Center for Basic Sciences
Pt. Ravishankar Shukla University, Raipur

Course structure for the M. Sc. (Integrated) Mathematics stream
w.e.f. July 1st , 2015

(P: **P**hysics, M: **M**athematics, C: **C**hemistry, B: **B**iology, G: **G**eneral, H: **H**umanity, ME: **M**ath **E**lective, MPr : **M**ath **P**roject)

Semester Scheme

There shall be 10 semesters in Integrated M.Sc. Mathematics Course. Five out of thirty elective courses should be taken from the elective courses offered by the School of Mathematical Sciences. Credit points in each semester is indicated in the table below. **Minimum credit points** required to pass each semester is **10.** A total of **minimum 100 credit points** is required to get **M.Sc. degree in Mathematics** from the School of Mathematical Sciences.

Year	Semester	Subjects			Credit Points Min	Credit Points Max	Cumulative Credit Points
		Theory	**Practical**	**Project**			
1st Year	Sem. I	5(x3)+ 1(x2) = 18	4(x2)= 08	----	10	25	25
	Sem. II	5(x3)+ 1(x2) = 18	4(x2)= 08	----	10	25	50
2nd Year	Sem. III	5(x4)+2(x2)= 24	1(x1)= 01	----	10	25	75
	Sem. IV	5(x4)= 20	1(x4)+1(x1) = 05	----	10	25	100
3rd Year	Sem. V	6(x4)= 24	1(x1)= 02	----	10	25	125
	Sem VI	5(x4)+1(x2)= 22	1(x3)=03	----	10	25	150
4th Year	Sem VII	5(x4) = 20	----	05	10	25	175
	Sem VIII	5(x4) = 20	----	05	10	25	200
5th Year	Sem IX	----	----	20	10	20	220
	Sem X	Elective Papers 5(x4)=20	----	----	10	20	240
Total Credit Points							240
Minimum Credit Points Required to get M.Sc. degree in Mathematics							100

SEMESTER –I

Subject Code	Subject	Contact Hours / Week Theory+Tutorials	Credits
B101	Biology – I	[2 + 1]	3
C101	Chemistry – I	[2 + 1]	3
MB101/M101	Mathematics – I	[2 + 1]	3
P101	Physics – I	[2 + 1]	3
G101	Computer Basics	[2 + 1]	3
H101	Communication Skills	[2 + 0]	2
		Lab Hours per Week	
BL101	Biology Laboratory – I	[4]	2
CL101	Chemistry Laboratory – I	[4]	2
PL101	Physics Laboratory – I	[4]	2
GL101	Computer Laboratory	[4]	2
		Semester Credits	**25**
		Subtotal	**25**

MB101: Mathematics – 1   (**For Biology Stream**)

Unit-I The idea of derivative of a function, polynomials, slope and tangent line, derivatives of trigonometric functions, product and quotient rules. Notion of limits and continuous functions.

Elementary results pertaining to limits of functions: product and quotient rules. Higher order derivatives, examples. Maxima and minima, curve tracing, Conic sections: circle, ellipse, hyperbola and parabola; equations, focus, directrix, latus rectum. Generalised conic section equation, exponential and logarithmic functions and their derivatives.

Unit-II Application of derivatives to root finding: Newton's method (to be supplemented by an introduction to iterative processes). Mean value theorem of differential calculus, Rolle's theorem, applications. l'Hôpital's rule. The chain rule of differentiation, Implicit differentiation, Inverse functions and their derivatives, Inverse trigonometric functions, Applications.

Concept of infinite series, Geometric series, convergence tests; Taylor series, Maclaurin series for elementary functions, power series, simple applications.

Unit-III Notion of an integral, integral as limit of sums; anti-derivatives, area under a curve, definite integrals, indefinite integrals. Rules of integration: integration by parts, integration by substitution. Properties of definite integrals including mean value theorem for integral calculus. Fundamental theorem of integral calculus. Integrals involving polynomial, exponential, logarithmic, trigonometric, inverse trigonometric functions. Application of integrals to areas, length of a plane curve, volumes of solids of revolution.

Unit-IV Complex numbers: real and imaginary parts, The complex plane, Complex algebra (complex conjugate, absolute value, complex equations, graphs, physical applications). Elementary functions of complex numbers, Euler's formula, Powers and roots of complex numbers. The exponential and trigonometric functions, Hyperbolic functions, Logarithms, Complex roots and powers, Inverse trigonometric and hyperbolic functions, Some applications.

Unit-V Separable equations, Linear first order equations, Other methods for first order equations, Second order linear equations with constant coefficients and both zero and non-zero right hand side, Other second order equations.

Suggested Texts and References:
1) Calculus: Gilbert Strang (MIT Courseware)
2) Calculus: M. Weir, J. Hass and F. R. Giordano (Pearson Education)

M101: Mathematics – I   (For Physics, Mathematics & Chemistry Stream)

Unit-I Introduction to coordinate geometry: Equation of a straight line and circle. Introduction to trigonometry (including addition formulas for sine and cosine) through coordinate geometry. AP and GP and inequalities of the mean. Binomial theorem for integer powers.

Unit-II Complex numbers: real and imaginary parts, the complex plane, complex algebra (complex conjugate, absolute value, complex equations, graphs, physical applications). Consequences of Euler's formula.

Unit-III The idea of derivative of a function, effects of small changes, slope and tangent line, derivatives of polynomials and trigonometric functions, product and quotient rules. Notion of limits and continuous functions. Higher order derivatives, examples. Maxima and minima. Graphical representation of elementary functions such as polynomials, conics, trigonometric functions, exponentials, logarithms and the sawtooth functions. Inverse functions and their graphical representations. Derivatives of exponential, hyperbolic and logarithmic functions. Application of derivatives to root finding: Newton – Raphson method. The chain rule of differentiation, implicit differentiation, inverse functions and their derivatives.

Unit-IV Concept of sum of infinite series, geometric series, harmonic series, simple convergence tests. Taylor series, applications to elementary functions, binomial expansion for non-integral powers. Notion of an integral, integral as limit of sums; anti-derivatives, area under a curve, definite integrals, indefinite integrals. Rules of integration: integration by parts, integration by substitution. Properties of definite integrals. Integrals involving elementary functions. Application of integrals to areas and volumes of solids of revolution.

Unit-V System of linear equations, notion of a matrix, determinant. Simple properties of matrices and their inverses. Examples of inverting 2X2 and 3X3 matrices. Elementary discussion on scalars and vectors, norm of a vector, dot product, projections, cross product, triple products, applications to areas and volumes.

Suggested Texts and References:
1. Calculus, Gilbert Strang (MIT Courseware) http://ocw.mit.edu/resources/res-18-001- calculus-online-textbook-spring-2005/textbook/
2. Thomas' Calculus, 11th Edition, M. Weir, J. Hass and F. R. Giordano, Pearson

Education.
3. Mathematical Methods in the Physical Sciences, 3rd Ed., Mary L. Boas, Wiley Student Ed., Wiley India (Reprint) 2009 (for complex numbers and differential equations)
4. Elementary Linear Algebra, 10th Ed., Howard Anton and Chris Rorres, Wiley, 2011.
5. Introduction to Linear Algebra, 4th Edition, Gilbert Strang, Wellesley Cambridge Press, 2009.

M101: Mathematics – I (For Physics, Mathematics & Chemistry Stream)

Unit I Numbers, Functions and Sequences: Real Numbers, Functions, Sequences – Convergent, Bounded and Monotone, Limit theorems. Limit and Continuity: Limit of a function at a point, Continuity of functions, Discontinuities of functions, Properties of continuous functions.
Differentiation: Differentiation, Chain rule, Successive differentiation, Rolle 's Theorem and mean value theorem.

Unit II Maxima, Minima and Curve Sketching: Sufficient conditions for a function to be increasing/decreasing, Sufficient conditions for a local extremum, Absolute minimum/maximum, Convex/concave functions, Asymptotes, Curve sketching.
Integration: Integral from upper and lower sums, Integral as a limit of Riemann sums, Fundamental theorem of calculus and its applications. Logarithmic and Exponential functions: Logarithmic functions, Exponential functions, Power functions, l'Hôpital's rule. Applications of Integration: Arc length of a plane curve, Arc length of a plane curve in parametric form, Area of a surface of revolution, Volume of a solid of revolution by slicing, by the washer method and by the shell method.

Unit-III Limit and Continuity of Scalar Fields: Spaces R^2 **and** R^3, Scalar fields, level curves and contour lines, Limit of a scalar field, Continuity of a scalar field, Properties of continuous scalar fields.
Differentiation of Scalar Fields: Partial derivatives, Differentiability, Chain rules, Implicit differentiation, Directional derivatives, Gradient of a scalar field, Tangent plane and normal to a surface, Higher order partial derivatives, Maxima and minima, Saddle points, Second derivative test for maxima/minima/saddle points.Vector Fields: Vector fields and their properties, Curves in space, Tangent vector, Basic idea of divergence and curl.

Unit-IV Complex Numbers: Real and imaginary parts, The complex plane, Complex algebra (complex conjugate, absolute value, complex equations, graphs, physical applications), Elementary functions of complex numbers, Euler's formula, Powers and roots of complex numbers, The exponential and trigonometric functions, Hyperbolic functions, Logarithms, Complex roots and powers, Inverse trigonometric and hyperbolic functions, Some applications.

Unit V Ordinary Differential Equations: Separable equations, Linear first order equations, Other methods for first order equations, Second order linear equations with constant coefficients and both zero and non-zero right hand side, Other second order equations, The Laplace transform, Solution of differential equations by Laplace transforms.

Suggested Texts and References:
1.Calculus @ iitb – Concepts,Examples and Quizzes, Inder K. Rana, Version 2, 2010 (Math4all).
2. Introduction to Real Analysis, 3rd Ed., Robert G. Bartle and Donald R. Sherbert, Wiley
3. Student Ed., Wiley India (4th Reprint) 2007.

4. Mathematical Methods in the Physical Sciences, Mary L. Boas, 3rd Edition, Wiley Student Ed.,Wiley India (Reprint) 2009 (for complex numbers and ordinary differential equations).

SEMESTER –II

Subject Code	Subject	Contact Hours / Week Theory+Tutorials	Credits
B201	Biology – II	[2 + 1]	3
C201	Chemistry – II	[2 + 1]	3
MB201/M201	Mathematics – II	[2 + 1]	3
P201	Physics – II (Optics, Electricity & Magnetism)	[2 + 1]	3
G201	Electronics and Instrumentation	[2 + 1]	3
G202	Glimpses of Contemporary Science	[2 + 0]	2
		Contact Hours / Week Laboratory	
BL201	Biology Laboratory	[4]	2
CL201	Chemistry Laboratory	[4]	2
PL201	Physics Laboratory	[4]	2
GL201	Electronics Laboratory	[4]	2
		Semester Credits	**25**
		Subtotal	**50**

MB201: Mathematics – II   (**For Biology Stream**)

Unit I Functions of several variables, partial derivatives, geometric interpretation, properties of partial derivatives, chain rule, applications. Elementary discussion on scalars and vectors, norm of a vector, dot product, projections. Linear equations and matrices, matrix operations. Concept of a determinant, its properties, evaluation of a determinant, cross product as a determinant, lines and planes. Elementary ideas of tensors.

Unit II Vector functions. Gradient of a function, geometric interpretation, properties and applications; divergence and curl of a vector function, geometric interpretation, properties and applications; higher derivatives, Laplacian. Line integrals. Double and triple integrals, their properties and applications to areas, volumes, etc.

Unit III Gradient theorem, Green's theorem, Stokes' theorem, divergence theorem, applications. Proofs of Stokes' and divergence theorems through physical examples (such as circulation in a 2 dimensional plane and accumulation of fluid in a given volume).

Unit IV Curvilinear coordinate systems, spherical and cylindrical coordinates, area and volume elements, illustrations. Gradient, divergence and curl in curvilinear coordinate systems.

Unit V Introduction to linear algebra. Vector spaces, linear dependence and independence, notion of basis, and dimension, subspaces. Examples. More on matrices: special kinds of matrices, their properties.

Eignevalues and eigenvectors, secular determinant, characteristic polynomial. Eigenvalues and eigenvectors of a real symmetric matrix. Illustrative examples. Applications of linear algebra.

Suggested Texts and References (for M100 and M200)
1) Calculus: Gilbert Strang (MIT Courseware)
2) Calculus: Thomas
3) Elementary Linear Algebra: Howard Anton and Chris Rorres
4) Introduction to Linear Algebra: Gilbert Strang (MIT Courseware)
5) Mathematical Methods for Scientists and Engineers: George B. Arfken and Hans J. Weber (for curvilinear coordinates, beta and gamma functions only)

M201: Mathematics – II (For Physics & Chemistry Stream)

Unit I Differential equations: separable equations, first order differential equations. Second order differential equations and Wronskian; equations with constant coefficients, homogeneous and inhomogeneous equations.

Unit II Scalar functions of several variables, partial derivatives, geometric interpretation (maxima, minima, saddle points), properties of partial derivatives, chain rule, applications. Gradient of a function, geometric interpretation, properties and applications.

Unit III Vector functions. Derivatives of a vector function, divergence and curl, geometric interpretation, properties and applications; higher derivatives, Laplacian.

Unit IV Spherical and cylindrical coordinates, area and volume elements, illustrations. Gradient and divergence in spherical and cylindrical coordinates.

Unit V Line integrals. Double and triple integrals, their properties and applications to areas, volumes, etc. Gradient theorem, divergence theorem, Stokes' theorem, applications. Illustrations from fluid flow and electromagnetism.

Suggested Texts and References
1. Calculus, Gilbert Strang (MIT Courseware) http://ocw.mit.edu/resources/res-18-001-calculus-online-textbook-spring-2005/textbook/
2. Thomas' Calculus, 11th Edition, M. Weir, J. Hass and F. R. Giordano, Pearson Education.
3. Mathematical Methods in the Physical Sciences, 3rd Ed., Mary L. Boas, Wiley Student Ed., Wiley India (Reprint) 2009 (for complex numbers and differential equations)
4. Elementary Linear Algebra, 10th Edition, Howard Anton and Chris Rorres, Wiley Student Ed., Wiley 2011.
5. Introduction to Linear Algebra, 4th Edition, Gilbert Strang, Wellesley Cambridge Press, 2009.

M201: Mathematics – II (For Physics & Chemistry Stream)

Unit I Algebra of matrices (real numbers and other fields), special matrices (scalar, diagonal, upper and lower triangular, etc.). Linear equations and their matrix representations, row-echelon form, Gauss- Jordan elimination, general and particular solutions, homogeneous equations. Invertible matrices and elementary matrices, computation of inverse using elementary row operations. Determinants and their properties, minors and cofactors, determinant of a product of matrices, adjoint of a matrix, invertible matrices and determinants. Cramer's rule. Rank of a

matrix, rank and invertibility. Vector spaces (real numbers and other fields). Examples including the space of polynomials, the space of functions, the solution space of a system of homogeneous linear equations, and row and column spaces of a matrix. Span, linear independence, basis, dimension and its uniqueness.

Unit II Linear transformations, isomorphisms, kernel and image, the dimension formula. Eigenvalues and eigenvectors of a square matrix or a linear operator, computation of eigenvalues and eigenvectors, characteristic polynomial, sums and products of eigenvalues, similar matrices, diagonalization.

Unit III Review of geometric properties of vectors in $\mathbf{R^2}$ **and** $\mathbf{R^3}$, dot, cross and scalar triple products, their properties and their geometric interpretation. Vector fields, review of definitions and basic properties of gradient, divergence, directional derivatives, divergence, curl and the Laplace operator. Paths and curves in $\mathbf{R^2}$ and $\mathbf{R^3}$, tangent, velocity, acceleration and force vectors, arc length.

Unit IV A brief overview of differentials. Double integrals as limits of Riemann sums and as volumes, their computation as iterated integrals, elementary regions. Triple integrals as limits of Riemann sums, their computation as iterated integrals, elementary regions. Change of variables, the Jacobian determinant, spherical and cylindrical coordinates.

Unit V Application of double and triple integrals to finding volume, centre of mass, etc. Line integrals, their dependence on parametrization, their computation, work done. Parametrized surfaces, normal to a surface, surface area, surface integrals and their dependence on parametrization, their computation. Oriented surfaces, statement of Green's theorem and its application to computing the area of a region, statements of Stokes' theorem, and Gauss' divergence theorem. Conservative vector fields.

Suggested Texts and References:
1. A Course in Linear Algebra with Applications, 2nd Edition, D. J. S. Robinson, World Scientific 2006.
2. Calculus and Analytic Geometry, 9th Edition, G. B. Thomas and R. L. Finney, Pearson Education 2002.
3. Basic Multivariable Calculus, J. Marsden, A. Tromba and A. Weinstein, Springer (India),2009.
4. Calculus @ iitb–Concepts, Examples and Quizzes, Inder K. Rana, Version 2, 2010(Math4all).

M201 : Mathematics II (Calculus and Linear Algebra)
(For Mathematics Stream only)

Unit I Recollection and rigorous treatment of continuity and differentiability of a function of one variable.Riemann integration, proof of the Fundamental Theorem of Calculus. Functions of two and three variables, double and triple integrals.

Unit II Line integrals. Parametrized surfaces, oriented surfaces. Stokes Theorem, Gauss Divergence Theorem (both without proof).

Unit III Recollection of the algebra of matrices (mainly over the field of real numbers, but mention other fields also), linear equations, row-echelon form, Gauss-Jordan elimination. Determinants, rank of a matrix, rank and invertibility.

Unit IV Vector spaces (mainly over the field of real numbers, but mention other fields also), span, linear independence, basis, dimension and its uniqueness (without proof).

Unit V Linear transformations, kernel and image, the rank-nullity formula. Eigen values and eigenvectors of a square matrix or a linear operator.

References
[1] D.J.S. Robinson, A Course in Linear Algebra with Applications, World Scientific.
[2] G. B. Thomas and R.L. Finney, Calculus and Analytic Geometry, 9th ed., Addison-Wesley/Narosa,1998.
[3] J. Marsden, A. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer
[4] Inder K. Rana, Calculus@iitb, Concepts and Examples, Version 1.2, math4all 2009.

<u>SECOND YEAR</u>
SEMESTER –III

Subject Code	Subject	Contact Hours / Week Theory+Tutorials	Credits
M301	Foundations	[3 + 1]	4
M302	Analysis I	[3+ 1]	4
M303	Algebra I	[3 + 1]	4
M304	Discrete Mathematics	[3 + 1]	4
M305	Computational Mathematics I	[3 + 1]	4
H301	World Literature	[2 + 0]	2
H302	History and Philosophy of Science	[2 + 0]	2
		Lab Hours per Week	
GL301	Computation Mathematics Laboratory	[2]	1
		Semester Credits	**25**
		Subtotal	**75**

M301 : Foundations

Unit I Logic: Quantifiers, negations, examples of various mathematical and non-mathematical statements. Exercises and examples.
Set Theory: Definitions, subsets, unions, intersections, complements, symmetric difference, De Morgan's laws for arbitrary collection of sets. Power set of a set.

Unit II Relations and maps: Cartesian product of two sets. Relations between two sets. Examples of relations. Definition of a map, injective, surjective and bijective maps. A map is invertible if and only if it is bijective. Inverse image of a set with respect to a map. Relation between inverse images and set theoretic operations. Equivalence relations (with lots of examples). Schroeder-Bernstein theorem.

Unit III Finite and Infinite sets: Finite sets, maps between finite sets, proof that number of elements in a finite set is well defined. Definition of a countable set (inclusive of a finite set). Countably infinite and uncountable sets. Examples. Proof that every infinite set has a proper, countably infinite subset. Uncountability of P(N).

Unit IV Partially Ordered Sets: Concept of partial order, total order, examples. Chains, Zorn's Lemma.

Unit V Peano's Axioms. Well-Ordering Principle. Weak and Strong Principles of Mathematical Induction. Transfinite Induction. Axiom of Choice, product of an arbitrary family of sets. Equivalence of Axiom of Choice, Zorn's Lemma and Well-ordering principle.

Additional Topics (Optional)
   (i) Dedekind's Construction of Real Numbers.
   (ii) Decimal, dyadic, triadic expansions of real numbers.
   (iii) Cantor Sets.

References
[1] Naive Set Theory, P. Halmos.
[2] Set Theory and Logic, R. Stoll.
      A lot of the material can be found in the beginning sections of the following books:
[3] Methods of Real Analysis, R. Goldberg.
[4] Topology, J. Munkres.
[5] Elementary Number Theory, D. Burton.
[6] Real Analysis, Bartle and Sherbert.

M302 : Analysis I

Unit I Real Number System: Concept of a field, ordered field, examples of ordered fields, supremum, infimum. Order completeness of **R, Q** is not order complete. Absolute values, Archimedean property of **R. C** as a field, and the fact that **C** cannot be made into an ordered field. Denseness of **Q** in **R.** Every positive real number has a unique positive n-th root.

Unit II Sequences: Sequences, limit of a sequence, basic properties like $\lim_n(x_n y_n) = (\lim_n x_n)(\lim_n y_n)$. Bounded sequences, monotone sequences, a monotone increasing sequence bounded above converges to it's supremum. Sandwich theorem and its applications. Using the Arithmetic mean-Geometric mean inequality to prove results like $\lim_{n\to\infty}\left(1+\frac{1}{n}\right)^n$ and $\lim_n(1-\frac{1}{n})^n$ and are equal, $\lim_n \sqrt[n]{n} = 1$ and $\lim_n a^{\frac{1}{n}} = 1$. Cauchy's first limit theorem, Cauchy's second theorem.
Subsequences and Cauchy sequences: Every sequence of real numbers has a monotone subsequence. Definition of a Cauchy sequence. Cauchy completeness of **R, Q** is not Cauchy complete.

Unit III Infinite Series: Basic notions on the convergence of infinite series. Absolute and conditional convergence. Comparison test, ratio test, root test, alternating series test, Theorem of Dirichlet, Statement of Riemann's rearrangement theorem, Cauchy product of two series. Power series, radius of convergence via examples.

Unit IV Continuous functions: Continuity, sequential and neighbourhood definitions, basic properties such as sums and products of continuous functions are continuous. Intermediate Value Theorem, Continuous functions on closed and bounded intervals, Monotone continuous functions, inverse functions, Uniform Continuity, examples and counter-examples.

Differentiable functions: Definition : as a function infinitesimally approximable by a linear map, equivalence with Newton ratio definition, basic properties. One-sided derivatives, The O; o and $\sim$ notations with illustrative examples. Chain rule with complete proof (using above definition). Local monotonicity, relation between the sign of f' and local monotonicity. Proofs of Rolle's theorem and the Cauchy-Lagrange Mean value theorem. L'Hospital's rule and applications. Higher derivatives and Taylor's theorem, estimation of the remainder in Taylor's theorem, example:

$$f(x) = \begin{cases} e^{-\frac{1}{x^2}} & x \neq 0 \\ 0 & x = 0 \end{cases} \text{. Convex functions.}$$

Unit V   Riemann Integration: Definition via upper and lower Riemann sums, basic properties. Riemann integrability, Thm : $f:[a,b] \rightarrow \boldsymbol{R}$ continuous implies f is Riemann integrable, examples of Riemann integrable functions which are not continuous on $[a,b]$. Thm : if $f:[a,b] \rightarrow \boldsymbol{R}$ is Riemann integrable then so is $|f|$ and $|\int_a^b f(x)dx| \leq \int_a^b |f(x)|dx$. Cauchy-Schwartz inequality

$$: \left|\int fg\right| \leq \sqrt{\int f^2}\sqrt{\int g^2}, \ \left|\int fg\right| \leq \left(\int f^p\right)^{\frac{1}{p}}\left(\int g^q\right)^{\frac{1}{q}} \text{ where } \frac{1}{p} + \frac{1}{q} = 1. \text{ Mean value theorem for integrals.}$$

Improper integrals, power series and elementary functions : Cauchy's condition for existence of improper integrals, test for convergence. Examples : $\int \frac{\sin x}{x} \, dx, \ \int \cos x^2 \, dx, \ \int \sin x^2 \, dx$. Power series and basic properties, continuity of the sum, validity of term by term differentiation. Binomial theorem for arbitrary real coeficients. Elementary transcendental functions e^x, sin x, cos x and their inverse functions, $\log x, \ tan^{-1} x$, Gudermannian and other examples.

References
[1] Introduction to Real Analysis : R. Bartle & D. Sherbert, Wiley.
[2] A First Course in Analysis : G. Pedrick

M303 : Algebra I (Groups, rings, fields)

Unit I Recollection of equivalence relations and equivalence classes, congruence classes of integers modulo n. Definition of a group, examples including matrices, permutation groups, groups of symmetry, roots of unity. First properties of a group, laws of exponents, finite and infinite groups.

Unit II Subgroups and cosets, order of an element, Lagrange theorem, normal subgroups, quotient groups. Detailed look at the group S_n of permutations, cycles and transpositions, even and odd permutations, the alternating group, simplicity of A_n for n ≥ 5.

Unit III Homomorphisms, kernel, image, isomorphism, the fundamental theorem of group Homomorphisms. Cyclic groups, subgroups and quotients of cyclic groups, finite and infinite cyclic groups.

Unit IV Cayleys theorem on representing a group as a permutation group. Conjugacy classes, centre, class equation, centre of a p-group. Sylow theorems, solvable and nilpotent groups.

Unit V Definition of a ring, examples including congruence classes modulo n, ideals and Homomorphisms, quotient rings, polynomial ring in one variable over a ring, units, fields, non-zero divisors, integral domains. Rings of fractions, field of fractions of an integral domain. PID, unique factorization in the ring of integers and in the polynomial ring over a field, Gauss Lemma.

References

[1] M. Artin, Algebra, Prentice Hall of India, 1994.
[2] D.S. Dummit and R.M. Foote, Abstract Algebra, 2nd Ed., John Wiley, 2002.
[3] N. Jacobson, Basic Algebra II, Hindustan Publishing Corporation, 1983.
[4] S. Lang, Algebra, 3rd ed. Springer (India) 2004.

M 304 : Discrete Mathematics

Unit I Combinatorics: Permutations and combinations. Linear equations and their relation to distribution into boxes.Distributions with repetitions and non-repetitions. Combinatorial derivation of these formulae. Pigeonhole Principle and applications.

Unit II Binomial and multinomial theorems. Inclusion-Exclusion Principle and Applications. Recurrence Relations and Generating Functions. Partitions of a number. Number of partitions. Brief introduction to the combinatorics of Young tableaux.

Unit III Graph theory: Vertices and edges. Graphs and special types like complete graph, bipartite graph. Degree of a vertex, weighted graphs. Traveling Salesman's Problem. Koenigsberg Seven-bridge puzzle. Walks, Paths, Circuits.

Unit IV Euler Graphs, Hamiltonian Paths and Circuits. Trees and algorithms to find trees in a given graph. Planar Graphs.

Unit V Spaning trees and cut sets. Minimal spanning trees and algorithms for their computer implementation: the Kruskal's algorithm. Coloring in graph theory. The four colour problem.

References

[1] Richard Stanley, Enumerative Combinatorics.
[2] Alan Tucker, Applied Combinatorics.
[3] F. Harrary, Graph Theory.
[4] Narsingh Deo, Graph Theory.

M305 : Computational Mathematics I

Unit I Basics of Spreadsheet Programmes (such as Libreoffce/gnumeric).

Unit II Inroduction to Mathematica including writing simple programmes.

Unit III   Detailed exploration of notion of calculus of one variable, and simple multivariable calculus using Mathematica.

Unit IV   Basic Linear Algebra Using Mathematica.

Unit V   Numerical Solutions of Linear and Non-linear equations using Mathematica. Developing Programmes for each of these methods.

References
[1] Selwyn Hollis, CalcLabs with Mathematica for Single Variable Calculus, Fifth Edition.
[2] Selwyn Hollis, CalcLabs with Mathematica for Multivariable Calculus, Fifth Edition.
[3] Kenneth Shiskowski, Karl Frinkle, Principles of Linear Algebra with Mathematica.

H301 : World Literature

Unit I   What is literature? - A discussion; introduction to literary terms, genres, and forms of various periods, countries, languages, etc.

Unit II   The novel: Class study of 'Brave New World' by Aldous Huxley; group discussions and student presentations on other genres such as the graphic novel, detective fiction, children's literature, etc.

Unit III Plays: Introduction to the history of theatre, class study of (mainly) two plays: 'Pygmalion' by G. B. Shaw and 'Fire and Rain' by Girish Karnad, the setting up of a play-reading group through which the students can be introduced to several other plays.

Unit IV   Poetry: Brief introduction, study of poetic genres, forms, topics, figures of speech, poetic language, etc. by analyzing various poems from around the world. Short stories, essays, and other types of writing by various authors.

Unit V Screening of films based on literary works, such as Pygmalion (My Fair Lady), Fire and Rain (Agnivarsha), Persepolis (a graphic novel), and many others.

SEMESTER –IV

Subject Code	Subject	Contact Hours / Week Theory+Tutorials	Credits
M401	Analysis II	[3 + 1]	4
M402	Algebra II	[3+ 1]	4
M403	Elementary Number Theory	[3 + 1]	4
M404	Topology I	[3 + 1]	4
G401	Statistical Techniques and Applications	[3 + 1]	4

		Lab Hours per Week	
GL401	Computational Laboratory & Numerical Methods	[8]	4
GL402	Statistical Techniques Laboratory	[2]	1
		Semester Credits	**25**
		Subtotal	**100**

M401 : Analysis II (Multivariable Calculus)

Unit I Linear maps from $\mathbf{R}^n$ to $\mathbf{R}^m$, Directional derivative, partial derivative, total derivative, Jacobian, Mean value theorem and Taylors theorem for several variables, Chain Rule.

Unit II Parametrized surfaces, coordinate transformations, Inverse function theorem , Implicit function theorem, Rank theorem.

Unit III Critical points, maxima and minima, saddle points, Lagrange multiplier method.

Unit IV   Multiple integrals, Riemann and Darboux integrals, Iterated integrals, Improper integrals, Change of
variables.

Unit V Integration on curves and surfaces, Greens theorem, Differential forms, Divergence, Stokes theorem.

References
[1] M. Spivak, Calculus on Manifolds.
[2] W. Fleming, Functions of Several Variables, 2nd Ed., Springer-Verlag, 1977.
[3] J.E.Marsden, A.J. Tromba and A. Weinstein, Basic Multivariable Calculus.
[4] W. Rudin, Principles of Mathematical Analysis, 3rd ed., McGraw-Hill, 1984.
[5] A Modern Approach to Classical Theorems of Advanced Calculus, W. A. Benjamin, Inc., 1965.

M402 : Algebra II (Linear Algebra)

Unit I Modules over a commutative ring, submodules and quotient modules, generators,homomorphisms, exact sequences, finitely generated free modules.

Unit II Vector spaces as modules over a field, subspaces, quotient spaces.Span and linear independence, basis, dimension.

Unit III Linear maps and their corrrespondence with matrices with respect to given bases, change of bases.

Unit IV Eigenvalues, eigenvectors, eigenspaces, characteristic polynomial, Cayley-Hamilton.

Unit V   Bilinear forms, inner product spaces, Gram-Schmidt process, diagonalization, spectral theorem.

Note: Jordan and rational canonical forms to be done in M602 in Semester VI as an application of

the structure of finitely generated modules over a PID.

References

[1] M. Artin, Algebra, Prentice Hall of India, 1994.
[2] D.S. Dummit and R. M. Foote, Abstract Algebra, 2nd Ed., John Wiley, 2002.
[3] K. Ho_man and R. Kunze, Linear Algebra, Prentice Hall, 1992.
[4] N. Jacobson, Basic Algebra II, Hindustan Publishing Corporation, 1983.
[5] S. Lang, Algebra, 3rd ed. Springer (India) 2004.

M403 : Elementary Number theory

Unit I Fundamental theorem of arithmetic, divisibility in integers.Prime numbers and infinitude of primes. Infinitude of primes of special types. Special primes like Fermat primes, Mersenne primes, Lucas primes etc. Euclidean algorithm, greatest common divisor, least common multiple.

Unit II Equivalence relations and the notion of congruences. Wilson's theorem and Fermat's little theorem. Chinese remainder theorem. Continued fractions and their applications. Primitive roots, Euler's Phi function. Sum of divisors and number of divisors, Möbius inversion.

Unit III Quadratic residues and non-residues with examples. Euler's Criterion, Gauss' Lemma. Quadratic reciprocity and applications. Applications of quadratic reciprocity to calculation of symbols.

Unit IV Legendre symbol: Definition and basic properties. Fermat's two square theorem, Lagrange's four square theorem.

Unit V Pythagorean triples. Diophantine equations and Bachet's equation. The duplication formula.

References

[1] D. Burton, Elementary Number Theory.
[2] Kenneth H. Rosen, Elementary number theory and its applications.
[3] Niven, Ivan M.; Zuckerman, Herbert S.; Montgomery, Hugh L, An Introduction to the Theory of Numbers.

M404 : Topology I

Unit I Recollection of some set theory, particularly the following topics:
(i) Equipotence of sets, Schroeder-Bernstein theorem, countable and uncountable sets, countability
of **Q** and uncountability of **R**:
(ii) Equivalence relations, Zorn's lemma, axiom of choice.
Metric spaces: Definition and basic examples including the following:
(i) The discrete metric on any set.
(ii) **R** and $\mathbf{R}^n$ with Euclidean metrics, Cauchy-Schwarz inequality, definition of a norm on a finite dimensional **R**-vector space and the metric defined by a norm.
(iii) The set **C**[0, 1] with the metric given by $\sup |f(t) - g(t)|$ (resp. $\int_0^1 |f(t) - g(t)| dt$).
(iv) Metric subspaces, examples.

Unit II Topology generated by a metric: Open and closed balls, open and closed sets, complement of an open (closed) set, arbitrary unions (intersections) of open (closed) sets, finite

intersections (unions) of open (closed) sets, open (closed) ball is an open (closed) set, a set is open if and only if it is a union of open balls, Hausdorff property of a metric space.

Equivalence of metrics, examples, the metrics on $\mathbf{R^2}$ given by $|x_1 - y_1| + |x_2 - y_2|$ (resp. $\max\{|x_1 - y_1|, |x_2 - y_2|\}$) is equivalent to the Euclidean metric, the shapes of open balls under these metrics. Limit points, isolated points, interior points, closure, interior and boundary of a set, dense and nowhere dense sets.

Unit III Continuous maps: $\varepsilon - \delta$ definition and characterization in terms of inverse images of open (resp. closed) sets, composite of continuous maps, pointwise sums and products of continuous maps into $\mathbf{R}$; homeomorphism, isometry, an isometry is a homeomorphism but not conversely, uniformly continuous maps, examples.

Complete metric spaces: Cauchy sequences and convergent sequences, a subspace of a complete metric space is complete if and only if it is closed, Cantor intersection theorem, Baire categorytheorem and its applications, completion of a metric space.

General topological spaces, stronger and weaker topologies, continuous maps, homeomorphisms, bases and subbases, finite products of topological spaces.

Unit IV Compactness for general topological spaces: Finite subcoverings of open coverings and finite intersection property, continuous image of a compact set is compact, compactness and Hausdorff property.

Compactness for metric spaces**:** Bolzano-Weierstrass property, the Lebesgue number for an open covering, sequentially compact and totally bounded metric spaces, Heine-Borel theorem, compact subsets of $\mathbf{R}$; a continuous map from a compact metric space is uniformly continuous.

Unit V Connectedness: definition, continuous image of a connected set is connected, characterization in terms of continuous maps into the discrete space $\mathbf{N}$, connected subsets of $\mathbf{R}$; intermediate value theorem as a corollary, countable (arbitrary) union of connected sets, connected components,

References
[1] E. T. Copson, Metric spaces.
[2] M. Eisenberg, Topology.
[3] R.H. Kasriel, Undergraduate topology.
[4] W. Rudin, Principles of mathematical analysis.
[5] G. F. Simmons, Topology and modern analysis.
[6] W. A. Sutherland, Introduction to metric and topological spaces.

G401: Statistical Techniques and Applications

Unit-I Purpose of Statistics, Events and Probabilities, Assignments of probabilities to events, Random events and variables, Probability Axioms and Theorems. Probability distributions and properties: Discrete, Continuous and Empirical distributions.

Unit-II Expected values: Mean, Variance, Skewness, Kurtosis, Moments and Characteristics Functions. Types of probability distributions: Binomial, Poisson, Normal, Gamma, Exponential, Chi-squared, Log-Normal, Student's t, F distributions, Central Limit Theorem.

Unit-III Monte Carlo techniques: Methods of generating statistical distributions: Pseudorandom numbers from computers and from probability distributions, Applications. Parameter inference: Given prior discrete hypotheses and continuous parameters, Maximum likelihood method for parameter inference.

Unit-IV Error Analysis: Statistical and Systematic Errors, Reporting and using uncertainties, Propagation of errors, Statistical analysis of random uncertainties, Averaging Correlated/ Uncorrelated Measurements. Deconvolution methods, Deconvolution of histograms, binning-free methods. Least-squares fitting: Linear, Polynomial, arbitrary functions: with descriptions of specific methods; Fitting composite curves.

Unit-V Hypothesis tests: Single and composite hypothesis, Goodness of fit tests, P-values, Chi-squared test, Likelihood Ratio, Kolmogorov- Smirnov test, Confidence Interval. Covariance and Correlation, Analysis of Variance and Covariance. Illustration of statistical techniques through hands-on use of computer programs.

Suggested Texts and References:
1. Statistics: A Guide to the Use of Statistical Methods in the Physical Sciences, R.J. Barlow, John Wiley 1989
2. The Statistical Analysis of Experimental Data, John Mandel, Dover Publications 1984
3. Data Reduction and Error Analysis for the Physical Sciences, 3rd Edition, Philip Bevington and Keith Robinson, McGraw Hill 2003

<u>**THIRD YEAR**</u>
SEMESTER –V

Subject Code	Subject	Contact Hours / Week Theory+Tutorials	Credits
M501	Analysis III	[3 + 1]	4
M502	Algebra III	[3+ 1]	4
M503	Topology II	[3 + 1]	4
M504	Probability Theory	[3 + 1]	4
G501	Earth Science & Energy & Environmental Sciences	[3 + 1]	4
PM501	Numerical Analysis	[3 + 1]	4
		Lab Hours per Week	
PML501	Numerical Methods Laboratory	[2]	1
		Semester Credits	**25**
		Subtotal	**125**

M501 : Analysis III (Measure Theory and Integration)

Unit I Sigma algebra of sets, measure spaces. Lebesgues outer measure on the Real line. Measurable set in the sense of Caratheodory. Translation invariance of Lebesgue measure. Existence of a non-Lebesgue measurable set. Cantor set- uncountable set with measure zero.

Unit II Measurable functions, types of convergence of measurable functions. The Lebesgue integral for simple functions, nonnegative measurable functions and Lebesgue integrable function, in general.

Unit III Convergence theorems- monotone and dominated convergence theorems. Comparison of Riemann and Lebesgue integrals. Riemanns theorem on functions which are continuous almost everywhere.

Unit V The product measure and Fubinis theorem. The L^p spaces and the norm topology. Inequalities of Hölder and Minkowski. Completeness of L^p and L^∞ spaces.

References
[1] H.L. Royden, Real Analysis, Pearson Education.
[2] G. DeBarra, Introduction to Measure Theory, Van Nostrand Reinhold.
[3] I. K. Rana, An Introduction to Measure and Integration, Narosa.
[4] H.S. Bear, A Primer on Lebesgue Integration, Academic press.

M502 : Algebra III (Galois Theory)

Unit I Prime and maximal ideals in a commutative ring and their elementary properties.

Unit II Field extensions, prime fields, characteristic of a field, algebraic field extensions, finite field extensions, splitting fields, algebraic closure, separable extensions, normal extensions,

Unit III Finite Galois extensions, Fundamental Theorem of Galois Theory.

Unit IV Solvability by radicals.

Unit V Extensions of finite fields.

References
[1] M. Artin, Algebra, Prentice Hall of India, 1994.
[2] D. S. Dummit and R. M. Foote, Abstract Algebra, 2nd Ed., John Wiley, 2002.
[3] N. Jacobson, Basic Algebra I & II, Hindustan Publishing Corporation, 1983.
[4] S. Lang, Algebra, 3rd ed. Springer (India) 2004.
[5] R. Lidl and H. Niederreiter, Introduction to Finite Fields and Their Applications, Cambridge University Press, 1986.

M503 : Topology II

Unit I Review of some notions from Topology I. Basic Separation axioms and first and second countability
axioms. Examples.

Unit II Products and quotients. Tychonoff's theorem. Product of connected spaces is connected. Weak

topology on X induced by a family of maps $f_\alpha : X \to X_\alpha$ where each X_α is a topological space. The coherent topology on Y induced by a family of maps $g_\alpha : Y_\alpha \to Y$ where Y_α are given topological spaces. Examples of quotients to illustrate the universal property such as embeddings of $\mathbf{RP^2}$ and the Klein's bottle in $\mathbf{R^4}$.

Unit III Completely regular spaces and its embeddings in a product of intervals. Compactification, Alexandroff and Stone-Cech compactifications.

Unit IV Normal spaces and the theorems of Urysohn and Tietze. The metrization theorem of Urysohn.

Unit V Local compactness, local connectedness and local path-connectedness and their basic properties. If $q: X \to Y$ is a quotient map and Z is locally compact Hausdorff space then q ×id : X ×Z →Y ×Z is also a quotient map. Locally finite families of sets and Partitions of unity. Baire Category theorem for locally compact Hausdorff spaces.

References

[1] G. F. Simmons, Topology and modern analysis
[2] W. A. Sutherland, Introduction to metric and topological spaces.
[3] S. Willard, General Topology, Dover, New York.

M 504 : Probability Theory

Unit I Probability as a measure, Probability space, conditional probability, independence of events, Bayes formula. Random variables, distribution functions, expected value and variance. Standard Probability distributions: Binomial, Poisson and Normal distribution.

Unit II Borel-Cantelli lemmas, zero-one laws. Sequences of random variables, convergence theorems, Various modes of convergence. Weak law and the strong law of large numbers.

Unit III Central limit theorem: DeMoivre-Laplace theorem, weak convergence, characteristic functions, inversion formula, moment generating function.

Unit IV Random walks, Markov Chains, Recurrence and Transience.

Unit V Conditional Expectation, Martingales.

References

[1] Marek Capinski and Tomasz Zastawniak, Probability through Problems, Springer, Indian Reprint 2008.
[2] P. Billingsley, Probability and Measure, 3rd ed., John Wiley & Sons, New York, 1995.
[3] J. Rosenthal, A First Look at Rigorous Probability, World Scientific, Singapore, 2000.
[4] A.N. Shiryayev, Probability, 2nd ed., Springer, New York, 1995.
[5] K.L. Chung, A Course in Probability Theory, Academic Press, New York, 1974.

SEMESTER –VI

Subject Code	Subject	Contact Hours / Week Theory+Tutorials	Credits

M601	Analysis IV	[3 + 1]	4
M602	Algebra IV	[3+ 1]	4
M603	Differential Geometry & Applications	[3 + 1]	4
M604	Differential Equations & Dynamical Systems	[3 + 1]	4
M605	Computational Mathematics II	[3 + 1]	4
PM601	Ethics of Science and IPR	[2 + 0]	2
		Lab Hours per Week	
PML601	Numerical Methods Laboratory	[6]	3
		Semester Credits	**25**
		Subtotal	**150**

M601 : Analysis IV (Complex Analysis)

Unit I Complex numbers and Riemann sphere. Mobius transformations.

Unit II Analytic functions. Cauchy-Riemann conditions, harmonic functions, Elementary functions, Power series, Conformal mappings.

Unit III Contour integrals, Cauchy theorem for simply and multiply connected domains. Cauchy integral formula, Winding number.

Unit IV Morera's theorem. Liouville's theorem, Fundamental theorem of Algebra. Zeros of an analytic function and Taylors theorem. Isolated singularities and residues, Laurent series, Evaluation of real integrals.

Unit V Zeros and Poles, Argument principle, Rouchs theorem.

References
[1] L.Ahlfors, Complex Analysis.
[2] R.V. Churchill and J. W. Brown, Complex Variables and Applications, International Student Edition,Mc-Graw Hill, 4th ed., 1984.
[3] B.R. Palka, An Introduction to Complex Function Theory, UTM Springer-Verlag, 1991.

M602 : Algebra IV (Rings and Modules: Some Structure Theory)

Unit I Recollection of modules, submodules, quotient modules, homomorphisms.

Unit II External and internal direct sums of modules. Tensor product of modules over a commutative ring. Functorial properties of and Hom.

Unit III Definitions and elementary properties of projective and injective modules over a commutative ring.

Unit IV Structure of finitely generated modules over a PID. Applications to matrices and linear maps over field: rational and Jordan canonical forms.

Unit V   Simple modules over a not necessarily commutative ring, modules of finite length, Jordan-Holder Theorem, Schur's lemma.

(**Optional, if time permits**) Semisimple modules over a not necessarily commutative ring, Wedderburn Structure Theorem for semisimple rings.

References
[1] M. Artin, Algebra, Prentice Hall of India, 1994.
[2] D.S. Dummit and R. M. Foote, Abstract Algebra, 2nd Ed., John Wiley, 2002.
[3] N. Jacobson, Basic Algebra I & II, Hindustan Publishing Corporation, 1983.
[4] S. Lang, Algebra, 3rd ed. Springer (India) 2004.

M603 : Differential Geometry & Applications

Unit I Curvature of curves in E^n: Parametrized Curves, Existence of Arc length parametrization, Curvature of plane curves, Frennet-Serret theory of (arc-length parametrized) curves in E^3, Curvature of (arc-length parametrized) curves in En, Curvature theory for parametrized curves in E^n. Significance of the sign of curvature, Rigidity of curves in E^n.

Unit II Euler's Theory of curves on Surfaces **:** Surface patches and local coordinates, Examples of surfaces in E^3, curves on a surface, tangents to the surface at a point, Vector fields along curves, Parallel vector   fields, vector fields on surfaces, normal vector _elds, the First Fundamental form, Normal curvature of curves on a surface, Geodesics, geodesic Curvature, Christoffel symbols, Gauss' formula,Principal Curvatures, Euler's theorem.

Unit III Gauss' theory of Curvature of Surfaces **:** The Second Fundamental Form, Weingarten map and the Shape operator, Gaussian Curvature, Gauss' Theorema Egregium, Guass-Codazzi equations,Computation of First/Second fundamental form, curvature etc. for surfaces of revolution and other examples.

Unit IV More Surface theory**:** Isoperimetric Inequality, Mean Curvature and Minimal Surfaces (introduction), surfaces of constant curvature, Geodesic coordinates, Notion of orientation, examples of non-orientable surfaces, Euler characteristic, statement of Gauss-Bonnet Theorem.

Unit V Modern Perspective on Surfaces: Tangent planes, Parallel Transport, Afine Connections, Riemannian metrics on surfaces.

References
[1] Elementary Differential Geometry : Andrew Pressley, Springer Undergraduate Mathematics Series.
[2] Elementary Differential Geometry : J. Thorpe, Elsevier.
[3] Differential Geometry of Curves and Surfaces : M. do Carmo.
[4] Elements of Differential Geometry : R. Millman & G. Parker.

M604 : Differential Equations & Dynamical Systems

Unit I Basic existence and uniqueness of systems of ordinary differential equations satisfying the Lipschitz's condition. Examples illustrating non-uniqueness when Lipschitz or other relevant conditions are dropped. Gronwall's lemma and its applications to continuity of the solutions with

respect to initial conditions. Smooth dependence on initial conditions and the variational equation. Maximal interval of existence and global solutions. Proof that if (a, b) is the maximal interval of existence and a < 1 then the graph of the solution must exit every compact subset of the domain on the differential equation.

Unit II Linear systems and fundamental systems of solutions. Wronskians and its basic properties. The Abel Liouville formula. The dimensionality of the space of solutions. Fundamental matrix. The method of variation of parameters.

Unit III Linear systems with constant coefficients and the structure of the solutions. Matrix exponentials and methods for computing them. Solving the in-homogeneous system. The Laplace transform and its applications.

Unit IV Second order scalar linear differential equations. The Sturm comparison and separation theorems and regular Sturm-Liouville problems.

Unit V Series solutions of ordinary differential equations and a detailed analytic study of the differential equations of Bessel and Legendre. Dynamical systems and basic notions of dynamical systems such as ows, rectification theorem, rest points and its stability. Liouville's theorem on the preservation of phase volume. First integrals and their applications.

References
[1] R. Courant and D. Hilbert, Methods of Mathematical Physics, Volume - I
[2] W. Hurewicz, Lectures on ordinary differential equations, Dover, New York.
[3] . F. Simmons, Differential equations with applications and historical notes, McGraw Hill.

M605 : Computational Mathematics II

Unit I Introduction to SAGE. Using SAGE to explore basics notions of Linear algebra, Number theory, Group Theory

Unit II Solving linear and non-linear optimization problems using Mathematica. Developing programmes for various numerical optimization techniques.

Unit III . Exploration of Galois theory and Finite Fields Using Sage/Singular/Kash etc.

Unit IV Basics of discrete mathematics using Sage/Mathematica. Exploring advanced notions of Complex Analysis and Differential Equations using Mathematica.

Unit V Applied Linear Algebra using Mathematica, various matrix factorizations and their applications.

<u>FOURTH YEAR</u>
SEMESTER –VII

Subject Code	Subject	Contact Hours / Week Theory+Tutorials	Credits

M701	Functional Analysis	[3 + 1]	4
M702	Commutative Algebra	[3+ 1]	4
M703	Differential Topology	[3 + 1]	4
M704	Partial Differential Equations	[3 + 1]	4
M705	Representation Theory of Finite Groups	[3 + 1]	4
MPr701	Project		5
		Semester Credits	**25**
		Subtotal	**175**

M701 : Functional Analysis

Unit I Normed linear spaces. Riesz lemma. Heine-Borel theorem. Continuity of linear maps. Hahn-Banach extension and separation theorems.

Unit II Banach spaces. Subspaces, product spaces and quotient spaces. Standard examples of Banach spaces like l^p, L^p, C([0; 1]) etc.Uniform boundedness principle. Closed graph theorem. Open mapping theorem. Bounded inverse theorem.

Unit III   Spectrum of a bounded operator. Eigenspectrum. Gelfand-Mazur theorem and spectral radius formula. Dual spaces. Transpose of a bounded linear map. Standard examples.

Unit IV   Hilbert spaces. Bessel inequality, Riesz-Schauder theorem, Fourier expansion, Parseval's formula.

Unit V In the framework of a Hilbert space: Projection theorem. Riesz representation theorem. Uniqueness of Hahn-Banach extension.

References
[1] J.B. Conway, A course in Functional Analysis, Springer-Verlag, Berlin, 1985.
[2] G. Go_man and G. Pedrick, First course in functional analysis, Prentice-Hall, 1974.
[3] E. Kreyszig, Introductory Functional Analysis with applications, John Wiley & Sons, NY, 1978.
[4] B.V. Limaye, Functional Analysis, 2nd ed., New Age International, New Delhi, 1996.
[5] A. Taylor and D. Lay, Introduction to functional analysis, Wiley, New York, 1980.

M702 : Commutative Algebra

Unit I Prime and maximal ideals in a commutative ring, nil and Jacobson radicals, Nakayamas lemma, local rings.

Unit II Rings and modules of fractions, correspondence between prime ideals, localization.

Unit III   Modules of finite length, Noetherian and Artinian modules. Primary decomposition in a Noetherian module, associated primes, support of a module.

Unit IV   Graded rings and modules, Artin-Rees, Krull-intersection, Hilbert-Samuel function of a local ring, dimension theory, principal ideal theorem.

Unit V Integral extensions, Noethers normalization lemma, Hilberts Nullstellensatz (algebraic and geometric versions).

References
[1] M.F Atiyah and I.G MacDonald, Introduction to Commutative Algebra, Addison-Wesley, 1969.
[2] D. Eisenbud, Commutative Algebra with a view toward algebraic geometry, Springer-Verlag, Berlin, 2003.
[3] H. Matsumura, Commutative ring theory, Cambridge Studies in Advanced Mathematics No. 8, Cambridge University Press, Cambridge, 1980.
[4] S. Raghavan, B. Singh and R. Sridharan, Homological methods in commutative algebra, TIFR Math. Pamphlet No.5, Oxford, 1975.
[5] B. Singh, Basic Commutative Algebra, World Scientific, 2011.

M703 : Differential Topology

Unit I Differentiable functions on $\mathbf{R}^n$: Review of differentiable functions $\mathbf{f} : \mathbf{R}^n \to \mathbf{R}^m$, Implicit and Inverse function theorems, Immersions and Submersions, critical points, critical and regular values.

Unit II Manifolds: Level sets, sub-manifolds of $\mathbf{R}^n$, immersed and embedded sub-manifolds, tangent spaces, differentiable functions between sub-manifolds of R_n, abstract differential manifolds and tangent spaces.

Unit III Differentiable functions on Manifolds: Differentiable functions $f : M \to N$, critical points, Sard's theorem, non-degenerate critical points, Morse Lemma, Manifolds with boundary, Brouwer fixed point theorem, mod 2 degree of a mapping.

Unit IV Transversality: Orientation of Manifolds, oriented intersection number, Brouwer degree, transverse intersections.

Unit V Integration on Manifolds: Vector field and Differential forms, integration of forms, Stokes' theorem, exact and closed forms, Poincar Lemma, Introduction to de Rham theory.

References
[1] Topology from a Di_erentiable Viewpoint : J. Milnor.
[2] Di_erential Topology : V. Guellemin & A. Pollack.
[3] Di_erential Topology : M. Hirsch.

M704 : Partial Differential Equations

Unit I Generalities on the origins of partial differential equations. Generalities on the Cauchy problem for a scalar linear equation of arbitrary order. The concept of characteristics. The Cauchy-Kowalevsky theorem and the Holmgren's uniqueness theorem. The fundamental equations of mathematical physics as paradigms for the study of Elliptic, Hyperbolic and Parabolic equations.

Unit II   Quasilinear first order scalar partial differential equations and the method of characteristics. Detailed discussion of the inviscid Burger's equation illustrating the formation of discontinuities in finite time. The fully nonlinear scalar equation and Eikonal equation. The Hamilton-Jacobi equation.

Unit III Detailed analysis of the Laplace and Poisson's equations. Green's function for the Laplacian and its basic properties. Integral representation of solutions and its consequences such as the analyticity of solutions. The mean value property for harmonic functions and maximum principles. Harnack inequality.

Unit IV The wave equation and the Cauchy problem for the wave equation. The Euler-Poisson-Darboux
equation and integral representation for the wave equation in dimensions two and three. Properties of solutions such as finite speed of propagation. Domain of dependence and domain of inuence.

Unit V The Cauchy problem for the heat equation and the integral representation for the solutions of The Cauchy problem for Cauchy data satisfying suitable growth restrictions. Infinite speed of propagation of signals. Example of non-uniqueness. Fourier methods for solving initial boundary value problems.

References
[1] R. Courant and D. Hilbert, Methods of Mathematical Physics, Volume - II
[2] R. C. McOwen, Partial differential equations, Pearson Education, 2004.

M705 : Representation Theory of Finite Groups

Unit I Recollection of left and right modules, direct sums, tensor products.

Unit II Semi-simplicity of rings and modules, Schur0s lemma, Maschke0s Theorem,

Unit III Wedderburn0s Structure Theorem. The group algebra.

Unit IV Representations of a finite group over a field, induced representations, characters, orthogonality relations.

Unit V Representations of some special groups. Burnside's $p^a q^b$ theorem.

References
[1] M. Artin, Algebra, Prentice Hall of India, 1994.
[2] M. Burrow, Representation Theory of Finite Groups, Academic Press, 1965.
[3] D.S. Dummit and R. M. Foote, Abstract Algebra, 2nd Ed., John Wiley, 2002.
[4] N. Jacobson, Basic Algebra I & II, Hindustan Publishing Corporation, 1983.
[5] S. Lang, Algebra, 3rd ed. Springer (India) 2004.
[6] J .P. Serre, Linear Representation of Groups, Springer-Verlag, 1977.

SEMESTER –VIII

Subject Code	Subject	Contact Hours / Week Theory+Tutorials	Credits
M801	Fourier Analysis	[3 + 1]	4
M802	Algebraic Number Theory	[3+ 1]	4

M803	Algebraic Topology	[3 + 1]	4
M804	Stochastic Analysis	[3 + 1]	4
M805	Computational Mathematics III	[3 + 1]	4
MPr801	Project		5
		Semester Credits	**25**
		Subtotal	**200**

M801 : Fourier Analysis

Unit I Fourier series. Discussion of convergence of Fourier series.

Unit II Uniqueness of Fourier Series, Convolutions, Cesaro and Abel Summability, Fejer`s theorem, Dirichlets theorem, Poisson Kernel and summability kernels. Example of a continuous function with divergent Fourier series.

Unit III Summability of Fourier series for functions in L^1, L^2 and L^p spaces. Fourier-transforms of integrable functions. Basic properties of Fourier transforms, Poisson summation formula, Hausdorff-Young inequality, Riesz-Thorin Interpolation theorem.

Unit IV Schwartz class of rapidly decreasing functions, Fourier transforms of rapidly decreasing functions, Riemann Lebesgue lemma, Fourier Inversion Theorem, Fourier transforms of Gaussians, Plancheral theorem, Paley-Weiner theorem.

Unit V Distributions and Fourier Transforms: Calculus of Distributions, Tempered Distributions: Fourier transforms of tempered distributions, Convolutions, Applications to PDEs.

References
[1] Y. Katznelson, Introduction to Harmonic Analysis, Dover.
[2] R. E. Edwards, Fourier Series, Academic Press.
[3] E. M. Stein and R. Shakarchi, Fourier Analysis: An Introduction, Princeton University Press, Princeton 2003.
[4] W. Rudin, Fourier Analysis on groups, Interscience.

M802 : Algebraic Number Theory

Unit I Field extensions and examples of field extensions of rational numbers, real numbers and complex numbers. Monic polynomials, Integral extensions, Minimal polynomial, Characteristic polynomial.

Unit II Integral closure and examples of rings which are integrally closed. Examples of rings which are not integrally closed. The ring of integers. The ring of Gaussian integers. Quadratic extensions and description of the ring of integers in quadratic number fields. Units in quadratic number fields and relations to continued fractions.

Unit III Noetherian rings, Rings of dimension one. Dedekind domains. Norms and traces. Derive formulae relating norms and traces for towers of field extensions. Discriminant and calculations of the discriminant in the special context of quadratic number fields. Different and it's applications.

Unit IV Cyclotomic extensions and calculation of the discriminant in this case. Factorization of ideals into prime ideals and its relation to the discriminant. Ramification theory, residual degree and its relation to the degree of the extension. Ramified primes in quadratic number fields.

Unit V Ideal class group. Geometric ideas involving volumes. Minkowski's theorem and its application to proving finiteness of the ideal class group. Real and complex embeddings. Structure of finitely generated abelian groups. Dirichlet's Unit Theorem and the rank of the group of units. Discrete valuation rings, Local fields.

References
[1] Janusz, Algebraic Number Fields.
[2] Neukirch, Algebraic Number Theory.
[3] Marcus, Number Fields.

M803 : Algebraic Topology

Unit I Review of quotient spaces and its universal properties. Examples on RP^n, Klein's bottle, Mobius band, CP^n, $SO(n, R)$. Connectedness and path connectedness of spaces such as $SO(n, R)$ and other similar examples. Topological groups and their basic properties. Proof that if H is a connected subgroup such that G/H is also connected (as a topological space) then G is connected. Quaternions, S^3 and $SO(3, R)$. Connected, locally path connected space is path connected.

Unit II Paths and homotopies of paths. The fundamental group and its basic properties. The fundamental group of a topological group is abelian. Homotopy of maps, retraction and deformation retraction. The fundamental group of a product. The fundamental group of the circle. Brouwer's fixed poin theorem. Degree of a map. Applications such as the fundamental theorem of algebra, Borsuk-Ulam theorem and the Perron Frobenius theorem.

Unit V Covering spaces and its basic properties. Examples such as the real line as a covering space of a circle, the double cover $\eta : S^n \to RP^n$, the double cover $\eta : S^3 \to SO(3, R)$. Relationship to the fundamental group. Lifting criterion and Deck transformations. Equivalence of covering spaces. Universal covering spaces. Regular coverings and its various equivalent formulations such as the transitivity of the action of the Deck group. The Galois theory of covering spaces.

Unit IV Orbit spaces. Fundamental group of the Klein's bottle and torus. Relation between covering spaces and Orientation of smooth manifolds. Non orientabilty of RP^2 illustrated via covering spaces.

Unit V Free groups and its basic properties, free products with amalgamations. Concept of push outs in the context of topological spaces and groups. Seifert Van Kampen theorem and its applications. Basic notions of knot theory such as the group of a knot. Wirtinger's algorithm for calculating the Group of a knot illustrated with simple examples.

References
[1] E. L. Lima, Fundamental groups and covering spaces, A. K. Peters, 2003.
[2] W. Massey, Introduction to algebraic topology. Springer Verlag.

M804 : Stochastic Analysis

Unit I Preliminaries: Martingales and properties. Brownian Motion- definition and construction, Markov property, stopping times, strong Markov property zeros of one dimensional Brownian motion.

Unit II Reection principle, hitting times, higher dimensional Brownian Motion, recurrence and transience,occupation times, exit times, change of time, Levys theorem.

Unit III Stochastic Calculus: Predictable processes, continuous local martingales, variance and covariance processes.

Unit IV Integration with respect to bounded martingales and local martingales, Kunita Watanabe inequality, Ito s formula, stochastic integral, change of variables.

Unit V Stochastic differential equations, weak solutions, Change of measure, Change of time, Girsanovs theorem.

References
[1] Richard Durrett, Stochastc Calculus A Practical Introduction, CRC Press 1996.
[2] Karatzas I. and Steven Shreve, Brownian Motion and Stochastic Calculus, Springer.
[3] Oksendal Bernt, Stochastic Differential Equations, Springer.
[4] J.Michael Steele, Stochastic Calculus and Financial Applications, Springer, 2000

M805 : Computational Mathematics III

Unit I Differential Geometry of curves and surfaces using Mathematica. Exploring Differential Equation and Dynamical System using XPPAUT or some other specialized software.

Unit II Design of Experiments and Statistics Quality control using R. Project/Math Modeling problem using any Mathematical Software and developing Mathematica packages for various specific methods.

Unit III Exploring solutions of Partial Differential equations using Mathematica. Developing programmes to solve problems numerically.

Unit IV Exploring basic Notions of Commutative algebra using Sage/Singular /Kash etc.

Unit V Advanced notion of optimization techniques using Mathematica. Project/Math Modeling problem using any Mathematical Software and developing Mathematica packages for various specific methods.

References
[1] Alfred Gray, Elsa Abbena, Simon Salamon, Modern Differential Geometry of Curves and Surfaces with Mathematica, Third Edition.

<u>FIFTH YEAR</u>
SEMESTER –IX

Subject Code	Subject	Contact Hours / Week Theory+Tutorials	Credits
MPr901	Project		20
		Semester Credits	**20**
		Subtotal	**220**

SEMESTER –X

Subject Code	Subject	Contact Hours / Week Theory+Tutorials	Credits
ME1001	Elective 1	[3 + 1]	4
ME1002	Elective 2	[3+ 1]	4
ME1003	Elective 3	[3 + 1]	4
ME1004	Elective 4	[3 + 1]	4
ME1005	Elective 5	[3 + 1]	4
		Semester Credits	**20**
	Total Credits (with 5 Electives)		**240**
	Minimum required		**240**

Electives

Students shall opt 5 Electives from the 30 Electives offered by School of Mathematical Sciences in the Xth semester

1. Advanced Commutative Algebra & Applications.
2. Advanced Differential Topology.
3. Advanced Numerical Techniques.
4. Combinatorics & Enumeration.
5. Lie Groups & Geometry
6. Topics in Algebraic Geometry.
7. Advanced Algebraic Topology & Applications.
8. Advanced Differential Geometry & Applications.
9. Algebraic curves.
10. Analytic number theory.
11. Class field theory.
12. Coding Theory & Cryptography.
13. Combinatorial Design Theory.
14. Econometrics.
15. Elliptic curves.
16. Financial Mathematics.
17. Finite Fields & Applications.
18. Fluid Mechanics.

19. Fractals & Applications.
20. Geometric algebra.
21. Homological Algebra & Applications.
22. Industrial Mathematics.
23. Introduction to algebraic groups.
24. Mathematical Applications to Engineering.
25. Mathematics & Nano Technology.
26. Modular forms.
27. Operator Theory.
28. Perturbation Theory.
29. Quantum Computing.
30. Wavelet Analysis & Applications.

Center for Basic Sciences (CBS)

SCHEME OF EXAMINATION
&
COURSE STRUCTURE
Of
SEMESTER IX and X
M.Sc. Integrated (Mathematics Stream)
UNDER
FACULTY OF SCIENCE
EFFECTIVE FROM JANUARY 2020

Center of Basic Science
Pt. Ravishankar Shukla University
Raipur (C.G.) 492010
PH: - 0771-2262864
WEBSITE: -www.prsu.ac.in

Approved by Board of Studies in Mathematics
Pt. Ravishankar Shukla University, Raipur (C.G.)

CENTER FOR BASIC SCIENCES
Pt. Ravishankar Shukla University, Raipur

5 Year Integrated M.Sc. (Mathematics)
Under
Faculty of Science

SEMESTER-X (Mathematics Stream)

Subject		Subject Contact hrs/per week Theory+Tutorial	Credits
ME 1001	Electives I	[4 + 1]	5
ME 1002	Electives II	[4 + 1]	5
ME 1003	Electives III	[4 + 1]	5
ME 1004	Elective IV	[4 + 1]	5
		Total	20

Min. 20
(Total 240 credits)

*Four Subjects will be offered according to the availability of instructors and more than 50% of students opting for a course.

<u>Elective-1: Integrated M.Sc. 10th Semester (Mathematics)</u>

Dynamical Systems Using Matlab

Introduction to Matlab

Unit-I: Arithmetic Operations, built-in-MATH functions, scalar variables, creating arrays, built-in functions for handling arrays, mathematical operations with arrarys, script files, two dimensional plots, programming in MATLAB, polynomial, curve fitting, and interpolation, three-dimensional plots.

Discrete Dynamical Systems
Unit-II: One-dimensional maps, cobweb plot: graphical representation of an orbit, stability of fixed points, periodic points, the family of logistic maps, sensitive dependence on initial conditions, analysis of logistic map, Periodic Windows, Feigenbaum number, chaos in logistic map.

Unit-III: higher-dimensional maps, sinks, sources, and saddles, nonlinear maps and the jacobian matrix, stable and unstable manifolds, lyapunov exponents, Numerical Calculation of Lyapunov Exponent, chaotic orbits, Strange Attractors, Gaussian and Hénon Maps. Julia Sets and the Mandelbrot Set.

Differential Dynamical Systems
Unit-IV: Differential dynamical systems, existence and uniqueness theorem, phase portraits, vector fields, nullclines, flows, fixed points, linearization of vector fields, planar systems, canonical forms, eigenvectors defining stable and unstable manifolds, phase portraits of linear systems in the plane, linearization and Hartman's theorem, limit cycles, existence and uniqueness of limit cycles in the plane, Lyapunov functions and stability.

Unit-V: Nonlinear systems and stability, bifurcations of nonlinear systems, normal forms, multistability and bistability, the Rössler system and chaos, the Lorenz equations, Chua's circuit, and the Belousov–Zhabotinski reaction.

Books and References:

1. Dynamical Systems with Applications using MATLAB® 2nd edition, Stephen Lynch, Springer International Publishing Switzerland 2014.
2. CHAOS: An Introduction to Dynamical Systems, Kathleen T. Alligood Tim D. Sauer James A. Yorke, Springer-Verlag.
3. Nonlinear Dynamics And Chaos: With Applications to Physics, Biology, Chemistry, and Engineering, Steven H. Strogatz, CRC Press Taylor & Francis Group, 2018.
4. Differential Equations, Dynamical Systems, and an Introduction to Chaos, Morris W. Hirsch, Stephen Smale, Robert L. Devaney, Elsevier, 2013.
5. Dynamical Systems with Applications using Mathematica, 2nd edition, Stephen Lynch, Springer International Publishing, 2017.

1

Elective-2: Integrated M.Sc. 10th Semester (Mathematics)

Mathematical Biology

Unit- I: Simple Single Species Models: **Continuous Population Models**, Exponential Growth, The Logistic Population Model, Harvesting in Population Models, Constant-Yield and Constant-Effort Harvesting, Eutrophication of a Lake: A Case Study.
Discrete–Time Metered Models, Systems of Two Difference Equations, Oscillation in Flour Beetle Populations: A Case Study.

Unit-II: Continuous Single-Species Population Models with Delays: Models with Delay in Per Capita Growth Rates, Delayed-Recruitment Models, Models with Distributed Delay, Harvesting in Delayed Recruitment Models, Nicholson's Blowflies: A Case Study.

Unit-III: Models for Interacting Species: The Lotka–Volterra Equations, The Chemostat Model, Equilibria and Linearization, Qualitative Behavior of Solutions of Linear Systems, Periodic Solutions and Limit Cycles, Species in Competition, Kolmogorov Models, Mutualism, The Spruce Budworm: A Case Study.
The Community Matrix, the Nature of Interactions Between Species, Invading Species and Coexistence.

Unit-IV: Harvesting in Two-species Models: Harvesting of Species in Competition, Harvesting of Predator–Prey Systems, Intermittent Harvesting of Predator–Prey Systems, Some Economic Aspects of Harvesting, Optimization of Harvesting Returns, A Nonlinear Optimization Problem, Economic Interpretation of the Maximum Principle.

Unit-V: Models for Populations with Age and Spatial Structure: Linear model with age structure, The Method of Characteristics, Nonlinear Continuous Models, Models with Discrete Age Groups, Some Simple Examples of Metapopulation Models, A General Metapopulation Model, A Metapopulation Model with Residence and Travel, The Diffusion Equation, Solution by Separation of Variables, Solutions in Unbounded Regions, Linear Reaction–Diffusion Equations, Nonlinear Reaction–Diffusion Equations, Diffusion in Two Dimensions.

Books and References:

1. Mathematical Models in Population Biology and Epidemiology, 2nd edition, Fred Brauer, Carlos Castillo-Chavez, Texts in Applied Mathematics 40, Springer, 2012.
2. Elements of Mathematical Ecology, Mark Kot, Cambridge University Press, 2001.
3. Mathematical Biology-I: An Introduction, James D. Murray, Springer, 2002.
4. Mathematical Biology-II: Spatial Models and Biomedical Applications, James D. Murray, Springer, 2003.

Elective-3: Integrated M.Sc. 10th Semester (Mathematics)

Financial Mathematics

Unit I: Review Of probability, finite probability space.

Unit II: Derivatives security, interest rates, other financial instruments, Arbitrage and pricing, risk less issue, yield curves, mean terms matching and immunization, interest rate models.

Unit III: Dependent annual rates of return, random walk and Markov process, stochastic calculus.

Unit IV: option pricing, portfolio optimization, Fokker-plank equation, distribution and green functions.

Unit V: Feynman-kac formula options, dividends revisited. Exotic options.

Books and References:
1. Financial mathematics, Richard Brass, Springer, 2003
2. Mathematics of financial derivatives, Wilmott & Howison, Springer, 2005
3. Hand book of stochastic methods, Gardiner, Wiely, 2000
4. The Mathematics of Financial Derivatives: A Student Introduction, Wilmott, Dewynne and Howison, Cambridge University Press, 1995
5. Futures, and Other Derivatives, 5th ed, Hull, Prentice Hall, 2000

Elective-4: Integrated M.Sc. 10th Semester (Mathematics)

Non-linear Analysis

Unit-I: Calculus in Banach space

Various form of continuiuty, geometry in normed spaces and duality mappings, Gateaux and Frechet derivative, properties of derivatives, Taylor theorem, inverse function theorem and impliocit function theorem, subdeifferential of convex function.

Unit-II: Monotone operators

Monotone operators, Maximal monotone operators and its propwerties, constructive solution of operator equations, subdifferential and monotonicity, some generalization of monotone operator.

Unit-III: Fixed point theorems

Banach contraction principle and its generalizations, nonexpansive mappings, fixed point theorem of Brouwder and Schauder. Fixed point theorems for multi-functions, common fixed point theorems, sequence of contractions, generalized contractions and fixed points.

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22-02-2020

Unit-IV: Applications of monotone operators theory

Introduction, Sobolev space, differential equation, nonlinear differential equations, integral equation, Nonlinear ammerstein integral equation, Generalized Hammerstein integral equation.

Unit-V: Applications of fixed point theorems

Application to Geometry of Banach Spaces, Application to System of Linear Equations, Perron–Frobenius, Fundamental Theorem of Algebra, Game Theory and Nash Equilibria, Differential eqautions, integral equations.

Books and References:

1. Some topics in nonlinear analysis, M. C. Joshi and R. K. Bose, Wiley Eastern limited, New Delhi, 1985.
2. An introduction to nonlinear analysis and fixed point theory, H. K. Pathak, Springer, 2018.
3. Nonlinear functional analysis and its applications-I, Fixed point theorem, Zeidler, Springer, Heidelberg, 1986.
4. Nonlinear functional analysis, Akerker, Narosa publishing house, New Delhi.

Elective-5: Integrated M.Sc. 10th Semester (Mathematics)

Operations Research

Unit I Introduction, Nature and Scope of operations research. Linear Programming: Introduction, Mathematical formulation of the problem, Graphical Solution methods, Mathematical solution of linear programming problem, Slack and Surplus variables. Matrix formulation of general linear programming problems.

Unit II The Simplex Method: Simplex algorithm, Computational procedures, Artificial variables, Two phase Simplex Method, Formulation of linear programming problems and its solution by simplex method.

Unit III Unrestricted variables, problems of degeneracy, Principle of duality in simplex method, Formation of dual with mixed type of constraints, Solution of primal and dual constraints.

Unit IV Elementary queuing and inventory models. Steady-state solutions of Markovian queuing models: M/M/1, M/M/1 with limited waiting space, M/M/C, M/M/C with limited waiting space, M/G/1.

Unit V Game Theory: Introduction, Two persons zero sum games, The maxmin and minimax principles. Graphical Solution: Reduction of game problem to LPP.

4

22-02-2020

Books and References:

1. Introduction to Operations Research', Hillier, F.S. and G.J. Lieberman, , 9th Ed; 2010, McGraw Hill, New York.
2. Operation Research, Kanti Swarup,P K Gupta, Man Mohan, Sultanchand and Sons.
3. Operation Research, Theory and Application, J.K. Sharma, Macmillan India.
4. Linear Programming, N.P. Loomba, Tata Mc-Graw Hill.
5. Operation Research: An Introduction, H.A. Taha, Macmillan India.

Elective-6: Integrated M.Sc. 10th Semester (Mathematics)

Introduction to Cryptography

Unit-I:

Classical Cryptosystems: Some Simple Cryptosystems, Monoalphabatic and Polyalphabatic cipher, The Shift Cipher, The Substitution Cipher, The Affine Cipher, The Vigenere Cipher, The Hill Cipher, The Permutation Cipher, Cryptanalysis, Some Cryptanalytic Attacks, Stream ciphers, Synchronous Stream Cipher, Linear Feedback Shift Register (LFSR), Non-Synchronous stream Cipher, Autokey Cipher.

Unit-II:

Block Ciphers: Mode of operations in block cipher: Electronic Codebook (ECB), Ciphertext Chaining (CBC), Ciphertext FeedBack (CFB), Output FeedBack (OFB), Counter (CTR),
DES & AES: The Data Encryption Standard (DES), Feistel Ciphers, Description of DES, Security analysis of DES, Differential & Linear Cryptanalysis of DES, Triple DES, The Advanced Encryption Standard (AES), Finite field GF(28), Description of AES, analysis of AES.

Unit-III:

Shannon's Theory of Perfect Secrecy: Perfect Secrecy, Birthday Paradox, Vernam One Time Pad, Random Numbers, Pseudorandom Numbers. **Prime Number Generation:** Trial Division, Fermat Test, Carmichael Numbers, Miller Rabin Test, Random Primes.

Unit-IV: Public Key Cryptography:

Principle of Public Key Cryptography, RSA Cryptosystem, Factoring problem, Cryptanalysis of RSA, RSA-OAEP, Rabin Cryptosystem, Security of Rabin Cryptosystem, Quadratic Residue Problem, Diffie-Hellman (DH) Key Exchange Protocol, Discrete Logarithm Problem (DLP), ElGamal Cryptosystem, ElGamal& DH, Algorithms for DLP. Elliptic Curve, Elliptic Curve Cryptosystem (ECC), Elliptic Curve Discrete Logarithm Problem (ECDLP).

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22-02-2020

Unit-V: Cryptographic Hash Functions:

Hash and Compression Functions, Security of Hash Functions, Modification Detection Code (MDC0, Message Authentication Codes (MAC), Random Oracle Model, Iterated Hash Functions, Merkle-Damgard Hash Function, MD-5, SHA-1, Others Hash Functions.

Digital Signatures: Security Requirements for Signature Schemes, Signature and Hash Functions, RSA Signature, ElGamal Signature, Digital Signature Algorithm (DSA), ECDSA, Undeniable Signature, Blind Signature.

Books and References:

1. J Buchmann, Introduction to Cryptography, Springer (India) 2004
2. S. Padhye, R A Sahu, V Saraswat, Introduction to Cryptography, CRC Press, 2018
3. D R Stinson, Cryptography: Theory and Practice. CRC Press, 2000.
4. Bruce Schenier, Applied cryptography, John Wiley & Sons, 1996.
5. B Forouzan, Cryptography and Network security, Tata McGraw Hill, 2011
6. Wenbo Mao, Modern Cryptography: Theory and Practice. Pearsion Education, 2004
7. W Starling, Cryptography and Network security, Pearson Education, 2004.

Elective-7: Integrated M.Se. 10th Semester (Mathematics)

Introduction to Nonlinear Optimization

Unit-I: Mathematical Preliminaries, the Space R^n, R^{nxn}, Inner Products and Norms, Eigen values and Eigen vectors, Basic Topological Concepts.

Unit-II: Optimality Conditions for Unconstrained Optimization: Global and Local Optima, Classification of Matrices, Second Order Optimality Conditions, Global Optimality Conditions, Quadratic Functions.

Unit-III: Least Squares: Solution of over determined Systems, Data Fitting, Regularized Least Squares, Denoising, Nonlinear Least Squares. Descent Directions Methods, The Gradient Method, The Condition Number, Diagonal Scaling, The Gauss–Newton Method, The Fermat–Weber Problem, Convergence Analysis of the Gradient Method.

Unit-IV: Newton's Method, Pure Newton's Method, Damped Newton's Method, The Cholesky Factorization. Convex Sets, Algebraic Operations with Convex Sets, The Convex Hull, Convex Cones, Topological Properties of Convex Sets, Extreme Points.

Unit-V: Convex Functions, First Order Characterizations of Convex Functions, Second Order Characterization of Convex Functions, Operations Preserving Convexity, Level Sets of Convex Functions, Maxima of Convex Functions, Convexity and Inequalities, Convex Optimization, The Orthogonal Projection Operator, Optimization over a Convex Set, Stationarity in Convex Problems, The Orthogonal Projection Revisited, The Gradient Projection Method, Sparsity Constrained Problems.

Books and References:

1. Introduction to Nonlinear Optimization Theory, Algorithms, and Applications with MATLAB, Amir Beck, Society for Industrial and Applied Mathematics, 2014.
2. Optimization Theory and Methods: Nonlinear Programming, Wenyu Sun, Ya-Xiang Yuan, Springer, 2006.
3. Nonlinear Optimization, Francisco J. Aragón, Miguel A. Goberna Marco A. López, Margarita M. L. Rodríguez, Springer Undergraduate Texts in Mathematics and Technology, 2019.
4. Nonlinear Optimization: Methods and Applications, H. A. Eiselt, Carl-Louis Sandblom, Springer 2019.

Elective-8: Integrated M.Sc. 10ᵗʰ Semester (Mathematics)

Complex Network

UNIT-I: Fundamentals of Graph Theory, Directed, Weighted and Bipartite Graphs, Trees. Complex Network, Basics, history and importance of Complex Network.

UNIT-II: Centrality Measures: The Importance of Being Central, Connected Graphs and Irreducible Matrices, Degree and Eigenvector Centrality, Measures Based on Shortest Paths, Group Centrality.

Unit –III: Random Graphs: Erd˝os and Rényi (ER) Models, Degree Distribution, Trees, Cycles and Complete Sub-graphs, Giant Connected Component, Scientific Collaboration Networks, Characteristic Path Length.

Unit-IV: Small-World Networks: Six Degrees of Separation, The Brain of a Worm, Clustering Coefficient, The Watts–Strogatz (WS) Model, Variations to the Theme, Navigating Small-World Networks.

Unit-V: Generalised Random Graphs: The World Wide Web, Power-Law Degree Distributions, The Configuration Model, Random Graphs with Arbitrary Degree Distribution, Scale-Free Random Graphs, Probability Generating Functions. Models of Growing Graphs, Degree Correlations.

Books and References:

1. Complex Networks : Principles, Methods and Applications , Vito Latora , Vincenzo Nicosia , Giovanni Russo , Cambridge University Press, 2017
2. Graph Theory and Complex Networks: An Introduction, Maarten van Steen, Maarten van Steen, 2010.
3. Lectures on Complex Networks, S. N. Dorogovtsev, Clarendon Press Oxford, 2010.
4. The Structure Of Complex Networks: Thoery and Applications, Ernesto Estrada, Oxford University Press, 2011

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मूल विज्ञान केन्द्र ,पं. रविशंकर शुक्ल विश्वविद्यालय ,रायपुर (छ.ग.)

रचनात्मक हिंदी भाषा

इकाई I– (1) मानक हिंदी भाषा , वर्तनी लेखन में अशुद्धियाँ , शब्द शुद्धि, वाक्य शुद्धि,
हिंदी भाषा के विकास में हिंदीतर एवं विदेशी विद्वानों का योगदान,

(2) उसने कहा था , कहानी– चंद्रधर शर्मा गुलेरी ।

इकाई II– (1) पत्राचार औपचारिक व अनौपचारिक पत्र एवं संप्रेषण कौशल ।

(2) मनुष्य ही साहित्य का लक्ष्य है । (हजारी प्रसाद द्विवेदी)

इकाई III– (1) पारिभाषिक शब्दावली की परिभाषा एवं स्वरुप तथा निर्माण की प्रक्रिया (विज्ञान
–तकनीकी), शब्द भंडार ।

(2) सादगी, सत्य और अहिंसा –मोहनदास करमचंद गांधी (आत्मकथांश)

इकाई IV– (1) देवनागरी लिपि, वाग्यंत्र और ध्वनि उत्पादन में उनकी भूमिका , स्वर व्यंजन का वर्गीकरण
,IPA अंतरराष्ट्रीय ध्वनि लिपि ।

(2) नमामि छत्तीसगढ. (छत्तीसगढ. का सांस्कृतिक वैभव) : डॉ हीरालाल शुक्ल (आलेख) ।

इकाई V– (1) अनुवाद , परिभाषा ,प्रक्रिया , अनुवादक के गुण , सफल अनुवाद, हिंदी से अंग्रेजी अनुवाद ।

(2) योग की शक्ति –डॉ. हरिवंश राय बच्चन (डायरी) ।

(3) पृथक छत्तीसगढ. राज्य –विष्णु खरे (कविता) ।

Suggested Texts and References:

Sr.No.	Author	Title	Publisher
1.	तिवारी भोलानाथ	हिन्दी भाषा की संरचना	पाण्डुलिपि प्रकाशन ,दिल्ली
2.	प्रसाद वासुदेवनंदन	आधुनिक हिंदी व्याकरण और रचना	भारती भवन प्रकाशन ,पटना
3.	बाहरी हरदेव	पारिभाषिक शब्दावली कोश	राजकमल प्रकाशन दिल्ली
4.	वधान अमरसिंह	भाषा और सूचना प्रौद्योगिकी	भावना प्रकाशन,दिल्ली
5.	गुरु कामता प्रसाद	हिंदी व्याकरण	लोकभारती प्रकाशन ,इलाहाबाद

ES101-ENVIRONMENTAL STUDIES

UNIT – I   THE MULTI DISCIPLINARY NATURE OF ENVIRONMENTAL STUDIES :
Definition ,scope and importance
Need for publish awareness.

(5 cr.)

UNIT-II   Natural Resources :
Renewable and non-renewable resources:
Natural resources and associated problems .

(a)   Forest resources : use and over – exploitation, deforestation, case studies, timber extraction,Mining, dams and their effects on forests and tribal people .

(b)   Water resources : use and over-utilization of surface and ground water,floods, drought,Conflicts over water , dams benefits and problems .

(c)   Mineral resources : use and explotation, environmental effects of extracting and using Mineral resources, case studies .

(d) Food resources : World food problems , changes caused by agriculture and overgrazing, Effects of modern agriculture , fertilizer –pesticide problems , water logging , salinity Case studies.

(e) Energy resources : Growing energy needs , renewable and non renewable energy sources Use of alternate energy sources ,case studies.

(f)   Land resources : land as a resources , land degradation, man induced landslides , soil erosion & desertification.

-      Role of an individual in consertification of natural resources.
-      Equitable use of resources for sustainable life –styles.

(5 cr.)

UNIT- III   Concept of an ecosystems.
Structure and function of an ecosystem.
-   Producers , consumers and decomposers .
-   Energy flow in the ecosystem .
-   Ecological succession.
-   Food chains, food webs and ecological pyramids .

(5 cr.)

UNIT-IV Introduction , types ,characteristic features , structure and function of the following

Ecosystem:
a. Forest ecosystem
b. Grassland ecosystem
c. Desert ecosystem
d. Aquatic ecosystem (ponds , streams, lakes, rivers, oceans,estuaries

(5 cr.)

UNIT- V SOCIAL ISSUES AND THE ENVIRONMENT
- Environment Protection Act.
- Air (prevention and control of pollution) Act.
- Wildlife protection Act.
- Forest conservation Act.
- Issues involved in enforcement of environmental legislation .
- Public awareness.
- Value Education
- HIV/ADIS
- Women and child welfare.
- Role of information technology in Environment and Human Health.
- Case studies.

(5 cr.)

Field work

- Visit to a local area to document environment assets – river / forest/grassland/hill/ Mountain.
- Visit to local polluted site : Urban/Rural/Industrial/Agriculture.

Sr.No.	Author	Title	Publisher
1.	Agarwal K.C.	Environmental Biology 2001	Nidi Publ. Ltd.Bikaner
2.	Bharucha Erach	The Biodiversity of India	Mapin Publishing Pvt. Ltd. Ahmedabad 380013, India .
3.	Bruinner R.C.	Hazardous Waste Incineration, 1989	Mc Graw Hill Inc. 480p.
4.	Bharucha E.	Textbook for Environmental Studies for undergraduate Cources.	UGC, New Delhi & Bharti Vidyapeeth Inst. Of Environment edu. & Research ,Pune.
5.	Begon M.,Town send C.R. ,Harper J.L.	Ecology From Individuals to Ecosystems	4th edition , Blackwell Publishing (TB)

(TB) Textbook.

H 101: Communication Skills(COMMON TO ALL BRANCHES)

Unit-I

An interactive session (with examples) on what is communication, communication in the natural and civilized worlds, types of human communication: visual / non-verbal / verbal, written / spoken, etc

Unit-II

An overview of mass media; a brief discussion of their types (with examples). The concepts of facilitating factors, barriers, and filters in communication; the seven C's of effective communication.

Unit-III

Verbal communication: How to speak / listen effectively (in interpersonal communication), types of publicspeaking, tips for effective public speaking, how to make effective presentations. The role of written text in communication,

Unit-IV

Types of writing (academic/creative/general; formal/informal etc.) with examples of good/bad writing and their analysis. Introduction to letter writing, with stress on formal correspondence; email do's and don'ts.

Unit-V

Academic writing- an overview; explanation of various terms used in academic writing; parts of a paper/thesis;aspects such as formal language, grammatical accuracy, etc. Common grammatical/punctuation errors andhow to avoid them (example-based instruction)

Books Recommended:

S.No	Author	Book	Publication
1	Rajendra Pal and JS Kurlahalli	Essentials of Business Communication	S.Chand& Sons
2	Michael Alley	The Craft of Scientific Writing (3rd Edition)	Springer, Newyork, 1996
3	Philip Reubens (General editor)	Science and Technical Writing – A Manual of Style (2nd Edition)	Routledge, Newyork, 2001
4	Edmond H. Weiss	Writing Remedies – Practical Exercises for Technical Writing	Universities Press (India) Ltd. , Hyderabad,2000
5	M. Ashraf Rizvi	Effective Technical Communication	Tata Mc Graw – Hill New Delhi, 2005
6	DH Menzel ,HM Jones& LGBoyd	Writing Technical Papers	Mc Graw Hill, 1961
7	KL Turbian	A Manual for Writers of Term Papers Thesis and Dissertation	University of Chicago Press, 1973.

ES201: Environmental Studies

Unit-I: Biodiversity and its Conservation: Introduction- Definition: genetics, species and ecosystem diversity. Bio geographical classification of India. Value of biodiversity: consumptive use productive use, social, ethical, aesthetical and option value. Biodiversity at global, National and local levels. India as mega-diversity nation. Hot-spots of biodiversity. Threats to biodiversity: habitat loss, poaching of wildlife, man wildlife conflicts. Endangered and endemic species of India. Conservation of biodiversity: in situ and ex-situ conservation of biodiversity.

Unit-II: Environmental pollution. Definition Causes, effects and control measures of- a. Air pollution b. Water pollution c. Soil pollution d. Marine pollution e. Noise pollution f. Nuclear hazards.

Unit-III: Solid waste management: Causes, effects and control measures of urban and industrial wastes. Role of an individual in prevention of pollution. Pollution case studies Disaster management: floods, earthquake, cyclone and landslides.

Unit-IV: Human population and the Environment: Population growth, variation among nation. Population explosion- Family welfare programme. Environment and human health. Human Rights.

Unit-V: Social Issues and the Envionment: From unsustainable to Sustainable development. Urban problems related to energy. Water conservation, rain water harvesting, watershed management. Resettlement and rehabilitation of people, its problems and concerns. Case studies. Environment ethies: Issues and possible solutions. Climate change, global warming, acid rain, ozone layer depletion, nuclear accidents and holocaust. Case studies. Wasteland reclamation. Consumerism and waste products.

H201Subject: Communication Skills (Lab)

Course Outcome: After learning the course the students should be able to
1. To know the process of communication and its components.
2. To improve the language skills i.e. Listening Skills, Speaking Skills, Reading Skills and Writing Skills (LSRW).
3. Construct basic and intermediate skills in English / Hindi language.
4. To enhance phonetic competence, comprehension skills, presentation skills, group discussion skills etc.
5. To build confidence for communicating in English /Hindi and create interest for the life-long learning of English/Hindi language.

Unit 1
Elementary Phonetics (Speech Mechanism. The Description of Speech Sounds, The Phoneme the syllable; Intonation and Word Accent)
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H301: World Literature (COMMON TO ALL BRANCHES)

Unit-I
What is Literature? - a discussion; Introduction to literary terms, genres, and forms of various periods, countries, languages, etc.

Unit-II
The Novel: Class study of 'Brave New World' by Aldous Huxley; Group discussions and student presentations on other genres such as the graphic novel, detective fiction, children's literature, etc.

Unit-III
Plays: Introduction to the history of theatre, class study of (mainly) two plays: 'Pygmalion' by G. B. Shaw and 'Fire and Rain' by Girish Karnad, the setting up of play –reading group through which the students can be introduced to several other plays.

Unit-IV
Poetry: Brief introduction; Study of poetic genres, forms, topics, figures of speech, poetic language etc. by analysing various poems from around the world

Unit-V
Short stories, essays and other types of writing by various authors. Screening of films based on literary works, such as Pygmalion (My Fair Lady), Fire and Rain (Agnivarsha), Persepolis (a graphic novel) and a few others.

Books Recommended:

S.No	Author	Book	Publication
1	IforIvans London	A Short History of English Literature	London: Penguin Books, 1976
2	Kettle Arnold	An Introduction to English Novel Vol. I, Vol. II	New. Delhi: Universal Book store, 1993.
3	Eagleton, Terry.	The English Novel: An Introduction	Oxford: Basil Blackwell. 1983
4	M.H. Abrams)	A Glossary of Literary Terms	Wadsworth Publishing; 10th edition (January 10, 2011
5	J.A. Cuddon	Dictionary of Literary Terms and Literary	(London: Penguin, 2004)
6	Girish Karnad	The Fire and the Rain	New Delhi, Oxford University Press, 1998
7	Aldous Huxley	'Brave New World'	New York: Harper Perennial, 1989
8	G. B. Shaw	Pygmalion	Longman Literature. Harlow: Longman, 1991

मूल विज्ञान केंद्र, पं. रविशंकर शुक्ल विश्वविद्यालय, रायपुर (छ.ग.)
एम.एस–सी. (इंटीग्रेटेड) तृतीय सेमेस्टर
प्रयोजनमूलक हिंदी (FH301)
Functional Hindi

इकाई I- (1) प्रयोजनमूलक हिंदी का स्वरूप एवं महत्व

(2) भाषा के विविध रूप– बोली, उपभाषा, राजभाषा, राष्ट्रभाषा, संपर्क भाषा, साहित्यिक भाषा।

इकाई II- (1) मीडिया की भाषा– समाचार पत्र, विज्ञापन

(2) श्रव्य माध्यम, दृश्य–श्रव्य माध्यम

इकाई III- (1) पल्लवन– परिभाषा, पल्लवन एवं व्याख्या, आशय कुशल विस्तारक के गुण, सूक्तिपरक वाक्यों का पल्लवन

(2) झलमला पदुमलाल पुन्नालाल बख्शी कहानी

इकाई IV- (1) शब्द रचना– उपसर्ग संस्कृत, हिंदी, उर्दू के उपसर्गों का परिचय

(2) प्रत्यय–परिभाषा, प्रत्यय के भेद

इकाई V- (1) चीफ की दावत – भीष्म साहनी कहानी

(2) मजदूरी और प्रेम – सरदार पूर्ण सिंह

संदर्भ ग्रंथ–

1. प्रयोजनमूलक हिंदी की नयी भूमिका कैलाश नाथ पाण्डेय, लोकभारती प्रकाशन, इलाहाबाद।
2. प्रयोजनमूलक व्यावहारिक हिंदी भाषा कैलाश चंद्र भाटिया, तक्षशिला प्रकाशन, जयपुर।
3. भाषा प्रौद्योगिकी एवं भाषा प्रबंधन सूर्य प्रसाद दीक्षित, किताबघर, नई दिल्ली
4. हिंदी भाषा और संस्कृति म.प्र. हिंदी ग्रंथ अकादमी, भोपाल सं. राजेन्द्र मिश्र
5. कार्यालयी हिंदी, श्री प्रकाशन, रायपुर, प्रो. केशरीलाल वर्मा
6. अच्छी हिंदी, रामचंद्र वर्मा, लोकभारती प्रकाशन, इलाहाबाद (उ.प्र.)
7. अच्छी हिंदी, किशोरी दास वाजपेयी, मीनाक्षी प्रकाशन मेरठ (उ.प्र.)
8. भारतीयता के अमर स्वर प्रधान सं. डॉ. घनंजय वर्मा, म.प्र. हिंदी ग्रंथ अकादमी भोपाल।
9. प्रयोजनमूलक हिंदी डॉ. चितरंजन कर वैभव प्रकाशन रायपुर (छ.ग.)

H401Subject: Communication Skills (Lab)

Course Outcome: After learning the course the students should be able to
1. To know the process of communication and its components.
2. To improve the language skills i.e. Listening Skills, Speaking Skills, Reading Skills and Writing Skills (LSRW).
3. Construct basic and intermediate skills in English / Hindi language.
4. To enhance phonetic competence, comprehension skills, presentation skills, group discussion skills etc.
5. To build confidence for communicating in English /Hindi and create interest for the life-long learning of English/Hindi language.

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CBS – Five Years Integrated Course, M.Sc. V Semester

Scientific Writing (H501)

Unit 1

Introduction: What is Scientific Writing; Needs and importance, main features and elements of scientific writing. Tools and types of Scientific Writing , Scientific writing Vs other forms of writing, Different methods of Research, Types of Research.

Unit 2

Scientific Writing in Research: Mechanics of writing. How to write a Research Paper, Project Proposal components of a full length research paper, Research/ Project Report writing, Formulation of Hypothesis, Do's and Don'ts of writing a Research Paper.

Unit 3

Technical Writing:
Types of technical documents: Full length research paper, Letters to editor, Book chapter, Review, Conference report, Title/Thesis statement, Abstract/key words, Aims and objectives, Rationale of the paper, Work plan, Materials and methodology, Results and discussion, Key issues and arguments, Acknowledgement, Conflict of interest statement, Reference and Bibliography.

Unit 4

Scientometrics: How to cite and how to do Referencing, Literature Search Technique: using SCOPUS, Google Scholar, PUBMED, Web of Science, Indian Citation Index, and RG Styles of referencing: APA, MLA, Oxford, Harvard, Chicago Annotated bibliography Tools for citing and referencing: Footnote, Endnote etc.

Unit 5

Research Paper and Thesis Designing: Components, Types and Importance Research ethics, Institutional ethics committee, Proof Reading, Studying Peer Review and Impact Factor of Journals, Synopsis Designing, Writing Preface, Acknowledgements, Plagiarism – Pitfall (software to check plagiarism).

Book Recommended :

S. No.	Author	Book	Publication
1	Various	The Oxford Book of Modern Science writing	Oxford University Press
2	Robert A. Day and Barbara	How to write and Publish a Scientific paper	Cambridge University Press
3	Angelika Hofmann	Scientific Writing and Communication: Papers Proposals and Presentations	Oxford University Press
4	Jennifer Peat, Elizabeth-Elliott, Louise Baur and Victoria Keena	Scientific Writing: Easy when you know how	BMJ Books
5	Hans F. Ebel, Claus Bliefert, William E. Russey	The Art of Scientific Writing	WILEY-VCH Publishers

CBS – Five Years Integrated Course, M.Sc. VI Semester

Scientific Writing Lab / Applications of Scientific Writing (H602)

Effective Writing skills: Structuring Scientific Paper for Journals (Category A, B, C and D) Tables, Figures, Equations and Pictures using Excel, Improving Writing Style, Punctuation, Mechanism of Scientific Writing, Capitalization and Spelling, Collecting, organizing and evaluating data, Making deductions and reading conclusions.

Project writing: Technical Resumes & Cover Letters Components of a research proposal: Project summary, Key words, Origin of the proposal, Major Objectives, Methodology, Instrument facility available in the PI's department, Overview of status of Research and Development in the subject, Importance of the proposed project in the context of current status, Bibliography, Making Report of a Project / Research Paper
Formulation of projects, Funding Agencies: their Templates and Assignments on Project Submission.
Presentations: Oral, and Power Point Presentation of Scientific Research Paper in Seminars, Conferences, Research Meetings and gatherings, Audience Analysis in Presentation, Conducting Seminars and Conferences etc.