

Proposal of

M. Sc. Mathematics Programme

**As modification of
M. Sc. in Mathematics
As suggested by
M.Sc. Committee**

**Department of Mathematics
IIT Delhi
May 2015**

Proposal for M. Sc. in Mathematics Programme of Mathematics Department

1. Framework of M. Sc. Programme in Mathematics

A. Objective

To build a broad-based theoretical background in Mathematical Sciences with some practice in computing, numerical methods, and statistical analysis. Graduates of this programme will be ready for careers in research and development in industries, financial institutions, and for a research-based career in academics.

B. Proposed Credit Distribution:

(i) Credit structures of M.Sc. in Mathematics

Total Credit: 75

(DC: 52 + 5(Project) + DE: 12 + OC: 6 =75)

- | | |
|-----------------------------|--------------------|
| 1. Department Core (DC) | 57 credits (52+5) |
| 2. Department Elective (DE) | 12 credits |
| 3. Open Category (OC) | 6 credits |

(ii) List of Department Core courses

	Course Number	Courses	L	T	P	C	Remarks
1	MTL 501	Algebra	3	1	0	4	DC in MSc
2	MTL 502	Linear Algebra	3	1	3	4	DC in MSc
3	MTL 503	Real Analysis	3	1	0	4	DC in MSc
4	MTL 504	Ordinary Differential Equations	3	1	0	4	DC in MSc
5	MTL 505	Computer Programming	3	1	0	4	DC in MSc
6	MTL 506	Complex Analysis	3	1	0	4	DC in MSc
7	MTL 507	Topology	3	1	0	4	DC in MSc
8	MTL 508	Mathematical Programming	3	1	0	4	DC in MSc
9	MTL 509	Numerical Analysis	3	1	0	4	DC in MSc
10	MTL 510	Measure and Integration	3	0	2	4	NEW
11	MTL 601	Probability and Statistics	3	1	0	4	NEW
12	MTL 602	Functional Analysis	3	1	0	4	DC in MSc
13	MTL 603	Partial Differential Equations	3	1	0	4	DC in MSc
14	MAD 701	Project I	0	0	10	5	NEW
	Total Credits					57	

(iii) List of Department Electives:

SN	Course Number	Course Name	L	T	P	C	Remark
1	MTL 773	Wavelets and Applications	3	0	0	3	DE in MT6
2	MTL 775	Programming Languages	3	0	0	3	DE in MT6
3	MTL 776	Graph Algorithms	3	0	0	3	DE in MT6
4	MTL 781	Finite Element Theory and Applications	3	0	0	3	DE in MT6
5	MTL 765	Parallel Computing	3	0	0	3	DE in MT6
6	MTL 766	Multivariate Statistical Methods	3	0	0	3	DE in MT6
7	MTL 768	Graph Theory	3	0	0	3	DE in MT6
8	MTL 704	Numerical Optimization	3	0	0	3	DE in MT6
9	MTL 710	Database Management Systems	3	0	2	4	DE in MT6
10	MTL 717	Fuzzy Sets and Applications	3	0	0	3	DE in MT6
11	MTL 720	Neurocomputing and Applications	3	0	0	3	DE in MT6
12	MTL 731	Introduction to Chaotic Dynamical systems	3	0	0	3	DE in MT6
13	MTL 732	Financial Mathematics	3	0	0	3	DE in MT6
14	MTL 733	Stochastic of Finance	3	0	0	3	DE in MT6
15	MTL 735	Advanced Number Theory	3	0	0	3	DE in MT6
16	MTL 737	Differential Geometry	3	0	0	3	DE in MT6
17	MTL 738	Commutative Algebra	3	0	0	3	DE in MT6
18	MTL 739	Representation of Finite Groups	3	0	0	3	DE in MT6
19	MTL 741	Fractal Geometry	3	0	0	3	DE in MT6
20	MTL 742	Operator Theory	3	0	0	3	DE in MT6
21	MTL 743	Fourier Analysis	3	0	0	3	DE in MT6
22	MTL 744	Mathematical Theory of Coding	3	0	0	3	DE in MT6
23	MTL 751	Symbolic Dynamics	3	0	0	3	DE in MT6
24	MTL 755	Algebraic Geometry	3	0	0	3	DE in MT6
25	MTL 756	Lie Algebras and Lie Groups	3	0	0	3	DE in MT6
26	MTL 757	Introduction to Algebraic Topology	3	0	0	3	DE in MT6

27	MTL 760	Advanced Algorithms	3	0	0	3	DE in MT6
28	MTL 761	Basic Ergodic Theory	3	0	0	3	DE in MT6
29	MTL 765	Probability and Computing	3	0	0	3	DE in MT6
30	MTL 770	Combinatorial Optimization	3	0	0	3	DE in MT6
31	MTL 785	Natural Language Processing	3	0	0	3	DE in MT6
32	MTL 792	Modern Methods in Partial Differential Equations	3	0	0	3	DE in MT6
33	MTL 793	Numerical Methods for Hyperbolic PDEs	3	0	0	3	DE in MT6
34	MTL 794	Advanced Probability Theory	3	0	0	3	DE in MT6
35	MTV 791	Special Module in Dynamical System	1	0	0	1	DE in MT6
36	MTL 762	Probability Theory	3	0	0	3	NEW
37	MTL 763	Introduction to Game Theory	3	0	0	3	NEW
38	MTL 725	Stochastic Processes and its Applications	3	0	0	3	DE in old MSc
39	MTL 729	Computational Algebra and its Applications	3	0	0	3	DE in old MSc
40	MTL 730	Cryptography	3	0	0	3	DE in old MSc
41	MTL 795	Numerical Method for Partial Differential Equations	3	1	0	4	NEW
42	MTL 745	Advanced Matrix Theory	3	0	0	3	DE in old MSc
43	MTL 625	Principles of Optimization Theory	3	0	0	3	DE in old MSc
44	MTL 712	Computational Methods for Differential Equations	3	0	2	4	DC in MT6
45	MTL 746	Methods of Applied Mathematics	3	0	0	3	NEW
46	MTL 728	Category Theory	3	0	0	3	DE in old MSc
47	MTL 747	Mathematical Logic	3	0	0	3	DE in old MSc
48	MAD 702	Project 2	0	0	12	6	NEW

(iv) **Proposed Semester-wise scheduling of courses**

Sem	Course 1	Course 2	Course 3	Course 4	Course 5	Credits
I	MTL 501 Algebra	MTL 502 Linear Algebra	MTL 503 Real Analysis	MTL 504 Ordinary Differential Equations	MTL 505 Computer Programming	20
II	MTL 506 Complex Analysis	MTL 507 Topology	MTL 508 Mathematical Programming	MTL 509 Numerical Analysis	MTL 510 Measure and Integration	20
III	MTL 601 Probability and Statistics	MTL 602 Functional Analysis	MTL 603 Partial Differential Equations	DE 1	MAD 701 Project 1	20
IV	DE 2	DE 3	DE 4	OC 1	OC 2	15

Head,
Department of Mathematics

Appendix

Changes made here from previous:

1. The number of credits is reduced to 75 credits from the existing 90 credits.
2. New courses (i) Measure and Integration (ii) Probability and Statistics (iv) Computer Programming and (iv) Mathematical Programming in DC to either expand or replace some core courses.
3. Project 1 is compulsory and will be of 5 credits.
4. MAD 702 Project 2 will be DE of 6 credits and will be offered only if the work in Project 1 is found satisfactory by the evaluating team and the supervisor advises so. It will subsume two DEs to be done by the student.

COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/School proposing the course	Mathematics		
2.	Course Title	Algebra		
3.	L-T-P structure	3-1-0		
4.	Credits	4	Non-graded Units	0
5.	Course number	MTL 501		
6.	Course Status (Course Category for Program) MAL			
	Institute Core for all UG programs		No	
	Programme Linked Core for:		Nil	
	Departmental Core for:		M.Sc.	
	Departmental Elective for:		Nil	
	Minor Area / Interdisciplinary Specialization Core for:		Nil	
	Minor Area / Interdisciplinary Specialization Elective for:		Nil	
	Programme Core for:		M.Sc.	
	Programme Elective for:		Nil	
	Open category Elective for all other programs (No if Institute Core)		No	
7.	Pre-requisite(s)	Nil		
8.	Status vis-à-vis other courses			
8.1	List of courses precluded by taking this course (significant overlap)		None	
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	MTL105	
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	None	
8.2	Supersedes any existing course		MAL516 (Modern Algebra)	
9.	Not allowed for	MT6		

10.	Frequency of offering (check one box)	☐ Every semester ☒ I sem ☐ II sem ☐ Either semester
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11.	Faculty who will teach the course A. Sharma, R.K.Sharma, R.Sarma, R. Barman
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12.	Will the course require any visiting faculty?	No
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13.	Course objectives (about 50 words. "On successful completion of this course, a student should be able to..."): To understand the concepts of modern mathematics (for instance, number theory, algebraic geometry, Lie theory and theory of physics) one requires to have prior knowledge of quite a large amount of group theory, ring theory and Galois theory. We revise certain concepts of group theory and teach certain important theorems of group theory and ring theory and the fundamental theorem of Galois theory.
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14.	Course contents (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Groups, subgroups, Lagrange theorem, quotient groups, isomorphism theorems; cyclic groups, dihedral groups, symmetric groups, alternating groups; simple groups, simplicity of alternating groups; Group action, Sylow theorems and applications; free abelian groups, structure of finitely generated abelian groups; Solvable and nilpotent groups, composition series, Jordan-Holder theorem. Rings, examples: polynomial rings, formal power series, matrix rings, group rings; prime ideals, maximal ideals, quotient rings, isomorphism theorems; Integral domains, PID, UFD, Euclidean domains, division rings, field of fractions; primes and irreducibles, irreducibility criteria; product of rings, Chinese remainder theorem. Field extension, algebraic extension, algebraic closure, straight edge and compass constructions, splitting fields, separable and inseparable extensions, fundamental theorem of Galois theory; solvability by radicals.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
1	Groups, subgroups, Lagrange theorem.	2
2	Quotient groups, isomorphism theorems	2
3	Cyclic groups, Dihedral groups, symmetric groups, alternating groups	4
4	Simple groups, simplicity of alternating groups	2
5	Group action, Sylow theorems and applications;	5
6	Free abelian groups, structure of finitely generated abelian groups;	3
7	Composition series, Jordan-Holder theorem.	2

8	Rings, examples: polynomial rings, formal power series, matrix rings, group rings.	3
9	Prime ideals, maximal ideals, quotient rings, isomorphism theorems	3
10	Integral domains, PID, UFD, Euclidean domains, division rings, field of fractions, primes and irreducibles, irreducibility criteria.	4
11	Product of rings, Chinese remainder theorem.	2
12	Field extension, algebraic extension, algebraic closure, straight edge and compass constructions	5
13	splitting fields, separable and inseparable extensions, fundamental theorem of Galois theory solvability by radicals.	5
Total Lecture hours (14 times 'L')		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	Solving problems based on the lectures	14
Total Tutorial hours (14 times 'T')		14

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	NIL	
Total Practical / Practice hours (14 times 'P')		

18. Description of module-wise activities pertaining to self-learning component

(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
	NIL

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

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. I.N.Herstien, Topics in Algebra, Wiley Student Edition, 2nd Edition.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	Name of software, number of licenses, etc.: Nil
20.2	Hardware	Nature of hardware, number of access points, etc.: Nil
20.3	Teaching aids (videos, etc.)	Description, Source , etc.: Nil
20.4	Laboratory	Type of facility required, number of students etc.: Nil
20.5	Equipment	Type of equipment required, number of access points, etc.: Nil
20.6	Classroom infrastructure	Type of facility required, number of students etc.: Nil
20.7	Site visits	Type of Industry/ Site, typical number of visits, number of students etc.: Nil
20.8	Others (please specify)	

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	Eg. 25% of student time of practical / practice hours: sample Circuit Design exercises from industry
21.2	Open-ended problems	Nil
21.3	Project-type activity	Nil
21.4	Open-ended laboratory work	Nil
21.5	Others (please specify)	Nil

Date:

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/School proposing the course	Mathematics		
2.	Course Title	Linear Algebra		
3.	L-T-P structure	3-1-0		
4.	Credits	4	Non-graded Units	0
5.	Course number	MTL 502		
6.	Course Status (Course Category for Program) MAL			
	Institute Core for all UG programs	No		
	Programme Linked Core for:	Nil		
	Departmental Core for:	M.Sc.		
	Departmental Elective for:	Nil		
	Minor Area / Interdisciplinary Specialization Core for:	Nil		
	Minor Area / Interdisciplinary Specialization Elective for:	Nil		
	Programme Core for:	M.Sc.		
	Programme Elective for:	Nil		
	Open category Elective for all other programs (No if Institute Core)	No		
7.	Pre-requisite(s)	Nil		
8.	Status vis-à-vis other courses			
8.1	List of courses precluded by taking this course (significant overlap)			None
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	MTL101	
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	None	
8.2	Supersedes any existing course			MAL503 (Linear Algebra)
9.	Not allowed for	MT6		

10.	Frequency of offering (check one box)	☐ Every semester ☒ I sem ☐ II sem ☐ Either semester
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11.	Faculty who will teach the course A. Sharma, R. K. Sharma, A. Priyadarshi, R. Sarma, R. Barman
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12.	Will the course require any visiting faculty?	No
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13.	Course objectives (about 50 words. "On successful completion of this course, a student should be able to..."): Most problems in linear algebra boil down to solving a system of linear equations. So revise the theory of solving a system of linear equations. The concepts included in this course are essential to several courses of pure and applied mathematics. This course is like a gate way to several other courses. Main purpose of this course is to train students with the basic concepts and practice solving problems so that students do not find any difficulty in following the advanced concepts of mathematics.
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14.	Course contents (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Revision of existence-uniqueness of solutions of a system of linear equations, elementary row operations, row-reduced echelon matrices. Vector spaces, span of a subset, bases and dimension, quotient spaces, direct sums. Linear transformations, rank-nullity, matrix representation of a linear transformation, algebra of linear transformations, dual space, transpose of a linear transformation. Eigenvalues, eigenvectors, annihilating polynomials, Cayley-Hamilton theorem, invariant subspaces, triangulable and diagonalizable linear operators. Simultaneous triangulation and diagonalization, Primary decomposition theorem, Jordan decomposition. Cyclic decomposition theorem, Rational and Jordan canonical forms. Inner product spaces over $\mathbb{R}$ (real numbers) and $\mathbb{C}$ (complex numbers), Gram-Schmidt orthogonalization process, orthogonal projection, best approximation. Adjoint of a linear operator, unitary and normal operators, spectral theory of normal operators. Bilinear forms, symmetric and skew-symmetric bilinear forms, quadratic forms.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
1	Revision of existence-uniqueness of solutions of a system of linear	3

	equations, elementary row operations, row-reduced echelon matrices.	
2	Vector spaces, span of a subset, bases and dimension, quotient spaces, direct sums.	3
3	Linear transformations, rank-nullity, matrix representation of a linear transformation, algebra of linear transformations,	4
4	Dual space, transpose of a linear transformation.	2
5	Eigenvalues, eigenvectors, annihilating polynomials, Cayley-Hamilton theorem.	4
6	Invariant subspaces, triangulable and diagonalizable linear operators.	2
7	Simultaneous triangulation and diagonalization, Primary decomposition theorem, Jordan decomposition.	5
8	Cyclic decomposition theorem, Rational and Jordan canonical forms.	5
9	Inner product spaces, Gram-Schmidt orthogonalization process, orthogonal projection, best approximation.	3
10	Adjoint of a linear operator, unitary and normal operators,	4
11	Spectral theory of normal operators.	3
12	Bilinear forms, symmetric and skew-symmetric bilinear forms, quadratic forms.	4
Total Lecture hours (14 times 'L')		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	Solving problems based on lectures	14
Total Tutorial hours (14 times 'T')		14

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	NIL	
Total Practical / Practice hours (14 times 'P')		

18. Description of module-wise activities pertaining to self-learning component

(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
	NIL
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. K. Hoffman and R. Kunze, Linear Algebra, Prentice-Hall, 2nd Edition.
2. M. Artin, Algebra, Prentice Hall of India, 1994.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	Name of software, number of licenses, etc.:NIL
20.2	Hardware	Nature of hardware, number of access points, etc. :NIL
20.3	Teaching aids (videos, etc.)	Description, Source , etc. :NIL
20.4	Laboratory	Type of facility required, number of students etc. :NIL
20.5	Equipment	Type of equipment required, number of access points, etc. :NIL
20.6	Classroom infrastructure	Type of facility required, number of students etc. :NIL
20.7	Site visits	Type of Industry/ Site, typical number of visits, number of students etc. :NIL
20.8	Others (please specify)	

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	Eg. 25% of student time of practical / practice hours: sample Circuit Design exercises from industry
21.2	Open-ended problems	NIL
21.3	Project-type activity	NIL
21.4	Open-ended laboratory work	NIL

21.5	Others (please specify)	NIL
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Date: (Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/School proposing the course	Mathematics		
2.	Course Title	Real Analysis		
3.	L-T-P structure	3-1-0		
4.	Credits	4	Non-graded Units	0
5.	Course number	MTL 503		
6.	Course Status (Course Category for Program) (list program codes: eg., EE1, CS5, etc.)			
	Institute Core for all UG programs		No	
	Programme Linked Core for:		-	
	Departmental Core for:		M.Sc.	
	Departmental Elective for:		-	
	Minor Area / Interdisciplinary Specialization Core for:		-	
	Minor Area / Interdisciplinary Specialization Elective for:		-	
	Programme Core for:		-	
	Programme Elective for:		-	
	Open category Elective for all other programs (No if Institute Core)		No	
7.	Pre-requisite(s)	NIL		
8.	Status vis-à-vis other courses			
8.1	List of courses precluded by taking this course (significant overlap)			
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	MTL122	
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	-	
8.2	Supersedes any existing course			MAL 513
9.	Not allowed for	-		

10.	Frequency of offering (check one box)	☐ Every semester ☒ I sem ☐ II sem ☐ Either semester
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11.	Faculty who will teach the course S. Kundu, A. Nagar, A. Priyadharshi, N. Shravan Kumar, K. Sreenadh, S. Sivananthan
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12.	Will the course require any visiting faculty? No
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13.	Course objectives (about 50 words. "On successful completion of this course, a student should be able to..."): It is one of the foundation courses for the students who are pursuing their career in Mathematics. On successful completion of this course, a student should be able to deal with as well to use basic real analysis.
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14.	Course contents: Elementary set theory, Countable and Uncountable sets, Real number system and its order completeness. Metric spaces, Continuous and uniformly continuous functions, Homeomorphism and isometry, Completeness, Fixed Points, Baire's Category Theorem, Totally bounded metrics, Compactness, Connectedness. Sequences and series of functions, Pointwise and uniform convergence of sequences of functions, Equicontinuity, Arzelà-Ascoli Theorem, Dini's Theorem, Stone-Weierstrass Theorems (Lattice and algebra versions). Functions of several variables, Linear transformations, Differentiation, Inverse function theorem, Implicit Function theorem, Derivatives of higher order.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
	Elementary set theory, Countable and Uncountable sets	3
	Real number system and its order completeness	3
	Metric spaces, Open sets, Closed sets	3
	Continuous and uniformly continuous functions, Homeomorphism and isometry	3
	Completeness, Fixed Points	3

	Baire's Category Theorem, Totally bounded metrics	3
	Compactness	5
	Connectedness	3
	Sequences and series of functions, Pointwise and uniform convergence of sequences of functions	2
	Equicontinuity, Arzelà-Ascoli Theorem, Dini's Theorem, Stone-Weierstrass Theorems	5
	Functions of several variables, Linear transformations, Differentiation	5
	Inverse function theorem, Implicit Function theorem, Derivatives of higher order	4
Total Lecture hours (14 times 'L')		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	Problem discussions based on lectures – weekly once	1
Total Tutorial hours (14 times 'T')		14

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Rudin W., Principles of Mathematical Analysis, 3rd Edition, McGraw Hill Education (India), 2013
2. Carothers N. L., Real Analysis, Cambridge University Press, 2009
3. Aliprantis C.D. and Burkinshaw O., Principles of Real Analysis, 3rd Edition, Elsevier, 2009
4. Apostol T.M., Mathematical Analysis, 2nd Edition, Pearson, 1974

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	-
20.2	Hardware	-
20.3	Teaching aids (videos, etc.)	-
20.4	Laboratory	-
20.5	Equipment	-
20.6	Classroom infrastructure	Chalkboard
20.7	Site visits	-
20.8	Others (please specify)	

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	Eg. 25% of student time of practical / practice hours: sample Circuit Design exercises from industry
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date:

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/Schoolproposing the course	Mathematics	
2.	Course Title	Ordinary Differential Equations	
3.	L-T-P structure	3-1-0	
4.	Credits	4	Non-graded Units 0
5.	Course number	MTL 504	
6.	Course Status (Course Category for Program) (list program codes: eg., EE1, CS5, etc.)		
	Institute Core for all UG programs		No
	Programme Linked Core for:		List of B.Tech. / Dual Degree Programs: NIL
	Departmental Core for:		List of B.Tech. / Dual Degree Programs: NIL
	Departmental Elective for:		List of B.Tech. / Dual Degree Programs: NIL
	Minor Area / Interdisciplinary Specialization Core for:		Name of Minor Area / Specialization Program: NIL
	Minor Area / Interdisciplinary Specialization Elective for:		Name of Minor Area / Specialization Program: NIL
	Programme Core for:		List of M.Tech. / Dual Degree Programs: NIL
	Programme Elective for:		List of M.Tech. / Dual Degree Programs: NIL
	Open category Elective for all other programs (No if Institute Core)		(Yes / No) No

7.	Pre-requisite(s)	NIL
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8.	Status vis-à-vis other courses		
8.1	List of courses precluded by taking this course (significant overlap)		(course number)
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	(course number)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	(course number)
8.2	Supersedes any existing course		MAL 517

9.	Not allowed for	(indicate program names) MT6
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10.	Frequency of offering (check one box)	☐ Every semester ☒ I sem ☐ II sem ☐ Either semester
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11.	Faculty who will teach the course (Minimum 2 names for core courses / 1 name for electives) K. Sreenadh, H. Kumar, Mani Mehra, SCS Rao, V.V.K. Srinivas
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12.	Will the course require any visiting faculty? (Yes/no)
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13.	Course objectives (about 50 words. "On successful completion of this course, a student should be able to..."): To use Calculus in solving differential equations and also to give a concise account of fundamental concepts of existence, uniqueness, stability and qualitative properties of solutions.
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14.	Course contents (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Initial value problems, Cauchy-Picard Theorem. General theory of linear differential systems. Sturms theory on separation and comparison properties of solutions, Boundary value problems, Green functions, Sturm-Liouville problems, Weyl-Titchmarsh theorem for unbounded interval- limit cycle, limit point cases. Power series method, regular singular points, Legendre and Bessel equations, Linear system with constant coefficients, fundamental matrix, linear systems with periodic coefficients. Critical points, phase plane analysis and concepts of linear and nonlinear stability. Autonomous systems and applications
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
1.	Initial value problems, Cauchy-Picard Theorem.	5
2.	General theory of linear differential systems.	5
3.	Sturms theory on separation and comparison properties of solutions, Boundary value problems, Green functions	5
4.	Sturm-Liouville problems, Weyl-Titchmarsh theorem for unbounded interval- limit cycle, limit point cases.	5

5.	Power series method, regular singular points, Legendre and Bessel equations.	5
6.	Linear system with constant coefficients, fundamental matrix, linear systems with periodic coefficients.	5
7.	Critical points, phase plane analysis.	5
8.	Concepts of linear and nonlinear stability.	5
9.	Autonomous systems and applications	2
Total Lecture hours(14 times 'L')		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	Problems based on the lectures	14
Total Tutorial hours(14 times 'T')		14

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	NIL	
Total Practical / Practice hours(14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
	NIL

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Coddington, Introduction to ODE
2. Coddington-Levinson Theory of ODE
3. G. F. Simmons Differential Equations with Applications and Historical Notes

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	Name of software, number of licenses, etc.: NIL
20.2	Hardware	Nature of hardware, number of access points, etc.: NIL
20.3	Teaching aids (videos, etc.)	Description, Source , etc.: NIL
20.4	Laboratory	Type of facility required, number of students etc.: NIL
20.5	Equipment	Type of equipment required, number of access points, etc.: NIL
20.6	Classroom infrastructure	Type of facility required, number of students etc.: NIL
20.7	Site visits	Type of Industry/ Site, typical number of visits, number of students etc.: NIL
20.8	Others (please specify)	NIL

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	Eg. 25% of student time of practical / practice hours: sample Circuit Design exercises from industry
21.2	Open-ended problems	NIL
21.3	Project-type activity	NIL
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date:

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

1.	Department / Centre / School proposing the course	MATHEMATICS	
2.	Course Title	COMPUTER PROGRAMMING	
3.	L-T-P structure	3 - 0 - 2	
4.	Credits	4	Non-graded Units 0
5.	Course number	MTL 505	
6.	Course Status (Course Category for Program) DC for MSc Mathematics		
	Institute Core for all UG programs	No	
	Programme Linked Core for:	No	
	Departmental Core for:	No	
	Departmental Elective for:	No	
	Minor Area / Interdisciplinary Specialization Core for:	No	
	Minor Area / Interdisciplinary Specialization Elective for:	No	
	Programme Core for:	MSc. Mathematics	
	Programme Elective for:	No	
	Open category Elective for all other programs (No if Institute Core)	No	
7.	Pre-requisite(s)	NIL	
8.	Status vis-à-vis other courses		
8.1	List of courses precluded by taking this course (significant overlap)		
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	None
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	None
8.2	Supersedes any existing course		MAL519
9.	Not allowed for	Any UG program or Dual degree program student.	
10.	Frequency of offering (check one box)	☐ Every semester ☒ I sem ☐ II sem ☐ Either semester	

11.	Faculty who will teach the course Dr.V.V.K. Srinivas,Dr. Mani Mehra, Prof B Chandra,
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12.	Will the course require any visiting faculty? No
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13.	Course objectives To teach the students basics of computer programming.T equip the students in writing programs in C and C++ and also to solve problems in pure and applied mathematics.
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14.	Course Contents Introductionto Computers - CPU, ALU, I/O devices, Introduction to C Programming - Data types , Looping Statements, Arrays,Structure, Functions (Both simple and Recursive function) ,Call by Value and Call by reference, Pointers , File Handling in C Introduction to C++ Programming , Looping Statements ,arrays and Structures in C++, Functions in C++,Basic OOPS concepts
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No of hours
1.	Introductionto Computers - CPU, ALU, I/O devices	2
2	Introduction to C Programming : Data types ,	2
	Looping Statements in C	5
3.	Arrays and its use, Structure and its applications in C	5
4.	Functions (Both simple and Recursive function) in C Call by Value and Call by reference	5
5.	Pointers	4
6	File Handling in C	4
7	Introduction to C++	3
8	arrays and Structures in C++	4
9	Functions in C++	4
10.	Basic OOPS concepts	4

Total Lecture hours (14 times 'L')	42
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16. Brief description of tutorial activities:

The tutorial sessions will essentially be problem sessions where students will solve problems based on the concepts discussed in the lectures.

Total Tutorial hours (14 times 'T')	14
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17. Brief description of Practical / Practice activities: NA

Module no.	Description	No. of hours
1 and 2	Expressions: The assignment Operator, Arithmetic Operators, Increment and Decrement Operators, Relational and Logical Operators, Bitwise Operators, The ? operator, The & and * Pointer operators, The comma operator and The Dot & Arrow operators. Not Applicable	2 Hours
3 and 4	Statements: Selection Statements--if, nested ifs, if-else-if ladder, The ? alternative, switch and nested switch statements. Iteration Statements: The for Loop, The infinite loop, The while Loop and the do-while Loop.	2 Hours
5 and 6	Arrays and Strings: Single-Dimension Arrays, Passing single-dimension arrays to functions. Two-Dimensional arrays and Arrays of Strings.	2 Hours
7 and 8	Pointers: Pointer assignments, Pointer Conversions, Pointer Arithmetic, Pointer Comparisons. Pointers and Arrays and Arrays of Pointers.	2 Hours
9 and 10	Functions: Function arguments: Call by Value, call by reference and calling functions with arrays. argc, argv--arguments to main(). Returning from a function, returning values, returning pointers.	2 Hours
11 and 12	Structures: Arrays of structures, Passing structures to functions. Structure pointers.	2 Hours
13 and 14	Classes and Objects: Nested Classes and Local Classes. Passing Objects to functions. Returning objects. Object assignment.	2 Hours
Total Practical / Practice hours(14 times 'P')		14 Hours

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not include assignments / term papers etc.)

Module no.	Description
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(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

E. Balaguruswamy, Programming in ANSI C, Tata McGraw-Hill Education
 AI Kelley and Ira Pohl, A book on C, Addison-Wesley
 Herbert Schildt, C: The Complete reference, Tata McGraw-Hill Education
 Kernighan, Brian W., and Dennis M. Ritchie, The C programming language. Vol. 2. Englewood Cliffs: prentice-Hall, 1988.

Lafore, Robert, Object-oriented programming in C++, Pearson Education, 1997.

Chandra, B. Object Oriented Programming Using C++, Narosa Publishers and Alpha Science Int'l Ltd., 2005.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	C and C++
20.2	Hardware	No
20.3	Teaching aids (videos, etc.)	Audio system for large classes
20.4	Laboratory	YES
20.5	Equipment	No
20.6	Classroom infrastructure	YES
20.7	Site visits	No
20.8	Others (please specify)	No

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	No
21.2	Open-ended problems	10% : In form of assignments, problems solving
21.3	Project-type activity	No
21.4	Open-ended laboratory work	30%: writing programs in C and C++ for solving problems in the area of pure and applied Mathematics
21.5	Others (please specify)	

Date: March 31, 2015

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/School proposing the course	Mathematics	
2.	Course Title	Complex Analysis	
3.	L-T-P structure	3-1-0	
4.	Credits	4	Non-graded Units 0
5.	Course number	MTL 506	
6.	Course Status (Course Category for Program) MAL		
	Institute Core for all UG programs	No	
	Programme Linked Core for:	Nil	
	Departmental Core for:	M.Sc.	
	Departmental Elective for:	Nil	
	Minor Area / Interdisciplinary Specialization Core for:	Nil	
	Minor Area / Interdisciplinary Specialization Elective for:	Nil	
	Programme Core for:	M.Sc.	
	Programme Elective for:	Nil	
	Open category Elective for all other programs (No if Institute Core)	No	
7.	Pre-requisite(s)	Nil	
8.	Status vis-à-vis other courses		
	8.1	List of courses precluded by taking this course (significant overlap)	None
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	MTL122
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	None
	8.2	Supersedes any existing course	MAL514 (Complex Analysis)
9.	Not allowed for	MT6	

10.	Frequency of offering (check one box)	☐ Every semester ☐ I sem ☒ II sem ☐ Either semester
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11.	Faculty who will teach the course S.Kundu, A. Nagar, R. Sarma, A. Priyadarshi, R Barman
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12.	Will the course require any visiting faculty?	No
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13.	Course objectives (about 50 words. "On successful completion of this course, a student should be able to..."): There are several results in Complex analysis which are surprisingly different from those of real analysis. Knowledge of complex analysis is essential to do further study or research in various branches of pure and applied mathematics. This course is a first course in functions of one complex variable. Apart from learning the basic concepts, students see certain proofs of the fundamental theorem of algebra and learn certain techniques of evaluating real integrals.
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14.	Course contents (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Field of complex numbers, complex plane, polar representation, stereographic projection. Analytic functions, Cauchy-Riemann equation, harmonic conjugates, power series, Möbius transforms. Contour integrals, power series representation of an analytic function, zeros of an analytic function, Liouville's theorem and applications. Index of a closed curve, Cauchy's theorem, Cauchy integral formula, Open mapping theorem, Goursat's theorem. Isolated singularities, Laurent Series, Residue theorem and application to real integrals. Meromorphic functions, Argument principle and Rouché's theorem. Maximum modulus principle and Schwarz's Lemma.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
1	Field of complex numbers, complex plane, polar representation, stereographic projection.	3
2	Analytic functions, Cauchy-Riemann equation, harmonic conjugates, power series.	5
3	Möbius transforms.	3
4	Riemann-Stieltjes integrals, power series representation of an analytic function.	5
5	Zeros of an analytic function, Liouville's theorem and applications.	4
6	Index of a closed curve, Cauchy's theorem, Cauchy integral formula.	5
7	Open mapping theorem, Goursat's theorem.	3

8	Isolated singularities, Laurent Series.	4
9	Residue theorem and application to real integrals.	3
10	Meromorphic functions, Argument principle and Rouché's theorem.	4
11	Maximum modulus principle and Schwarz's Lemma.	3
Total Lecture hours (14 times 'L')		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	Solving problems	14
Total Tutorial hours (14 times 'T')		14

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	NIL	
Total Practical / Practice hours (14 times 'P')		

18. Description of module-wise activities pertaining to self-learning component

(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
	NIL
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. J. B. Conway, Functions of One Complex variable, Springer International Student Edition, 2nd Edition.
2. L. V. Ahlfors, Complex Analysis, McGraw Hill Education (India) Pvt Ltd, 3rd Edition.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	Name of software, number of licenses, etc.:NIL
20.2	Hardware	Nature of hardware, number of access points, etc. :NIL
20.3	Teaching aids (videos, etc.)	Description, Source , etc. :NIL
20.4	Laboratory	Type of facility required, number of students etc. :NIL
20.5	Equipment	Type of equipment required, number of access points, etc. :NIL
20.6	Classroom infrastructure	Type of facility required, number of students etc. :NIL
20.7	Site visits	Type of Industry/ Site, typical number of visits, number of students etc. :NIL
20.8	Others (please specify)	

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	Eg. 25% of student time of practical / practice hours: sample Circuit Design exercises from industry
21.2	Open-ended problems	NIL
21.3	Project-type activity	NIL
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date:

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/School proposing the course	Mathematics	
2.	Course Title	Topology	
3.	L-T-P structure	3-1-0	
4.	Credits	4	Non-graded Units 0
5.	Course number	MTL 507	
6.	Course Status (Course Category for Program) (list program codes: eg., EE1, CS5, etc.)		
	Institute Core for all UG programs	No	
	Programme Linked Core for:	NIL	
	Departmental Core for:	MSc	
	Departmental Elective for:	NIL	
	Minor Area / Interdisciplinary Specialization Core for:	NIL	
	Minor Area / Interdisciplinary Specialization Elective for:	NIL	
	Programme Core for:	MSc Mathematics	
	Programme Elective for:	NIL	
	Open category Elective for all other programs (No if Institute Core)	No	
7.	Pre-requisite(s)	NIL	
8.	Status vis-à-vis other courses		
8.1	List of courses precluded by taking this course (significant overlap)	None	
	(a) Significant Overlap with any UG/PG course of the Dept./Centre/ School		
	(b) Significant Overlap with any UG/PG course of other Dept./Centre/ School	None	
8.2	Supersedes any existing course	MAL 601	
9.	Not allowed for	(indicate program names)	

10.	Frequency of offering (check one box)	☐ Every semester ☐ I sem ☒ II sem ☐ Either semester
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11.	Faculty who will teach the course S. Kundu, A. Nagar, R. Sarma, S. Sivananthan, N. Shravan Kumar, A. Priyadarshi
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12.	Will the course require any visiting faculty? No
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13.	Course objectives: To introduce basic Point Set Topology which is needed in several areas of Mathematics.
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14.	Course contents: Topological spaces: Definitions and Examples, Basis and Subbasis for a Topology, limit points, closure, interior; Continuous functions, Homeomorphisms; Subspace Topology, Metric Topology, Product & Box Topology, Order Topology; Quotient spaces. Connectedness and Compactness: Connectedness, Path connectedness; Connected subspaces of the real line; Components and local connectedness; Compact spaces, Limit point compactness, Sequential compactness; Local compactness, One point compactification; Tychonoff theorem. Countability Axioms: First countable spaces, Second countable spaces, Separable spaces, Lindeloff spaces. Separation Axioms: Hausdorff, Regular and Normal spaces; Urysohn's lemma; Urysohn's Metrization theorem; Tietze extension theorem. Complete Metric Spaces and Function Spaces: Characterization of compact metric spaces; Equicontinuity, Ascoli-Arzelà theorem.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
1.	Topological spaces: Definitions and Examples, Basis and Subbasis for a Topology, limit points, closure, interior.	5
2.	Continuous functions, Homeomorphisms.	2
3.	Subspace Topology, Metric Topology, Product & Box Topology, Order Topology.	5
4.	Quotient Topology, examples of quotient spaces.	2
5.	Connectedness, Path connectedness; Connected subspaces of the real line	4
6.	Components and local connectedness.	2
7.	Compact spaces, Limit point compactness, Sequential compactness.	4
8.	Local compactness, One point compactification.	2
9.	Tychonoff theorem.	2
10.	First and Second countable spaces, Separable spaces, Lindeloff spaces.	3
11.	Hausdorff, Regular and Normal spaces; Urysohn's lemma; Completely Regular spaces.	4
12.	Urysohn's Metrization theorem; Tietze extension theorem.	3
13.	Characterization of compact metric spaces, Equicontinuity, Ascoli-Arzelà theorem.	4
Total Lecture hours(14 times 'L')		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	Problem Solving.	14
Total Tutorial hours(14 times 'T')		14

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours

Total Practical / Practice hours(14 times 'P')		

18. Brief description of module-wise activities pertaining to self-

learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. J. R. Munkres, Topology, 2nd Edition, Pearson Education (Asia), 2001.
2. J. B. Conway, A Course in Point Set Topology, Springer, 2014.
3. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill (India), 2004.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	NIL
20.2	Hardware	NIL
20.3	Teaching aids (videos, etc.)	NIL
20.4	Laboratory	NIL
20.5	Equipment	NIL
20.6	Classroom infrastructure	NIL
20.7	Site visits	NIL
20.8	Others (please specify)	

21. Design content of the course(Percent of student time with examples, if possible)

21.1	Design-type problems	Eg. 25% of student time of practical / practice hours: sample Circuit Design exercises from industry
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date:

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

1.	Department / Centre / School proposing the course	MATHEMATICS	
2.	Course Title	MATHEMATICAL PROGRAMMING	
3.	L-T-P structure	3 - 1 - 0	
4.	Credits	4	Non-graded Units Please fill appropriate details in S. No. 21
5.	Course number	MTL 508	
6.	Course Status (Course Category for Program) DC for MSc Mathematics		
	Institute Core for all UG programs	No	
	Programme Linked Core for:	No	
	Departmental Core for:	No	
	Departmental Elective for:	No	
	Minor Area / Interdisciplinary Specialization Core for:	No	
	Minor Area / Interdisciplinary Specialization Elective for:	No	
	Programme Core for:	MSc. Mathematics	
	Programme Elective for:	No	
	Open category Elective for all other programs (No if Institute Core)	No	
7.	Pre-requisite(s)	None	
8.	Status vis-à-vis other courses		
8.1	List of courses precluded by taking this course (significant overlap)		
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	MTL103
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	MEL221, CHL774
8.2	Supersedes any existing course		MAL526
9.	Not allowed for	Any UG program or Dual degree program student.	
10.	Frequency of offering (check one box)	☐ Every semester ☐ I sem ☒ II sem ☐ Either semester	

11.	Faculty who will teach the course Prof B Chandra, Prof BS Panda, Prof SCS Rao, Prof S Dharmaraja, DrAparnaMehra
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12.	Will the course require any visiting faculty? No
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13.	Course objectives To provide quantitative insight and understanding of fundamental methods of linear programming and quadratic programming. The course aims to demonstrate the powerful capabilities of optimization theory to enable reducing costs, improving efficiency, optimal usage of resources and providing benefits in many other key dimensions in engineering / industry / managerial / decision making problems. The course designed to have flavor of both sound theoretical foundation of various methods and their actual implementations in problems solving.
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14.	Course Contents Linear programs formulation through examples from engineering / business decision making problems, preliminary theory and geometry of linear programs, basic feasible solution, simplex method, variants of simplex method, like two phase method and revised simplex method; duality and its principles, interpretation of dual variables, dual simplex method, primal-dual method; linear integer programs, their applications in real decision making problems, cutting plane and branch and bound methods, transportation problems, assignment problems, network maximum flow problems; complexity of simplex method, ellipsoid method, Karmarkar's interior point method; nonlinear programming, Lagrange multipliers, Farkas lemma, constraint qualification, KKT optimality conditions, sufficiency of KKT under convexity; quadratic programs, Wolfe method, applications of quadratic programs in some domains like portfolio optimization and support vector machines, etc.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No of hours
1.	Linear programming problems (LPP) formulations, notion of optimal solution, graphical interpretation of optimality	2
2	Convex sets, supporting hyperplane, extreme point, basic feasible solutions (BFS), fundamental theorem of LPP, relationship between extreme point of feasible set and BFS of LPP, standard form of LPP	5
3.	Improving current BFS, simplex algorithm, artificial variable and its interpretation in context of feasibility, Two phase method, revised simplex method	5
4.	Dual linear program, duality theorems, complementary slackness theorem, Economic interpretation of dual variables, dual simplex method, primal-dual method	5
5.	Linear integer program formulations and applications, cutting plane algorithm, branch and bound algorithms	5
6.	Transportation programming problems (TPP), unimodular matrix, optimal solution of TPP	4
7.	Assignment problems, Hungarian method, method of maximum flow problems	4
8.	Complexity of linear programming and the ellipsoid method, Karmarkar's interior point method	4
9.	Nonlinear programming, Lagrange multipliers, Farkas Lemma, constraint qualifications, KKT optimality conditions, sufficiency of KKT under convexity	5
10.	Quadratic programming problems (QPP), Wolfe's method, dual of QPP, applications of QPP in portfolio and support vector machines etc.	3

Total Lecture hours (14 times 'L')	42
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16. Brief description of tutorial activities:

The tutorial sessions will essentially be problem sessions where students will solve problems based on the methods being discussed in the lectures.

Total Tutorial hours (14 times 'T')	14
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17. Brief description of Practical / Practice activities: NA

Module no.	Description	No. of hours
	Not Applicable	
Total Practical / Practice hours(14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

- 1) M. S.Bazarra, J. J. Jarvis and H. D.Sherali, Linear Programming and Network Flows, Wiley, 2009.
- 2) D. Bertsimas and J. N. Tsitsiklis, Introduction to Linear Optimization, Athena Scientific, 1997.
- 3) Robert J Vanderbei, Linear Programming: Foundations and Extensions, Springer, 4thed, 2014.
- 4) S. Chandra, Jayadeva, A. Mehra, Numerical Optimization with Applications, Narosa, 2009.
- 5) V.Chvatal, Linear Programming, W. H. Freeman Publishers, 1983.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	MATLAB and LINDO for computational practice problems.
20.2	Hardware	No
20.3	Teaching aids (videos, etc.)	Audio system for large classes
20.4	Laboratory	No
20.5	Equipment	No
20.6	Classroom infrastructure	YES
20.7	Site visits	No
20.8	Others (please specify)	No

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	No
21.2	Open-ended problems	20% : In form of assignments, problems solving
21.3	Project-type activity	No
21.4	Open-ended laboratory work	10%: computational questions requiring implementation of some methods studied in course to get hand on learning.
21.5	Others (please specify)	

Date: April 01, 2015

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/School proposing the course	Mathematics	
2.	Course Title	Numerical Analysis	
3.	L-T-P structure	3-1-0	
4.	Credits	4	Non-graded Units 0
5.	Course number	MTL 509	
6.	Course Status (Course Category for Program) MAL		
	Institute Core for all UG programs	No	
	Programme Linked Core for:	NIL	
	Departmental Core for:	M.Sc.	
	Departmental Elective for:	NIL	
	Minor Area / Interdisciplinary Specialization Core for:	NIL	
	Minor Area / Interdisciplinary Specialization Elective for:	NIL	
	Programme Core for:	MSc	
	Programme Elective for:	NIL	
	Open category Elective for all other programs (No if Institute Core)	No	
7.	Pre-requisite(s)	NIL	
8.	Status vis-à-vis other courses		
8.1	List of courses precluded by taking this course (significant overlap)	(course number)	
	(a) Significant Overlap with any UG/PG course of the Dept./Centre/ School	(course number)	
	(b) Significant Overlap with any UG/PG course of other Dept./Centre/ School	(course number)	
8.2	Supersedes any existing course	MAL524	
9.	Not allowed for	(indicate program names)	

10.	Frequency of offering (check one box)	☐ Every semester ☐ I sem ☒ II sem ☐ Either semester
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11.	Faculty who will teach the course (Minimum 2 names for core courses / 1 name for electives) Dr. H. Kumar, Prof. S.C.S. Rao, Dr. V.V.K. Srinivas, Dr. Mani Mehra
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12.	Will the course require any visiting faculty? (Yes/no)
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13.	Course objectives (about 50 words. "On successful completion of this course, a student should be able to..."): To discuss some of the central problems which arise in application of mathematics, to develop p constructive methods for the numerical solution of these problems, and to study the associated questions of accuracy.
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14.	Course contents (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Numerical Algorithms and errors, Floating point systems, Roundoff error accumulations. Interpolation: Lagrange Interpolation Newton's divided difference interpolation. Finite differences. Hermite Interpolation. Cubic splines. Numerical differentiation. Numerical Integration: Newton cotes formulas, Gaussian Quadrature composite quadrature formulas Approximation: Least squares approximation, minimum maximum error techniques. Legendre and Chebyshev polynomials. Solution of Nonlinear equations: Fixed point iteration, bisection, Secant, Regula-Falsi, Newton-Raphson methods. Solution of linear systems: Direct methods, Gauss elimination, LU and Cholesky factorizations. Iterative methods – Jacobi, Gauss- Seidel and SOR methods. System of nonlinear equation, Eigen-Value problems: Power and Inverse power method. Numerical Solution of ODE. Taylor series, Euler and Runge-Kutta methods.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
1.	Numerical Algorithms and errors, Floating point systems, Round-off error accumulations.	4

2.	Interpolation: Lagrange Interpolation Newton's divided difference interpolation. Finite differences. Hermite Interpolation, Cubic Splines.	5
3.	Numerical differentiation. Numerical Integration: Newton cotes formulas, Gaussian Quadrature composite quadrature formulas	5
4.	Approximation: Least squares approximation, minimum maximum error techniques. Legendre and Chebyshev polynomials.	5
5.	Solution of Nonlinear equations: Fixed point iteration, bisection, Secant, Regula-Falsi, Newton-Raphson methods.	5
6.	Solution of linear systems: Direct methods, Gauss elimination, LU and Cholesky factorizations.	5
7.	Iterative methods – Jacobi, Gauss-Seidel and SOR methods. System of nonlinear equation.	5
8.	Eigen-Value problems: Power and Inverse power method.	3
9.	Numerical Solution of ODE. Taylor series, Euler and Runge-Kutta methods.	5
Total Lecture hours(14 times 'L')		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	Tutorial problems will be designed to supplement the theory covered in lectures.	14
Total Tutorial hours(14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours

Total Practical / Practice hours(14 times 'P')		

18. Brief description of module-wise activities pertaining to self-

learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Richard L. Burden, J. Douglas Faires, Numerical Analysis (9th Ed.), 2011
2. Uri Ascher & Chen Greif, A First Course in Numerical Methods, SIAM, 2011
3. Samuel D. Conte, Boor, Elementary Numerical Analysis: Algorithmic Approach,
4. Alfio Quarteroni, Riccardo Sacco, Fausto Saleri, Numerical Mathematics (2nd Ed.), Springer, 2007.
5. C. F. Gerald & P. O. Wheatley, *Applied numerical analysis*, Pearson, (2004)

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	NIL
20.2	Hardware	NIL
20.3	Teaching aids (videos, etc.)	NIL
20.4	Laboratory	NIL
20.5	Equipment	NIL
20.6	Classroom infrastructure	NIL
20.7	Site visits	NIL
20.8	Others (please specify)	

21. Design content of the course(Percent of student time with examples, if possible)

21.1	Design-type problems	Eg. 25% of student time of practical / practice hours: sample Circuit Design exercises from industry
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date:

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/School proposing the course	Mathematics	
2.	Course Title	Measure and Integration	
3.	L-T-P structure	3-1-0	
4.	Credits	4	Non-graded Units 0
5.	Course number	MTL 510	
6.	Course Status (Course Category for Program) MAL		
	Institute Core for all UG programs	No	
	Programme Linked Core for:	NIL	
	Departmental Core for:	M.Sc.	
	Departmental Elective for:	NIL	
	Minor Area / Interdisciplinary Specialization Core for:	NIL	
	Minor Area / Interdisciplinary Specialization Elective for:	NIL	
	Programme Core for:	M.Sc.	
	Programme Elective for:	NIL	
	Open category Elective for all other programs (No if Institute Core)	No	
7.	Pre-requisite(s)	NIL	
8.	Status vis-à-vis other courses		
	8.1	List of courses precluded by taking this course (significant overlap)	number)
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	MTL270
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	(course number)
	8.2	Supersedes any existing course	
9.	Not allowed for	(indicate program names)	

10.	Frequency of offering (check one box)	☐ Every semester ☐ I sem ☒ II sem ☐ Either semester
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11.	Faculty who will teach the course S. Kundu, A. Nagar, K. Sreenadh, S. Sivananthan, A. Priyadarshi, N. Shravan Kumar
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12.	Will the course require any visiting faculty?	no
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13.	Course objectives (about 50 words. "On successful completion of this course, a student should be able to..."): The objective of this course is to present a detailed analysis of measure and integration.
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14.	Course contents (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Outer measures, measures and measurable sets, Lebesgue measure on R, Borel measure Measurable functions, simple functions, Egoroff's theorem, Lebesgue integral and its properties, monotone convergence theorem, Fatou's Lemma, Dominated convergence theorem various modes of convergence and their relations Signed measures, Hahn and Jordan decomposition theorems, Lebesgue-Radon-Nikodym theorem, Lebesgue decomposition theorem, the representation of positive linear functionals on $C_c(X)$ Product measures, iterated integrals, Fubini's and Tonelli's theorems L_p spaces and their completeness, conjugate space of L_p for $1 < p < \infty$, conjugate space of L_1 for sigma-finite measure space Differentiation of monotone functions, functions of bounded variation, differentiation of an integral, absolute continuity
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
	Outer measures, measures and measurable sets	5

	Lebesgue measure on , Borel measure	1
	Measurable functions, simple functions, Egoroff's theorem	3
	Lebesgue integral and its properties	3
	monotone convergence theorem, Fatou's Lemma, Dominated convergence theorem	2
	various modes of convergence and their relations	3
	Signed measures, Hahn and Jordan decomposition theorems,	3
	Lebesgue-Radon-Nikodym theorem, Lebesgue decomposition theorem	2
	the representation of positive linear functionals on $C_c(X)$	5
	Product measures, iterated integrals, Fubini's and Tonelli's theorems	3
	L_p spaces and their completeness	3
	conjugate space of L_p for $1 < p < \infty$, conjugate space of L_1 for sigma-finite measure space	4
	Differentiation of monotone functions, functions of bounded variation	2
	differentiation of an integral, absolute continuity	3
Total Lecture hours (14 times 'L')		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Description of module-wise activities pertaining to self-learning component

(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1) H. L. Royden, Real Analysis, 3 rd Edition, Macmillan, 1988.
2) R. G. Bartle, The elements of integration and Lebesgue measure, Wiley Classics Library, 1995.
3) G. B. Folland, Real analysis: Modern techniques and their applications, Wiley, 1999.
4) C. D. Aliprantis and O. Burkinshaw, Principles of real analysis, Academic Press, 1998.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	NIL
20.2	Hardware	NIL
20.3	Teaching aids (videos, etc.)	NIL
20.4	Laboratory	NIL
20.5	Equipment	NIL
20.6	Classroom infrastructure	NIL
20.7	Site visits	NIL
20.8	Others (please specify)	

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	Eg. 25% of student time of practical / practice hours: sample Circuit Design exercises from industry
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date:

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/School proposing the course	Mathematics		
2.	Course Title	Probability and Statistics		
3.	L-T-P structure	3-1-0		
4.	Credits	4	Non-graded Units	
5.	Course number	MTL 601		
6.	Course Status (Course Category for Program) PC for MAS			
	Institute Core for all UG programs		No	
	Programme Linked Core for:		NIL	
	Departmental Core for:		M.Sc.	
	Departmental Elective for:			
	Minor Area / Interdisciplinary Specialization Core for:		NIL	
	Minor Area / Interdisciplinary Specialization Elective for:		NIL	
	Programme Core for:		M.Sc.	
	Programme Elective for:			
	Open category Elective for all other programs (No if Institute Core)		Yes	
7.	Pre-requisite(s)			
8.	Status vis-à-vis other courses			
8.1	List of courses precluded by taking this course (significant overlap)			
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School		
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	MTL108	
8.2	Supersedes any existing course		MAL 509	
9.	Not allowed for			

10.	Frequency of offering (check one box)	☐ Every semester ☒ I sem ☐ II sem ☐ Either semester
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11.	Faculty who will teach the course S Dharmaraja, N. Chatterjee, A. Mehra, N Shravan Kumar
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12.	Will the course require any visiting faculty? No
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13.	Course objectives: • Explanations and expositions of probability and statistical concepts which they need for their experiments and research. • Theoretical concepts pertaining to handling of large data sets and inference from them.
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14.	Course contents: Probability definition, conditional probability, Bayes theorem, random variables, expectation and variance, specific discrete and continuous distributions, e.g. uniform, Binomial, Poisson, geometric, Pascal, hypergeometric, exponential, normal, gamma, beta, moment generating function, Poisson process, Chebyshev's inequality , bivariate and multivariate distributions, joint, marginal and conditional distributions , order statistics, law of large numbers, central limit theorem, sampling distributions - Chi-sq, Student's t, F, theory of estimation, maximum likelihood test, testing of hypothesis, nonparametric analysis, test of goodness of fit
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
1	Probability, Conditional probability, Bayes Theorem	4
2	Random variables, expectation and variance, specific discrete distributions	5
3	Specific continuous distributions, moment generating functions	5
4	Concepts of bivariate and multivariate distributions, joint and marginal distributions, order statistics	3
5	Law of large numbers, Central limit theorem	3
5	Sampling distributions : Chi-sq, Student's t, F	4
6	Theory of estimation, properties of an estimator, maximum likelihood	5

7	MVUE, Cramer Rao theorem	4
8	One-sample and two sample tests of proportion, mean, variance, critical regions, Neyman Pearson Lemma	4
9	Tests for goodness of fit, Chi-square test, Kolmogorov Smirnov test, one sample and paired sample tests: sign test, signed-rank test, run tests etc	5
Total Lecture hours(14 times 'L')		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	Solving of problems on theories taught in lecture classes	14
Total Tutorial hours(14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours(14 times 'P')		

18. Brief description of module-wise activities pertaining to self-

learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

- | |
|---|
| 1. Paul L Meyer, Introductory Probability and Statistical Applications, Addison-Wesley, Second Edition, 1970. |
| 2. Sheldon Ross, Introduction to Probability and Statistics for Engineers and Scientists, Academic Press, Fourth Edition, 2009. |
| 3. Irwin Miller and J. E. Freund, Probability and Statistics for Engineers, Prentice-Hall, 1977. |

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	NO
20.2	Hardware	NO
20.3	Teaching aids (videos, etc.)	YES
20.4	Laboratory	NO
20.5	Equipment	NO
20.6	Classroom infrastructure	YES
20.7	Site visits	NO
20.8	Others (please specify)	NO

21. Design content of the course(Percent of student time with examples, if possible)

21.1	Design-type problems	
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date:

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/School proposing the course	Mathematics	
2.	Course Title	Functional Analysis	
3.	L-T-P structure	3-1-0	
4.	Credits	4	Non-graded Units 0
5.	Course number	MTL 602	
6.	Course Status (Course Category for Program) M. Sc.		
	Institute Core for all UG programs	No	
	Programme Linked Core for:	List of B.Tech. / Dual Degree Programs: NIL	
	Departmental Core for:	List of B.Tech. / Dual Degree Programs: NIL	
	Departmental Elective for:	List of B.Tech. / Dual Degree Programs: NIL	
	Minor Area / Interdisciplinary Specialization Core for:	Name of Minor Area / Specialization Program: NIL	
	Minor Area / Interdisciplinary Specialization Elective for:	Name of Minor Area / Specialization Program: NIL	
	Programme Core for:	List of M.Tech. / Dual Degree Programs: NIL	
	Programme Elective for:	List of M.Tech. / Dual Degree Programs: NIL	
	Open category Elective for all other programs (No if Institute Core)	Yes	

7.	Pre-requisite(s)	Linear Algebra, Real Analysis, Measure and Integration
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8.	Status vis-à-vis other courses		
8.1	List of courses precluded by taking this course (significant overlap)		(number)
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	MTL411
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	NIL
8.2	Supersedes any existing course		MAL 602

9.	Not allowed for	MT6
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10.	Frequency of offering (check one box)	☐ Every semester ☒ I sem ☐ II sem ☐ Either semester
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11.	Faculty who will teach the course S. Kundu, Anima Nagar, K. Sreenadh, S. Sivananthan, AmitPriyadarshi, N. Shravan Kumar
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12.	Will the course require any visiting faculty?	no
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13.	Course objectives (about 50 words. "On successful completion of this course, a student should be able to..."): To give the students a flavour of functional analysis with some basic operator theory which are the modern techniques for solving problems in applied Mathematics.
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14.	Course contents (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Normed linear spaces, Banach spaces and their examples, quotient spaces, bounded linear operators, finite dimensional Banach spaces, L_p Spaces, L_p spaces as examples for Banach spaces Hahn Banach theorems, Uniform boundedness principle, open mapping theorem, closed graph theorem, transpose of an operator Characterization of the dual of certain concrete Banach spaces Geometry of Banach spaces - Weak and weak* convergence, Annihilators, reflexivity, separability and Schauder basis, complemented subspaces Geometry of Hilbert spaces - Inner product spaces and its properties, Hilbert spaces and examples, best approximation in Hilbert spaces, orthogonal complements, orthonormal basis, dual of a Hilbert space Basic operator theory - Adjoint of an operator, self-adjoint operators, normal and unitary operators, projections Compact operators, examples and properties, spectral theorem for the compact self-adjoint operator
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
1	Normed linear spaces, Banach spaces and their examples, quotient spaces, bounded linear operators	5
2	finite dimensional Banach spaces, L_p Spaces, L_p spaces as examples for Banach spaces	3
3	Hahn Banach theorems	3
4	Uniform boundedness principle, open mapping theorem, closed graph theorem, transpose of an operator	5
5	Characterization of the dual of certain concrete Banach spaces	3
6	Weak and weak* convergence	2
7	Annihilators, reflexivity, separability and Schauder basis, complemented subspaces	5
8	Inner product spaces and its properties, Hilbert spaces and examples, best approximation in Hilbert spaces	3
9	orthogonal complements, orthonormal basis, dual of a Hilbert space	3
10	Adjoint of an operator, self-adjoint operators, normal and unitary operators, projections	5
11	Compact operators, examples and properties, spectral theorem for the compact self-adjoint operator	5
Total Lecture hours (14 times 'L')		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	Tutorial problems will be designed to supplement the theory covered in lectures.	14
Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	NIL	

Total Practical / Practice hours (14 times 'P')		

18. Description of module-wise activities pertaining to self-learning component

(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
	NIL

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1) E. Kreyszig, Introductory functional analysis with applications, Wiley (India), 2014. 2) G. F. Simmons, Introduction to topology and modern analysis, Tata McGraw-Hill Edition, 2004. 3) B. V. Limaye, Functional analysis, New Age International, 1996. 4) C. D. Aliprantis and O. Burkinshaw, Principles of real analysis, Academic Press, 1998.
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20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	Name of software, number of licenses, etc.: NIL
20.2	Hardware	Nature of hardware, number of access points, etc.: NIL
20.3	Teaching aids (videos, etc.)	Description, Source, etc.: NIL
20.4	Laboratory	Type of facility required, number of students etc.: NIL
20.5	Equipment	Type of equipment required, number of access points, etc.: NIL
20.6	Classroom infrastructure	Type of facility required, number of students etc.: NIL
20.7	Site visits	Type of Industry/ Site, typical number of visits, number of students etc.: NIL
20.8	Others (please specify)	NIL

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	Eg. 25% of student time of practical / practice hours: sample Circuit Design exercises from industry
21.2	Open-ended problems	NIL
21.3	Project-type activity	NIL
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date:

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/School proposing the course	Mathematics	
2.	Course Title	Partial Differential Equations	
3.	L-T-P structure	3-1-0	
4.	Credits	4	Non-graded Units 0
5.	Course number	MTL 603	
6.	Course Status (Course Category for Program) (list program codes: eg., EE1, CS5, etc.)		
	Institute Core for all UG programs	(Yes / No) No	
	Programme Linked Core for:	List of B.Tech. / Dual Degree Programs: NIL	
	Departmental Core for:	M.Sc.	
	Departmental Elective for:	List of B.Tech. / Dual Degree Programs: NIL	
	Minor Area / Interdisciplinary Specialization Core for:	Name of Minor Area / Specialization Program: NIL	
	Minor Area / Interdisciplinary Specialization Elective for:	Name of Minor Area / Specialization Program: NIL	
	Programme Core for:	List of M.Tech. / Dual Degree Programs: NIL	
	Programme Elective for:	List of M.Tech. / Dual Degree Programs: NIL	
	Open category Elective for all other programs (No if Institute Core)	(Yes / No) No	

7.	Pre-requisite(s)	NIL
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8.	Status vis-à-vis other courses		
8.1	List of courses precluded by taking this course (significant overlap)		(course number)
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	(course number)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	(course number)
8.2	Supersedes any existing course		MAL 630

9.	Not allowed for	(indicate program names)
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10.	Frequency of offering (check one box)	☐ Every semester ☒ I sem ☐ II sem ☐ Either semester
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11.	Faculty who will teach the course (Minimum 2 names for core courses / 1 name for electives) H. Kumar, K. Sreenadh, Mani Mehra, V.V.K. Srinivas
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12.	Will the course require any visiting faculty? (Yes/no)
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13.	Course objectives (about 50 words. "On successful completion of this course, a student should be able to..."): To use students knowledge in Multivariable calculus in solving Partial differential equations and also to give a concise account of fundamental concepts of existence, uniqueness and qualitative properties of strong and weak solutions.
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14.	Course contents (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Linear and semi-linear equations, Cauchy problem, Method of characteristics. Cauchy-Kowalewsky theorem, Holmgren's Uniqueness Theorem. Classification of second order equations, wave equation in one space dimension, classical and weak solutions, Duhamel's principle. Laplace equation, fundamental solutions, maximum principles and mean value formulas, Properties of harmonic functions, Green's function, Energy methods, Perron's method, Parabolic equations in one space dimension, fundamental solution, maximum principle, existence and uniqueness theorems. Wave equation, Solutions by spherical means, Non-Homogeneous Problems, Duhamel's principle, Energy Methods. Nonlinear first order PDE's: Complete integrals, Envelopes and singular solutions. Some special methods for finding solutions: Similarity solutions, Hopf-Cole transformation.
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15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
1.	Linear and semi-linear equations, Cauchy problem, Method of characteristics.	5

2.	Cauchy-Kowalewsky theorem, Holmgren's Uniqueness Theorem.	5
3.	Classification of second order equations, wave equation in one space dimension, classical and weak solutions, Duhamel's principle.	5
4.	Laplace equation, fundamental solutions, maximum principles and mean value formulas,	5
5.	Properties of harmonic functions, Green's function, Energy methods, Perron's method.	5
6.	Parabolic equations in one space dimension, fundamental solution, maximum principle, existence and uniqueness theorems.	5
7.	Wave equation, Solutions by spherical means, Non-Homogeneous Problems, Duhamel's principle, Energy Methods.	5
8.	Nonlinear first order PDE's: Complete integrals, Envelopes and singular solutions.	5
9.	Some special methods for finding solutions: Similarity solutions, Hopf-Cole transformation.	2
Total Lecture hours(14 times 'L')		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	Tutorial problems will be designed to supplement the theory covered in lectures.	14
Total Tutorial hours(14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	NIL	

Total Practical / Practice hours(14 times 'P')	
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18. Brief description of module-wise activities pertaining to self-

learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
	NIL

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. L. C. Evans, Partial Differential Equations, AMS, 1998.
2. R. McOwen, Partial Diffrential Equations, Pearson, 2002.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	Name of software, number of licenses, etc. NIL
20.2	Hardware	Nature of hardware, number of access points, etc. NIL
20.3	Teaching aids (videos, etc.)	Description, Source , etc. NIL
20.4	Laboratory	Type of facility required, number of students etc. NIL
20.5	Equipment	Type of equipment required, number of access points, etc. NIL
20.6	Classroom infrastructure	Type of facility required, number of students etc. NIL
20.7	Site visits	Type of Industry/ Site, typical number of visits, number of students etc. NIL
20.8	Others (please specify)	NIL

21. Design content of the course(Percent of student time with examples, if possible)

21.1	Design-type problems	Eg. 25% of student time of practical / practice hours: sample Circuit Design exercises from industry
21.2	Open-ended problems	NIL

21.3	Project-type activity	NIL
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date: (Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/School proposing the course	Mathematics		
2.	Course Title	Project 1		
3.	L-T-P structure	0-0-10		
4.	Credits	5	Non-graded Units	0
5.	Course number	MAD 701		
6.	Course Status (Course Category for Program) MAL			
	Institute Core for all UG programs	No		
	Programme Linked Core for:	Nil		
	Departmental Core for:	M.Sc.		
	Departmental Elective for:	Nil		
	Minor Area / Interdisciplinary Specialization Core for:	Nil		
	Minor Area / Interdisciplinary Specialization Elective for:	Nil		
	Programme Core for:	M.Sc.		
	Programme Elective for:	Nil		
	Open category Elective for all other programs (No if Institute Core)	No		
7.	Pre-requisite(s)	Nil		
8.	Status vis-à-vis other courses			
8.1	List of courses precluded by taking this course (significant overlap)	None		
	(a) Significant Overlap with any UG/PG course of the Dept./Centre/ School	NIL		
	(b) Significant Overlap with any UG/PG course of other Dept./Centre/ School	NIL		
8.2	Supersedes any existing course	MAD 703 (Project Part 1)		
9.	Not allowed for	Any program other than MSc in Mathematics		

10.	Frequency of offering (check one box)	☐ Every semester ☒ I sem ☐ II sem ☐ Either semester
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11.	Faculty who will teach the course All faculty members of the Department
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12.	Will the course require any visiting faculty?	No
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13.	Course objectives (about 50 words. "On successful completion of this course, a student should be able to..."): To carryout innovative work on the assigned topic.
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14.	Course contents (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Contents will be related to topic related to the courses undertaken by the students in the programme.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
Total Lecture hours (14 times 'L')		

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Description of module-wise activities pertaining to self-learning component

(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
	NIL

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

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20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	As per project
20.2	Hardware	Computing Machines
20.3	Teaching aids (videos, etc.)	Nil
20.4	Laboratory	Computing laboratory

20.5	Equipment	Computing lab with some softwares depending on project
20.6	Classroom infrastructure	Nil
20.7	Site visits	Nil
20.8	Others (please specify)	

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	NIL
21.2	Open-ended problems	NIL
21.3	Project-type activity	100%
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date: 11-05-15

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/School proposing the course	Mathematics		
2.	Course Title	Probability Theory		
3.	L-T-P structure	3-0-0		
4.	Credits	3	Non-graded Units	
5.	Course number	MTL 762		
6.	Course Status (Course Category for Program) PE for MAS			
	Institute Core for all UG programs		No	
	Programme Linked Core for:		NIL	
	Departmental Core for:		NIL	
	Departmental Elective for:		MSc	
	Minor Area / Interdisciplinary Specialization Core for:		NIL	
	Minor Area / Interdisciplinary Specialization Elective for:		NIL	
	Programme Core for:		NIL	
	Programme Elective for:		PE for MAS	
	Open category Elective for all other programs (No if Institute Core)		Yes	
7.	Pre-requisite(s)	MTL 510		
8.	Status vis-à-vis other courses			
	8.1	List of courses precluded by taking this course (significant overlap)		
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School		
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School		
	8.2	Supersedes any existing course		NIL
9.	Not allowed for			

10.	Frequency of offering (check one box)	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester
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11.	Faculty who will teach the course S. Dharmaraja, S. Kundu, N. Shravan Kumar
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12.	Will the course require any visiting faculty? No
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13.	Course objectives: • Explanations and expositions of probability which they need for their research. • Theoretical concepts pertaining to handling of large data sets.
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14.	Course contents: Axiomatic definition of a probability measure, examples, properties of the probability measure, finite probability space, conditional probability and Bayes formula, countable probability space, general probability space. Random variables, examples, sigma-field generated by a random variable, tail sigma-field, probability space on R induced by a random variable. Independent events, sigma-fields and random variables, Borel 0-1 criteria, Kolmogorov 0-1 criteria. Distribution - definition and examples, properties, characterization, Jordan decomposition theorem, discrete, continuous and mixed random variables, standard discrete and continuous distributions, convolution of distributions. Two dimension random variables, joint distributions, marginal distributions, operations on random variables and their corresponding distributions, multidimensional random variables and their distributions. Expectation of a random variable, expectation of a discrete and a continuous random variable, moments and moment generating function, correlation, covariance and regression. Various modes of convergence, Weak law of large numbers, strong law of large numbers. Convergence in distribution, weak convergence of generalized distributions, Helly-Bray
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	theorems, Scheffe's theorem. Characteristic function – definition and examples, properties, uniqueness and inversion theorems, moments using characteristic function, Paul Levy's continuity property of characteristic functions, characterization of independent random variables. Central limit theorem – Liapunov's and Lindberg's condition, Lindeberg-Levy form. Infinite divisibility, Levy-Khintchine theorem.
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15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
	Axiomatic definition of a probability measure, examples, properties of the probability measure, finite probability space, conditional probability and Bayes formula, countable probability space, general probability space	3
	Random variables, examples, sigma-field generated by a random variable, tail sigma-field, probability space on $\mathbb{R}$ induced by a random variable	4
	Independent events, sigma-fields and random variables, Borel 0-1 criteria, Kolmogorov 0-1 criteria	4
	Distribution - definition and examples, properties, characterization, Jordan decomposition theorem, discrete, continuous and mixed random variables, standard discrete and continuous distributions, convolution of distributions	4
	Two dimension random variables, joint distributions, marginal distributions, operations on random variables and their corresponding distributions, multidimensional random variables and their distributions	2
	Expectation of a random variable, expectation of a discrete and a continuous random variable, moments and moment generating function, correlation, covariance and regression	3
	Various modes of convergence, Weak law of large numbers, strong law of large numbers	4
	Convergence in distribution, weak convergence of generalized distributions, Helly-Bray theorems, Scheffe's theorem	4
	Characteristic function – definition and examples, properties	2
	Uniqueness and inversion theorems, moments using characteristic function	2
	Paul Levy's continuity property of characteristic functions,	2

	characterization of independent random variables	
	Central limit theorem – Liapunov's and Lindberg's condition, Lindeberg-Levy form	4
	Infinite divisibility, Levy-Khintchine theorem	4
Total Lecture hours(14 times 'L')		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
Total Tutorial hours(14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours(14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. K. B. Athreya and S. N. Lahiri, Probability theory, Hindustan Book Agency, 2006.
2. B. R. Bhat, Modern probability theory, New Age international publishers, 2014.
3. P. Billingsley, Probability and measure, John Wiley and Sons, 1995.
4. K. L. Chung, A course in probability theory, Academic Press, 2001.
5. V. K. Rohatgi and A. K. Md. Ehsanes Saleh, Introduction to probability and Statistics, John-Wiley and Sons, second edition, 2001.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	
20.2	Hardware	
20.3	Teaching aids (videos, etc.)	
20.4	Laboratory	
20.5	Equipment	
20.6	Classroom infrastructure	
20.7	Site visits	
20.8	Others (please specify)	

21. Design content of the course(Percent of student time with examples, if possible)

21.1	Design-type problems	
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date:

(Signature of the Head of the Department/ Centre / School)

MATHEMATICS COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/School proposing the course	MATHEMATICS	
2.	Course Title	INTRODUCTION TO GAME THEORY	
3.	L-T-P structure	3 - 0 - 0	
4.	Credits	3 CREDITS	Non-graded Units Please fill appropriate details in S. No. 21
5.	Course number	MTL 763	
6.	Course Status (Course Category for Program) DE for MT1 MT5 MSc OC for others		
	Institute Core for all UG programs	No	
	Programme Linked Core for:	None	
	Departmental Core for:	None	
	Departmental Elective for:	MT1 MT5 MSc	
	Minor Area / Interdisciplinary Specialization Core for:	Name of Minor Area / Specialization Program	
	Minor Area / Interdisciplinary Specialization Elective for:	Name of Minor Area / Specialization Program	
	Programme Core for:	List of M.Tech. / Dual Degree Programs	
	Programme Elective for:	List of M.Tech. / Dual Degree Programs	
	Open category Elective for all other programs (No if Institute Core)	Yes	
7.	Pre-requisite(s)	MTL108/ MTL106/ MTL601	
8.	Status vis-à-vis other courses		
	8.1	List of courses precluded by taking this course (significant overlap)	(course number)
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	(course number)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	(course number)
	8.2	Supersedes any existing course	NIL
9.	Not allowed for	(indicate program names)	

10. Frequency of offering (check one box)	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester
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11. Faculty who will teach the course	Prof. Niladri Chatterjee, , Dr. Aparna Mehra
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12. Will the course require any visiting faculty?	NO
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13. Course objectives	To provide the mathematical tool for strategic decision making by analyzing different competitive situations. Such situations may arise in different facets of human interactions. Game theory helps to design mathematical models for conflict and cooperation between rational decision makers. The course intends to give fundamentals of games including non-cooperative and cooperative games. It further provides the basics of evolutionary stable strategies and population games.
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14. Course contents:	Game Trees, Choice Functions and Strategies, Choice Subtrees, Equilibrium N-tuples Strategies, Normal Forms, Non-cooperative games, Nash Equilibrium and its computation, The von Neumann Minimax Theorem, Mixed strategies, Best Response Strategies, Matrix Games and Linear Programming, Simplex Algorithm, Avoiding cycles and Achieving Feasibility, Dual-Simplex Algorithm, Duality Theorem, 2x2 Bimatrix Games, Nonlinear Programming Methods for Non-zero Sum Two-Person Games, Coalitions and Characteristic Functions, Imputations and their Dominance, The Core of a game, Strategic Equivalence, Stable Sets of Imputations, Shapley Values, N-Person Non-Zero Sum Games with continuum of strategies – Duels, Auctions, Nash Model with Security Point, Threats, Evolution, Stable Strategies, Population Games, Bayesian Games
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Course c
Practical / Prac

15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
1.	Game Theory Introduction: Overview, Examples and applications of Game Theory, Normal forms, Payoffs, Nash Equilibrium, Dominate Strategies, Perfect Information Games	5
2.	Games in Extensive Form Game Trees, Choice Functions and Strategies, Choice Subtrees, Two-Person Matrix Games, Mixed strategies, Best Response Strategies,	5
3.	Equilibrium in Games: Nash equilibrium, The von Neumann Minimax Theorem, Fixed point theorems, Computational aspects of Nash equilibrium	4
4.	Solution Methods for Matrix Games: Linear Programming, Simplex Algorithm, Dual-Simplex Algorithm, Duality Theorems,	5
5.	Two Person Non-zero Sum Games: 2x2 Bimatrix Games, Nonlinear Programming Methods for Non-zero Sum Two-Person Games	5
6.	N-Person Cooperative Games: Coalitions and Characteristic Functions, Imputations	5

	and their Dominance, The Core, Strategic Equivalence, Stable Sets of Imputations, Shapley Values,	
7.	Continuum Strategies: N-Person Non-Zero Sum Games with continuum of strategies, Duels, Auctions, Nash Model with Security Point, Threats	5
8.	Evolutionary Strategies: Evolution, Stable Strategies	4
9.	Introduction to Special Games, e.g. Coalitional Games, Population Games, Bayesian Games	4
Total Lecture hours (14 times 'L')		42

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours
Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities: NA

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

- 1) Introduction to Game Theory, Peter Morris, Springer-Verlag, 1994.
- 2) Game Theory – An Introduction, E.N.Barron, Wiley Student Edition, 2012.
- 3) Game Theory and Mechanism Design, Y. Narhari, IISc Press and World Scientific, 2014.
- 4) Essential Game Theory, K. Leyton Brown & Y. Shoham, Morgan & Clayful, 2008.
- 5) Models of Conflicts and Cooperation, R. Gillman & D Housman, University Press, 2013.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	Name of software, number of licenses, etc.
20.2	Hardware	Nature of hardware, number of access points, etc.
20.3	Teaching aids (videos, etc.)	Audio System for large classes
20.4	Laboratory	Type of facility required, number of students etc.
20.5	Equipment	Type of equipment required, number of access points, etc.
20.6	Classroom infrastructure	Type of facility required, number of students etc.
20.7	Site visits	Type of Industry/ Site, typical number of visits, number of students etc.
20.8	Others (please specify)	

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	Eg. 25% of student time of practical / practice hours: sample Circuit Design exercises from industry
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date: March 26, 2015 (Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/School proposing the course	Mathematics		
2.	Course Title	Stochastic Processes and its Applications		
3.	L-T-P structure	3-0-0		
4.	Credits	3	Non-graded Units	0
5.	Course number	MTL 725		
6.	Course Status (Course Category for Program) DE, PE for MT1, MT5, MSc			
	Institute Core for all UG programs	No		
	Programme Linked Core for:	NIL		
	Departmental Core for:	NIL		
	Departmental Elective for:	MT1		
	Minor Area / Interdisciplinary Specialization Core for:	Name of Minor Area / Specialization Program		
	Minor Area / Interdisciplinary Specialization Elective for:	Name of Minor Area / Specialization Program		
	Programme Core for:	List of M.Tech. / Dual Degree Programs		
	Programme Elective for:	MT5, MSc		
	Open category Elective for all other programs (No if Institute Core)	Yes		
7.	Pre-requisite(s)	MTL106//MTL108/MTL601		
8.	Status vis-à-vis other courses			
8.1	List of courses precluded by taking this course (significant overlap)	(course number)		
	(a) Significant Overlap with any UG/PG course of the Dept./Centre/ School	(course number)		
	(b) Significant Overlap with any UG/PG course of other Dept./Centre/ School	(course number)		
8.2	Supersedes any existing course	MAL 725		
9.	Not allowed for	(indicate program names)		

10.	Frequency of offering (check one box)	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester
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11.	Faculty who will teach the course S Dharmaraja
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12.	Will the course require any visiting faculty? no
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13.	Course objectives (about 50 words. "On successful completion of this course, a student should be able to..."): • Explanation of stochastic processes which they need for their experiments and research. • Discussion on the various applications of stochastic process with detailed theoretical concepts.
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14.	Course contents (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Stochastic processes, specification of stochastic processes, stationary processes, discrete time and continuous time Markov chains, birth and death processes, applications in queueing theory. Markov processes with continuous state space, martingales, applications in financial mathematics. Renewal processes and theory, Markov renewal and semi-Markov processes, branching processes.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
1.	Definition, examples and classification of random processes according to state space and parameter space.	5
2.	Stationary processes	4
3.	Discrete time Markov chain, classification or states, stationary distribution, reducible Markov chain	5
4.	Continuous time Markov chain, stationary distribution, time dependent probabilities	5
5.	Poisson processes	4

6.	Birth and death processes, applications in queueing theory	5
7.	Markov processes with continuous state space, Brownian motion, martingales, applications in financial mathematics	5
8.	Renewal processes and theory, Markov renewal and semi-Markov processes, applications in queueing theory	5
9.	branching processes, Definition and examples branching processes, probability generating function, mean and variance, Galton-Watson branching process, probability of extinction.	4
Total Lecture hours(14 times 'L')		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
Total Tutorial hours(14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours(14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Stochastic Processes, J Medhi, 3rd edition, New Age International Publishers, 2009.
2. An Introduction to Stochastic Modeling, S Karlin and H M Taylor, Elsevier, 1998.
3. Introduction to Probability and Stochastic Processes with Applications, Liliana Blanco Castaneda, Viswanathan Arunachalam, Selvamuthu Dharmaraja, Wiley, New Jersey, June 2012.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	Name of software, number of licenses, etc.
20.2	Hardware	Nature of hardware, number of access points, etc.
20.3	Teaching aids (videos, etc.)	Description, Source, etc.
20.4	Laboratory	Type of facility required, number of students etc.
20.5	Equipment	Type of equipment required, number of access points, etc.
20.6	Classroom infrastructure	Type of facility required, number of students etc.
20.7	Site visits	Type of Industry/ Site, typical number of visits, number of students etc.
20.8	Others (please specify)	

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	Eg. 25% of student time of practical / practice hours: sample Circuit Design exercises from industry
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date:

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/School proposing the course	Mathematics	
2.	Course Title	Computational Algebra and its Applications	
3.	L-T-P structure	3-0-0	
4.	Credits	3	Non-graded Units 0
5.	Course number	MTL 729	
6.	Course Status (Course Category for Program) (list program codes: eg., EE1, CS5, etc.)		
	Institute Core for all UG programs	(Yes / No)	
	Programme Linked Core for:	NIL	
	Departmental Core for:	NIL	
	Departmental Elective for:	MSc	
	Minor Area / Interdisciplinary Specialization Core for:	NIL	
	Minor Area / Interdisciplinary Specialization Elective for:	NIL	
	Programme Core for:	NIL	
	Programme Elective for:	List of M.Tech. / Dual Degree Programs	
	Open category Elective for all other programs (No if Institute Core)	(Yes / No) No	
7.	Pre-requisite(s)	MTL105/ MAL 516	
8.	Status vis-à-vis other courses		
8.1	List of courses precluded by taking this course (significant overlap)	(course number)	
	(a) Significant Overlap with any UG/PG course of the Dept./Centre/ School	(course number)	
	(b) Significant Overlap with any UG/PG course of other Dept./Centre/ School	(course number)	
8.2	Supersedes any existing course	MAL729	
9.	Not allowed for	(indicate program names)	

10.	Frequency of offering (check one box)	☐ Every semester ☐ I sem ☐ II sem ☐ Either semester Either semester
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11.	Faculty who will teach the course (Minimum 2 names for core courses / 1 name for electives) Dr. Anuradha Sharma, Dr. Ritumoni Sarma
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12.	Will the course require any visiting faculty?	No
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13.	Course objectives: To update and empower students with the advances computations in modern algebraic structures and their applications in coding theory, cryptography.
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14.	Course contents (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Finite fields: Construction and examples. Polynomials over finite fields, their factorization/irreducibility and their applications to coding theory. Combinatorial applications. Symmetric and Public key cryptosystems particularly on Elliptic curves. Combinatorial group theory: investigation of groups on computers, finitely presented groups, coset enumeration. Fundamental problem of combinatorial group theory. Coset enumeration, Nielsen transformations. Braid Group cryptography. Automorphism groups. Computational methods for determining automorphism groups of certain finite groups. Computations of characters and representations of finite groups. Computer algebra programs. Computations of units in rings and group rings. Calculations in Lie algebras.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
1.	Finite fields: Construction and examples. Polynomials on finite fields and their factorization/irreducibility and their application to coding theory, Combinatorial applications	6
2.	Cryptography on symmetric channels	4

3.	Public key cryptosystems particularly based upon Elliptic curves	6
4.	Combinatorial group theory: investigation of groups on computers, finitely presented groups, coset enumeration	4
5.	Nielsen transformations	4
6.	Automorphism groups. Computational methods for determining automorphism groups of certain finite groups	4
7.	Combinatorial construction of subgroups	3
8.	Programs for computations of characters and representations of finite groups	4
9.	Computer algebra programs, computations of units in rings and group rings	4
10.	Calculations in Lie algebras	3
Total Lecture hours (14 times 'L')		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

(i)	W. Magnus, A. Karrass and D. Soliter, Combinatorial Group Theory, Wiley (1996).
(ii)	Rudolf Lidl and Harald Niederreiter, Introduction to finite fields and their applications, second edition, Cambridge University Press, (1994)
(iii)	Bruce Schneier, Applied cryptography, second edition, John Wiley & Sons (1995).
(iv)	R E Blahut, Algebraic codes for data transmission, Cambridge University Press (2012).

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	Name of software, number of licenses, etc.
20.2	Hardware	Nature of hardware, number of access points, etc.
20.3	Teaching aids (videos, etc.)	Description, Source , etc.
20.4	Laboratory	Type of facility required, number of students etc.
20.5	Equipment	Type of equipment required, number of access points, etc.
20.6	Classroom infrastructure	Type of facility required, number of students etc.
20.7	Site visits	Type of Industry/ Site, typical number of visits, number of students etc.
20.8	Others (please specify)	

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	Eg. 25% of student time of practical / practice hours: sample Circuit Design exercises from industry
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date:

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/School proposing the course	Mathematics	
2.	Course Title	Cryptography	
3.	L-T-P structure	3-0-0	
4.	Credits	3	Non-graded Units 0
5.	Course number	MTL 730	
6.	Course Status (Course Category for Program) DE/ PE/OE/OC		
	Institute Core for all UG programs	(Yes / No)	
	Programme Linked Core for:	M.Sc.	
	Departmental Core for:	Mathematics	
	Departmental Elective for:	All	
	Minor Area / Interdisciplinary Specialization Core for:	B. Tech. EE	
	Minor Area / Interdisciplinary Specialization Elective for:	B. Tech. CS	
	Programme Core for:	M.Sc.	
	Programme Elective for:	MT5	
	Open category Elective for all other programs (No if Institute Core)	(Yes / No)	
7.	Pre-requisite(s)	B.Sc.(Mathematics), B. Tech. Ist year (MTL 101)	
8.	Status vis-à-vis other courses		
8.1	List of courses precluded by taking this course (significant overlap)	MTL 101	
	(a) Significant Overlap with any UG/PG course of the Dept./Centre/ School	None	
	(b) Significant Overlap with any UG/PG course of other Dept./Centre/ School	None	
8.2	Supersedes any existing course	MAL730	
9.	Not allowed for	None	

10.	Frequency of offering (check one box)	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester
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11.	Faculty who will teach the course: R. K. Sharma, A. Sharma
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12.	Will the course require any visiting faculty?	No
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13.	Course objectives (about 50 words. "On successful completion of this course, a student should be able to..."): To update knowledge in modern cryptosystems their analysis and applications to other fields.
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14.	Course contents (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Applying the corresponding algorithms programmes.(laboratory/design activities could also be included) Classical cryptosystems, Preview from number theory, Congruences and residue class rings, DES- security and generalizations, Prime number generation. Public Key Cryptosystems of RSA, Rabin, etc. their security and cryptanalysis. Primality, factorization and quadratic sieve, efficiency of other factoring algorithms. Finite fields: Construction and examples. Diffie-Hellman key exchange. Discrete logarithm problem in general and on finite fields. Cryptosystems based on Discrete logarithm problem such as Massey-Omura cryptosystems. Algorithms For finding discrete logarithms, their analysis. Polynomials on finite fields and Their factorization/irreducibility and their application to coding theory. Elliptic curves, Public key cryptosystems particularly on Elliptic curves. Problems of key exchange, discrete logarithms and the elliptic curve logarithm problem. Implementation of elliptic curve cryptosystems. Counting of points on Elliptic Curves over Galois Fields of order 2^m . Other systems such as Hyper Elliptic Curves And cryptosystems based on them. Combinatorial group theory: investigation of groups on computers, finitely presented groups, coset enumeration. Fundamental problems of combinatorial group theory. Coset enumeration, Nielsen and Tietze transformations. Braid Group cryptography. Cryptographic hash functions. Authentication, Digital Signatures, Identification, certification infrastructure and other applied aspects.
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15. Lecture Outline (with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
1.	Classical cryptosystems, Preview from number theory, Congruences and residue class rings,	5
2.	Cryptography on symmetric channels: DES generalizations and security	4
3.	Public Key Cryptosystems of RSA, Rabin, etc. their security and cryptanalysis. Prime number generation, Primality, factorization and quadratic sieve, efficiency of other factoring algorithms.	5
4.	Finite fields: Construction and examples. Diffie-Hellman key exchange Discrete logarithm problem in general and on finite fields. Cryptosystems based on Discrete logarithm problem such as Massey-Omura cryptosystems and their crypt analysis. Algorithms for finding discrete logarithms, their analysis.	5
5.	Polynomials on finite fields and their factorization/irreducibility and their application to coding theory ciphers.	3
6.	Elliptic curves, Public key cryptosystems particularly on Elliptic curves.	4
7.	Problems of key exchange, discrete logarithms and the elliptic curve logarithm problem. Implementation of elliptic curve cryptosystems. Counting of points on Elliptic Curves over Galois Fields of order 2^m .	5
8.	Hyper Elliptic Curves Public key Cryptosystems. And Cryptosystems based on other mathematical concepts such as graph theory.	2
9.	Combinatorial group theory: Construction of groups, investigation of groups on computers, finitely presented groups, coset enumeration	3
10.	Fundamental Problems of combinatorial group theory, Neilson transformation, Titze transformations and Braid group cryptography	3
11.	Cryptographic hash functions. Authentication, Digital Signatures, Identification, certification infrastructure and other applied aspects.	3
Total Lecture hours (14 times 'L')		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

- (i) Neal Koblitz, Introduction to number theory and cryptography
- (ii) Neal Koblitz, Algebraic aspects of cryptography
- (iii) A. Menezes, Elliptic curve public key cryptography
- (iv) Blake, Seroussi, Smart, Elliptic curves in cryptography
- (v) Bruce Schneier, Applied cryptography
- (vi) Karrass, Magnus and Soliter, Combinatorial Group Theory
- (vii) Wade Trappe, Lawrence C. Washington, Introduction to Cryptography with Coding Theory
- (viii) Christian Kassel, Vladimir Turaev, O. Dodane, Braid Groups
- (ix) Alexei Myasnikov, Vladimir Shpilrain, Alexander Ushakov, Group Based Cryptography

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20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	Name of software, number of licenses, etc.
20.2	Hardware	Nature of hardware, number of access points, etc.
20.3	Teaching aids (videos, etc.)	Description, Source , etc.
20.4	Laboratory	Type of facility required, number of students etc.
20.5	Equipment	Type of equipment required, number of access points, etc.
20.6	Classroom infrastructure	Type of facility required, number of students etc.
20.7	Site visits	Type of Industry/ Site, typical number of visits, number of students etc.
20.8	Others (please specify)	

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	Eg. 25% of student time of practical / practice hours: sample Circuit Design exercises from industry
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	There are many problems in each category. Depending on progress, problems will be assigned.

Date:

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/School proposing the course	Mathematics	
2.	Course Title	Numerical Methods for Partial Differential Equations	
3.	L-T-P structure	3-1-0	
4.	Credits	4	Non-graded Units 0
5.	Course number	MTL 795	
6.	Course Status (Course Category for Program) (list program codes: eg., EE1, CS5, etc.)		
	Institute Core for all UG programs		(Yes / No) No
	Programme Linked Core for:		List of B.Tech. / Dual Degree Programs
	Departmental Core for:		NIL
	Departmental Elective for:		List of B.Tech. / Dual Degree Programs
	Minor Area / Interdisciplinary Specialization Core for:		Name of Minor Area / Specialization Program
	Minor Area / Interdisciplinary Specialization Elective for:		Name of Minor Area / Specialization Program
	Programme Core for:		List of M.Tech. / Dual Degree Programs
	Programme Elective for:		M.Sc., MT6
	Open category Elective for all other programs (No if Institute Core)		(Yes / No)
7.	Pre-requisite(s)	combinations of courses: eg. (XYZ123 & XYW214) / XYZ234	
8.	Status vis-à-vis other courses		
8.1	List of courses precluded by taking this course (significant overlap)		(course number)
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	(course number)
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	(course number)
8.2	Supersedes any existing course		NIL
9.	Not allowed for	(indicate program names)	

10.	Frequency of offering (check one box)	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester
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11.	Faculty who will teach the course (Minimum 2 names for core courses / 1 name for electives) H. Kumar
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12.	Will the course require any visiting faculty? (Yes/no)
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13.	Course objectives (about 50 words. "On successful completion of this course, a student should be able to..."): To present numerical methods for the partial differential equations.
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14.	Course contents (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Two point boundary value problem: Variational approach, Discretization and convergence of numerical schemes. Second order Elliptic boundary value problem, Variational formulation and Boundary conditions, Finite element Methods, Galerkin Discretization, Implementation, Finite difference and Finite volume methods, Convergence and Accuracy. Parabolic initial value problems, Heat equations, variational formulation, Method of lines, Convergence. Wave Equations, Method of lines, Timestepping.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
1.	Two point boundary value problem: Variational approach	5
2.	Discretization and convergence of numerical schemes.	5
3.	Second order Elliptic boundary value problem, Variational formulation and Boundary conditions	5
4.	Finite element Methods, Galerkin Discretization, Implementation.	5
5.	Finite difference and Finite volume methods	4
6.	Convergence and Accuracy.	5
7.	Parabolic initial value problems, Heat equations, variational formulation	5

8.	Method of lines, Convergence.	3
9.	Wave Equations, Method of lines, Time-stepping	5
Total Lecture hours(14 times 'L')		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	Problems based on the lectures	
Total Tutorial hours(14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours(14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component

(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. T. Hughes, *The Finite Element Method*, Dover Publications, 2000.
2. C. Johnson, *Numerical Solution of Partial Differential Equations by the Finite Element Method*, Cambridge University Press, 1987.
3. P. Knabner and L. Angermann, *Numerical Methods for Elliptic and Parabolic Partial Differential Equations*, volume 44 of *Texts in Applied Mathematics*. Springer, Heidelberg, 2003.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	Name of software, number of licenses, etc.
20.2	Hardware	Nature of hardware, number of access points, etc.
20.3	Teaching aids (videos, etc.)	Description, Source , etc.
20.4	Laboratory	Type of facility required, number of students etc.
20.5	Equipment	Type of equipment required, number of access points, etc.
20.6	Classroom infrastructure	Type of facility required, number of students etc.
20.7	Site visits	Type of Industry/ Site, typical number of visits, number of students etc.
20.8	Others (please specify)	

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	Eg. 25% of student time of practical / practice hours: sample Circuit Design exercises from industry
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date:

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/School proposing the course	Mathematics		
2.	Course Title	Advanced Matrix Theory		
3.	L-T-P structure	3-0-0		
4.	Credits	3	Non-graded Units	0
5.	Course number	MTL 745		
6.	Course Status (Course Category for Program) (list program codes: eg., EE1, CS5, etc.)			
	Institute Core for all UG programs		(Yes / No)	
	Programme Linked Core for:		List of B.Tech. / Dual Degree Programs	
	Departmental Core for:		List of B.Tech. / Dual Degree Programs	
	Departmental Elective for:		List of B.Tech. / Dual Degree Programs	
	Minor Area / Interdisciplinary Specialization Core for:		Name of Minor Area / Specialization Program	
	Minor Area / Interdisciplinary Specialization Elective for:		Name of Minor Area / Specialization Program	
	Programme Core for:		List of M.Tech. / Dual Degree Programs	
	Programme Elective for:		List of M.Tech. / Dual Degree Programs	
	Open category Elective for all other programs (No if Institute Core)		(Yes / No)	
7.	Pre-requisite(s)	MAL 503, MAL255		
8.	Status vis-à-vis other courses			
8.1	List of courses precluded by taking this course (significant overlap)		(course number)	
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	(course number)	
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	(course number)	
8.2	Supersedes any existing course		MAL 614	
9.	Not allowed for	(indicate program names)		

10.	Frequency of offering (check one box)	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester Either semester
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11.	Faculty who will teach the course: A. Sharma, S. C. S. Rao
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12.	Will the course require any visiting faculty?	no
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13.	Course objectives: To provide indepth knowledge about special topics in Matrix Theory that have applications in Science and Engineering.
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14.	Course contents (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Review of Linear Algebra; Matrix calculus, Diagonalization, Canonical forms and invariant Factors. Quadratic forms, Courant-Fischer minimax and related Theorems. Perron-Frobenius theory, Matrix stability, Inequalities, g-inverses. Direct, iterative, projection and rotation methods for solving linear systems and eigenvalue problems. Applications
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
1.	Review of linear algebra: Matrix calculus, Diagonalization	4
2.	Canonical Forms and invariant factors	5
3.	Quadratic Forms	5
4.	Minimax Theorems of Courant-Fisher Theory	5
5.	Perron-Frobenius Theory	5

6.	Generalized inverses and their applications	4
7.	Direct iterative method for solving linear systems	5
8.	Eigen value Problem	5
9.	Applications to DE	4
Total Lecture hours (14 times 'L')		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component

(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. J. H. Ortega, **Matrix Theory: A Second Course, Plenum Press, 1988**
2. G. H. Golub and C. F. Van Loan, **Matrix Computations, 3rd edition, Johns Hopkins University Press, 1996.**
3. R. A. Horn and C. R. Johnson, **Matrix Analysis, Cambridge University Press, 1990.**

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	Name of software, number of licenses, etc.
20.2	Hardware	Nature of hardware, number of access points, etc.
20.3	Teaching aids (videos, etc.)	Description, Source , etc.
20.4	Laboratory	Type of facility required, number of students etc.
20.5	Equipment	Type of equipment required, number of access points, etc.
20.6	Classroom infrastructure	Type of facility required, number of students etc.
20.7	Site visits	Type of Industry/ Site, typical number of visits, number of students etc.
20.8	Others (please specify)	

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	Eg. 25% of student time of practical / practice hours: sample Circuit Design exercises from industry
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date:

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

1.	Department/Centre/School proposing the course	Mathematics	
2.	Course Title	Principles of Optimization Theory	
3.	L-T-P structure	3 – 0 – 0	
4.	Credits	3	Non-graded Units NIL
5.	Course number	MTL625	
6.	Course Status (Course Category for Program) PE		
	Institute Core for all UG programs	No	
	Programme Linked Core for:	No	
	Departmental Core for:	No	
	Departmental Elective for:	No	
	Minor Area / Interdisciplinary Specialization Core for:	No	
	Minor Area / Interdisciplinary Specialization Elective for:	No	
	Programme Core for:	No	
	Programme Elective for:	MSc Mathematics	
	Open category Elective for all other programs (No if Institute Core)	No	
7.	Pre-requisite(s)	MTL526	
8.	Status vis-à-vis other courses		
8.1	List of courses precluded by taking this course (significant overlap)		
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	20% with MTL704
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	No
8.2	Supersedes any existing course		MAL726
9.	Not allowed for	BTech, Dual Degree MTech students of any branch	
10.	Frequency of offering (check one box)	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester	
11.	Faculty who will teach the course Dr Aparna Mehra, Prof B Chandra, Prof SCS Rao, Prof B S Panda		

12.	Will the course require any visiting faculty?	No
13.	To give a concise view of the fundamental concepts of optimization theory so as to probe into topics like convex optimization and nonsmooth optimization both from theoretical and numerical perspectives with applications specifically to support vector machines optimization problems.	

14.	Course contents Convex set, hyperplane, relative interior and closure, separation theorems, theorems of alternatives for linear systems, convex functions and properties of continuity, differentiability etc., quasiconvex and pseudoconvex functions and their properties and interrelationships, minimax theorems for convex and quasiconvex functions, nonlinear programming, Lagrange function, saddle point, Fritz John optimality conditions, constraint qualifications, Karush-Kuhn-Tucker (KKT) necessary and sufficient optimality conditions, Wolfe and Mond-Weir duals, Wolfe method for quadratic programs, Projection gradient method, steepest descent method, conjugate gradient method, rank-1 methods, convergence, conjugate function, Fenchel duality, subgradient and subdifferential, nonsmooth optimization, tangent cone, normal cone, nonsmooth KKT conditions, nonsmooth optimality conditions, subgradient method, proximal method, convergence of these methods, applications to support vector machines optimization problems.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Convex sets, hyperplane, separation theorems, theorems of alternatives, Convex functions	4
2	Properties of convex functions like continuity, differentiability etc., quasiconvex and pseudoconvex functions, properties examples & interrelation between them	5
3	Minimax theorems for convex and quasiconvex functions, nonlinear programming, Lagrange function, saddle point, necessary and sufficient condition for existence of saddle point	5
4	Fritz John optimality conditions, constraint qualification, KKT optimality conditions, Wolfe dual, Mond-Weir dual, Wolfe method for quadratic programs, Projection gradient method	5
5	steepest descent method, conjugate gradient method, Rank-1 method, convergence	5
6	Conjugate function, Fenchel duality, subgradient, subdifferential, tangent and normal cones	5
7	Nonsmooth analysis, nonsmooth KKT conditions, sufficiency of the KKT conditions	4
8	Subgradient method, proximal method and their convergence	4
9	Applications of theory to specifically support vector machines	5
Total Lecture hours (14 times 'L')		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
All modules	Practice sheets of problems to be designed for better understanding and appreciation of the theory and algorithms studied in lecture classes.	
Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
4, 5, 8 & 9	Practice purpose and part of assignments with this course: To design and develop codes for various algorithms studied in course, implementation on smooth and non-smooth optimization problems; codes for support vector machines models.	
Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component

(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
5 & 8	Convergence analysis of some of the algorithms studied in lecture from research papers. Complexity aspect of prominent algorithms for nonlinear, nonsmooth optimization problems.

19. Suggested texts and reference materials

1. C. R. Bector, S. Chandra, J. Dutta, Principle of Optimization Theory, Narosa, 2006. 2. M. S. Bazaraa, H. D. Sherali, C. M. Shetty, Nonlinear Programming: Theory and Algorithms, Wiley, 2006. 3. J. M. Borwein and A. S. Lewis, Convex Analysis and Nonlinear Optimization, Springer, 2000. 4. D. P. Bertsekas, Convex Optimization Theory, Athena Scientific Press, 2009. 5. S. Sra, S. Nowozin, S. J. Wright, Optimization for Machine Learning, MIT Press, 2011.
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20. Resources required for the course

20.1	Software	MATLAB
20.2	Hardware	YES
20.3	Teaching aids (videos, etc.)	YES
20.4	Laboratory	No
20.5	Equipment	No
20.6	Classroom infrastructure	YES
20.7	Site visits	No
20.8	Others (please specify)	No

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	20% weightage for coding related assignments as mentioned in item 17.
21.2	Open-ended problems	No
21.3	Project-type activity	10% weightage to preparing and presenting a term paper relevant to course as assignment
21.4	Open-ended laboratory work	No
21.5	Others (please specify)	No

Date: May 9, 2015

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

1.	Department / Centre / School proposing the course	MATHEMATICS	
2.	Course Title	METHODS OF APPLIED MATHEMATICS	
3.	L-T-P structure	3 - 0 - 0	
4.	Credits	3	Non-graded Units 0
5.	Course number	MTL 746	
6.	Course Status (Course Category for Program) DE for MSc Mathematics		
	Institute Core for all UG programs	No	
	Programme Linked Core for:	No	
	Departmental Core for:	No	
	Departmental Elective for:	No	
	Minor Area / Interdisciplinary Specialization Core for:	No	
	Minor Area / Interdisciplinary Specialization Elective for:	No	
	Programme Core for:	No	
	Programme Elective for:	MSc. Mathematics	
	Open category Elective for all other programs (No if Institute Core)	No	
7.	Pre-requisite(s)	None	
8.	Status vis-à-vis other courses		
8.1	List of courses precluded by taking this course (significant overlap)		
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	None
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	None
8.2	Supersedes any existing course		MAL 518
9.	Not allowed for	Any UG program or Dual degree program student.	
10.	Frequency of offering (check one box)	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester	

11.	Faculty who will teach the course M. Mehra, V.V. K. Srinivas Kumar, K. Sreenadh, H. Kumar, S. C. S. Rao
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12.	Will the course require any visiting faculty? No
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13.	Course objectives The course objective is to provide its student with a thorough knowledge of applicable mathematics and to develop their expertise in applying methods and tools of mathematics to problems in science and engineering.
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14.	Course Contents Expansion in Eigen functions, Fourier series and Fourier Integral, orthogonal expansion, mean square approximation, completeness, orthogonal polynomials and their properties. Integral transform and their applications Linear function, general variation of a functional, direct variation methods for solution of boundary value problems Integral equations of voltera and Fredhlom type, seperable and symmetric kernels, Hilbert-Schmidth theory, Singular integral equations, approximation methods of solving integral equations
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No of hours
1.	Expansion in Eigen functions, Fourier series and Fourier integrals	5
2	orthogonal expansion, mean square approximation, completeness, orthogonal polynomials and their properties	7
3	Integral transform and their applications	5
4.	Linear function, general variation of a functional	2
5.	direct variation methods for solution of boundary value problems	6
6.	Integral equations of voltera and Fredhlom type, seperable and symmetric kernels	6
7	Hilbert-Schmidth theory	4
8	Singular integral equations	1
9	approximation methods of solving integral equations	6
Total Lecture hours (14 times 'L')		42

16. Brief description of tutorial activities:

Total Tutorial hours (14 times 'T')	0

17. Brief description of Practical / Practice activities: NA

Module no.	Description	No. of hours
	Not Applicable	
Total Practical / Practice hours(14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component (Only for 700 / 800level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

S. Nair, Advanced topics in applied mathematics, Cambridge University Press.
 Courant and Hilbert, *Methods of Mathematical Physics*, John Wiley, India Reprint 2010
 Brown and Churchill, *Fourier Series and Boundary Value Problems*, McGraw-Hill Higher Education

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	No
20.2	Hardware	No
20.3	Teaching aids (videos, etc.)	Audio system for large classes
20.4	Laboratory	No
20.5	Equipment	No
20.6	Classroom infrastructure	YES
20.7	Site visits	No
20.8	Others (please specify)	No

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	No
21.2	Open-ended problems	30% : In form of assignments, problems solving
21.3	Project-type activity	No
21.4	Open-ended laboratory work	No
21.5	Others (please specify)	

Date: March 31, 2015

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

(Please avoid changing the number of tables, rows and columns or text in dark black, but fill only the columns relevant to the template by editing the columns in grey letters or blank columns: this would help in automating the processing of template information for curricular use)

1.	Department/Centre/School proposing the course	Mathematics		
2.	Course Title	Category Theory		
3.	L-T-P structure	3-0-0		
4.	Credits	3	Non-graded Units	0
5.	Course number	MTL 728		
6.	Course Status (Course Category for Program) MAL			
	Institute Core for all UG programs	No		
	Programme Linked Core for:	Nil		
	Departmental Core for:	MSc		
	Departmental Elective for:	Nil		
	Minor Area / Interdisciplinary Specialization Core for:	Nil		
	Minor Area / Interdisciplinary Specialization Elective for:	Nil		
	Programme Core for:	MSc		
	Programme Elective for:	Nil		
	Open category Elective for all other programs (No if Institute Core)	No		
7.	Pre-requisite(s)	Nil		
8.	Status vis-à-vis other courses			
	8.1	List of courses precluded by taking this course (significant overlap)	None	
	(a)	Significant Overlap with any UG/PG course of the Dept./Centre/ School	Nil	
	(b)	Significant Overlap with any UG/PG course of other Dept./Centre/ School	None	
	8.2	Supersedes any existing course	MAL728 (Category Theory)	
9.	Not allowed for			

10.	Frequency of offering (check one box)	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester
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11.	Faculty who will teach the course R. Sarma, R. Barman
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12.	Will the course require any visiting faculty?	No
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13.	Course objectives (about 50 words. "On successful completion of this course, a student should be able to..."): To have a bird eye view of abstract mathematics.
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14.	Course contents (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Categories, functors and natural transformations, adjoints (of functors), representable functors, Yoneda Lemma and applications. Limits and colimits, interaction between functors and limits. Limits in terms of representables and adjoints, limits and colimits of presheaves, interaction between adjoint functors and limits. Application to abelian category: complexes of R-modules, long exact sequence, mapping cone and cylinder, projective and injective resolution, derived functors, right and left exactness, Ext and Tor. Concept of presheaf and sheaf, group scheme and Hopf algebra.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
1	Definition and examples of categories	2
2	Definition and examples of functors	2
3	Natural transformation, left and right adjoints with examples	3
4	Representable functors, yoneda lemma and applications	3
5	Limits and colimits, interaction between functors and limits	4
6	Limits in terms of representables and adjoints	3
7	Presheafs and sheavs examples	3
8	Limits and colimits of presheaves	2
9	Interaction between adjoint functors and limits	2
10	Complexes of R-modules, long exact sequences, mapping cone and cylinder	4
11	Projective and injective resolution	4
12	Derived functors, right and left exactness, Ext and Tor	5
13	Group scheme and Hopf algebra	5

Total Lecture hours (14 times 'L')	42
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16. Brief description of tutorial activities:

Module no.	Description	No. of hours
Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Description of module-wise activities pertaining to self-learning component

(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Tom Leinster, Basic Category Theory, Cambridge studies in advanced mathematics, Cambridge, 2014.
2. Charles A. Weibel An introduction to homological algebra, Cambridge studies in advanced mathematics, Cambridge, 1995.
3. W.C. Waterhouse, An introduction to Group Scheme, GTM 66, Springer, 1979.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	NIL
20.2	Hardware	NIL.
20.3	Teaching aids (videos, etc.)	NIL
20.4	Laboratory	NIL
20.5	Equipment	NIL
20.6	Classroom infrastructure	NIL
20.7	Site visits	NIL
20.8	Others (please specify)	

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	Eg. 25% of student time of practical / practice hours: sample Circuit Design exercises from industry
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	

Date:

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

1.	Department/Centre/School proposing the course	Mathematics		
2.	Course Title	Mathematical Logic		
3.	L-T-P structure	3-0-0		
4.	Credits	3	Non-graded Units	NIL
5.	Course number	MTL 747		
6.	Course Status (Course Category for Program) MAS			
	Institute Core for all UG programs	No		
	Programme Linked Core for:	No		
	Departmental Core for:	No		
	Departmental Elective for:	No		
	Minor Area / Interdisciplinary Specialization Core for:	No		
	Minor Area / Interdisciplinary Specialization Elective for:	No		
	Programme Core for:	No		
	Programme Elective for:	MSc		
	Open category Elective for all other programs (No if Institute Core)	YES		

7.	Pre-requisite(s)	
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8.	Status vis-à-vis other courses		
8.1	List of courses precluded by taking this course (significant overlap)	(course number)	
	(a) Significant Overlap with any UG/PG course of the Dept./Centre/ School	No	
	(b) Significant Overlap with any UG/PG course of other Dept./Centre/ School	COL303, more than 30%	
8.2	Supersedes any existing course	MAL607	

9.	Not allowed for	BTech & MTech of CS and students who have done COL303.
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10.	Frequency of offering (check one box)	☐ Every semester ☐ I sem ☐ II sem ☒ Either semester
11.	Faculty who will teach the course Prof Niladri Chatterjee, Dr Aparna Mehra	
12.	Will the course require any visiting faculty?	No

13.	Course Objective: To get familiarize with techniques in logic and its applications to computing.
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14.	Course contents Propositional Logic - Syntax, Semantics and Normal Forms, First Order Logic Syntax, Semantics and Normal Forms, Herbrand interpretation, Resolution of PL and FL, Proofs in PL and FL, Axiomatic Systems, Adequacy and Compactness, Program Verification, Hoare Proof, Godels completeness and incompleteness Theorem, Turing Machines and undecidability of Predicate calculus, Gentzen systems, Introduction to other logics - Description Logic, Default & Defeasible Logic, Courteous Logic, Modal Logic, Fuzzy logic.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
1	Propositional Logic - Syntax, Semantics and Normal Forms	5
2	First Order Logic Syntax, Semantics and Normal Forms, Herbrand interpretation	4
3	Resolution of PL and FL, Proofs in PL and FL	5
4	Adequacy and Compactness	5
5	Program Verification, Hoare Proof	4
6	Godels completeness and incompleteness Theorem,	5
7	Turing Machines and undecidability of Predicate calculus	4
8	Gentzen systems	4
9	Introduction to other logics - Description Logic, Default & de-feasible Logic, Courteous Logic	3
10	Modal Logic, Fuzzy logic	3
Total Lecture hours (14 times 'L')		42

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	Practice sheets comprising of problems and conceptual understanding for all modules covered in lecture class will be designed.	
Total Tutorial hours (14 times 'T')		Not Applicable

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
	No	
Total Practical / Practice hours (14 times 'P')		

18. Brief description of module-wise activities pertaining to self-learning component

Module no.	Description
	No
(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)	

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. J. R. Shoenfield, Mathematical Logic, Addison Wesley, 2001.
2. J. A. Gallier, Logic for Computer Science: Foundations of Automatic Theorem Proving, John Wiley and Sons, 2003.
3. Arindama Singh, Logics for Computer Science, PHI Learning, 2004.
4. E. Mendelson, Introduction to Mathematical Logic, CRC Press, 2010.

20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	No
20.2	Hardware	No
20.3	Teaching aids (videos, etc.)	YES
20.4	Laboratory	No
20.5	Equipment	No
20.6	Classroom infrastructure	YES
20.7	Site visits	No
20.8	Others (please specify)	NIL

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	
21.2	Open-ended problems	
21.3	Project-type activity	
21.4	Open-ended laboratory work	
21.5	Others (please specify)	20% weightage for problem solving assignments

Date:

(Signature of the Head of the Department/ Centre / School)

COURSE TEMPLATE

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1.	Department/Centre/School proposing the course	Mathematics		
2.	Course Title	Project 2		
3.	L-T-P structure	0-0-12		
4.	Credits	6	Non-graded Units	0
5.	Course number	MAD 702		
6.	Course Status (Course Category for Program) MAL			
	Institute Core for all UG programs	No		
	Programme Linked Core for:	Nil		
	Departmental Core for:	Nil.		
	Departmental Elective for:	M.Sc		
	Minor Area / Interdisciplinary Specialization Core for:	Nil		
	Minor Area / Interdisciplinary Specialization Elective for:	Nil		
	Programme Core for:	Nil		
	Programme Elective for:	MSc		
	Open category Elective for all other programs (No if Institute Core)	No		
7.	Pre-requisite(s)	Nil		
8.	Status vis-à-vis other courses			
8.1	List of courses precluded by taking this course (significant overlap)	None		
	(a) Significant Overlap with any UG/PG course of the Dept./Centre/ School	NIL		
	(b) Significant Overlap with any UG/PG course of other Dept./Centre/ School	NIL		
8.2	Supersedes any existing course	MAD 704 (Project Part 2)		
9.	Not allowed for	Any program other than MSc in Mathematics		

10.	Frequency of offering (check one box)	☒ Every semester ☐ I sem ☐ II sem ☐ Either semester
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11.	Faculty who will teach the course All faculty members of the Department
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12.	Will the course require any visiting faculty?	No
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13.	Course objectives (about 50 words. "On successful completion of this course, a student should be able to..."): To carryout innovative work on the assigned topic.
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14.	Course contents (about 100 words; Topics to appear as course contents in the Courses of Study booklet) (Include Practical / Practice activities): Contents will be related to topic related to the courses undertaken by the students in the programme.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours (not exceeding 5h per topic)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
Total Lecture hours (14 times 'L')		

16. Brief description of tutorial activities:

Module no.	Description	No. of hours

Total Tutorial hours (14 times 'T')		

17. Brief description of Practical / Practice activities

Module no.	Description	No. of hours
Total Practical / Practice hours (14 times 'P')		

18. Description of module-wise activities pertaining to self-learning component

(Only for 700 / 800 level courses) (Include topics that the students would do self-learning from books / resource materials: Do not Include assignments / term papers etc.)

Module no.	Description
	NIL

(The volume of self-learning component in a 700-800 level course should typically be 25-30% of the volume covered in classroom contact)

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

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20. Resources required for the course (itemized student access requirements, if any)

20.1	Software	As per project
20.2	Hardware	Computing Machines
20.3	Teaching aids (videos, etc.)	Nil
20.4	Laboratory	Computing laboratory

20.5	Equipment	Computing lab with some softwares depending on project
20.6	Classroom infrastructure	Nil
20.7	Site visits	Nil
20.8	Others (please specify)	

21. Design content of the course (Percent of student time with examples, if possible)

21.1	Design-type problems	NIL
21.2	Open-ended problems	NIL
21.3	Project-type activity	100%
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date: 11-05-15

(Signature of the Head of the Department/ Centre / School)