UMATMIN20002				
Paper (Type)	Minor Course (Theory)		**Credit**				**Marks**				
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**PRC**	**CE**	**ATT**	**Total**
200	4 Hours/week	2 Hr. 30 Min	3	1	-- -	4	60	---	10	5	75

CALCULUS, GEOMETRY AND GROUP THEORY

Calculus:

Unit 1: **10 classes**

Reduction formulae, derivations and illustrations of reduction formulae of the type $\int sin^n x\, dx, \int \cos^n x\, dx, \int \sec^n x\, dx, \int \tan^n x\, dx,\ \int (logx)^n\, dx,\ \int \sin^n x \cos^m x\, dx$ etc. Successive derivatives, Leibnitz rule and its applications. Indeterminate forms, L'Hospital's rule and it's applications.

Unit 2: **13 classes**

Volume and surface areas of solids formed by revolution of known plane curves and areas (simple problems only). Concept of parameterizations of a curve. Envelopes, asymptotes, radius of curvature. Concavity, convexity, and inflection points.

Geometry:

Unit 3: **13 classes**

2D: Rotation of axes and second-degree equations, pair of straight lines, classification of conics using the discriminant, polar equations of conics.

Unit 4: **13 classes**

3D: Spheres, cylindrical surfaces, cones, ellipsoids, paraboloids, hyperboloids, classification of quadrics.

Group Theory:

Unit 5: **11 classes**

Equivalence relations, functions, permutations, even and odd permutations. Definitions and examples of Groups, finite and infinite groups, commutative groups. Elementary properties of groups. Some well-known groups: $\mathbb{Z}_n$, U_n, $M_n(R)$, Klein's 4-group, multiplicative group of n-th roots of unity, symmetric group S_n etc. Definition and examples of subgroup. Statement of necessary and sufficient condition for a subset of a group to be a subgroup and its simple applications.

Suggested Reading Books:

1. G.B. Thomas and R.L. Finney, Calculus, Pearson Education, Delhi.
2. M.J. Strauss, G. L. Bradley, and K. J. Smith, Calculus, Pearson Education, Delhi.
3. H. Anton, I. Bivens and S. Davis, Calculus, John Wiley and Sons (Asia) P. Ltd., Singapore.
4. R. Courant and F. John, Introduction to Calculus and Analysis (Volumes I & II), Springer Verlag.
5. S.K. Mapa, Introduction to Real Analysis, *Levant.*
6. S.C. Malik and S. Arora, Mathematical Analysis, *New Age International.*
7. R.K. Ghosh and K.C. Maity, Integral Calculus, *New Central Book Agency.*
8. J.G.Chakravorty and P.R. Ghosh, Advanced Mathemetical Geometry, Dhar & Sons.

Semester-5												
Paper Description	Differential Equations and Integral Transforms		**Paper Code**				UMATMIN30003				
Paper (Type)	Minor Course (Theory)		**Credit**				**Marks**				
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**PRC**	**CE**	**ATT**	**Total**
200	4 Hours/week	2 Hr. 30 Min	3	1	--	4	60	---	10	5	75

DIFFERENTIAL EQUATIONS AND INTEGRAL TRANSFORMS

Unit 1: **15 classes**

Differential equations: Lipschitz condition and Picard's Theorem (Statement only). General, particular, explicit, implicit and singular solutions of a differential equation. First order and first-degree equations: Existence theorem (statement only). Exact equation, integrating factors and different calculating rules (statement of relevant results). Linear equations and Bernoulli equation. First order but not of first-degree equations: Singular solution of Clairaut's equation only

Unit 2: **15 classes**

General solution of homogeneous equation of second order, principle of super position for homogeneous equation. Wronskian: Its properties and applications. Higher order linear equations with constant coefficients: Complementary function and particular integral. Method of undetermined coefficients, method of variation of parameters. Euler's homogeneous equation. Second order linear equations with variable coefficients: Method of variation of parameters. Reduction to normal form.

Unit 3: **10 classes**

Partial differential equations: PDE of the first order, Lagrange's solution, nonlinear first order partial differential equations, Charpit's general method of solution.

Classification of second order linear equations as hyperbolic, parabolic or elliptic. Reduction of second order linear equations to canonical forms.

Unit 4 **10 classes**

Fourier Transform: Definition and properties of Fourier transform, Transform of derivatives. Fourier cosine and sine transforms. Convolution theorem(statement), Inverse Fourier transform. Application to solve ordinary and partial differential equation up to second order.

Unit 5 **10 classes**

Laplace Transform: Concept of Laplace and Inverse Laplace Transform. Sufficient conditions for the existence of Laplace Transform. Elementary properties of Laplace Transform and its inverse. Laplace Transform of derivatives and integrals. Convolution theorem (statement only). Initial and final value theorems (Statement only). Application to solve ordinary differential equations with constant coefficient (up to third order)

Suggested Reading Books:

1. H. Anton, I. Bivens and S. Davis, Calculus, John Wiley and Sons (Asia) P. Ltd., Singapore.
2. R. Courant and F. John, Introduction to Calculus and Analysis (Volumes I & II), Springer Verlag.
3. S.K. Mapa, Introduction to Real Analysis, *Levant.*
4. S.C. Malik and S. Arora, Mathematical Analysis, *New Age International.*
5. R.K. Ghosh and K.C. Maity, Integral Calculus, *New Central Book Agency.*
6. J.G.Chakravorty and P.R. Ghosh, Advanced Mathemetical Geometry, Dhar & Sons.

Semester-6												
Paper Description	Differential Equations and Integral Transforms		**Paper Code**				UMATMIN30003				
Paper (Type)	Minor Course (Theory)		**Credit**				**Marks**				
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**PRC**	**CE**	**ATT**	**Total**
200	4 Hours/week	2 Hr. 30 Min	3	1	--	4	60	---	10	5	75

DIFFERENTIAL EQUATIONS AND INTEGRAL TRANSFORMS

Unit 1: **15 classes**

Differential equations: Lipschitz condition and Picard's Theorem (Statement only). General, particular, explicit, implicit and singular solutions of a differential equation. First order and first-degree equations: Existence theorem (statement only). Exact equation, integrating factors and different calculating rules (statement of relevant results). Linear equations and Bernoulli equation. First order but not of first-degree equations: Singular solution of Clairaut's equation only

Unit 2: **15 classes**

General solution of homogeneous equation of second order, principle of super position for homogeneous equation. Wronskian: Its properties and applications. Higher order linear equations with constant coefficients: Complementary function and particular integral. Method of undetermined coefficients, method of variation of parameters. Euler's homogeneous equation. Second order linear equations with variable coefficients: Method of variation of parameters. Reduction to normal form.

Unit 3: **10 classes**

Partial differential equations: PDE of the first order, Lagrange's solution, nonlinear first order partial differential equations, Charpit's general method of solution.

Classification of second order linear equations as hyperbolic, parabolic or elliptic. Reduction of second order linear equations to canonical forms.

Unit 4 **10 classes**

Fourier Transform: Definition and properties of Fourier transform, Transform of derivatives. Fourier cosine and sine transforms. Convolution theorem(statement), Inverse Fourier transform. Application to solve ordinary and partial differential equation up to second order.

Unit 5 **10 classes**

Laplace Transform: Concept of Laplace and Inverse Laplace Transform. Sufficient conditions for the existence of Laplace Transform. Elementary properties of Laplace Transform and its inverse. Laplace Transform of derivatives and integrals. Convolution theorem (statement only). Initial and final value theorems (Statement only). Application to solve ordinary differential equations with constant coefficient (up to third order)

Suggested Reading Books:

1. H. Anton, I. Bivens and S. Davis, Calculus, John Wiley and Sons (Asia) P. Ltd., Singapore.
2. R. Courant and F. John, Introduction to Calculus and Analysis (Volumes I & II), Springer Verlag.
3. S.K. Mapa, Introduction to Real Analysis, *Levant.*
4. S.C. Malik and S. Arora, Mathematical Analysis, *New Age International.*
5. R.K. Ghosh and K.C. Maity, Integral Calculus, *New Central Book Agency.*
6. J.G.Chakravorty and P.R. Ghosh, Advanced Mathemetical Geometry, Dhar & Sons.

Semester-7												
Paper Description	Real Analysis and Vector Calculus		**Paper Code**				UMATMIN40004				
Paper (Type)	Minor Course (Theory)		**Credit**				**Marks**				
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**PRC**	**CE**	**ATT**	**Total**
300	4 Hours/week	2 Hr. 30 Min	3	1	--	4	60	---	10	5	75

REAL ANALYSIS AND VECTOR CALCULUS

Real Analysis

Unit 1: **10 classes**

Finite and Infinite sets: Definitions and Examples, well-ordered properties of $\mathbb{N}$ (statement only). Countable, Denumerable and Uncountable sets: Definitions and Examples, countability of union, intersection, product, subset, superset of countable sets, Rational numbers are countable. Uncountable subsets of R.

Unit 2: **10 classes**

Review of Algebraic and order properties of $\mathbb{R}$, ε-neighborhood of a point in $\mathbb{R}$. Bounded above sets, bounded below sets, bounded sets, unbounded sets. Suprema and infima with their properties and supporting examples. Archimedean property, density property , order property of $\mathbb{R}$, Intervals in $\mathbb{R}$, Limit point and isolated point of a set. Open set, closed set, derived set and their properties. Bolzano-Weierstrass theorem on limit point. Nested interval theorem. Examples of Compact sets in $\mathbb{R}$, statement of Heine-Borel Theorem.

Unit 3: (Statement of the theorems and their applications in relevant problem solving) **10 classes**

Sequences: Sequence, bounded sequence, convergent sequence. Limit and limit points of a sequence. Uniqueness of limit of convergent sequences. Limit theorems. Monotone sequences, monotone convergence theorem. Sandwich theorem. Subsequences. Monotone subsequence theorem (statement only). Bolzano Weierstrass theorem for sequences. Cauchy sequence, Cauchy's convergence criterion. Completeness property of $\mathbb{R}$.

Unit 4: (Statement of the theorems and their applications in relevant problem solving) **10 classes**

Series: Infinite series, convergence and divergence of infinite series, Cauchy criterion (only statement). Tests for convergence (only statement and applications): comparison test, limit comparison test, D'Alembert's ratio test, Cauchy's nth root test. Absolutely convergent series (Ratio test, Root test), conditionally convergent series (Leibniz's test) and alternating series. Only problems on power series and its radius of convergence.

Vector Calculus:

Unit 1 **10 classes**

Scalar triple product, Vector triple product. Lagrange's identity for four vectors, Vector product of four vectors. Reciprocal system of vectors. Applications in geometric, trigonometric and simple mechanical problems (work done by a force, moment of a force about a point).

Unit 2: **10 classes**

Vector function. Limit, continuity of a vector function. Derivative of a vector, Conditions for a vector $\vec{r} = \vec{f}(t)$ having constant magnitude, constant direction. Velocity and acceleration vectors as derivatives. Partial derivatives of vectors

Scalar and Vector fields. Directional derivative. Gradient, Divergence, Curl and the rules associated with them. Second order vector differential operators- Laplacian operator. Irrotational and Solenoiddal vectors.

Suggested Reading Books:

1. R. Bartle and D.R. Sherbert, Introduction to Real Analysis, John Wiley and Sons, 2003.
2. K. A. Ross, Elementary Analysis : The Theory of Calculus, Springer, 2004.

A. Mattuck, Introduction to Analysis, Prentice Hall, 1999.

3. S. R. Ghorpade and B. V. Limaye, a Course in Calculus and Real Analysis, Springer, 2006.
4. T. Apostol, Mathematical Analysis, Narosa Publishing House.
5. Courant and John, Introduction to Calculus and Analysis, ,Voll II, Springer.
6. W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill
7. T. Tao, Analysis II, Hindustan Book Agency, 2006.
8. Borisenko and I. E. Tarapov, Vector and Tensor Analysis with Applications, Dover Publications Inc., New York.
9. E. C. Young, Vector and Tensor Analysis, Revised second edition, CRC Press, Taylor & Francis Group..
10. Speigel, M.R. Vector Analysis and Introduction to Tensor Analysis(MgGraw Hill).
11. J. Marsden and Tromba, Vector Calculus, McGraw Hill.
12. K. C. Maity and R. K. Ghosh, Vector Analysis, New Central Book Agency(P) Ltd. Kolkata (India).
13. Chakravorty, J. G. 7 Ghosh, P.R., Vector Analysis (U. N. Dhur and Sons).
14. Khan R.M., Analytical Geometry in two and three Dimensions & Vector Analysis(New Central Book Agency.

Semester-8												
Paper Description	Real Analysis and Vector Calculus		**Paper Code**				UMATMIN40004				
Paper (Type)	Minor Course (Theory)		**Credit**				**Marks**				
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**PRC**	**CE**	**ATT**	**Total**
300	4 Hours/week	2 Hr. 30 Min	3	1	--	4	60	---	10	5	75

REAL ANALYSIS AND VECTOR CALCULUS

Real Analysis

Unit 1: **10 classes**

Finite and Infinite sets: Definitions and Examples, well-ordered properties of $\mathbb{N}$ (statement only). Countable, Denumerable and Uncountable sets: Definitions and Examples, countability of union, intersection, product, subset, superset of countable sets, Rational numbers are countable. Uncountable subsets of R.

Unit 2: **10 classes**

Review of Algebraic and order properties of $\mathbb{R}$, ε-neighborhood of a point in $\mathbb{R}$. Bounded above sets, bounded below sets, bounded sets, unbounded sets. Suprema and infima with their properties and supporting examples. Archimedean property, density property , order property of $\mathbb{R}$, Intervals in $\mathbb{R}$, Limit point and isolated point of a set. Open set, closed set, derived set and their properties. Bolzano-Weierstrass theorem on limit point. Nested interval theorem. Examples of Compact sets in $\mathbb{R}$, statement of Heine-Borel Theorem.

Unit 3: (Statement of the theorems and their applications in relevant problem solving) **10 classes**

Sequences: Sequence, bounded sequence, convergent sequence. Limit and limit points of a sequence. Uniqueness of limit of convergent sequences. Limit theorems. Monotone sequences, monotone convergence theorem. Sandwich theorem. Subsequences. Monotone subsequence theorem (statement only). Bolzano Weierstrass theorem for sequences. Cauchy sequence, Cauchy's convergence criterion. Completeness property of $\mathbb{R}$.

Unit 4: (Statement of the theorems and their applications in relevant problem solving) **10 classes**

Series: Infinite series, convergence and divergence of infinite series, Cauchy criterion (only statement). Tests for convergence (only statement and applications): comparison test, limit comparison test, D'Alembert's ratio test, Cauchy's nth root test. Absolutely convergent series (Ratio test, Root test), conditionally convergent series (Leibniz's test) and alternating series. Only problems on power series and its radius of convergence.

Vector Calculus:

Unit 1 **10 classes**

Scalar triple product, Vector triple product. Lagrange's identity for four vectors, Vector product of four vectors. Reciprocal system of vectors. Applications in geometric, trigonometric and simple mechanical problems (work done by a force, moment of a force about a point).

Unit 2: **10 classes**

Vector function. Limit, continuity of a vector function. Derivative of a vector, Conditions for a vector $\vec{r} = \vec{f}(t)$ having constant magnitude, constant direction. Velocity and acceleration vectors as derivatives. Partial derivatives of vectors

Scalar and Vector fields. Directional derivative. Gradient, Divergence, Curl and the rules associated with them. Second order vector differential operators- Laplacian operator. Irrotational and Solenoiddal vectors.

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A. Mattuck, Introduction to Analysis, Prentice Hall, 1999.

3. S. R. Ghorpade and B. V. Limaye, a Course in Calculus and Real Analysis, Springer, 2006.
4. T. Apostol, Mathematical Analysis, Narosa Publishing House.
5. Courant and John, Introduction to Calculus and Analysis, ,Voll II, Springer.
6. W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill
7. T. Tao, Analysis II, Hindustan Book Agency, 2006.
8. Borisenko and I. E. Tarapov, Vector and Tensor Analysis with Applications, Dover Publications Inc., New York.
9. E. C. Young, Vector and Tensor Analysis, Revised second edition, CRC Press, Taylor & Francis Group..
10. Speigel, M.R. Vector Analysis and Introduction to Tensor Analysis(MgGraw Hill).
11. J. Marsden and Tromba, Vector Calculus, McGraw Hill.
12. K. C. Maity and R. K. Ghosh, Vector Analysis, New Central Book Agency(P) Ltd. Kolkata (India).
13. Chakravorty, J. G. 7 Ghosh, P.R., Vector Analysis (U. N. Dhur and Sons).
14. Khan R.M., Analytical Geometry in two and three Dimensions & Vector Analysis(New Central Book Agency)

Prof. Manoranjan Singha
Chairperson
UG-BOS in Mathematics, NBU

FOUR-YEAR UNDERGRADUATE PROGRAM

OLD SYLLABUS

Graduate Program with Honours (FYUGHONS)

SEMESTER-7

Paper Code	Paper Level	Paper	Paper Description	Paper Type	Full Marks	Credit		Page No.
						L	T/P	
	400	MAJ	Algebra and Complex Analysis	TH	75	3	1	
	400	MAJ	Analysis of Several Variables and Measure Theory	TH	75	3	1	
	400	MAJ	Partial Differential Equations and Integral Equations	TH	75	3	1	
	300	MIN	Real analysis and Vector calculus	TH	75	3	1	

SEMESTER-8

Paper Code	Paper Level	Paper	Paper Description	Paper Type	Full Marks	Credit		Page No.
						L	T/P	
	400	MAJ	Elements of Topology and Functional Analysis	TH	75	3	1	
	400	MAJ	Advanced Numerical Analysis	TH	75	3	1	
	400	MAJ	Classical Mechanics, Calculus of Variation and Special Functions	TH	75	3	1	
	400	MAJ	Research Methodology, Seminar Presentation and Grand Viva*	TH+P	75	2	2	
	300	MIN	Real analysis and Vector calculus	TH	75	3	1	

*Research Methodology (2 credit, 40 Marks (TH)), Seminar Presentation (1 Credit, 20 Marks) and Grand Viva (1Credit, 15 Marks).

Seminar presentation will be on some topic as an extension of any areas of Mathematics taught during the entire course.

Prof. Manoranjan Singha
Chairperson
UG-BOS in Mathematics, NBU

FOUR-YEAR UNDERGRADUATE PROGRAM

OLD SYLLABUS

Graduate Program with Honours with Research (FYUGHWRS)

SEMESTER-7

Paper Code	Paper Level	Paper	Paper Description	Paper Type	Full Marks	Credit		Page No.
						L	T/P	
	400	MAJ	Algebra and Complex Analysis	TH	75	3	1	
	400	MAJ	Analysis of Several Variables and Measure Theory	TH	75	3	1	
	400	MAJ	Partial Differential Equations and Integral Equations	TH	75	3	1	
	300	MIN	Real analysis and Vector calculus	TH	75	3	1	

SEMESTER-8

Paper Code	Paper Level	Paper	Paper Description		Paper Type	Full Marks	Credit		Page No.
							L	T/P	
	400	MAJ	Elements of Topology and Functional Analysis		TH	75	3	1	
	400	IARD	Research Project /Dissertation**	Research Methodology	TH	40	2	---	
				Annexure	TH	75	3	1	
				Annexure	TH	75	3	1	
				Bachelor's thesis, Presentation and Viva Voce	P	20+15	---	1+1	
	300	MIN	Real analysis and Vector calculus						

** Research Methodology (2 Credit, 40 Marks),
Bachelor's thesis (Literature Review and development of current results and proofs/validation) (1 Credit, 20 Marks),
Presentation and Viva Voce (1 Credit, 15 Marks).
Bachelor's thesis Presentation and Viva Voce (To be evaluated by a panel of External Subject Experts nominated jointly by the Chairperson, UGBoS and Chairperson, Departmental Research Committee (DRC), Mathematics, NBU).
Presentation will be on the Bachelor's thesis and viva voce will be on the presentation as well as the courses taught.

Prof. Manoranjan Singha
Chairperson
UG-BOS in Mathematics, NBU

GRADUATE PROGRAM WITH HONOURS

(FYUGHONS)

DETAILED SYLLABUS

SEMESTER-7
(MAJOR COURSES)

Semester-7										
Paper Description	Algebra and Complex Analysis				**Paper Code**					
Paper (Type)	Major Course (Theory)		**Credit**				**Marks**			
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**TU**	**PRC**	**Total**
400	4 Hours/week	2 Hr. 30 Min	3	1	---	4	60	15	---	75

Algebra and Complex Analysis

Algebra:

Groups: Direct product of groups. Group action, orbit-stabilizer theorem, conjugacy classes and the class equation, Cauchy's theorem, Sylow's 1st, 2nd & 3rd theorems, and the classification of finite groups of small order. Normal, subnormal and composition series, Jordan–Holder theorem (statement), commutator subgroups. Solvable groups. Finite Abelian groups, finitely generated Abelian groups, Fundamental Theorem of Finitely generated Abelian groups via invariant factors and elementary divisors.

Rings: Quotient Field of an Integral Domain. Polynomial rings, Division algorithm in polynomial rings, Irreducibility of Polynomials, Eisenstein's criterion of irreducibility. Noetherian Rings, Artinian Rings, Hilbert Basis Theorem. Radical of an ideal, associated primes, Primary ideals, Primary decomposition theorem.

Linear Algebra: Direct sum decompositions, Primary decomposition theorem, Triangularizations, Rational canonical form, Quadratic forms, Reduction and classification of quadratic forms. Bilinear forms, Symmetric and skew symmetric bilinear forms.

Complex Analysis:

Complex integration, line integral and its properties, Winding number or Index of a closed curve, Cauchy's fundamental theorem, Morera's theorem, Cauchy's integral formula, power series expansion of analytic functions, Primitives of analytic functions.

Zeros of analytic functions and their limit points, entire functions, Liouville's theorem. Fundamental theorem of algebra. Open mapping theorem, Inverse function theorem. The Maximum modulus Theorems and related problems.

Singularities and their classification, Laurent's series expansion, Riemann's theorem, Limit points of zeros and poles, Casorati-Weierstrass's theorem, behavior of a function at the point at infinity.

Theory of residues, Cauchy's residue theorem and evaluation of improper integrals. Argument principle, Rouche's theorem and its application, Conformal mappings, Möbius transformation, Principle of symmetry

Suggested Readings Books:

Algebra:

1. Fraleigh, J. B., *A First Course in Abstract Algebra*, 7th Edition, Addison-Wesley.
2. Herstein, I. N., *Topics in Algebra*, 2nd Edition, Wiley.
3. Gallian, J. A., *Contemporary Abstract Algebra*, 10th Edition, Cengage Learning.
4. Dummit, D. S., and Foote, R. M., *Abstract Algebra*, 3rd Edition, Wiley.
5. Artin, M., *Algebra*, 2nd Edition, Pearson.

6. Malik, D. S., Mordeson, J. N., and Sen, M. K., *Fundamentals of Abstract Algebra*, McGraw-Hill Education.
7. Sen, M. K., *Algebra*, Books and Allied (India).
8. Hoffman, K., and Kunze, R., *Linear Algebra*, 2nd Edition, Pearson.
9. Friedberg, S. H., Insel, A. J., and Spence, L. E., *Linear Algebra*, 5th Edition, Pearson.

Complex Analysis:

1. J. B. Conway, *Functions of one complex variable, 2nd Ed*., Narosa Publishing House, New Delhi, 1997.
2. L. V. Ahlfors – *Complex Analysis- 3rd Edn*, McGraw-Hill, 1979
3. R. V. Churchill and J. W. Brown: Complex Variables and applications.
4. I. Markushevich, Theory of Functions of a Complex Variable (Vol. I &II), Prentice-Hall, 1965 & 1967.
5. E. C. Titchmarsh, The Theory of Functions, Oxford University Press, 1939.
6. R. P. Boas – *Entire Functions,* Academic Press, 1954
7. H. Cartan – *Elementary Theory of Analytic Functions of One or Several Complex Variables,* Dover Publication, 1995.
8. E. T. Copson, *Introduction to the Theory of Function of a Complex Variable,* Oxford University press, 1970
9. K. Kodaria, *Complex Analysis,* Cambridge University Press, 2007.
10. R. Remmmert, *Theory of complex functions*, Springer-Verlag, New York, 1991.
11. W. Rudin – *Real and Complex Analysis,* Tata McGraw-Hill Education, 1987
12. J. M. Howie: Complex Analysis

Semester-7										
Paper Description	Analysis of Several Variables and Measure Theory		**Paper Code**							
Paper (Type)	Major Course (Theory)		**Credit**				**Marks**			
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**TU**	**PRC**	**Total**
400	4 Hours/week	2 Hr. 30 Min	3	1	-- -	4	60	15	---	75

Analysis of Several Variables and Measure Theory

Analysis of Several Variables:

Topology of $\mathbb{R}_n, GL_n(\mathbb{R})$ etc. Differentiability of maps from $\mathbb{R}m$ to $\mathbb{R}n$ and the derivative as a linear map.

Determinant as mapping; its continuity and differentiability, is a real square matrix.

Higher derivatives, Chain Rule, mean value theorem for differentiable functions, Taylor expansions in several variables, Local maxima and minima, Lagrange multiplier, Sard's theorem.

Multiple integrals, Existence of the Riemann integral for sufficiently well-behaved functions on rectangles, i.e., product of intervals. Multiple integrals expressed as iterated simple integrals. Brief treatment of multiple integrals on more general domains. Change of variables and the Jacobian formula, illustration with plenty of examples. Inverse and implicit function theorems. Picard's Theorem.

Curves in $\mathbb{R}2$ and $\mathbb{R}3$. Line integrals, Surfaces in $\mathbb{R}3$, Surface integrals, Integration of forms, Divergence, Gradient and Curl operations, Green's theorem, Gauss Divergence theorem and Stoke's theorem.

Measure Theory:

Extended real numbers, algebraic operations and convergence in extended real number system, Lebesgue outer measure on R, elementary properties of Lebesgue measure space including σ-finiteness, translation invariance, positive homogeneity, existence of non-Lebesgue measurable sets, regularity of Lebesgue outer measure, Borel measurability on R, measurable functions, operations with measurable functions, sequence of measurable functions, Cantor ternary set and Cantor-Lebesgue function.

Abstract measure spaces, σ-algebra of sets, limits of sequences of sets, Borel σ-algebra, measure on σ-algebra, measurable spaces and measure spaces, monotone convergence theorems for sequences of measurable sets.

Suggested Readings Books:

Analysis of Several Variables

1. Spivak, M. (1965). *Calculus on Manifolds: A Modern Approach to Classical Theorems of Advanced Calculus*. Benjamin.
2. Rudin, W. (1976). *Principles of Mathematical Analysis* (3rd ed.). McGraw-Hill.
3. Apostol, T. M. (2007). *Mathematical Analysis* (2nd ed.). Addison-Wesley.
4. Munkres, J. (2018). *Analysis on Manifolds*. CRC Press.
5. Apostol, T. M. (1969). *Calculus, Volume II: Multi-Variable Calculus and Linear Algebra with Applications* (2nd ed.). John Wiley & Sons.

Measure Theory:

1. Berberian, S. K. (1998). *Fundamentals of Real Analysis*. Springer.
2. de Barra, G. (1981). *Measure Theory and Integration*. New Age International Publishers.
3. Royden, H. L. (1988). *Real Analysis* (3rd ed.). Prentice-Hall of India.
4. Rudin, W. (2013). *Principles of Mathematical Analysis*. McGraw-Hill.
5. Yeh, J. (2000). *Lectures on Real Analysis*. World Scientific.
6. Bartle, R. G. (1966). *The Elements of Integration*. John Wiley & Sons.

Semester-7										
Paper Description	Partial Differential Equations and Integral Equations					**Paper Code**				
Paper (Type)	Major Course (Theory)		**Credit**				**Marks**			
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**TU**	**PRC**	**Total**
400	4 Hours/week	2 Hr. 30 Min	3	1	--	4	60	15	---	75

Partial Differential Equations and Integral Equations

Partial Differential Equations:

General solution and complete integral of a partial differential equation, singular solution, integral surface passing through a curve and circumscribing a surface.

Formation and solution of PDE, integral surfaces, Cauchy's method of characteristic, orthogonal surfaces, First order non-linear PDE, compatible system, Charpit's method, classification and canonical forms of PDE.
Linear partial differential equations of second and higher order, classification of Second order PDE, Monge's method. reduction to canonical form, solution of equations with constant coefficients by (i) factorization of operators (ii) separation of variables, linear PDE with variable coefficients, canonical forms, canonical transformation of linear second order PDE.

Derivation of Laplace and Poisson equation, Boundary Value Problem, Harmonic functions, characterization of harmonic function by their mean value property, method of separation of variables for the solutions of Laplace's equations, Dirichlet Problem and Neumann Problem for a rectangle, interior and exterior Dirichlet problems for a circle and a semi-circle, interior Neumann problem for a circle, solution of Laplace equation in cylindrical and spherical coordinates, steady-state heat flow equation Problems.
Formation and solution of diffusion equation, initial and boundary conditions, separation of variables method, solution of heat equation under Dirichlet and Neumann condition, heat conduction problem for an infinite rod, heat conduction in a finite rod, solution of diffusion equation in cylindrical and spherical coordinates, examples.

Formation and solution of one-dimensional wave equation, initial value problem, D'Alembert's solution, vibrating string, forced vibration, method of separation of variables, initial and boundary value problem for two-dimensional wave equation, periodic solution of one-dimensional wave equation in cylindrical and spherical coordinate systems, Duhamel's Principle, examples.

Fundamental solution and its properties, Green's functions, fundamental solution in 2D and 3D of Laplace equation, Poissoin equation and Heat equation.

Integral Equations:

Classifications, successive approximations, separable kernels, Fredholm alternative, Hilbert-Schmidt theory of symmetric kernels, construction of Green's function, convoluted kernels, Abel's equations and solutions.

Suggested Readings Books:

Partial Differential Equations

1. Sneddon, I. N. (1986). *Elements of Partial Differential Equations*. McGraw-Hill.
2. Evans, L. C. (1998). *Partial Differential Equations*. Graduate Studies in Mathematics, Vol. 19. American Mathematical Society.
3. McOwen, R. C. (2003). *Partial Differential Equations*. Pearson Education.
4. Amarnath, T. (2003). *Partial Differential Equations*. Alpha Science International.
5. Prasad, P. P., & Ravichandran, R. (1985). *Partial Differential Equations*. Wiley Eastern.
6. Smith, M. G. (1967). *Introduction to the Theory of Partial Differential Equations*. Van Nostrand.
7. Miller, F. H. (1941). *Partial Differential Equations*. Wiley.
8. Greenspan, G. (2012). *Introduction to Partial Differential Equations*. Dover Publications.
9. Jones, D. S. (1982). *Generalized Functions*. Cambridge University Press.
10. Churchill, R. V., & Brown, J. W. (1987). *Fourier Series and Boundary Value Problems* (4th ed.). McGraw-Hill.

Integral Equations

1. Tricomi, F. G. (1985). *Integral Equations*. Dover Publications.
2. Wazwaz, A. M. (2011). *Linear and Nonlinear Integral Equations: Methods and Applications*. Springer.

GRADUATE PROGRAM WITH HONOURS

(FYUGHONS)

DETAILED SYLLABUS

SEMESTER-8
(MAJOR COURSES)

Semester-8										
Paper Description	Elements of Topology and Functional Analysis		**Paper Code**							
Paper (Type)	Major Course (Theory)		**Credit**				**Marks**			
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**TU**	**PRC**	**Total**
400	4 Hours/week	2 Hr. 30 Min	3	1	--	4	60	15	---	75

Elements of Topology and Functional Analysis

Elements of Topology:

Axiom of choice and existence of choice function. Partially ordered set, linearly ordered set, well ordered set and product of the same kinds, Zorn's lemma, well ordering principle with special emphasis on Ordinal and Cardinal numbers.

Topological spaces, open and closed sets, basis and sub-basis, closure, interior and boundary of a set. Subspace topology. Continuous maps: properties and constructions; Pasting Lemma. Open and closed maps, Homeomorphisms. Product topology, Quotient topology and examples of Topological Manifolds.

Countability and separation axioms: Urysohn's lemma, Tietze extension theorem and applications. Urysohn embedding lemma and metrization theorem for second countable spaces.

Connected, path-connected and locally connected spaces. Lindelof and compact spaces. Net, filters.

Functional Analysis:

Definitions and examples; spaces likelp, $l\infty$, $C[a,\ b]$, Holder and Minkowski inequalities for sums, completeness of metric spaces, isometric mapping, isometric spaces, completion of metric spaces, Baire category theorem, Banach's fixed point theorem and its applications.

Normed linear spaces, Banach spaces and examples, quotient space of normed spaces and its completeness, Schauder basis, normed space and its completion, equivalent norms, finite dimensional normed linear spaces and compactness, Riesz Lemma, bounded linear operators, its equivalence with continuity, normed linear spaces of bounded linear operators, linear functional, bounded linear functional, dual space and second dual space, canonical embedding, algebraic reflexivity, strong and weak convergence, uniform boundedness theorem and some of its consequences, open mapping theorem, closed graph theorem, Hahn-Banach theorem for real linear spaces, complex linear spaces and some of its consequences.

Inner product spaces, Hilbert spaces and examples, Cauchy-Schwarz inequality, triangle inequality, parallelogram law, Inner product spaces and its completion, orthonormal sets and sequences, orthogonal complements and direct sums, Bessel's inequality, Gram-Schmidt orthonormalization process, complete orthonormal sets and Parseval's identity, Riesz representation theorem, Sesquilinear form, separable and non-separable Hilbert space, reflexivity of Hilbert spaces.

Adjoint of an operator on a Hilbert space, Self-adjoint operators, normal and unitary operators, convergence of sequences of operators and functionals, positive operators, projection operators, compact operators.

Suggested Readings Books:

Elements of Topology

1. Munkres, J. R. (2000). *Topology: A First Course*. Prentice Hall.
2. Simmons, G. F. (1963). *Introduction to Topology and Modern Analysis*. McGraw-Hill.
3. Armstrong, M. A. (1983). *Basic Topology*. Springer.
4. Kelley, J. L. (1955). *General Topology*. Springer-Verlag.
5. Dugundji, J. (1966). *Topology*. Universal Book Stall (UBS).
6. Willard, S. (2004). *General Topology*. Dover Publications.

Functional Analysis

1. Kreyszig, E. (1978). *Introductory Functional Analysis with Applications*. John Wiley & Sons.
2. Simmons, G. F. (1963). *Introduction to Topology and Modern Analysis*. McGraw-Hill.
3. Conway, J. B. (1990). *A Course in Functional Analysis*. Springer-Verlag.

Semester-8										
Paper Description	Advanced Numerical Analysis				**Paper Code**					
Paper (Type)	Major Course (Theory)		**Credit**				**Marks**			
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**TU**	**PRC**	**Total**
400	4 Hours/week	2 Hr. 30 Min	3	1	-- -	4	60	15	---	75

Advanced Numerical Analysis

Advanced Numerical Analysis:

Errors in Polynomial Interpolation, Finite differences, Interpolation with evenly spaced points: Newton forward and backward interpolation formula, Central difference interpolation formula (Gauss's formula, Stirling's formula, Bessel's formula, Everett formula, Relation between Bessel's and Everett's formula), Interpolation with unevenly spaced points: Lagrange's Interpolation formula, Hermite Interpolation formula, Newton's divide difference interpolation formula, Interpolation by iteration, inverse interpolation, double interpolation.

Least Square and Curve fitting procedure, Weighted least square approximations, Method of least square for continuous functions: orthogonal polynomials, Gram-Schmidt orthogonalization, Approximation of functions: Chebyshev polynomials, Economization of Power Series, Fourier Approximation: Fourier Transformation, Discrete Fourier Transformation, Fast Fourier Transform, Cooley Turkey Algorithm.Linear, Quadratic, Cubic Spline, Cubic B-spline.

Gauss Jordan, LU decomposition, Cholesky's decomposition, Gauss Jacobi, Gauss-Seidel method, successive over-relaxation method (SOR), Solution of Tridiagonal System, Ill conditioned system, Eigenvalues of a symmetric tridiagonal system. Householder's method, QR method,Power method, Jacobi method. Generalized Runge Kutta methods (implicit and explicit), Predictor -Corrector Methods: Adam-Moultons method, Milne's method, shooting method, and Galerkin method.

Finite difference method for Laplace equation, heat equation, and the wave equation, forward in time centered in space (FTCS), backward in time centered in space (BTCS), Crank-Nicolson method, ADI method, general five-point formula, etc.

Power Series Solution of ODE, Singular points, Frobenious method.

Suggested Readings Books:

1. Jain, M. K., Iyengar, S. R. K., & Jain, R. K. (2003). *Numerical Methods for Scientific and Engineering Computations*. New Age International Publishers.
2. Atkinson, K. E. (2008). *An Introduction to Numerical Analysis* (2nd ed.). John Wiley & Sons.
3. Hamming, R. W. (1986). *Numerical Methods for Scientists and Engineers* (2nd rev. ed.). Dover Publications.
4. Epperson, J. F. (2013). *An Introduction to Numerical Methods and Analysis* (2nd ed.). John Wiley & Sons.
5. Kincaid, D., & Cheney, W. (2002). *Numerical Analysis: Mathematics of Scientific Computing* (3rd ed.). American Mathematical Society.

Semester-8										
Paper Description	Classical Mechanics, Calculus of Variation and Special Functions				**Paper Code**					
Paper (Type)	Major Course (Theory)		**Credit**				**Marks**			
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**TU**	**PRC**	**Total**
400	4 Hours/week	2 Hr. 30 Min	3	1	-- -	4	60	15	---	75

Classical Mechanics, Calculus of Variation and Special Functions

Classical Mechanics:

Introduction, Generalized coordinates, degrees of freedom, virtual work, D'Alembert's principle, Constraint of motion, unilateral and bilateral constraints, holonomic and nonholonomic systems, scleronomic and rheonomic systems, Lagrange's equations for holonomic systems, Lagrange's equations for impulsive forces and for systems involving dissipative forces, conservation theorems, Cyclic coordinates, Generalized momentum.

Hamilton's canonical equation, Symmetry, Noether's theorem, Routh's equation, Hamilton's principle and principle of least action, canonical transformation with different generating functions, Lagrange and Poisson brackets and their properties, Hamilton-Jacobi equations,

Calculus of Variation:

Introduction, Euler's equation, different forms of Euler's equations, solutions of Euler's equation, geometrical problems, Geodesics, Minimum surface of revolution, Isoperimetric problems, Brachistochrone problem, Variational problems involving several unknown functions, Functionals dependent on higher order derivatives.

Variation problems involving several independent variables, Constraints and Lagrange's multipliers, Moving boundaries.

Special Functions:

Power series solution of ODEs, Singular points, Frobenius method of solution, Hypergeometric functions, properties of hypergeometric functions. Solution of Bessel's equation, Bessel function, and its properties, generating function, integral representation of Bessel's function, Hankel functions, recurrence relations. Solution of Legendre equation, Legendre functions, Generating function, Legendre functions of the first and second kinds

Suggested Readings Books:

Classical Mechanics:

1. Classical Mechanics, H. Goldstein, Pearson New International edition, Third edition, (2014).
2. Classical Mechanics, P. S. Jog, N. C. Rana, McGraw-Hill, First edition, (2001).
3. Classical Mechanics, S. L. Gupta, V. Kumar, H. V. Sharma,Pragati Prakashan, (2010). Introduction to Classical Mechanics, R. G. Takwale, P.S. Puranik, Tata McGraw-Hill, (1979).
4. Dynamics: A different outlook, S. Chakraborty, arXiv:2309.02857v4 [physics.class-ph]

Calculus of Variation:

1. Calculus of Variations with Applications, A. S. Gupta, Prentice Hall of India, (2015).
2. Calculus of Variation, Dover Publication, L. D. Elsgole, Inc. New York, (2007).
3. Calculus of Variation, M. Gelfand, S. V. Fomin, Dover books on Mathematics (2000).

Research Methodology, Seminar Presentation and Grand Viva

Semester-8										
Paper Description	Research Methodology				**Paper Code**					
Paper (Type)	Major Course (Theory)		**Credit**				**Marks**			
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**TU**	**PRC**	**Total**
400	4 Hours/week	2 Hr. 30 Min	2		---	2	40			40
Paper Description	Seminar Presentation and Grand Viva				**Paper Code**					
Paper (Type)	Major Course (Theory)		**Credit**				**Marks**			
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**TU**	**PRC**	**Total**
400	4 Hours/week	2 Hr. 30 Min			1+1	2			20+15	35

Research Methodology

Research Methodology:

Introduction:
Meaning, purpose, objectives, characteristics, motivation, significance, types of research; approaches, process, methods and methodology used in research ; criteria of good research; research methods in general and Mathematical Sciences in particular.

The Research Problem:
Research problems and sub-problems identification, stating, defining, techniques involved in defining problem.

Interpretation and Report Writing:
Techniques of interpretation- significance, types, steps, checklist/precautions and characteristics of research documentation i.e. reviews, treatise, monographs, abstracts, articles, technical reports, white papers, research papers, thesis etc.- issues and techniques of writing project proposals, paper presentation and soft skills.

Mathematical Reasoning, Ethical issues and Professional Conduct:
Mathematical logic and reasoning, methods of proofs (direct proof, proof by contradiction, proof by contrapositive, mathematical induction), construction of examples and counter examples, Ethics in general, Professional Ethics,

ethical Issues and their significance those arise from Computer Technology, General Moral Imperatives, Concepts and issues related to plagiarism and Intellectual Property Rights

Literature Review:
Importance of Literature review in defining a problem, including literature in research proposal, critique, survey & peer review process, identifying gap areas from literature review; Major Research areas, Journals, Publication, Conferences and Status of Research in the field of Mathematical Sciences.

Mathematical Type Setting and communication:
Structure of a mathematical research paper, Writing definitions, propositions, lemmas, theorems and proofs, Writing abstracts and introductions, Preparation of references and bibliography, Basic introduction to LaTeX, Oral presentation and seminar skills.

Suggested Readings Books:

1. Creswell, J. W., & Creswell, J. D. (2023). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (6th ed.). SAGE Publications.
2. Kumar, R. (2019). *Research Methodology: A Step-by-Step Guide for Beginners* (5th ed.). SAGE Publications.
3. Babbie, E. (2020). *The Practice of Social Research* (15th ed.). Cengage Learning.
4. Kothari, C. R., & Garg, G. (2019). *Research Methodology: Methods and Techniques* (4th ed.). New Age International Publishers.
5. Booth, W. C., Colomb, G. G., Williams, J. M., Bizup, J., & Fitzgerald, W. T. (2016). *The Craft of Research* (4th ed.). University of Chicago Press.
6. Turabian, K. L. (2018). *A Manual for Writers of Research Papers, Theses, and Dissertations* (9th ed.). University of Chicago Press.
7. Walliman, N. (2021). *Research Methods: The Basics* (3rd ed.). Routledge.
8. Punch, K. F. (2016). *Developing Effective Research Proposals* (3rd ed.). SAGE Publications.
9. Zikmund, W. G., Babin, B. J., Carr, J. C., & Griffin, M. (2013). *Business Research Methods* (9th ed.). Cengage Learning.
10. Field, A. (2018). *Discovering Statistics Using IBM SPSS Statistics* (5th ed.). SAGE Publications.
11. Kothari, C. R., & Garg, G. (2019). *Research Methodology: Methods and Techniques* (4th ed.). New Age International Publishers.
12. Higham, N. J. (1998). *Handbook of Writing for the Mathematical Sciences* (2nd ed.). Society for Industrial and Applied Mathematics (SIAM).
13. Krantz, S. G. (1997). *A Primer of Mathematical Writing: Being a Disquisition on Having Your Ideas Recorded, Typeset and Read*. American Mathematical Society.

Seminar Presentation and Grand Viva

Seminar Presentation (1 Credit, 20 Marks) and Grand Viva (1Credit, 15 Marks).

Seminar presentation will be on some topic as an extension of any areas of Mathematics taught during the entire course.

Prof. Manoranjan Singha
Chairperson
UG-BOS in Mathematics, NBU

GRADUATE PROGRAM WITH HONOURS WITH RESEARCH

(FYUGHWRS)

DETAILED SYLLABUS

SEMESTER-7
(MAJOR COURSES)

Semester-7										
Paper Description	Algebra and Complex Analysis				**Paper Code**					
Paper (Type)	Major Course (Theory)		**Credit**				**Marks**			
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**TU**	**PRC**	**Total**
400	4 Hours/week	2 Hr. 30 Min	3	1	---	4	60	15	---	75

Algebra and Complex Analysis

Algebra:

Groups: Direct product of groups. Group action, orbit-stabilizer theorem, conjugacy classes and the class equation, Cauchy's theorem, Sylow's 1st, 2nd & 3rd theorems, and the classification of finite groups of small order. Normal, subnormal and composition series, Jordan–Holder theorem (statement), commutator subgroups. Solvable groups. Finite Abelian groups, finitely generated Abelian groups, Fundamental Theorem of Finitely generated Abelian groups via invariant factors and elementary divisors.

Rings: Quotient Field of an Integral Domain. Polynomial rings, Division algorithm in polynomial rings, Irreducibility of Polynomials, Eisenstein's criterion of irreducibility. Noetherian Rings, Artinian Rings, Hilbert Basis Theorem. Radical of an ideal, associated primes, Primary ideals, Primary decomposition theorem.

Linear Algebra: Direct sum decompositions, Primary decomposition theorem, Triangularizations, Rational canonical form, Quadratic forms, Reduction and classification of quadratic forms. Bilinear forms, Symmetric and skew symmetric bilinear forms.

Complex Analysis:

Complex integration, line integral and its properties, Winding number or Index of a closed curve, Cauchy's fundamental theorem, Morera's theorem, Cauchy's integral formula, power series expansion of analytic functions, Primitives of analytic functions.

Zeros of analytic functions and their limit points, entire functions, Liouville's theorem. Fundamental theorem of algebra. Open mapping theorem, Inverse function theorem. The Maximum modulus Theorems and related problems.

Singularities and their classification, Laurent's series expansion, Riemann's theorem, Limit points of zeros and poles, Casorati-Weierstrass's theorem, behavior of a function at the point at infinity.

Theory of residues, Cauchy's residue theorem and evaluation of improper integrals. Argument principle, Rouche's theorem and its application, Conformal mappings, Möbius transformation, Principle of symmetry

Suggested Readings Books:

Algebra:

10. Fraleigh, J. B., *A First Course in Abstract Algebra*, 7th Edition, Addison-Wesley.
11. Herstein, I. N., *Topics in Algebra*, 2nd Edition, Wiley.
12. Gallian, J. A., *Contemporary Abstract Algebra*, 10th Edition, Cengage Learning.
13. Dummit, D. S., and Foote, R. M., *Abstract Algebra*, 3rd Edition, Wiley.
14. Artin, M., *Algebra*, 2nd Edition, Pearson.

15. Malik, D. S., Mordeson, J. N., and Sen, M. K., *Fundamentals of Abstract Algebra*, McGraw-Hill Education.
16. Sen, M. K., *Algebra*, Books and Allied (India).
17. Hoffman, K., and Kunze, R., *Linear Algebra*, 2nd Edition, Pearson.
18. Friedberg, S. H., Insel, A. J., and Spence, L. E., *Linear Algebra*, 5th Edition, Pearson.

Complex Analysis:

13. J. B. Conway, *Functions of one complex variable, 2nd Ed*., Narosa Publishing House, New Delhi, 1997.
14. L. V. Ahlfors – *Complex Analysis- 3rd Edn*, McGraw-Hill, 1979
15. R. V. Churchill and J. W. Brown: Complex Variables and applications.
16. I. Markushevich, Theory of Functions of a Complex Variable (Vol. I &II), Prentice-Hall, 1965 & 1967.
17. E. C. Titchmarsh, The Theory of Functions, Oxford University Press, 1939.
18. R. P. Boas – *Entire Functions,* Academic Press, 1954
19. H. Cartan – *Elementary Theory of Analytic Functions of One or Several Complex Variables,* Dover Publication, 1995.
20. E. T. Copson, *Introduction to the Theory of Function of a Complex Variable,* Oxford University press, 1970
21. K. Kodaria, *Complex Analysis,* Cambridge University Press, 2007.
22. R. Remmmert, *Theory of complex functions*, Springer-Verlag, New York, 1991.
23. W. Rudin – *Real and Complex Analysis,* Tata McGraw-Hill Education, 1987
24. J. M. Howie: Complex Analysis

Semester-7										
Paper Description	Analysis of Several Variables and Measure Theory		**Paper Code**							
Paper (Type)	Major Course (Theory)		**Credit**				**Marks**			
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**TU**	**PRC**	**Total**
400	4 Hours/week	2 Hr. 30 Min	3	1	-- -	4	60	15	---	75

Analysis of Several Variables and Measure Theory

Analysis of Several Variables:

Topology of $\mathbb{R}_n, GL_n(\mathbb{R})$ etc. Differentiability of maps from $\mathbb{R}m$ to $\mathbb{R}n$ and the derivative as a linear map.

Determinant as mapping; its continuity and differentiability, is a real square matrix.

Higher derivatives, Chain Rule, mean value theorem for differentiable functions, Taylor expansions in several variables, Local maxima and minima, Lagrange multiplier, Sard's theorem.

Multiple integrals, Existence of the Riemann integral for sufficiently well-behaved functions on rectangles, i.e., product of intervals. Multiple integrals expressed as iterated simple integrals. Brief treatment of multiple integrals on more general domains. Change of variables and the Jacobian formula, illustration with plenty of examples. Inverse and implicit function theorems. Picard's Theorem.

Curves in $\mathbb{R}2$ and $\mathbb{R}3$. Line integrals, Surfaces in $\mathbb{R}3$, Surface integrals, Integration of forms, Divergence, Gradient and Curl operations, Green's theorem, Gauss Divergence theorem and Stoke's theorem.

Measure Theory:

Extended real numbers, algebraic operations and convergence in extended real number system, Lebesgue outer measure on R, elementary properties of Lebesgue measure space including σ-finiteness, translation invariance, positive homogeneity, existence of non-Lebesgue measurable sets, regularity of Lebesgue outer measure, Borel measurability on R, measurable functions, operations with measurable functions, sequence of measurable functions, Cantor ternary set and Cantor-Lebesgue function.

Abstract measure spaces, σ-algebra of sets, limits of sequences of sets, Borel σ-algebra, measure on σ-algebra, measurable spaces and measure spaces, monotone convergence theorems for sequences of measurable sets.

Suggested Readings Books:

Analysis of Several Variables

1. Spivak, M. (1965). *Calculus on Manifolds: A Modern Approach to Classical Theorems of Advanced Calculus*. Benjamin.
2. Rudin, W. (1976). *Principles of Mathematical Analysis* (3rd ed.). McGraw-Hill.
3. Apostol, T. M. (2007). *Mathematical Analysis* (2nd ed.). Addison-Wesley.
4. Munkres, J. (2018). *Analysis on Manifolds*. CRC Press.
5. Apostol, T. M. (1969). *Calculus, Volume II: Multi-Variable Calculus and Linear Algebra with Applications* (2nd ed.). John Wiley & Sons.

Measure Theory:

1. Berberian, S. K. (1998). *Fundamentals of Real Analysis*. Springer.
2. de Barra, G. (1981). *Measure Theory and Integration*. New Age International Publishers.
3. Royden, H. L. (1988). *Real Analysis* (3rd ed.). Prentice-Hall of India.
4. Rudin, W. (2013). *Principles of Mathematical Analysis*. McGraw-Hill.
5. Yeh, J. (2000). *Lectures on Real Analysis*. World Scientific.
6. Bartle, R. G. (1966). *The Elements of Integration*. John Wiley & Sons.

Semester-7										
Paper Description	Partial Differential Equations and Integral Equations				**Paper Code**					
Paper (Type)	Major Course (Theory)		**Credit**				**Marks**			
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**TU**	**PRC**	**Total**
400	4 Hours/week	2 Hr. 30 Min	3	1	---	4	60	15	---	75

Partial Differential Equations and Integral Equations

Partial Differential Equations:

General solution and complete integral of a partial differential equation, singular solution, integral surface passing through a curve and circumscribing a surface.

Formation and solution of PDE, integral surfaces, Cauchy's method of characteristic, orthogonal surfaces, First order non-linear PDE, compatible system, Charpit's method, classification and canonical forms of PDE.
Linear partial differential equations of second and higher order, classification of Second order PDE, Monge's method. reduction to canonical form, solution of equations with constant coefficients by (i) factorization of operators (ii) separation of variables, linear PDE with variable coefficients, canonical forms, canonical transformation of linear second order PDE.

Derivation of Laplace and Poisson equation, Boundary Value Problem, Harmonic functions, characterization of harmonic function by their mean value property, method of separation of variables for the solutions of Laplace's equations, Dirichlet Problem and Neumann Problem for a rectangle, interior and exterior Dirichlet problems for a circle and a semi-circle, interior Neumann problem for a circle, solution of Laplace equation in cylindrical and spherical coordinates, steady-state heat flow equation Problems.
Formation and solution of diffusion equation, initial and boundary conditions, separation of variables method, solution of heat equation under Dirichlet and Neumann condition, heat conduction problem for an infinite rod, heat conduction in a finite rod, solution of diffusion equation in cylindrical and spherical coordinates, examples.

Formation and solution of one-dimensional wave equation, initial value problem, D'Alembert's solution, vibrating string, forced vibration, method of separation of variables, initial and boundary value problem for two-dimensional wave equation, periodic solution of one-dimensional wave equation in cylindrical and spherical coordinate systems, Duhamel's Principle, examples.

Fundamental solution and its properties, Green's functions, fundamental solution in 2D and 3D of Laplace equation, Poissoin equation and Heat equation.

Integral Equations:

Classifications, successive approximations, separable kernels, Fredholm alternative, Hilbert-Schmidt theory of symmetric kernels, construction of Green's function, convoluted kernels, Abel's equations and solutions.

Suggested Readings Books:

Partial Differential Equations

11. Sneddon, I. N. (1986). *Elements of Partial Differential Equations*. McGraw-Hill.
12. Evans, L. C. (1998). *Partial Differential Equations*. Graduate Studies in Mathematics, Vol. 19. American Mathematical Society.
13. McOwen, R. C. (2003). *Partial Differential Equations*. Pearson Education.
14. Amarnath, T. (2003). *Partial Differential Equations*. Alpha Science International.
15. Prasad, P. P., & Ravichandran, R. (1985). *Partial Differential Equations*. Wiley Eastern.
16. Smith, M. G. (1967). *Introduction to the Theory of Partial Differential Equations*. Van Nostrand.
17. Miller, F. H. (1941). *Partial Differential Equations*. Wiley.
18. Greenspan, G. (2012). *Introduction to Partial Differential Equations*. Dover Publications.
19. Jones, D. S. (1982). *Generalized Functions*. Cambridge University Press.
20. Churchill, R. V., & Brown, J. W. (1987). *Fourier Series and Boundary Value Problems* (4th ed.). McGraw-Hill.

Integral Equations

3. Tricomi, F. G. (1985). *Integral Equations*. Dover Publications.
4. Wazwaz, A. M. (2011). *Linear and Nonlinear Integral Equations: Methods and Applications*. Springer.

GRADUATE PROGRAM WITH HONOURS

(FYUGHONS)

DETAILED SYLLABUS

SEMESTER-8
(MAJOR COURSES)

Semester-8										
Paper Description	Elements of Topology and Functional Analysis		**Paper Code**							
Paper (Type)	Major Course (Theory)		**Credit**				**Marks**			
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**TU**	**PRC**	**Total**
400	4 Hours/week	2 Hr. 30 Min	3	1	---	4	60	15	---	75

Elements of Topology and Functional Analysis

Elements of Topology:

Axiom of choice and existence of choice function. Partially ordered set, linearly ordered set, well ordered set and product of the same kinds, Zorn's lemma, well ordering principle with special emphasis on Ordinal and Cardinal numbers.

Topological spaces, open and closed sets, basis and sub-basis, closure, interior and boundary of a set. Subspace topology. Continuous maps: properties and constructions; Pasting Lemma. Open and closed maps, Homeomorphisms. Product topology, Quotient topology and examples of Topological Manifolds.

Countability and separation axioms: Urysohn's lemma, Tietze extension theorem and applications. Urysohn embedding lemma and metrization theorem for second countable spaces.

Connected, path-connected and locally connected spaces. Lindelof and compact spaces. Net, filters.

Functional Analysis:

Definitions and examples; spaces likelp, $l\infty$, $C[a, b]$, Holder and Minkowski inequalities for sums, completeness of metric spaces, isometric mapping, isometric spaces, completion of metric spaces, Baire category theorem, Banach's fixed point theorem and its applications.

Normed linear spaces, Banach spaces and examples, quotient space of normed spaces and its completeness, Schauder basis, normed space and its completion, equivalent norms, finite dimensional normed linear spaces and compactness, Riesz Lemma, bounded linear operators, its equivalence with continuity, normed linear spaces of bounded linear operators, linear functional, bounded linear functional, dual space and second dual space, canonical embedding, algebraic reflexivity, strong and weak convergence, uniform boundedness theorem and some of its consequences, open mapping theorem, closed graph theorem, Hahn-Banach theorem for real linear spaces, complex linear spaces and some of its consequences.

Inner product spaces, Hilbert spaces and examples, Cauchy-Schwarz inequality, triangle inequality, parallelogram law, Inner product spaces and its completion, orthonormal sets and sequences, orthogonal complements and direct sums, Bessel's inequality, Gram-Schmidt orthonormalization process, complete orthonormal sets and Parseval's identity, Riesz representation theorem, Sesquilinear form, separable and non-separable Hilbert space, reflexivity of Hilbert spaces.

Adjoint of an operator on a Hilbert space, Self-adjoint operators, normal and unitary operators, convergence of sequences of operators and functionals, positive operators, projection operators, compact operators.

Suggested Readings Books:

Elements of Topology

2. Munkres, J. R. (2000). *Topology: A First Course*. Prentice Hall.
3. Simmons, G. F. (1963). *Introduction to Topology and Modern Analysis*. McGraw-Hill.
4. Armstrong, M. A. (1983). *Basic Topology*. Springer.
5. Kelley, J. L. (1955). *General Topology*. Springer-Verlag.
6. Dugundji, J. (1966). *Topology*. Universal Book Stall (UBS).
7. Willard, S. (2004). *General Topology*. Dover Publications.

Functional Analysis

4. Kreyszig, E. (1978). *Introductory Functional Analysis with Applications*. John Wiley & Sons.
5. Simmons, G. F. (1963). *Introduction to Topology and Modern Analysis*. McGraw-Hill.
6. Conway, J. B. (1990). *A Course in Functional Analysis*. Springer-Verlag.

Research Project /Dissertation with Research Methodology

Semester-8										
Paper Description	Research Methodology				**Paper Code**					
Paper (Type)	Major Course (Theory)		**Credit**				**Marks**			
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**TU**	**PRC**	**Total**
400	4 Hours/week	2 Hr. 30 Min	2		---	2	40			40
Paper Description	Bachelor's thesis, Presentation and Viva Voce				**Paper Code**					
Paper (Type)	Major Course (Theory)		**Credit**				**Marks**			
Paper Level	**Class Hours**	**Sem. End Exam.**	**L**	**T**	**P**	**Total**	**TH**	**TU**	**PRC**	**Total**
400	4 Hours/week	2 Hr. 30 Min			1+1	2			20+ 15	35

Research Methodology

Research Methodology:

Introduction:
Meaning, purpose, objectives, characteristics, motivation, significance, types of research; approaches, process, methods and methodology used in research ; criteria of good research; research methods in general and Mathematical Sciences in particular.

The Research Problem:
Research problems and sub-problems identification, stating, defining, techniques involved in defining problem.

Interpretation and Report Writing:
Techniques of interpretation- significance, types, steps, checklist/precautions and characteristics of research documentation i.e. reviews, treatise, monographs, abstracts, articles, technical reports, white papers, research papers, thesis etc.- issues and techniques of writing project proposals, paper presentation and soft skills.

Mathematical Reasoning, Ethical issues and Professional Conduct:
Mathematical logic and reasoning, methods of proofs (direct proof, proof by contradiction, proof by contrapositive, mathematical induction), construction of examples and counter examples, Ethics in general, Professional Ethics, ethical Issues and their significance those arise from Computer Technology, General Moral Imperatives, Concepts and issues related to plagiarism and Intellectual Property Rights

Literature Review:
Importance of Literature review in defining a problem, including literature in research proposal, critique, survey & peer review process, identifying gap areas from literature review; Major Research areas, Journals, Publication, Conferences and Status of Research in the field of Mathematical Sciences.

Mathematical Type Setting and communication:
Structure of a mathematical research paper, Writing definitions, propositions, lemmas, theorems and proofs, Writing abstracts and introductions, Preparation of references and bibliography, Basic introduction to LaTeX, Oral presentation and seminar skills.

Suggested Readings Books:

1. Creswell, J. W., & Creswell, J. D. (2023). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (6th ed.). SAGE Publications.
2. Kumar, R. (2019). *Research Methodology: A Step-by-Step Guide for Beginners* (5th ed.). SAGE Publications.
3. Babbie, E. (2020). *The Practice of Social Research* (15th ed.). Cengage Learning.
4. Kothari, C. R., & Garg, G. (2019). *Research Methodology: Methods and Techniques* (4th ed.). New Age International Publishers.
5. Booth, W. C., Colomb, G. G., Williams, J. M., Bizup, J., & Fitzgerald, W. T. (2016). *The Craft of Research* (4th ed.). University of Chicago Press.
6. Turabian, K. L. (2018). *A Manual for Writers of Research Papers, Theses, and Dissertations* (9th ed.). University of Chicago Press.
7. Walliman, N. (2021). *Research Methods: The Basics* (3rd ed.). Routledge.
8. Punch, K. F. (2016). *Developing Effective Research Proposals* (3rd ed.). SAGE Publications.
9. Zikmund, W. G., Babin, B. J., Carr, J. C., & Griffin, M. (2013). *Business Research Methods* (9th ed.). Cengage Learning.
10. Field, A. (2018). *Discovering Statistics Using IBM SPSS Statistics* (5th ed.). SAGE Publications.
11. Kothari, C. R., & Garg, G. (2019). *Research Methodology: Methods and Techniques* (4th ed.). New Age International Publishers.
12. Higham, N. J. (1998). *Handbook of Writing for the Mathematical Sciences* (2nd ed.). Society for Industrial and Applied Mathematics (SIAM).
13. Krantz, S. G. (1997). *A Primer of Mathematical Writing: Being a Disquisition on Having Your Ideas Recorded, Typeset and Read*. American Mathematical Society.
14. Hammack, R. (2013). *Book of Proof* (3rd ed.). Virginia Commonwealth University.
15. Pólya, G. (1973). *How to Solve It: A New Aspect of Mathematical Method* (2nd ed.). Princeton University Press.

Bachelor's thesis, Presentation and Viva Voce

Research Methodology (2 Credit, 40 Marks),

Bachelor's thesis (Literature Review and development of current results and proofs/validation) (1 Credit, 20 Marks),

Presentation and Viva Voce (1 Credit, 15 Marks).

Bachelor's thesis Presentation and Viva Voce (To be evaluated by a panel of External Subject Experts nominated jointly by the Chairperson, UGBoS and Chairperson, Departmental Research Committee (DRC), Mathematics, NBU).

Presentation will be on the Bachelor's thesis and viva voce will be on the presentation as well as the courses taught.

Prof. Manoranjan Singha
Chairperson
UG-BOS in Mathematics, NBU