New Teaching Programme at the Central Department of Mathematics Tribhuvan University, Kirtipur, Kathmandu, Nepal

In a project report entitled *Improving Mathematics Education at the Central Department of Mathematics*, Professor Stephan Ruscheweyh, of Würzburg University Germany, made the following remarks:

> In Mathematics, an independent but guided work on the matters taught is extremely important. In practice this means that students should do homework, which then must be graded by teachers (or assistants) and later discussed in tutorial classes. This part of teaching and understanding is almost unknown in the present teaching system. Everything focusses on lectures. Only in the Certificate and Bachelor levels some drill on basic techniques is done, which again leads away from the fundamental meaning of Mathematics, namely training of independent and abstract thinking. It is typical that on the question papers for the final examinations, one finds the statement: 'Use your own words as far as practicable.' This somewhat helplessly tries to force the students not to do what they usually do, namely memorize the wording of theorems, definitions, and whole proofs, only to reproduce them word for word in the examinations, without any understanding.
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> In a 'normal' environment, a teacher has the possibility to prepare the problems for a final examination on the basis of the specific contents of his/her lectures, and to use formulations that do not permit the student just to 'copy' the answer from a book, via memory. In the present system this fine-tuning is impossible, since the question papers are prepared on a country-wide basis. Nothing special is permitted, for the questions have to make sense to all students of the university at the same level and taking the same course.
>
> This system makes it very difficult to update and adjust classical courses to modern knowledge, let alone introduce new subjects. This, on the long run, can only imply that mathematics education in Nepal further loses (and it visibly does) in the international context.

All this was said almost two decades ago, when Prof. Ruscheweyh was on his second visit to this university in connection with the oral examination of one of his PhD students. A project proposal specially for the Central Department of Mathematics was drawn up with the active participation of faculty members. It was pointed out at that time, that the implementation of the project would require some independence of the Department from the general system, as far as courses and examinations were concerned. Some of the basic components of the project were as follows:

1. Restructuring and modernizing the Master level courses, including the implementation of courses in Applied Mathematics. This could also mean an extension of the 2-years program to 5 or 6 semesters.

2. Introduction of tutorials and supervised homework for students.

3. Introduction of MPhil program to provide upgrading facilities for interested teachers, and as a provision for students at the Master's level to upgrade and/or prepare for PhD work.

4. Provision to enable the faculty to work 'full-time' in the Department.

5. Provision of suitable teaching facilities (including computing facilities) and a basic library.

The project never came to fruition, mainly due to lack of fund and the rigid structure of the university.

Many years have passed, and to our pleasant surprise the case for the project appears brighter now as never before. Indeed, with the enactment of the 'Autonomy Act', our authorities actively promote autonomy for institutions. As for fund for the project, regular fees on a par with that of other science central departments would go some way in providing for suitable facilities for teaching and research, and extra remuneration of the faculty and support staff. And last but not the least, the Department enjoys considerable goodwill, trust, and support from all quarters, just about enough, we believe, to make this well-intentioned project a success.

It is interesting to note that what Prof. Ruscheweyh told us then about how mathematics should be taught has now become common knowledge. Web sites of mathematics departments of all standard universities, as also web sites of their faculty members are bursting with information on which courses are being taught, and on how they are being taught. Also the grading policies of individual instructors are available for all to see. They talk of weekly homework, quizzes, mid and end of semester examinations, and even oral examinations.

Another interesting fact to note is that, the Master Level Programme of the Institute of Engineering has already brought into practice most of the teaching and evaluation methods that we have been advocating for so long! It may be helpful to present some fragments of their curriculum. Here is what the curriculum of the Master of Science in Structural Engineering has to say under *Instructional Methods* :

> Every course is co-ordinated by a member of the faculty of the Department which is offering the course in a given semester. This faculty member, called the Course Coordinator, has the full responsibility for conducting the course, coordinating the work of the other members of the faculty involved in that course, holding the tests and assignments, and awarding the marks. For any difficulty the student is encouraged to approach the Course Coordinator for advice and clarification. Apart from the lectures, through which the course is delivered, a certain number of assignments will be given in each course. Each assignment or a tutorial sheet consists of a number of problems that covers a particular section of the course. The problems are set in such a fashion that the student understands thoroughly the subject matters presented in the section after solving them. Generally, 4 to 8 assignments are given in each course. Tutorial contact hours, allotted in a course, are utilized for assignment discussions and augmentation of lectures. Practical classes in the form of laboratory works

> or computations, are used to verify the concepts and to develop necessary technical and analytical skills. The program, in general, emphasizes on the process of self-learning.

Under the heading *Evaluation System*, the curriculum says:

> The evaluation of a student in any course will be based on his performance in 2 minor tests, a major test and assignments. A major test will be conducted at the end of the semester and will generally cover the contents of the entire course. Two minor tests will be conducted in between the semester; generally portions covered in the first minor test is not included in the second minor test. The relative weightages attached to the major test, minor tests and assignments depend on the nature of the course, and the distribution of weightage will be decided by the Course Coordinator. However, in general a weightage of about 20% is attached to the assignment component of the evaluation, another 40% weightage is given to the minor tests and the rest 40% weightage is attached to the major test. Where a course does not have significant assignments, the scheme of evaluation and relative weightage attached to each component may deviate from the general pattern as described above, and are decided by the Course Coordinator.

Having dwelt on some of the shortcomings of teaching higher mathematics, and having found that one has to look no further than a sister institute of Tribhuvan University for possible solutions, we turn now to a description of a new curriculum for the Master of Arts/Master of Science in Mathematics. This curriculum is to be viewed as an addendum or supplement to the existing curriculum.

M.A./M.Sc. Mathematics (Semester System)
Curriculum for the
Central Department of Mathematics

Introduction:
A new teaching programme is being introduced at the Central Department of Mathematics. This necessitates the introduction of a new curriculum. Also a switch over to the semester system is called for, in order to achieve the necessary flexibility in introducing new instruction and evaluation methods. There are no changes under the headings *Objectives*, *Eligibility for Admission*, and *Admission Criteria* in the new curriculum. However, there are major changes in *course structure* and *evaluation methods*.

Course Structure:
The new programme runs for two academic years, i.e., four semesters. The total aggregate of credit hours for the four semesters is at least 100. Most courses are of 5 credit hours and come bundled with 2 credit hour courses for problem solving. Some courses may have practical or laboratory component as well. Here is a table of the courses available so far.

Course No.	**Course Title**	**Credit Hours**	**Full Marks**	**Pass Mark**
Math 551	Topology I	5	50	25
Math 551a	Problems in Topology I	2	20	10
Math 552	Topology II	5	50	25
Math 552a	Problems in Topology II	2	20	10
Math 553	Measure Theory and Integration I	5	50	25
Math 553a	Problems in Measure Theory and Integration I	2	20	10
Math 554	Functional Analysis I	5	50	25
Math 554a	Problems in Functional Analysis I	2	20	10
Math 555	Complex Analysis and Applications I	5	50	25
Math 555a	Problems in Complex Analysis and Applications I	2	20	10
Math 556	Differential Equations	5	50	25
Math 556a	Problems in Differential Equations	2	20	10
Math 557	Theory of Functions I	5	50	25
Math 557a	Problems in Theory of Functions I	2	20	10
Math 558	Theory of Functions II	5	50	25
Math 558a	Problems in Theory of Functions II	2	20	10
Math 559	Differential Geometry	5	50	25
Math 559a	Problems in Differential Geometry	2	20	10

Course No.	Course Title	Credit Hours	Full Marks	Pass Mark
Math 560	Combinatorial Optimization	5	50	25
Math 560a	Problems in Combinatorial Optimization	2	20	10
Math 561	Mathematical Programming	5	50	25
Math 561a	Problems in Mathematical Programming	2	20	10
Math 562	Mathematical Analysis I	5	50	25
Math 562a	Problems in Mathematical Analysis I	2	20	10
Math 563	Functions of Several Variables	5	50	25
Math 563a	Problems in Functions of Several Variables	2	20	10
Math 564	Elementary Harmonic Analysis	5	50	25
Math 564a	Problems in Elementary Harmonic Analysis	2	20	10
Math 565	Algebra I	5	50	25
Math 565a	Problems in Algebra I	2	20	10
Math 566	Algebra II	5	50	25
Math 566a	Problems in Algebra II	2	20	10
Math 567	Linear Algebra	5	50	25
Math 567a	Problems in Linear Algebra	2	20	10
Math 568	Linear Algebra and Its Applications	5	50	25
Math 568a	Problems in Linear Algebra and Its Applications	2	20	10
Math 569	Introduction to the Theory of Sets	5	50	25
Math 569a	Problems in Introduction to the Theory of Sets	2	20	10
Math 570	Theory of Numbers I	5	50	25
Math 570a	Problems in Theory of Numbers I	2	20	10
Math 571	Mechanics	5	50	25
Math 571a	Problems in Mechanics	2	20	10
Math 572	Functional Analysis II	5	50	25
Math 572a	Problems in Functional Analysis II	2	20	10
Math 573	Harmonic Analysis	5	50	25
Math 573a	Problems in Harmonic Analysis	2	20	10
Math 574	Special Functions I	5	50	25
Math 574a	Problems in Special Functions I	2	20	10
Math 575	Special Functions II	5	50	25
Math 575a	Problems in Special Functions II	2	20	10
Math 576	Partial Differential Equations I	5	50	25
Math 576a	Problems in Partial Differential Equations I	2	20	10

Course No.	Course Title	Credit Hours	Full Marks	Pass Mark
Math 577	Integral Transforms I	5	50	25
Math 577a	Problems in Integral Transforms I	2	20	10
Math 578	Measure Theory and Integration II	5	50	25
Math 578a	Problems in Measure Theory and Integration II	2	20	10
Math 579	Scheduling Theory	5	50	25
Math 579a	Problems in Scheduling Theory	2	20	10
Math 580	Integer Programming	5	50	25
Math 580a	Problems in Integer Programming	2	20	10
Math 581	Network Optimization	5	50	25
Math 581a	Problems in Network Optimization	2	20	10
Math 582	Graph Theory	5	50	25
Math 582a	Problems in Graph Theory	2	20	10
Math 583	Numerical Analysis	5	50	25
Math 583a	Problems in Numerical Analysis	2	20	10
Math 584	Numerical Optimization	5	50	25
Math 584a	Problems in Numerical Optimization	2	20	10
Math 585	Dynamical Systems	5	50	25
Math 585a	Problems in Dynamical Systems	2	20	10
Math 586	Dynamics of Viscous Fluids	5	50	25
Math 586a	Problems in Dynamics of Viscous Fluids	2	20	10
Math 587	Partial Differential Equations II	5	50	25
Math 587a	Problems in Partial Differential Equations II	2	20	10
Math 588	Introduction to C Programming	3	30	15
Math 589	Seminar	2	20	10
Math 590	Thesis	5	50	25
Math 591	Integral Transforms II	5	50	25
Math 591a	Problems in Integral Transforms II	2	20	10
Math 592	Complex Analysis and Applications II	5	50	25
Math 592a	Problems in Complex Analysis and Applications II	2	20	10
Math 593	Theory of Numbers II	5	50	25
Math 593a	Problems in Theory of Numbers II	2	20	10
Math 594	Scientific Computing	5	50	25
Math 595	Analysis of Finite Difference Schemes	5	50	25
Math 596	Introduction to Commutative Algebra	5	50	25
Math 597	Location Analysis	5	50	25
Math 598	Mathematical Models in Biology	5	50	25
Math 599	Advanced Ordinary Differential Equations	5	50	25

Note: One credit hour equals ten marks. Four courses, namely, Math 551, 553, 554, and 565 are compulsory. Which optional courses are taught and when they are taught are at the discretion of the head of department. Care should be taken that all prerequisites are met. Syllabi of some courses will be prescribed later. More courses will be introduced as necessary, and courses will be revised if necessary, all subject to the approval of the Mathematics Subject Committee.

Course Duration:
The duration of the programme is two academic years, that is, four semesters.

Hours of Instruction:

a) Working days	:	75 days in a semester
b) Class hour	:	A general course of 5 credit hours will usually have 5 contact hours per week.
c) Attendance	:	70 percent attendance in the class is compulsory.

Examination:
There will be internal assessments and final examinations, although some courses may have no final examination. Unless prescribed otherwise under *Course Details*, a course will have 60% of marks alloted for final examination, and 40% for internal assessment.

Evaluation:
The final examination will be conducted by the department. The answer sheets will be returned to the students after they have been marked. If not specified otherwise under *Course Details*, a course will have a final examination of two hours' duration. Students will have to pass the internal assessment and the final examination of a course separately. The minimum pass mark is 50 percent in both cases: in internal assessments, and in final examinations. A student who fails in the internal assessment of a course will not be allowed to appear in the final examination of that course.

A student who has successfully completed a programme of course work of at least 100 credit hours, that is, a programme of course work of at least 1000 marks, will be graded on the basis of his/her average mark as follows:

80 percent and above Distinction
70 percent and above First Division
60 percent and above Second Division
50 percent and above Third Division.

But a student is not required to pass a course offered on an extra optional (i.e., extra elective) basis. Nor will such a course contribute in any way in calculating the average mark.

Course Details:
The following pages contain the *Course Details*.

Topology I

Course Title: Topology I | Credit Hours: 5
Course No.: Math 551 | Full Marks: 50
Nature of the Course: Theory | Pass Mark: 25

Course Contents:
Some set theory and logic, topological spaces, continuous functions, product topology, metric topology, quotient topology, connected spaces, local connectedness, compact spaces, limit point compactness, local compactness, countability and separation axioms, Urysohn lemma, Urysohn metrization theorem, Tietze extension theorem.

Textbooks/Reference Books:

1. Croom, F.H., *Principles of Topology*, Saunders, New York, 1989.
2. Dugundji, J., *Topology*, Allyn and Bacon, Boston, 1966.
3. Kelley, J.L., *General Topology*, Van Nostrand Reinhold Company, New York, 1955.
4. Munkres, J.R., *Topology*, Second Edition, Pearson Education, Inc., Singapore, 2000.

Problems in Topology I

Course Title: Problems in Topology I | Credit Hour: 2
Course No.: Math 551a | Full Marks: 20
Nature of the Course: Theory | Pass Mark: 10

Course Contents:
Problems in Math 551, Topology I, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Topology II

Course Title: Topology II | Credit Hours: 5
Course No.: Math 552 | Full Marks: 50
Nature of the Course: Theory | Pass Mark: 25

Course Contents:
Point Set Topology: Imbedding of manifolds, Tychonoff theorem, Stone-Čech compactification, local finiteness, Nagata-Smirnov metrization theorem, paracompactness, Smirnov metrization theorem, complete metric spaces, compactness in metric spaces, pointwise and compact convergence, Ascoli's theorem, Baire spaces.
Algebraic Topolgy: Homotopy and path homotopy, fundamental group, covering spaces, fundamental group of the circle, retractions and fixed points, fundamental theorem of algebra, deformation retracts and homotopy types, fundamental group of S^n, fundamental groups of some surfaces.

Textbooks/Reference Books:

1. Dugundji, J., *Topology*, Allyn and Bacon, Boston, 1966.
2. Munkres, J.R., *Topology*, Second Edition, Pearson Education, Inc., Singapore, 2000.
3. Rotman, J.J., *An Introduction to Algebraic Topology*, Springer-Verlag, New York, 1988.

Problems in Topology II

Course Title: Problems in Topology II | Credit Hour: 2
Course No.: Math 552a | Full Marks: 20
Nature of the Course: Theory | Pass Mark: 10

Course Contents:
Problems in Math 552, Topology II, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Measure Theory and Integration I

Course Title: Measure Theory and Integration I	Credit Hours: 5
Course No.: Math 553	Full Marks: 50
Nature of the Course: Theory	Pass Mark: 25

Course Contents:
Systems of sets, measures on semirings, outer measures, measurable functions, simple and step functions, Lebesgue measure, convergence in measure, abstract measurability, upper functions, integrable functions, Riemann integral as a Lebesgue integral, applications of Lebesgue integral, approximating integrable functions, product measures, iterated integrals, L_p-spaces, signed measures, Radon-Nikodym theorem.

Textbooks/Reference Books:

1. Aliprantis, C. D. and Burkinshaw, O., *Principles of Real Analysis*, Academic Press, 1998.

2. Swartz C., *Measure, Integration and Function Spaces*, World Scientific, 1994.

Problems in Measure Theory and Integration I

Course Title: Problems in Measure Theory and Integration I	Credit Hour: 2
Course No.: Math 553a	Full Marks: 20
Nature of the Course: Theory	Pass Mark: 10

Course Contents:
Problems in Math 553, Measure Theory and Integration I, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Functional Analysis I

Course Title: Functional Analysis I — Credit Hours: 5
Course No.: Math 554 — Full Marks: 50
Nature of the Course: Theory — Pass Mark: 25

Course Contents:
Metric spaces, complete metric spaces, Banach fixed point theorem and its application to differential and integral equations; normed spaces, Banach spaces, finite dimensional normed spaces, subspaces and quotient spaces, completions, compactness and finite dimension; linear operators, bounded linear operators, linear operators and functionals on finite dimensional spaces, spaces of operators, duals; Zorn's lemma, Hahn-Banach theorem, Baire category theorem, open-mapping theorem, closed-graph theorem, uniform boundedness principle.

Textbooks/Reference Books:

1. Goffman, C. and Pedrick, G., *First Course in Functional Analysis*, Prentice Hall of India Pvt. Ltd., New Delhi.
2. Kreyszig, E., *Introductory Functional Analysis with Applications*, John Wiley & Sons, New York, 1978.

Problems in Functional Analysis I

Course Title: Problems in Functional Analysis I — Credit Hour: 2
Course No.: Math 554a — Full Marks: 20
Nature of the Course: Theory — Pass Mark: 10

Course Contents:
Problems in Math 554, Functional Analysis I, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Complex Analysis and Applications I

Course Title: Complex Analysis and Applications I — Credit Hours: 5
Course No.: Math 555 — Full Marks: 50
Nature of the Course: Theory — Pass Mark: 25

Course Contents:
Complex numbers, analytic functions, elementary functions, integrals, series, residues and poles.

Textbooks/Reference Books:

1. Brown, J. W. and Churchill, R. V., *Complex Variables and Applications* , Seventh Edition, McGraw-Hill, 2003.
2. Saff, E. B. and Snider, A. D., *Fundamentals of Complex Analysis*, Third Edition, Pearson Education Inc., 2003.

Problems in Complex Analysis and Applications I

Course Title: Problems in Complex Analysis and Applications I — Credit Hour: 2
Course No.: Math 555a — Full Marks: 20
Nature of the Course: Theory — Pass Mark: 10

Course Contents:
Problems in Math 555, Complex Analysis and Applications I, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Differential Equations

Course Title: Differential Equations	Credit Hours: 5
Course No.: Math 556	Full Marks: 50
Nature of the Course: Theory	Pass Mark: 25

Course Contents:
Introduction, second order linear equations, power series solutions and special functions, matrix methods, Laplace transforms, Fourier series, introduction to partial differential equations, numerical methods, systems of first order equations, nonlinear theory.

Textbooks/Reference Books:

1. Boyce, W. E. and DiPrima, R. C., *Elementary Differential Equations and Boundary Value Problems*, John Wiley & Sons, 2009.

2. Derric, W.R. and Grossman, S.I., *A First Course in Differential Equations with Applications*, CBS Publishers & Distributers, Delhi.

3. King, A.C., Billingham, J., and Otto, S.R., *Differential Equations: Linear, Nonlinear, Ordinary, Partial*, Cambridge University Press, Cambridge, 2003.

4. Simmons, G.F. and Krantz, S.G., *Differential Equations*, Tata McGraw-Hill, New Delhi, 2007.

Problems in Differential Equations

Course Title: Problems in Diferential Equations	Credit Hour: 2
Course No.: Math 556a	Full Marks: 20
Nature of the Course: Theory	Pass Mark: 10

Course Contents:
Problems in Math 556, Differential Equations, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Theory of Functions I

Course Title: Theory of Functions I	Credit Hours: 5
Course No.: Math 557	Full Marks: 50
Nature of the Course: Theory	Pass Mark: 25

Course Contents:
Power Series, analytic functions, analytic functions as mappings, Mobius transformation, R-S integrals, power series representation of analytic functions, zeros of analytic functions, index of closed curve, Cauchy's theorem and integral formula, homotopic version of Cauchy's theorem, simple onnectivity, counting zeros, open mapping theorem, Goursat's theorem, classification of singularities, residues, argument principle, maximum modulus theorem, Phragmen-Lindelöf theorem.

Textbooks/Reference Books:

1. Ahlfors, L.V., *Complex Analysis*, Third Edition, McGraw-Hill, 1979.

2. Conway, J.B., *Functions of One Complex Variable*, Narosa Publishing House, New Delhi, 1980.

Problems in Theory of Functions I

Course Title: Problems in Theory of Functions I	Credit Hour: 2
Course No.: Math 557a	Full Marks: 20
Nature of the Course: Theory	Pass Mark: 10

Course Contents:
Problems in Math 557, Theory of Functions I, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Theory of Functions II

Course Title: Theory of Functions II — Credit Hours: 5
Course No.: Math 558 — Full Marks: 50
Nature of the Course: Theory — Pass Mark: 25

Course Contents:
Space of continuous functions, spaces of analytic functions, spaces of meromorphic functions, Riemann mapping theorem, Weierstrass factorization theorem, factorization of sine function, Runge's theorem, simple connectedness, Mittag-Leffler's theorem, Schwarz reflection principle, analytic continuation along a path, monodromy theorem, basic properties of harmonic functions, harmonic functions on a disk, Jensen's formula, genus and order of an entire function.

Textbooks/Reference Books:

1. Ahlfors, L.V., *Complex Analysis*, Third Edition, McGraw-Hill, 1979.
2. Conway, J.B., *Functions of One Complex Variable*, Narosa Publishing House, New Delhi, 1980.

Problems in Theory of Functions II

Course Title: Problems in Theory of Functions II — Credit Hour: 2
Course No.: Math 558a — Full Marks: 20
Nature of the Course: Theory — Pass Mark: 10

Course Contents:
Problems in Math 558, Theory of Functions II, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Differential Geometry

Course Title: Differential Geometry | Credit Hours: 5
Course No.: Math 559 | Full Marks: 50
Nature of the Course: Theory | Pass Mark: 25

Course Contents:
Theory of space curves, local intrinsic properties of a surface, geodesics, second fundamental form, local non-intrinsic properties of a surface, envelopes and developables, fundamental equation of surface theory.

Textbooks/Reference Books:

1. Weatherburn, C.E., *Differential Geometry*, ELBS.
2. Willmore, T.J., *An Introduction to Differential Geometry*, Oxford University Press, Delhi.

Problems in Differential Geometry

Course Title: Problems in Differential Geometry | Credit Hour: 2
Course No.: Math 559a | Full Marks: 20
Nature of the Course: Theory | Pass Mark: 10

Course Contents:
Problems in Math 559, Differential Geometry, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Combinatorial Optimization

Course Title: Combinatorial Optimization	Credit Hours: 5
Course No.: Math 560	Full Marks: 50
Nature of the Course: Theory	Pass Mark: 25

Course Contents:
Simplex algorithm for linear programming, integer programming, network flow problems, complexity status, solution techniques of combinatorial optimization problems.

Textbooks/Reference Books:

1. Bertsimas, D. and Weismantel, R.,*Optimization over Integers*, Dynamic Ideas, Belmont, Massachusetts.
2. Papadimitriou, C.H. and Steiglitz, K., *Combinatorial Optimization: Algorithm and Complexity*, Prentice-Hall of India Pvt. Ltd.
3. Wolsey, L.A., *Integer Programming*, John Wiley & Sons.

Problems in Combinatorial Optimization

Course Title: Problems in Combinatorial Optimization	Credit Hour: 2
Course No.: Math 560a	Full Marks: 20
Nature of the Course: Theory	Pass Mark: 10

Course Contents:
Problems in Math 560, Combinatorial Optimization, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Mathematical Programming

Course Title: Mathematical Programming | Credit Hours: 5
Course No.: Math 561 | Full Marks: 50
Nature of the Course: Theory | Pass Mark: 25

Course Contents:
Linear programming (briefly), analytical and numerical approach to convex and nonlinear optimization problems, modeling and application of optimization techniques to real-life problems.

Textbooks/Reference Books:

1. Bazara, M.S., Sherali, H.D., and Shetty, C.M.,*Nonlinear Programming*, John Wiley & Sons.
2. Bertsimas, D. and Weismantel, R.,*Optimization over Integers*, Dynamic Ideas, Belmont, Massachusetts.
3. Luenberger, D.G., *Linear and Nonlinear Programming*, Addison-Wesley, 1984.

Problems in Mathematical Programming

Course Title: Problems in Mathematical Programming | Credit Hour: 2
Course No.: Math 561a | Full Marks: 20
Nature of the Course: Theory | Pass Mark: 10

Course Contents:
Problems in Math 561, Mathematical Programming, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Mathematical Analysis I

Course Title:	Credit Hours: 5
Course No.: Math 562	Full Marks: 50
Nature of the Course: Theory	Pass Mark: 25

Course Contents:
To be fixed later.

Textbooks/Reference Books:

Problems in Mathematical Analysis I

Course Title: Problems in Mathematical Analysis I	Credit Hour: 2
Course No.: Math 562a	Full Marks: 20
Nature of the Course: Theory	Pass Mark: 10

Course Contents:
Problems in Math 562, Mathematical Analysis I, normally form the contents of this problem solving course. However, this course may be offered independent of Math 562, and even when Math 562 itself is not offered. In this case, it will be based on some topics in analysis selected by the department and/or the instructor and may vary from one semester to another.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Elementary Harmonic Analysis

Course Title: Elementary Harmonic Analysis — Credit Hours: 5
Course No.: Math 564 — Full Marks: 50
Nature of the Course: Theory — Pass Mark: 25

Course Contents:
Definition, examples and elementary properties of commutative Banach algebra, maximal ideals and multiplicative linear functional, *-algebras, symmetric *-algebra, C^*-algebras, commutative C^*-algebras and functional calculus in C^*-algebras, definition and examples of topological group, subgroups, quotient groups, connected groups and homogeneous space, Haar integral, left and right translate, left and right invariant Haar measure and examples on Haar measures and integrals, some simple matrix groups, modular function, convolution with special emphasis on $L^1(\mathbb{R})$, $L^1(\mathbb{T})$, and $L^1(\mathbb{Z})$; approximate identity, character of a group and dual group, characters and dual of $\mathbb{R}$, $\mathbb{T}$, and $\mathbb{Z}$.

Textbooks/Reference Books:

1. Fell, J. M. G. and Doron, R. S., *Representation of *-Algebras, Locally Compact Groups and Banach *-Algebriac Bundles*, Academic Press, Inc., Harcourt Brace Jovanvich Publisher, 1988.

2. Hewitt, E. and Ross, K. A., *Abstract Harmonic Analysis I and II*, Springer-Verlag, 1963 and 1970.

3. Katznelson, Y., *An Introduction to Harmonic Analysis*, Dover Publications, Inc., New York, 1968.

Problems in Elementary Harmonic Analysis I

Course Title: Problems in Elementary Harmonic Analysis I — Credit Hour: 2
Course No.: Math 564a — Full Marks: 20
Nature of the Course: Theory — Pass Mark: 10

Course Contents:
Problems in Math 564, Elementary Harmonic Analysis I, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Algebra I

Course Title: Algebra I	Credit Hours: 5
Course No.: Math 565	Full Marks: 50
Nature of the Course: Theory	Pass Mark: 25

Course Contents:
Review of group, subgroup, cyclic group, permutation group, cosets, normal subgroup, quotient group, centre, homomorphism, isomorphism, normalizer, Cayley's theorem, conjugacy, alternating group, quaternion group, Klein's four group, dihedral group, commutator group. action of a group on a set, class equation, Cauchy's Theorem, Sylow's Theorems, application of Sylow's Theorems; free group, free abelian group, finitely generated abelian group; review of basic concept of rings, subring and ideal, polynomial ring, primitive polynomial, Gauss lemma, Eisenstein criterion, polynomial rings over commutative rings, rings of quotient and localization, Chinese remainder theorem; modules, submodules, quotient modules, homomorphism and exact sequence of module homomorphism, short exact sequence, split exact sequence.

Textbooks/Reference Books:

1. Dummit, D.S. and Foote, R.M., *Abstract Algebra*,John Wiley & Sons, 1999.
2. Herstein, I.N., *Topics in Algebra*,Vikas Publishing House Pvt. Ltd., India.
3. Hungerford, T.W., *Algebra*, Springer-Verlag, New York, 1974.

Problems in Algebra I

Course Title: Problems in Algebra I	Credit Hour: 2
Course No.: Math 565a	Full Marks: 20
Nature of the Course: Theory	Pass Mark: 10

Course Contents:
Problems in Math 565, Algebra I, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Algebra II

Course Title: Algebra II | Credit Hours: 5
Course No.: Math 566 | Full Marks: 50
Nature of the Course: Theory | Pass Mark: 25

Course Contents:
Nilpotent and solvable groups, subnormal series, Zassenhaus lemma, ascending chain condition, Noetherian rings, descending chain condition, Artinian rings, free modules, projective and injective modules, field extensions, minimal polynomial, fundamental theorem of Galois theory, splitting field, algebraic closure and normality, Galois group of polynomials, finite fields, separability, cyclic extension, spectral theorem, unitary operators, Jordan normal form, tensor product, isomorphism of tensor products, alternating product.

Textbooks/Reference Books:

1. Dummit, D.S. and Foote, R.M.,*Abstract Algebra*, Second Edition, John Wiley & Sons, 1999.

2. Hungerford, T.W., *Algebra*, Springer-Verlag, New York, 1974.

3. Lang, S. , *Linear Algebra*, Addison-Wesley Publishing Company.

Problems in Algebra II

Course Title: Problems in Algebra II | Credit Hour: 2
Course No.: Math 566a | Full Marks: 20
Nature of the Course: Theory | Pass Mark: 10

Course Contents:
Problems in Math 566, Algebra II, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Linear Algebra

Course Title: Linear Algebra	Credit Hours: 5
Course No.: Math 567	Full Marks: 50
Nature of the Course: Theory	Pass Mark: 25

Course Contents:
Vector spaces, subspaces, basis and dimension, direct sum, Gauss elimination, pivots, block matrices, linear transformations and matrices, similarity, dual spaces, annihilation, elementary row operations, determinants, diagonalization, T-invariant subspaces, T-cyclic subspaces, inner product and positive definite matrices, minimal polynomial, nilpotent operators, Jordan and rational canonical forms, primary decomposition theorem.

Textbooks/Reference Books:

1. Friedberg, S. H., Insel, A. J., and Spence, L. E., *Linear Algebra*, Fourth Edition, PHI Learning Pvt. Ltd., New Delhi, 2010.
2. Hoffman, K. and Kunze, R., *Linear Algebra*, Second Edition, Prentice Hall of India Pvt. Ltd., New Delhi, 1986.

Problems in Linear Algebra

Course Title: Problems in Linear Algebra	Credit Hour: 2
Course No.: Math 567a	Full Marks: 20
Nature of the Course: Theory	Pass Mark: 10

Course Contents:
Problems in Math 567, Linear Algebra, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Theory of Numbers I

Course Title: Theory of Numbers I
Course No.: Math 570
Nature of the Course: Theory

Credit Hours: 5
Full Marks: 50
Pass Mark: 25

Course Contents:
Divisibility, primes, congruences, solutions of congruences, the Chinese remainder theorem, quadratic reciprocity and quadratic forms, quadratic residues, quadratic reciprocity, Jacobi symbol, some functions of number theory, greatest integer function, arithmetic functions, Mobius inversion functions, some Diophantine equations, the equation ax +by = c, simultaneous linear equations, simple continued fractions, the Euclidean algorithm, uniqueness, infinite continued fractions, irrational numbers, approximations to irrational numbers, best possible approximations.

Textbooks/Reference Books:

1. Niven Ivan,Zuckerman, Herbert S., and Montgomery, Hugh L.,*An Introduction to the Theory of Numbers*, Fifth Edition, Wiley India, 2010.

Problems in Theory of Numbers I

Course Title: Problems in Theory of Numbers I
Course No.: Math 570a
Nature of the Course: Theory

Credit Hour: 2
Full Marks: 20
Pass Mark: 10

Course Contents:
Problems in Math 570, Theory of Numbers I, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Mechanics

Course Title: Mechanics | Credit Hours: 5
Course No.: Math 571 | Full Marks: 50
Nature of the Course: Theory | Pass Mark: 25

Course Contents:
Statics
Forces in three dimensions: Systems of forces in three dimensions, principle of virtual work in three dimensions, Poinsot's central axis and wrenches.
Dynamics
D'Alembert's principle and motion in two dimensions: D'Alembert's principle and equation of motion, motion in two dimensions under finite forces including sliding and rolling friction.
Hydrodynamics
Kinematics of fluid: Lagrangian and Eulerian methods, equation of continuity, boundary surfaces, stream lines and velocity potential.
Equation of motion: Equation of motion for ideal fluid and their integrals.
Motion in two dimensions: Irrotational motion in two dimensions, sources, sinks, doublets, images in two dimensions.

Textbooks/Reference Books:

1. Loney, S.L., *An Elementary Treatise in Statics*, Cambridge University Press.

2. Loney, S.L., *An Elementary Treatise on the Dynamics of a Particle and of Rigid Bodies*, Cambridge University Press.

3. Ramsey, A.S., *Dynamics Vol. II*, Cambridge University Press.

4. Ramsey, A.S., *Hydrodynamics*, CBS Publishers & Distributors, Delhi.

Problems in Mechanics

Course Title: Problems in Mechanics | Credit Hour: 2
Course No.: Math 571a | Full Marks: 20
Nature of the Course: Theory | Pass Mark: 10

Course Contents:
Problems in Math 571, Mechanics, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Functional analysis II

Course Title: Functional analysis II — Credit Hours: 5
Course No.: Math 572 — Full Marks: 50
Nature of the Course: Theory — Pass Mark: 25

Course Contents:
Orthonormal sets and sequences, representation of functional on Hilbert spaces, Hilbert-adjoint operator, self-adjoint operator, unitary and normal operators, Zorn's lemma, Hahn-Banach theorem and its application to bounded linear functional on $C[a, b]$, adjoint operators, reflexive spaces, Baire category theorem, uniform boundedness theorem, strong and weak convergences, convergence of sequences of operators and functionals, open mapping theorem, closed graph theorem, Banach fixed point theorem, spectral theory in finite dimensional normed spaces, spectral properties of bounded linear operators, use of complex analysis in spectral theory, Banach algebras.

Textbooks/Reference Books:

1. Arnold, D. N., *Functional Analysis*, www.ima.umn.edu/~arnold/502.s97/functional.pdf

2. Kreyszig, E., *Introductory Functional Analysis with Applications*, John Wiley & Sons, New York, 1978.

3. Sylvia, S., *Functional Analysis Notes*, www.math.nyu.edu/~vilensky/Functional_Analysis.pdf

4. Teschl, G., *Topics in Real and Functional Analysis*, www.mat.univie.ac.at/~gerald/ftp/book-fa/fa.pdf

5. Ward, T.B., *Functional Analysis Lecture Notes*, www.uea.ac.uk/~h720/teaching/functionalanalysis/materials/FAnotes.pdf

Problems in Functional Analysis II

Course Title: Problems in Functional Analysis II — Credit Hour: 2
Course No.: Math 572a — Full Marks: 20
Nature of the Course: Theory — Pass Mark: 10

Course Contents:
Problems in Math 572, Functional Analysis II, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Harmonic Analysis

Course Title: Harmonic Analysis	Credit Hours: 5
Course No.: Math 573	Full Marks: 50
Nature of the Course: Theory	Pass Mark: 25

Course Contents:
Fourier series and integrals, Fejer's kernel, Poisson's kernel, homogeneous space for T, Riemann Lebesgue lemma, inequality of Hausdorff and Young, Fourier transform and its properties; Introduction to representation theory, star representation, unitary representation, positive functional, extendable positive functional, conjugation on Hilbert space, positive definite functions; Complex Borel measure on G, Fourier transform on $M(G)$, involution in $(C_0(G))^*$, weak and weak* topology, Krein-Millman theorem, left regular representation, Gelfond-Raikov theorem, L_2 and L_p transforms.

Textbooks/Reference Books:

1. Hewitt, E. and Ross, K.A., *Abstract Harmonic Analysis I and II*, Springer-Verlag, 1963 and 1970.

2. Katznelson, Y., *An Introduction to Harmonic Analysis*, Dover Publications, Inc., New York, 1968.

Problems in Harmonic Analysis

Course Title: Problems in Harmonic Analysis	Credit Hour: 2
Course No.: Math 573a	Full Marks: 20
Nature of the Course: Theory	Pass Mark: 10

Course Contents:
Problems in Math 573, Harmonic Analysis, form the contents of this problem solving course.

Examination:
The course will have 100% of marks allocated for internal assessments. There will be no final examination.

Special Functions I

Course Title: Special Functions I	Credit Hours: 5
Course No.: Math 574	Full Marks: 50
Nature of the Course: Theory	Pass Mark: 25

Course Contents:
Gamma and Beta Functions: Euler's product, integral representation, difference equation, factorial functions, Legendre's duplication formula, Beta function, various properties and relations, asymptotic series and its relations.
Hypergeometric Functions: Hypergeometric functions, integral representation, contiguous function relations, differential equations, elementary series manipulation, transformation and Properties.
Generalized Hypergeometric Function and Confluent Hypergeometric Function: Generalized hypergeometric function, contiguous function relations, confluent hypergeometric functions and relations, Kummer's first and second formulae.
Bessel Function: Bessel function, recurrence relations, generating functions, Bessel integral, modified Bessel function, Neumann polynomial and series.

Textbooks/Reference Books:

1. Askey R., *Orthogonal Polynomials and Special Functions*, Soc. Industr. Appl. Math, Philadelphia, Pennsylvania, 1975.
2. Carlson, B.C., *Special Functions of Applied Mathematics*, Academic Press, New York, 1978.
3. Rainville, E.D. , *Special Functions*, Chelsea Publishing Company, New York, 1960.
4. Talman, J. and Benjamin, W.A., *Special Functions*, INC New York, 1968.

Problems in Special Functions I

Course Title: Problems in Special Functions I	Credit Hour: 2
Course No.: Math 574a	Full Marks: 20
Nature of the Course: Theory	Pass Mark: 10

Course Contents:
Problems in Math 574, Special Fuinctions I, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Special Functions II

Course Title: Special Functions II	Credit Hours: 5
Course No.: Math 575	Full Marks: 50
Nature of the Course: Theory	Pass Mark: 25

Course Contents:

Concept of Generating Functions and Legendre Polynomials: Generating functions of the form $G(2xt-t^2)$, $e^t\psi(xt)$, $A(t)\exp\left(\frac{-xt}{1-t}\right)$ and orthogonality, Legendre polynomials, recurrence and differential equation, Rodrigues formula, hypergeometric form, Laplace integral form and generating functions, orthogonal properties.
Hermite Polynomials: Hermite polynomials, recurrence relations, Rodrigues formula, orthogonal property, generating functions.
Laguerre Polynomials: Laguerre polynomials, Rodrigues formula, orthogonality, recurrence relations, generating functions.
Jacobi, Ultraspherical, and Gegenbauer Polynomials: Jacobi polynomial, Rodrigues formula, recurrence relation, orthogonal property, ultraspherical and Gegenbauer polynomials, properties and relations.

Textbooks/Reference Books:

1. Askey R., *Orthogonal Polynomials and Special Functions*, Soc. Industr. Appl. Math, Philadelphia, Pennsylvania, 1975.

2. Carlson, B.C., *Special Functions of Applied Mathematics*, Academic Press, New York, 1978.

3. Rainville, E.D. , *Special Functions*, Chelsea Publishing Company, New York, 1960.

4. Szegö, G., *Orthogonal Polynomials*, Amer. Math. Soc. Colloq. Pub., vol. 23, 1975.

Problems in Special Functions II

Course Title: Problems in Special Functions II	Credit Hour: 2
Course No.: Math 575a	Full Marks: 20
Nature of the Course: Theory	Pass Mark: 10

Course Contents:

Problems in Math 575, Special Functions II, form the contents of this problem solving course.

Examination:

The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Partial Differential Equations I

Course Title: Partial Differential Equations I	Credit Hours: 5
Course No.: Math 576	Full Marks: 50
Nature of the Course: Theory	Pass Mark: 25

Course Contents:
Dimensional analysis, scaling, asymptotics, regular perturbation method, singular perturbation method, introduction to partial differential equations(PDEs), method of solving PDEs, classification of second order PDEs., parabolic equations, diffusion type problem, hyperbolic equations, wave propagation in continuous systems, method of characteristic for linear and nonlinear waves, quasi-linear equations, derivation of Laplace equation, Dirichlet problem for a rectangle, Neumann problem for a rectangle, Laplace equation, sum solving PDEs by Laplace and Fourier transform method.

Textbooks/Reference Books:

1. Logan, J. D., *Applied Mathematics*, John Wiley and & Sons.
2. Rao, K.S., *Introduction to Partial Differential Equations*, Prentice Hall of India.
3. Sneddon, I.N., *Elements of Partial Equations*, McGraw-Hill.

Problems in Partial Differential Equations I

Course Title: Problems in Partial Differential Equations I	Credit Hour: 2
Course No.: Math 576a	Full Marks: 20
Nature of the Course: Theory	Pass Mark: 10

Course Contents:
Problems in Math 576, Partial Differential Equations I, form the contents of this problem solving course.

Examination:
The course will have 100% of marks allocated for internal assessments. There will be no final examination.

Integral Transforms I

Course Title: Integral Transforms I	Credit Hours: 5
Course No.: Math 577	Full Marks: 50
Nature of the Course: Theory	Pass Mark: 25

Course Contents:
Introduction of integral transform, Fourier kernel, Fourier integral theorem, Fourier transform and its properties, convolution, Fourier sine and cosine transform and their properties, related problems; introduction of Mellin transform and its properties, Weyl fractional integral of Mellin transform, inversion theorem for Mellin transform and related problems; introduction of Hankel transform and its elementary properties, inversion theorem and Parseval relation for Hankel transform and related problems; introduction of Laplace transform, region of convergence, absolute and uniform convergence, complex inversion formula for Laplace transform, summability of divergent integral and related problems; Abelian theorems and Tauberian theorems for Laplace transform, iteration of Laplace transform and related problems. introduction of Z-transform and its properties, convolution, Parseval's relation, differentiation property, initial and final value theorems and related problems; introduction of wavelet transform, continuous wavelet, Parseval's relation for wavelet transform, inversion formula and related problems.

Textbooks/Reference Books:

1. Devnath, L. and Bhatta, D., *Integral Transforms and Their Application*, Chapman and Hall, India, 2010.
2. Snedden, I.N., *The Use of Integral Transform*, McGraw-Hill Book Co., N.Y., 1974.
3. Snedden, I.N., *Fourier Transform*, McGraw-Hill Book Co., N.Y., 1951.
4. Widder, D.V., *Laplace Transform*, Princeton University Press 1946.

Problems in Integral Transforms I

Course Title: Problems in Integral Transforms I	Credit Hour: 2
Course No.: Math 577a	Full Marks: 20
Nature of the Course: Theory	Pass Mark: 10

Course Contents:
Problems in Math 577, Integral Transforms I, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Measure Theory and Integration II

Course Title: Measure Theory and Integration II	Credit Hours: 5
Course No.: Math 578	Full Marks: 50
Nature of the Course: Theory	Pass Mark: 25

Course Contents:
Differentiation and Integration: Differentiation of monotone functions, functions of bounded variation,differentiation of integral.
General Measure Spaces: Measure and measurable sets, the Hann and Jordan decomposition, the Caratheodory measure induced by outer measure, the construction of outer measure, the Carathedory-Hahn theorem.
Integration over General Measure Spaces: Integration of general measurable functions, the Radon- Nikodym theorem, the Nikodym metric space.
General L^p Spaces: Completeness, duality, and weak convergence, the completeness of $L^p(X, \mu)$, $1 \leq p \leq \infty$, the Riesz representation theorem, the Kantorovitch repretation theorem for the dual of L^∞ (X, μ), weak sequential compactness, the Dunford- Pettis theorem.

Textbooks/Reference Books:

1. Royden, H. L. and Fitzpatrick, P.M., *Real Analysis*, Fourth Edition, Prientice Hall of India.

2. Rudin, Walter, *Real and Complex Analysis*, Third Edition, McGraw Hill international.

Problems in Measure Theory and Integration II

Course Title: Problems in Measure Theory and Integration II	Credit Hour: 2
Course No.: Math 578a	Full Marks: 20
Nature of the Course: Theory	Pass Mark: 10

Course Contents:
Problems in Math 578, Measure Theory and Integration II, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Scheduling Theory

Course Title: Scheduling Theory — Credit Hours: 5
Course No.: Math 579 — Full Marks: 50
Nature of the Course: Theory — Pass Mark: 25

Course Contents:
Problem classification, complexity status, disjunctive graph and block matrices models, single machine, parallel machine and shop scheduling problems. The course covers the mathematical modeling, solution techniques and complexity analysis of deterministic dedicated and parallel processors easy and hard scheduling problems.

Textbooks/Reference Books:

1. Brucker, P., *Scheduling Algorithms*, Springer-Verlag.
2. Blazewicz, J., Ecker, K.H., Pesch, E., Schmidt, G., and Weglarz, J., *Scheduling Computer and Manufacturing Processes*, Springer-Verlag.
3. Brucker, P. and Knust, S., *Complex Scheduling*, Springer-Verlag.

Problems in Scheduling Theory

Course Title: Problems in Scheduling Theory — Credit Hour: 2
Course No.: Math 579a — Full Marks: 20
Nature of the Course: Theory — Pass Mark: 10

Course Contents:
Problems in Math 579, Scheduling Theory, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Integer Programming

Course Title: Integer Programming | Credit Hours: 5
Course No.: Math 580 | Full Marks: 50
Nature of the Course: Theory | Pass Mark: 25

Course Contents:
Problem formulations, duality and relaxations in integer programming, cutting plane algorithms, well-solved problems, exact, heuristic and approximation methods, algebraic geometric method and geometry in integer programming. The course covers the mathematical modeling, solution techniques and complexity analysis of selected optimization problems over integers.

Textbooks/Reference Books:

1. Bertsimas, D. and Weismantel, R., *Optimization over Integers*, Dynamic Ideas, Belmont, Massachusetts, 2005.

2. Wolsey, L.A., *Integer Programming*, John Wiley & Sons, 1998.

Problems in Integer Programming

Course Title: Problems in Integer Programming | Credit Hour: 2
Course No.: Math 580a | Full Marks: 20
Nature of the Course: Theory | Pass Mark: 10

Course Contents:
Problems in Math 580, Integer Programming, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Network Optimization

Course Title: Network Optimization — Credit Hours: 5
Course No.: Math 581 — Full Marks: 50
Nature of the Course: Theory — Pass Mark: 25

Course Contents:
Static and dynamic networking designs, algorithms and their efficiency in flow, matching, transportation, assignment, spanning tree, routing, and location. The course covers the exact and approximation algorithms, solution techniques, and applicability of selected network flow optimization problems.

Textbooks/Reference Books:

1. Bertsimas, D., *Network Optimization: Continuous and Discrete Models*, Athena Scientific, Belmont, Massachusetts.
2. Bertsimas, D. and Weismantel, R., *Optimization over Integers*, Dynamic Ideas, Belmont, Massachusetts, 2005.
3. Hamacher, H.W. and Klamroth, K., *Linear and Network Optimization Problems*, Vieweg Verlag.
4. Papadimitriou, C.H. and Steiglitz, K., *Combinatorial Optimization: Algorithm and Complexity*, Prentice-Hall of India Pvt. Ltd.

Problems in Network Optimization

Course Title: Problems in Network Optimization — Credit Hour: 2
Course No.: Math 581a — Full Marks: 20
Nature of the Course: Theory — Pass Mark: 10

Course Contents:
Problems in Math 581, Network Optimization, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Graph Theory

Course Title: Graph Theory	Credit Hours: 5
Course No.: Math 582	Full Marks: 50
Nature of the Course: Theory	Pass Mark: 25

Course Contents:
This course aims to build graph theoretical foundations, design and analysis of algorithms and applicability of graphs in solving real-life problems. It includes classes of graphs, connectivity, paths and cycles, Hamiltonian properties, graph colorings, flows in networks, algebraic properties, recognization problems and comparability graphs.

Textbooks/Reference Books:

1. Bang-Jensen, J., *Digraphs*, Springer-Verlag.
2. Golumbic, M.C., *Algorithmic Graph Theory and Perfect Graphs*, Elsevier.

Problems in Graph Theory

Course Title: Problems in Graph Theory	Credit Hour: 2
Course No.: Math 582a	Full Marks: 20
Nature of the Course: Theory	Pass Mark: 10

Course Contents:
Problems in Math 582, Graph Theory, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Numerical Analysis

Course Title: Numerical Analysis	Credit Hours: 5
Course No.: Math 583	Full Marks: 50
Nature of the Course: Theory	Pass Mark: 25

Course Contents:
Binary numbers, error analysis, solutions of equations in one variable, interpolation and polynomial approximation, numerical differentiation and integration, one-step methods for solving ODE's IVP, solving linear systems, curve fitting, iterative techniques in matrix algebra, eigenvalues and eigenvectors, numerical solutions of nonlinear systems of equations, boundary value problems.

Textbooks/Reference Books:

1. Atkinson, K. E., *An Introduction to Numerical Analysis*, Second Edition, John Wiley & Sons, 1988.
2. Burden, R. L. and Faires, J. D., *Numerical Analysis, Theory and Techniques*, Cengage Learning, India Edition, 2010.
3. Mathews, J. H., *Numerical Methods for Mathematics, Science, and Engineering*, Second Edition, Eastern Economy Edition, 2001.
4. Stoer, J. and Bulirsch, R., *Introduction to Numerical Analysis*, Second Edition, Springer-Verlag, 1993.

Problems in Numerical Analysis

Course Title: Problems in Numerical Analysis	Credit Hour: 2
Course No.: Math 583a	Full Marks: 20
Nature of the Course: Theory	Pass Mark: 10

Course Contents:
Problems in Math 583, Numerical Analysis, form the contents of this problem solving course.

Examination:
The course will have 100% of marks allocated for internal assessments. There will be no final examination.

Numerical Optimization

Course Title: Numerical Optimization — Credit Hours: 5
Course No.: Math 584 — Full Marks: 50
Nature of the Course: Theory — Pass Mark: 25

Course Objectives:
This course is about numerical optimization designed for Masters Degree students. This course on numerical optimization deals with numerical solutions of different nonlinear optimization problems, that may be constrained or unconstrained. The course covers the numerical solution techniques, the descent, Newton's, quasi-Newton's and trust region methods in continuous optimization problems. After the completion of this course, the students will be able to tackle the computationally hard as well as tractable continuous optimization problems.

Course Contents: Unconstrained continuous optimization: Mathematical formulations, necessary and sufficient optimality conditions of unconstrained problem, overview of algorithms, scaling, rate of convergence, selected line search and trust-region methods.

Conjugate gradient method. The linear conjugate gradient method, conjugate direction method, basic properties and practical form of the methods, nonlinear conjugate gradient methods.

Newton methods. Inexact steps, line search Network and Newton-CG method, modifications, trust-region Newton and Newton-CG methods, calculation of derivatives.

Quasi-Newton method and separable optimization. Properties and classes of the method, algorithms, convergence analysis, large scale quasi-Newton method, relation to conjugate gradient methods, partially separable optimization, algorithms.

Constrained optimization. Problem formulations, local and global solutions, first and second optimality conditions, constraint qualifications, geometry, algorithms for nonlinear constrained problems.

Textbooks/Reference Books:

1. Jorge and Nocedal Stephen J. Wright, *Numerical Optimization*, Springer.

2. Bazara, M.S., Sherali, H. D., and Shetty, C. M. *Nonlinear Programming*: *Theory and Algorithms*, 3rd Edition, John Wiley & Sons, 2006.

Dynamics of Viscous Fluids

Course Title: Dynamics of Viscous Fluids — Credit Hours: 5
Course No.: Math 586 — Full Marks: 50
Nature of the Course: Theory — Pass Mark: 25

Course Contents:
The Equations of Motion:
Euler's equations, rotation and vorticity, The Navier-Stokes equations.
Potential Flow and Slightly Viscous Flow:
Potential flow, boundary layers, vortex sheets, remarks on stability and bifurcation.
Gas Flow in One Dimension:
Characteristics, shocks, The Riemann problem, combustion waves.

Textbooks/Reference Books:

1. Chorin Alexandre J., *A Mathematical Introduction to Fluid Mechanics*, Third edition, Springer, 1992.
2. Acheson D. J., *Elementary Fluid Dynamics*, Oxford 1990.
3. Tsutomu Kambe, *Elementary Fluid Mechanics*, World Scientific Publishing Co. Pte. Ltd. Singapore.
4. Clement Kleinstreuer, *Modern Fluid Dynamics*, Springer, 2010.

Partial Differential Equations II

Course Title: Partial Differential Equations II | Credit Hours: 5
Course No.: Math 587 | Full Marks: 50
Nature of the Course: Theory | Pass Mark: 25

Course Contents:
Nonlinear first order partial differential equations (conservation equations), traffic flow problem, second order partial differential equations, adjoint operators, Riemann's method, polar forms of the equations, nonhomogeneous diffusion equations, calculus of variations method, stability for linear and nonlinear systems, solution of some differential equations and boundary value problems using Maple.

Textbooks/Reference Books:

1. Artocolo, G. A., *Partial Differential Equations and Boundary Value Problems with MAPLE*, Second Edition, Academic Press, 2010.

2. Farlow, S. J., *Partial Differential Equations*, Dover Publications Inc., New York, 1993.

3. Logan, J. D., *Applied Mathematics*, John Wiley and Sons, New York, 1987.

4. Rao, K. S., *Introduction to Partial Differential Equations*, Prentice-Hall of India, New Delhi, 1997.

5. Simmons, G. F. and Krantz, S. G., *Differential Equations*, Tata McGraw-Hill, New Delhi, 2007.

Problems in Partial Differential Equations II

Course Title: Problems in Partial Differential Equations II | Credit Hour: 2
Course No.: Math 587a | Full Marks: 20
Nature of the Course: Theory | Pass Mark: 10

Course Contents:
Problems in Math 587, Partial Differential Equations II, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Introduction to C Programming

Course Title: Introduction to C Programming	Credit Hours: 3
Course No.: Math 588	Full Marks: 30
Nature of the Course: Theory and Practical	Pass Mark: 15

Course Contents:
Types, operators, expressions, control flow, functions, program structure.

Textbooks/Reference Books:

1. Kernighan, B. W. and Ritchie, D. M., *The C Programming Language*, Second Edition, Prentice-Hall of India, New-Delhi, 1993.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Seminar

Course Title: Seminar	Credit Hours: 2
Course No.: Math 589	Full Marks: 20
Nature of the Course: Theory	Pass Mark: 10

Course Contents:
Up to two seminars on different topics and with a maximum of four credit hours may be offered. So Math 589 can be repeated just once for credit.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Integral Transforms II

Course Title: Integral Transforms II	Credit Hours: 5
Course No.: Math 591	Full Marks: 50
Nature of the Course: Theory	Pass Mark: 25

Course Contents:
Bilateral Laplace Transform: Normalized function $\alpha(t)$, region of convergence, integration by parts, abscissa of convergence, inversion formulas, uniqueness formula and related problems.
Stieltjes Transform: Elementary properties, relation with Laplace transform, a singular integral, inversion operator formula for Stieltjes transform, application of Stieltjes transform to PDE and ODE.
Finite Fourier Transform: Finite Fourier sine and cosine transforms and their inversion formula, convolution theorem for finite Fourier sine and cosine transform, application of finite Fourier sine and cosine transform to PDE and ODE.
Wavelet Transform: Continuous wavelet, continuous-time wavelet, inversion theorem for continuous wavelet transform and related problems.

Textbooks/Reference Books:

1. Devnath, L. and Bhatta, D., *Integral Transforms and Their Application*, Chapman and Hall, India, 2010.
2. Rao, R. M. and Bopardikar, A. S., *Wavelet Transforms*, Addision-Wesley, 2000.
3. Snedden, I.N., *The Use of Integral Transform*, McGraw-Hill Book Co., N.Y., 1974.
4. Widder, D.V., *Laplace Transform*, Princeton University Press 1946.

Problems in Integral Transforms II

Course Title: Problems in Integral Transforms II	Credit Hour: 2
Course No.: Math 591a	Full Marks: 20
Nature of the Course: Theory	Pass Mark: 10

Course Contents:
Problems in Math 591, Integral Transforms II, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Complex Analysis and Applications II

Course Title: Complex Analysis and Applications II — Credit Hours: 5
Course No.: Math 592 — Full Marks: 50
Nature of the Course: Theory — Pass Mark: 25

Course Contents:
Mapping by elementary functions,preseavation of angles, harmonic conjugates, transformation of harmonic functions, mapping the real axis onto a polygon, The Schwarz-Christoffel transformation, triangles and rectangles and degenerate polygons, Poisson and Schwarz integral formula, Dirichlet and Neumann problem for disk and a half plane, related boundary value problems, analytical continuation, principle of reflection, removable and essential singularities, argument principle, Riemann surface for $\log z$, a surface of $\sqrt{z}$, surface for related functions

Textbooks/Reference Books:

1. Brown, J. W. and Churchill, R.V., *Complex Variables and Application*, Seventh Edition, McGraw- Hill, 2003.

Problems in Complex Analysis and Applications II

Course Title: Problems in Complex Analysis and Applications II — Credit Hour: 2
Course No.: Math 592a — Full Marks: 20
Nature of the Course: Theory — Pass Mark: 10

Course Contents:
Problems in Math 592,Complex Analysis and Applications II, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Theory of Numbers II

Course Title: Theory of Numbers II | Credit Hours: 5
Course No.: Math 593 | Full Marks: 50
Nature of the Course: Theory | Pass Mark: 25

Course Contents:
Farey fraction and irrational numbers, the Euclidean algorithm, uniqueness, infinite continued fractions, approximation to irrational numbers, best possible approximation, periodic continued fractions, Pell's equations, elementary prime number estimates,Dirichlet series, algebraic numbers, quadratic fields, units and primes in quadratic fields, unique factorization and primes in quadratic fields having the factorizations properties.
Textbooks/Reference Books:

1. Niven Ivan,Zuckerman, Herbert S., and Montgomery, Hugh L.,*An Introduction to the Theory of Numbers*, Fifth Edition, Wiley India, 2010.

Problems in Theory of Numbers II

Course Title: Problems in Theory of Numbers II | Credit Hour: 2
Course No.: Math 593a | Full Marks: 20
Nature of the Course: Theory | Pass Mark: 10

Course Contents:
Problems in Math 593, Theory of Numbers II, form the contents of this problem solving course.

Examination:
The course will have 100% of marks alloted for internal assessments. There will be no final examination.

Scientific Computing

Course Title: Scientific Computing | Credit Hours: 5
Course No.: Math 594 | Full Marks: 50
Nature of the Course: Theory, Problems, and Practical | Pass Mark: 25

Course Contents:
Introduction to Computer Programming, Numerical linear algebra, Numerical integration, Numerical solutions initial value problem(Ordinary differential equations ODE), Finite difference method(FDM), NUmerical solutions of partial differential equations(PDE), Finite element method(FDM), Solutions of PDE by FEM.

Textbooks/Reference Books:

1. Yang WY, Cao W, Chung, and T-S Morris J., *Numerical methods using MATLAB*,A John Wiley and Sons, Inc, 2005.

2. Thomas JW, *Numerical partial differential equations: Finite difference methods*, Springer, New York, 1998.

3. Reddy J. N., *An introduction to the finite element method*, Second edition, Mc Graw- Hill, New York, 1993.

4. Evans G. A., Blackledge J., and Yardley P., *Numerical methods for partial differential equations*, Springer Berlin Heidelberg, 1999.

5. Burden R. L., and Faires J.D., *Numerical analysis*, Ninth edition, Cengage Learning, 2011.

Examination:
There will be a final examination of the theory of 15 marks for the period of one hour. However practical examination of 15 marks for the period of one hour will be conducted by the Department of Mathematics and the marks will be submitted to office of the examination section, Dean IOST. The candidate must pass in theory and practical separately.

Analysis of Finite Difference Schemes

Course Title: Analysis of Finite Difference Schemes — Credit Hour: 5
Course No.: Math 595 — Full Marks: 50
Nature of the Course: Theory — Pass Mark: 25

Course Contents:
Hyperbolic PDE (partial differential equation), analysis of finite difference schemes, order of accuracy of finite difference schemes, stability of multistep schemes, dissipation and dispersion, parabolic PDEs, second order equations and systems of PDEs in higher dimensions, convergence estimates for IVPs (initial value problems), elliptic PDEs and difference schemes, linear iterative methods.
Textbooks/Reference Books :

1. Strikwerda John C., *Finite Difference Schemes and PDEs*, Second Edition, (Society for Industrial and Applied Mathematics).

Introduction to Commutative Algebra

Course Title: Introduction to Commutative Algebra	Credit Hour: 5
Course No.: Math 596	Full Marks: 50
Nature of the Course: Theory	Pass Mark: 25

Course Contents:
Ring and Ring homomorphisms, ideal and quotient rings, zero divisors, nilpotent elements, units, prime and maximal ideals, nilradical and Jacobson radical, extension and contraction of ideals, modules, free and flat modules, direct sums and direct products, algebras, localization, local properties, primary decomposition, integral dependence, going up and going down theorems, valuation rings.

Textbooks/Reference Books:

1. Atiyah, M.F. and Macdonald, I.G., *An Introduction to Commutative Algebra*, Addison- Wesley Publishing Company, 1969.

2. Matsumura, H., *Commutative Ring Theory*, Cambridge University Press, 1986.

Location Analysis

Course Title: Location Analysis | Credit Hours: 5
Course No.: Math 597 | Full Marks: 50
Nature of the Course: Theory | Pass Mark: 25

Course Contents:

Planar Locations:

Introduction to location problems, convexity, 1- location median problems, N- location median problems, 1- location center problems, N- location center problems.

Network Locations :

covering problems, center problems, median problems.

Textbooks/Reference Books:

1. Hamacher, H. W., *Mathematical Methods for Planar Location Problems*, Kaiserslautern,2016.
2. Daskin M.S., *Network and Discrete Location: Models, Algorithms, and Applications*, John Wiley and Sons, 2011
3. Eiselt H. A. and Marianov, V. (Eds), *Foundations of Location Analysis*, Springer Science and Business Media, 2011.

Mathematical Models in Biology

Course Title: Mathematical Models in Biology | Credit Hours: 5
Course No.: Math 598 | Full Marks: 50
Nature of the Course: Theory | Pass Mark: 25

Course Contents:

The theory of linear difference equations applied to population growth, nonlinear difference equations, an introduction to continuous models, population dynamics, an introduction to partial differential equations and diffusion in biological settings, partial differential equation models in biology.

Text books/References Books:

1. Leah Edelstein - Keshet, *Models in Biology*, Siam, copyright 2005.
2. Nicholas F. Britton, *Essential Mathematical Biology*, Springer 2002.

Advanced Ordinary Differential Equations

Course Title: Advanced Ordinary Differential Equations — Credit Hour: 5
Course No.: Math 599 — Full Marks: 50
Nature of the Course: Theory — Pass Mark: 25

Course Contents:

Basic Concepts and Definitions:
ODEs and PDEs with examples-solution of an ODE- Wellposed mathematical problems-applications.

First Order ODEs: Some Integral Cases
Explicit first order equations, the linear differential equations, differential equations for family of curves, implicit first order equations, existence and uniqueness of solutions, approximate solutions and method of successive approximation.

Theory of First Order ODEs:
Tools from functional analysis, existence and uniqueness theorems, complex differential equations, power series expansions, upper and lower solutions, maximal and minimal integrals, maximum interval of existence, continuous dependence on initial conditions.

First Order Systems: Equations of Higher Order
The IVP for a system of first order, IVP for equations of higher order, existence and uniqueness theorems.

Nonlinear Differential Equations: Stability and Asymptotic Behaviour
The phase plane, linear systems, Gronwall's lemma (stability and instability theorems), autonomous systems and stability, locally linear systems, the generalized lemma of Gronwall, Liapunov's method, periodic solutions and limit cycles.

Textbooks/Reference Books:

1. Walter W., *Ordinary Differential Equations*, Springer, 1998.
2. Perko L., *Differential Equations and Dynamical systems* Third Edition, Springer, 2001
3. Nagle R. K., Saff E. B., Sinder A. D.,*Fundamentals of Differential Equations and Boundary Value Problems*, Sixth Edition, Addison- Wesley, 2012.
4. Basker S.,*Ordinary Differential Equations.*