Indira Gandhi University, Meerpur (Rewari)

Scheme of Examination and Syllabi

for

M.Sc.(Mathematics)

Learning Outcomes Based Curriculum Framework (LOCF)

w.e.f. session 2022-23

Program Outcomes for M.Sc.(Mathematics)
Learning Outcomes Based Curriculum Framework
w.e.f. Session 2022-23

PO1	Disciplinary knowlegde	Capability of demonstrating comprehensive knowledge of mathematics gained during course of study.
PO2	Communications skills	Ability to communicate various concepts of Mathematics effectively using examples and their geometrical visualizations, and also demonstrate the importance of Mathematics in other subjects.
PO3	Critical thinking and analytical reasoning	Ability to employ critical thinking in understanding the concepts in every area of mathematics and analytical reasoning to apply them in various problems appearing in different branches of mathematics
PO4	Problem Solving	Ability to solve real life problems and provide new solutions using the acquired domain knowledge of mathematics.
PO5	Research-related skills	Capability for inquiring about appropriate questions relating to the concepts in various fields of mathematics, and developing passion for the related research.
PO6	Information/digital literacy	Capability to learn and apply the programming skills and softwares for mathematical investigations and problem solving.
PO7	Self-directed learning	Ability to work independently and do in-depth study of various notions of mathematics
PO8	Moral and ethical awareness/reasoning	Ability to identify unethical behaviour such as fabrication, falsification or misrepresentation of data and adopting objective, unbiased and truthful actions in all aspects.
PO9	Life-long Learning	Ability to think, acquire knowledge and skills through logical reasoning and to inculcate a habit of self-learning
PO10	Applications	Ability to demonstrate fundamental systematic knowledge of mathematics and its applications in engineering, science, technology and mathematical sciences

Programme Specific Outcomes (PSOs)

On successful completion of the M.Sc. Programme, a student will

PSO1	Have a strong foundation in core areas of Mathematics, both pure and applied
PSO2	Be able to apply mathematical skills and logical reasoning for problem solving
PSO3	Communicate mathematical ideas effectively, in writing as well as orally
PSO4	Have sound knowledge of mathematical modeling, programming and computational techniques as required for employment in industry

Indira Gandhi University, Meerpur (Rewari)
Scheme of Examination
M.Sc. Mathematics
Learning Outcomes Based Curriculum Framework (LOCF)
w.e.f. Session 2022-23

Semester-I

Core Courses

Course Code	Title of the Course	Theory Marks	Internal Marks	Practical Marks	Credits L:T:P	Contact hrs per week	Total Credits
MAT-101	Abstract Algebra	80	20	-	4:0:0	4	4
MAT-102	Mathematical Analysis	80	20	-	4:0:0	4	4
MAT-103	Ordinary Differential Equations	80	20	-	4:0:0	4	4
MAT-104	Complex Analysis	80	20	-	4:0:0	4	4
MAT-105	Mathematical Statistics	80	20	-	4:0:0	4	4
MAT-106	Computer Applications	60	-	40	2:0:2	6	4
MAT-107	Mathematical Lab-I	-	-	50	0:0:2	4	2
MAT-108	Seminar	-	-	25	-	-	1
MAT-109	Self Study Paper	-	-	25	-	-	1

Total Credits : 28
Total Contact Hours per Week : 30
Max Marks : 700

Note: The criteria for awarding internal assessment of 20 marks for each paper shall be as under :

(i) Sessional test : 10 marks
(ii) Assignment/Presentation : 5 marks
(iii) Attendance : 5 marks
Less than 65% : 0 marks
65% and above but upto 70% : 2 marks
Above 70% but upto 75% : 3 marks
Above 75% but upto 80% : 4 marks
Above 80% : 5 marks

General Guidelines

1. Seminar

In each semester, there will be a paper on seminar presentation of 25 marks with 01 credit. In this paper, the student will be required to present a seminar of about 15-20 minutes on the theme/topic such as review of research papers/articles published in National/International Journals in his /her area of interest. The topic will be selected by the student in consultation with the teacher alloted to him/her by the department.

An internal committee of two teachers constituted by the Chairperson of the department for each student will evaluate the seminar presentation. The evaluation (Internal evaluation only) will be based on the presentation of student, depth of subject matter and answer to questions. There will be a Coordinator to be nominated by the Chairperson of the Department among the teachers of the Department.

For seminar, the topics should be chosen in the following manner:

1st Semester	Any topic (not related to the syllabi)
2nd Semester	Any Basic Research Paper/Article
3rd Semester	Any National Level Research Paper/Article
4th Semester	Any Foreign Research Paper/Article

2. Self Study Paper

In each semester, there will be a self study paper of 25 marks with 01 credit. The objective of this paper is to create habits of reading books and to develop writing skills in a manner of creativity and originality. The students will select a topic of their own interest in the given area in consulation with their teachers/incharge/mentors. After selecting a suitable title for the paper, the students will be required to prepare a hand written report of about 6-10 pages in his/her own handwritng. The students will be required to submit the report after getting it checked by the concerned teacher and will be asked to re-submit the report after making the required corrections(if any) before the commencment of the examinations of that semester. The structure of the paper will include the following:

- Introduction
- Main Body
- Conclusion

The thoughts presented in the paper must be original work of the students.

The paper will be evaluated by the panel (one external and one internal examiner) to be appointed by the Chairperson of Department from the prescribed panel of the University.

The evaluation of Self Study paper will be done as given below:

- Evaluation of the paper : 15 marks
- Viva-Voce on the paper : 10 marks
- Total : 25 marks

CO-PSO matrix for the Course MAT-101: Abstract Algebra

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	M	S
CO2	S	M	M	S
CO3	S	S	S	S
CO4	S	S	S	S

CO-PO matrix for the Course MAT-101: Abstract Algebra

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	S	S	M	S	M	M	M
CO2	S	S	S	M	S	S	S	S	M	S
CO3	S	S	S	M	S	M	M	M	S	S
CO4	S	S	M	S	S	S	S	M	M	M

S=Strong, M=Medium, W=Weak

MAT-101: Abstract Algebra

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The course aims to familiarize the learner with Sylow theory, Solvable and Nilpotent groups and a new algebraic structure module. Modules are the generalizations of vector spaces when the underlying field is replaced by an arbitrary ring.

Course Outcomes: After studying this course, the student will be able to

CO1. Learn about Sylow theory and apply Sylow's theoerms to describe the structure of some finite groups.

CO2. Learn properties of solvable and nilpotent groups, analyze and illustrate examples of normal series, subnormal series and composition series.

CO3. Identify and construct examples of modules, and apply homomorphism theorems on the same. Study modules over principal ideal domain and its applications to finitely generated abelian groups.

CO4. define and characterize Noetherian & artinian modules and rings, and prove Hilbert basis theorem, Wedderburn-Artin theorem and Maschke theorem.

Course Contents:

Section-I

p-groups, Sylow p-subgroups, Sylow theorems, Applications of Sylow theorems, Description of groups of order p^2 and pq, Survey of groups upto order 15.

Section-II

Normal and subnormal series, Solvable series, Derived series, Solvable groups, Solvability of S_n-the symmetric group of degree n $\geq$2, Central series, Nilpotent groups and their properties, Upper and lower central series.
Composition series, Zassenhaus lemma, Jordan-Holder theorem.

Section-III

Modules, Cyclic modules, Simple modules, Schur lemma, Free modules, Torsion modules, Torsion free modules, Fundamental structure theorem for finitely generated free modules, Modules over principal ideal domain and its applications to finitely generated abelian groups.

Section-IV

Noetherian and Artinian modules, Noetherian and Artinian rings, Nil and nilpotent ideals in Noetherian and Artinian rings, Hilbert basis theorem.
Hom_R(R,R), Opposite rings, Wedderburn-Artin theorem, Maschke theorem.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. I. S. Luther and I.B.S. Passi, Algebra, Vol. I-Groups, Narosa Publishing House, 2013.

2. I. S. Luther and I.B.S. Passi, Algebra, Vol. III-Modules, Narosa Publishing House, 2013.

3. Charles Lanski, Concepts in Abstract Algebra, American Mathematical Society, First Indian Edition, 2010.

4. Vivek Sahai and Vikas Bist, Algebra, Narosa Publishing House, 1999.

5. D. S. Malik, J. N. Mordenson and M. K. Sen, Fundamentals of Abstract Algebra, McGraw-Hill International Edition, 1997.

6. P. B. Bhattacharya, S. K. Jain and S. R. Nagpaul, Basic Abstract Algebra (2nd Edition), Cambridge University Press, Indian Edition, 1997.

7. C. Musili, Introduction to Rings and Modules, Narosa Publication House, 1994.

8. N. Jacobson, Basic Algebra, Vol. I and II, W.H Freeman, 1980.

9. M. Artin, Algebra, Prentice-Hall of India, 1991.

10. Ian D. Macdonald, The Theory of Groups, Clarendon Press, 1968.

CO-PSO matrix for the Course MAT-102: Mathematical Analysis

COs	PSO1	PSO2	PSO3	PSO4
CO1	**S**	**S**	**S**	**M**
CO2	**S**	**S**	**S**	**M**
CO3	**S**	**S**	**S**	**M**
CO4	**S**	**S**	**S**	**M**

CO-PO matrix for the Course MAT-102: Mathematical Analysis

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	**S**	**S**	**S**	**S**	**M**	**M**	**S**	**M**	**S**	**M**
CO2	**S**	**S**	**S**	**S**	**M**	**M**	**S**	**M**	**S**	**M**
CO3	**S**	**S**	**S**	**S**	**S**	**S**	**M**	**M**	**S**	**S**
CO4	**S**	**M**	**S**	**S**	**S**	**S**	**M**	**M**	**S**	**S**

S=Strong, M=Medium, W=Weak

MAT-102: Mathematical Analysis

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: This course aims to familiarize the learner with Riemann-Stieltjes integral, pointwise and uniform convergence of sequence and series of functions, functions of several variables and power series. The course also enables the students to find extreme values of explicit functions, stationary values of implicit functions and acquaint with several properties of Jacobians.

Course Outcomes: After studying this course, the student will be able to

CO1. Understand Riemann-Stieltjes integral, its properties and rectifiable curves.

CO2. Learn about the concept of pointwise and uniform convergence of sequence and series of functions and various tests for uniform convergence.

CO3. Learn about power series, differentiability and continuity of functions of several variables and their relation to partial derivatives.

CO4. Find the extreme values of explicit functions, stationary values of implicit functions and understand various properties of Jacobians.

Course Contents:

Section-I

Riemann-Stieltjes integral, Existence and properties, Integration and differentiation, The fundamental theorem of calculus, Integration of vector-valued functions, Rectifiable curves.

Section-II

Sequence and series of functions, Pointwise and uniform convergence, Cauchy criterion for uniform convergence, M_n-test for uniform convergence, Weierstrass M-test, Abel's and Dirichlet's tests for uniform convergence, Uniform convergence and continuity, Uniform convergence and Integration, Uniform convergence and differentiation, Weierstrass approximation theorem.

Section-III

Power series, uniform convergence and uniqueness theorem, Abel's theorem, Tauber's theorem.

Functions of several variables, Linear Transformations, Euclidean space R^n, Derivatives in an open subset of R^n, Chain Rule, Partial derivatives, Continuously Differentiable Mapping, Young and Schwarz theorems.

Section-IV

Taylor theorem, Higher order differentials, Explicit and implicit functions, Implicit function theorem, Inverse function theorem, Change of variables, Extreme values of explicit functions, Stationary values of implicit functions, Lagrange multipliers method, Jacobian and its properties.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. Walter Rudin, Principles of Mathematical Analysis (3rd edition) McGraw-Hill, International Student Edition, 1976.

2. T. M. Apostol, Mathematical Analysis, Narosa Publishing House, New Delhi, 1974.

3. H. L. Royden, Real Analysis, Macmillan Pub. Co., Inc. 4th Edition, New York, 1993.

4. R. R. Goldberg, Methods of Real Analysis, Oxford and IBH Pub. Co. Pvt. Ltd, 1976.

5. R. G. Bartle, The Elements of Real Analysis, Wiley International Edition, 2011.

6. S. C. Malik and Savita Arora, Mathematical Analysis, New Age International Limited, New Delhi, 2012.

CO-PSO matrix for the Course MAT-103: Ordinary Differential Equations

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	S
CO2	S	S	S	S
CO3	S	S	S	S
CO4	S	S	S	S

CO-PO matrix for the Course MAT-103: Ordinary Differential Equations

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	M	M	S	M	M	S
CO2	S	M	S	S	S	S	S	S	S	S
CO3	S	S	S	S	M	S	S	M	M	S
CO4	S	M	S	S	M	M	S	M	M	S

S=Strong, M=Medium, W=Weak

MAT-103: Ordinary Differential Equations

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The objective of this course is to study the solutions of first order ODE's, linear second order ODE's, some basic results of Sturm theory, stability of critical points of autonomous systems, eigen values and eigen functions of Sturm-Liouville's problems.

Course Outcomes: After studying this course, the student will be able to

CO1. know about existence, uniqueness and continuity of solutions of first order ODE's.

CO2. Learn about linear systems, self-adjoint equations of second order and some basic results of Sturm theory.

CO3. Learn about critical points of autonomous systems and their stability.

CO4. Learn about critical points and paths of almost linear systems, existence and nonexistence of limit cycles, eigen values and eigen functions of Sturm-Liouville's problems.

Course Contents:

Section-I

Preliminaries, ϵ-approximate solution, Cauchy-Euler construction of an ϵ-approximate solution of an initial value problem, Equicontinuous family of functions, Ascoli-Arzela Lemma, Cauchy-Peano existence theorem.

Lipschitz condition, Picard-Lindelof existence and uniqueness theorem for $\dfrac{dy}{dt} = f(t, y)$, Solution of initial-value problems by Picard's method, Dependence of solutions on initial conditions.
(Relevant topics from the books by Coddington and Levinson, and Ross).

Section-II

Linear systems, Matrix method for homogeneous first order system of linear differential equations, Basic theory of the homogeneous linear system, Fundamental set of solutions, Fundamental matrix of solutions, Wronskian of solutions, Abel-Liouville formula, Non-homogeneous linear system.
Strum Theory: Self-adjoint equations of the second order, Some basic results of Sturm theory, Abel's formula, Strum Separation theorem, Strum's Fundamental comparison theorem.
(Relevant topics from chapters 7 and 11 of book by Ross)

Section-III

Nonlinear differential systems, Phase plane, Path, Critical points, Autonomous systems, Isolated critical point, Path approaching a critical point, Path entering a critical point, Types of critical points - Center, Saddle points, Spiral points, Node points. Stability of critical points, Stable critical points, Asymptotically stable critical points, Unstable critical points, Critical points and paths of linear systems.
(Relevant topics from chapter 13 of book by Ross).

Section-IV

Almost linear systems, Critical points and paths of almost linear systems, Nonlinear conservative dynamical systems, Dependence on a parameter, Liapunov's direct method.
Limit Cycles and Periodic solutions: Limit cycles, Periodic solutions, Existence and nonexistence of limit cycles, Bendixson's nonexistence criterion, Poincare-Bendixson theorem (statement only), Index of a critical point.

Strum-Liouville problems, Orthogonality of characteristic functions.
(Relevant topics from chapters 12 and 13 of the book by Ross).

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. E. A. Coddington and N. Levinson, Theory of ordinary differential equations, Tata McGraw Hill, 2000.

2. S. L. Ross, Differential equations, John Wiley and Sons Inc., New York, 1984.

3. W. E. Boyce and R. C. Diprima, Elementary differential equations and boundary value problems, John Wiley and Sons, Inc., New York, 4th edition, 1986.

4. G. F. Simmon, Differential Equations, Tata McGraw Hill, New Delhi, 1993.

CO-PSO matrix for the Course MAT-104: Complex Analysis

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	M	S	S
CO2	S	S	M	S
CO3	S	S	S	S
CO4	M	S	S	S

CO-PO matrix for the Course MAT-104: Complex Analysis

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	S	S	S	S	M	S	S
CO2	S	M	S	M	S	M	S	S	M	S
CO3	M	S	S	S	S	S	S	M	S	S
CO4	S	S	S	S	S	M	S	S	S	S

S=Strong, M=Medium, W=Weak

MAT-104: Complex Analysis

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The objective of this course is to extend the notions of continuity, derivatives, and integrals, familiar from calculus to the case of complex functions of a complex variable. Introduce the concept of analyticity, entire function, Cauchy-Riemann equations, fundamental theorem of algebra, sequences and series of analytic functions, types of convergence, Cauchy integral theorem and its various versions, Taylor, power, and Laurent series. The singularity and type of singularity, residues and evaluate complex integrals using the residue theorem.

Course Outcomes: After studying this course, the student will be able to

CO1. Learn about basics of complex numbers, power series, complex valued functions and their properties.

CO2. Study about complex integration, Couchy integral formula, Poisson integral formula and inverse function theorem.

CO3. Understand analytic functions, some fundamental results such as Cauchy integral formula, Poisson integral formula, Liouville theorem.

CO4. Evaluate the complex integration with infinite limit, residues and Montel theorem, Riemann mapping theorem.

Course Contents:

Section-I

Functions of a complex variable, Continuity, Differentiability, Analytic functions and their properties, Cauchy-Riemann equations in Cartesian and polar coordinates.

Power series, Radius of convergence, Differentiability of sum function of a power series, Branches of many valued functions with special reference to arg$z$, Log$z$ and z^a.

Section-II

Path in a region, Contour, Complex integration, Cauchy theorem, Cauchy integral formula, Extension of Cauchy integral formula for multiple connected domain, Poisson integral formula, Higher order derivatives, Complex integral as a function of its upper limit, Morera theorem, Cauchy inequality, Liouville theorem, Taylor theorem.

Section-III

Zeros of an analytic function, Laurent series, Isolated singularities, Cassorati-Weierstrass theorem, Limit point of zeros and poles. Maximum modulus principle, Schwarz lemma, Meromorphic functions, Argument principle, Rouche theorem, Fundamental theorem of algebra, Inverse function theorem.

Section-IV

Calculus of residues, Cauchy residue theorem, Evaluation of integrals of the types

$$\int_0^{2\pi} f(\cos\theta, \sin\theta)d\theta,\ \int_{-\infty}^{\infty} f(x)dx,\ \int_0^{\infty} f(x)\sin mx\ dx \text{ and } \int_0^{\infty} f(x)\cos mx\ dx.$$

Conformal mappings, Space of analytic functions and their completeness, Hurwitz theorem, Montel theorem, Riemann mapping theorem.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. H. A. Priestly, Introduction to Complex Analysis, Clarendon Press, Oxford, 1990.

2. J. B. Conway, Functions of One Complex Variable, Springer-Verlag, International Student Edition, Narosa Publishing House, 2002.

3. Ruel V. Churchill and James Ward Brown, Complex Variables and Applications, McGraw-Hill Publishing Company, 2009.

4. E. T. Copson, An Introduction to the Theory of Functions of a Complex Variable, Oxford University Press, London, 1972.

5. E. C. Titchmarsh, The Theory of Functions, Oxford University Press, London.

6. H. S. Kasana, Complex Variables: Theory and Applications, PHI Learning Private Ltd, 2013.

7. Dennis G. Zill and P. D. Shanahan, A First Course in Complex Analysis with Applications, John Bartlett Publication, 2nd Edition, 2010.

CO-PSO matrix for the Course MAT-105: Mathematical Statistics

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	S
CO2	S	S	S	S
CO3	S	S	S	S
CO4	S	S	S	S

CO-PO matrix for the Course MAT-105: Mathematical Statistics

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	S	M	S	M	S	S
CO2	S	S	S	S	S	M	S	M	S	S
CO3	S	S	S	S	S	M	S	M	S	S
CO4	S	S	S	S	S	M	S	M	S	S

S=Strong, M=Medium, W=Weak

MAT-105: Mathematical Statistics

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: Probability theory deals with many real life problems, which either inherently involve the chance phenomena or describe the behavior of the system explicitly with statistical properties. Interpretation of the system behavior in many aspects depends on concept of probability and statistics that familiarize with the computational aspects. The course deals with basic properties of various distributions and other related things.

Course Outcomes: After studying this course, the student will be able to

CO1. know basics of probability.

CO2. understand discrete and continuous probability distributions.

CO3. learn joint probability distributions, random samples, point estimation and confidence intervals.

CO4. understand Hypotheses testing and inferences based on two samples.

Course Contents:

Section-I

Probability: Definition and various approaches of probability, Addition theorem, Boole's inequality, Conditional probability and multiplication theorem, Independent events, Mutual and pairwise independence of events, Bayes' theorem and its applications.

Section-II

Random variable and probability functions: Definition and properties of random variables, Discrete and continuous random variables, Probability mass and density functions, Distribution function, Concepts of bivariate random variable: joint, marginal and conditional distributions.
Mathematical expectation: Definition and its properties, Variance, Covariance, Moment generating function- Definitions and their properties.

Section-III

Discrete distributions: Uniform, Bernoulli, Binomial, Poisson and Geometric distributions with their properties.
Continuous distributions: Uniform, Exponential and Normal distributions with their properties.

Section-IV

Testing of hypothesis: Parameter and statistic, Sampling distribution and standard error of estimate, Null and alternative hypotheses, Simple and composite hypotheses, Critical region, Level of significance, One tailed and two tailed tests, Two types of errors.
Tests of significance: Large sample tests for single mean, Single proportion, Difference between two means and two proportions.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. A. M. Mood, F. A. Graybill, and D. C. Boes, Introduction to the Theory of Statistics, McGraw-Hill,1974.

2. S. C. Gupta and V. K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand and Sons, New Delhi.

3. J. E. Freund, Mathematical Statistics, Prentice Hall College Div, 1992.

4. M. Spiegel, Probability and Statistics, Schaum Outline Series.

MAT-107: Mathematical Lab-I

Max. Marks : 50
Credits : 0:0:2

Mathematical problem solving techniques based on paper MAT-101 to MAT-105 will be taught. There will be problems based on 5-6 problem solving techniques from each paper.

Note: Every student will have to maintain practical record of atleast 25 problems solved during practical class work in a file. Examination will be conducted through a question paper set jointly by the external and internal examiners. The question paper will consists of four questions based on problem solving techniques/algorithm. An examinee will be asked to write the solutions of any two in the answer book. Evaluation will be made on the basis of the examinee's performance in written solutions, practical record and viva-voce.

Practical examination will be conducted as per the following distribution of marks:
Writing solutions of problems : 20 marks
Viva Voce : 20 marks
Practical record : 10 marks.

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Semester-II

Core Courses

Course Code	Title of the Course	Theory Marks	Internal Marks	Practical Marks	Credits L:T:P	Contact hrs per week	Total Credits
MAT-201	Field Extensions and Galois Theory	80	20	-	4:0:0	4	4
MAT-202	Measure and Integration Theory	80	20	-	4:0:0	4	4
MAT-203	Integral Equations and Calculus of Variations	80	20	-	4:0:0	4	4
MAT-204	General Topology	80	20	-	4:0:0	4	4
MAT-205	Computing Lab-I (Documentation in LaTex)	-	-	50	0:0:2	4	2
MAT-206	Seminar	-	-	25	-	-	1
MAT-207	Self Study Paper	-	-	25	-	-	1

Discipline Centric Elective Courses (Any one)

Course Code	Title of the Course	Theory Marks	Internal Marks	Credits L:T:P	Contact hrs per week	Total Credits
MAT-208	Operations Research Techniques	80	20	4:0:0	4	4
MAT-209	Information Theory	80	20	4:0:0	4	4

Foundation Elective Courses (Any one)

Course Code	Title of the Course	Theory Marks	Internal Marks	Credits L:T:P	Contact hrs per week	Total Credits
MAT-210	Value Education	40	10	2:0:0	2	2
MAT-211	Communication Skills and Personality Development	40	10	2:0:0	2	2
MAT-212	Goods & Service Tax (GST)	40	10	2:0:0	2	2
MAT-213	Quantitative Mathematics and Reasoning	40	10	2:0:0	2	2
MAT-215	Yoga: A Way of Life	40	10	2:0:0	2	2
MAT-216	Intellectual Property Rights	40	10	2:0:0	2	2

Total Credits : 26
Total Contact Hours per Week : 26
Max Marks : 650

CO-PSO matrix for the Course MAT-201: Field Extensions and Galois Theory

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	M	S	S
CO2	S	S	S	M
CO3	S	M	S	S
CO4	S	S	S	S

CO-PO matrix for the Course MAT-201: Field Extensions and Galois Theory

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	S	S	S	S	M	S	M	S
CO2	S	S	S	S	M	S	S	M	S	S
CO3	S	M	S	M	S	S	S	S	M	S
CO4	S	S	S	S	S	S	M	M	S	M

S=Strong, M=Medium, W=Weak

MAT-201: Field Extensions and Galois Theory

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: To provide students exposure of Finite field and their field extension, Algebraic closed field, separable & inseparable extensions Primitive element and Solve polynomial equations by radicals along with the understanding of ruler and compass constructions.

Course Outcomes: After studying this course, the student will be able to

CO1. To use diverse properties of field extensions in various areas.

CO2. To establish the connection between the concept of field extensions and Galois theory.

CO3. To describe the concept of automorphism, monomorphism and their linear independence in field theory.

CO4. To solve polynomial equations by radicals along with the understanding of ruler and compass constructions.

Course Contents:

Section-I

Fields, Prime fields, Finite field extensions, Degree of field extensions, Simple Extensions, Algebraic extensions, Splitting fields, Algebraically closed fields.

Section-II

Separable and inseparable extensions, Perfect fields.

Monomorphisms and their linear independence, Automorphism of fields, Fixed fields, Normal extensions, The fundamental theorem of Galois theory.

Section-III

Finite fields, Existence of GF(p^n), Construction of finite fields, Primitive elements, Langrage's theorem on primitive elements, Roots of unity, Cyclotomic polynomials, Cyclotomic extensions of rational number field.

Section-IV

Solutions by radicals, Extension by radicals, Generic polynomial, Insolvability of the general polynomial of degree $n \geq 5$ by radicals, Ruler and compasses construction.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. I. S. Luther and I.B.S.Passi, Algebra, Vol. IV-Field Theory, Narosa Publishing House, 2012.

2. Ian Stewart, Galois Theory, Chapman and Hall/CRC, 2004.

3. Vivek Sahai and Vikas Bist, Algebra, Narosa Publishing House, 1999.

4. P. B. Bhattacharya, S. K. Jain and S. R. Nagpaul, Basic Abstract Algebra (2nd Edition), Cambridge University Press, Indian Edition, 1997.

5. S. Lang, Algebra, 3rd edition, Addison-Wesley, 1993.

6. Ian T. Adamson, Introduction to Field Theory, Cambridge University Press, 1982.

7. I. N. Herstein, Topics in Algebra, Wiley Eastern Ltd., New Delhi, 1975.

CO-PSO matrix for the Course MAT-202: Measure and Integration Theory

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	M
CO2	S	S	S	M
CO3	S	S	S	M
CO4	S	S	S	M

CO-PO matrix for the Course MAT-202: Measure and Integration Theory

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	M	M	M	M	S	M
CO2	S	S	S	S	M	M	M	M	S	M
CO3	S	S	S	S	S	S	S	M	S	S
CO4	S	M	S	S	S	S	S	M	S	S

S=Strong, M=Medium, W=Weak

MAT-202: Measure and Integration Theory

Time : 3 hours | **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The main objective of this course is to familiarize with the concepts of Lebesgue outer measure, measurable sets, measurable functions, Lebesgue integral, differentiation of monotone functions, functions of bounded variations and absolutely continuous functions

Course Outcomes: After studying this course, the student will be able to

CO1. Understand the concepts of Lebesgue measure and measurable sets; construct a non-measurable set.

CO2. Learn about measurable functions, their properties and related concepts.

CO3. Understand the requirement and the concept of Lebesgue integral along its properties and various convergence theorems.

CO4. Learn about concepts of functions of bounded variations, absolutely continuous functions, convex functions and their properties

Course Contents:

Section-I

Set functions, Intuitive idea of measure, Elementary properties of measure, Measurable sets and their fundamental properties. Lebesgue measure of sets of real numbers, Algebra of measurable sets, Borel sets and their measurability, Equivalent formulation of measurable sets in terms of open, closed, F_σ and G_δ sets, Non-measurable sets.

Section-II

Measurable functions and their equivalent formulations, Properties of measurable functions, Approximation of a measurable function by a sequence of simple functions, Measurable functions as nearly continuous functions, Egoroff's theorem, Lusin's theorem, Convergence in measure and F. Riesz theorem for convergence in measure, Almost uniform convergence.

Section-III

Shortcomings of Riemann Integral, Lebesgue Integral of a bounded function over a set of finite measure and its properties, Lebesgue integral as a generalization of Riemann integral, Bounded convergence theorem, Integral of non-negative functions, Fatou's Lemma, Monotone convergence theorem, General Lebesgue Integral, Lebesgue convergence theorem.

Section-IV

Vitali's covering lemma, Differentiation of monotonic functions, Functions of bounded variation and their representation as difference of monotonic functions, Differentiation of indefinite integral, Fundamental theorem of calculus, Absolutely continuous functions and their properties, Convex functions, Jensen's Inequality.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. H. L. Royden, Real Analysis, Macmillan Pub. Co., Inc. 4th Edition, New York, 1993.

2. P. K. Jain and V. P. Gupta, Lebesgue Measure and Integration, New Age International (P) Limited Published, New Delhi, 1986.

3. G. De Barra, Measure Theory and Integration, Wiley Eastern Ltd., 1981.

4. Walter Rudin, Principles of Mathematical Analysis (3rd edition) McGraw-Hill, Kogakusha, 1976, International Student Edition.

5. R. R. Goldberg, Methods of Real Analysis, Oxford and IBH Pub. Co. Pvt. Ltd, 1976.

6. R. G. Bartle, The Elements of Real Analysis, Wiley International Edition, 2011.

CO-PSO matrix for the Course MAT-203: Integral Equations and Calculus of Variations

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	S
CO2	S	S	S	S
CO3	S	S	S	S
CO4	S	S	S	S

CO-PO matrix for the Course MAT-203: Integral Equations and Calculus of Variations

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	S	S	M	M	S	M	M	S
CO2	S	M	S	S	M	M	S	M	M	S
CO3	S	M	S	S	M	M	S	M	M	S
CO4	S	M	M	S	M	M	S	M	M	S

S=Strong, M=Medium, W=Weak

MAT-203: Integral Equations and Calculus of Variations

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The main objective of this course is to make the learner familiarize with the concept of integral equations, various methods for solving Volterra and Freedholm integral equations and to solve some mathematical and physical problems using variational techniques.

Course Outcomes: After studying this course, the student will be able to

CO1. Know about integral equations and various methods to solve Volterra integral equations.

CO2. Understand various methods to solve Freedholm integral equations.

CO3. Construct Green's function for solving boundary value problems associated with ordinary differential equations.

CO4. Solve some mathematical and physical problems using variational techniques.

Course Contents:

Section-I

Linear Integral equations, Some basic identities, Initial value problems reduced to Volterra integral equations, Methods of successive substitution and successive approximation to solve Volterra integral equations of second kind, Iterated kernels and Neumann series for Volterra equations, Resolvent kernel as a series, Laplace transform method for a difference kernel, Solution of a Volterra integral equation of the first kind.

Section-II

Boundary value problems reduced to Fredholm integral equations, Methods of successive approximation and successive substitution to solve Fredholm equations of second kind, Iterated kernels and Neumann series for Fredholm equations, Resolvent kernel as a sum of series, Fredholm resolvent kernel as a ratio of two series, Fredholm equations with separable kernels, Approximation of a kernel by a separable kernel, Fredholm Alternative, Non homogeneous Fredholm equations with degenerate kernels.

Section-III

Green's function, Use of method of variation of parameters to construct the Green's function for a non-homogeneous linear second order boundary value problem, Basic four properties of the Green's function, Alternate procedure for construction of the Green's function by using its basic four properties. Reduction of a boundary value problem to a Fredholm integral equation with kernel as Green's function, Hilbert-Schmidt theory for symmetric kernels.

Section-IV

Motivating problems of calculus of variations, Shortest distance, Minimum surface of resolution, Brachistochrone problem, Isoperimetric problem, Geodesics, Fundamental lemma of calculus of variations, Euler's equation for one dependant function and its generalization to 'n' dependant functions and to higher order derivatives, Conditional extremum under geometric constraints and under integral constraints.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. A. J. Jerri, Introduction to Integral Equations with Applications, A Wiley Interscience Publication, 1999.

2. R. P. Kanwal, Linear Integral Equations, Theory and Techniques, Academic Press, New York.

3. J. M. Gelfand and S.V. Fomin, Calculus of Variations, Prentice Hall, New Jersy, 1963.

4. W. V. Lovitt, Linear Integral Equations, McGraw Hill, New York.

5. F. B. Hilderbrand, Methods of Applied Mathematics, Dover Publications.

CO-PSO matrix for the Course MAT-204: General Topology

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	M
CO2	S	S	S	S
CO3	S	S	S	M
CO4	S	S	S	M

CO-PO matrix for the Course MAT-204: General Topology

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	S	M	S	M	S	S
CO2	S	S	S	S	S	M	S	M	S	S
CO3	S	S	S	S	S	M	S	M	S	S
CO4	S	S	S	S	S	M	S	M	S	S

S=Strong, M=Medium, W=Weak

MAT-204: General Topology

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: This course aims to introduce basic concepts of point set topology, basis and subbasis for a topology, relative topology. Further, to study continuity, homeomorphims, open and closed maps, topological properties, notions of connectdness and local connectedness, separation axioms, countability axioms, compactness of spaces, local compactness and one point compactification.

Course Outcomes: After studying this course, the student will be able to

CO1. Determine interior, closure, boundary, exterior, limit points of subsets of topological spaces and define topology in terms of closure operator, interior operator, exterior operator, and neighbourhood system.

CO2. Learn about the concepts of relative topology, basis and subbasis for a topology, continuous functions, homeomorphism, topological properties, connectedness and local connectedness.

CO3. Learn about separation axioms, countability axioms and concept of convergence of sequences in topological spaces.

CO4. Learn about compact, sequentially compact, countably compact and locally compact spaces,and one point compactification.

Course Contents:

Section-I

Definition and examples of topological spaces, Comparison of topologies on a set, Intersection and union of topologies on a set, Limit point of a set, Derived set, Closed set, Closure of a set, Kuratowski closure axioms, Closure operator, Dense sets, Interior point and Interior of a set, Interior axioms, Exterior of a set, Exterior axioms, Boundary of a set, Interior, exterior and boundary operators, Neighborhoods, Alternative methods of defining a topology in terms of neighborhood system and Kuratowski closure operator.

Section-II

Relative (Induced) topology, Base and subbase for a topology, Base for neighbourhood system.

Continuous functions, Composition of continuous functions, Pasting lemma, Open and closed functions, Homeomorphisms, Topological properties.

Connectedness and its characterization, Connected subsets and their properties, Continuity and connectedness, Components, Locally connected spaces.

Section-III

Separation axioms: T_0, T_1, T_2-spaces, their characterization and basic properties, T_2-spaces and sequences.

First countable, Second countable and Separable spaces, Hereditary and topological property, Countability of a collection of disjoint open sets in separable and second countable spaces, Lindelöf theorem.

Section-IV

Compact spaces and subsets, Compactness in terms of finite intersection property, Continuity and compact sets, Basic properties of compactness, Closedness of compact subset of a Hausdorff space and of a continuous map from a compact space into a Hausdorff and its consequence. Sequentially and Countably compact spaces, Locally compact spaces and One point compactification.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. W. J. Pervin, Foundations of General Topology, Academic Press Inc. New York, 1964.

2. C. W. Patty, Foundation of Topology, Jones and Bartlett, 2009.

3. Fred H. Croom, Principles of Topology, Cengage Learning, 2009.

4. K. D. Joshi, Introduction to General Topology, New Age International, 1983.

5. J. L. Kelly, General Topology, Springer Verlag, New York, 2000.

6. J. R. Munkres, Topology, Pearson Education, 2002.

7. K. Chandrasekhara Rao, Topology, Alpha Science International, 2009.

CO-PSO matrix for the Course MAT-205: Computing Lab-I (Documentation in LaTex)

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	S
CO2	S	S	S	S
CO3	S	S	S	S
CO4	S	S	S	S

CO-PO matrix for the Course MAT-205: Computing Lab-I (Documentation in LaTex)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	S	M	S	M	S	S
CO2	S	S	S	S	S	S	S	M	S	S
CO3	S	S	S	S	S	S	S	M	S	S
CO4	S	S	S	S	S	M	S	M	S	S

S=Strong, M=Medium, W=Weak

MAT-205: Computing Lab-I (Documentation in LaTex)

Time : 4 hours **Max. Marks : 50**
Credits : 0:0:2

Course Objectives: The purpose of this course is to get the students familiar with LaTeX, a mathematical typesetting system designed for the creation of documents such as report, article, books that contain a lot of mathematics, complicated symbols and formatting.

Course Outcomes: After studying this course, the student will be able to

CO1. Create and typeset a LaTeX document.

CO2. Typeset a mathematical document using LaTeX.

CO3. Use tabular and array environments within LaTeX document.

CO4. Write a report, research paper and thesis in LaTeX.

Course Contents:

Note: (A) The question paper will consist of four questions and the students will be required to attempt two questions. The student will first prepare the docoment in LaTeX of the questions in the answer-book and then run the same on the computer, and finally add the print-outs of these programs in the answer-book. This work will consist of 30 marks, 15 marks for each question.

(B) The practical file of each student will be checked and Viva-Voce examination based upon the practical file and the theory will be jointly conducted by external and internal examiners. This part of the practical examination shall be of 20 marks.
The following practicals of typing documents using LaTeX software will be done and records of all these will be maintained in the practical notebook.

List of Practicals

1. Create a new file in the work directory with the name note1.tex and to write a simple document in LaTeX using following commands:
\documentclass[a4paper,12pt]{article}
\begin{document}
A paragraph of text
\end{document}

2. Create a document to write code for a title page using
\title{ }, \author{ }, \date{ }, \today, \maketitle{ } commands and \emph{ }, \textbf{ }, \textit{ }, \textrm{ }, etc. commands.

3. Create a document to write code using
\section{ }, \subsection{ }, \subsubsection{ }, \paragraph{ }, \subparagraph{ } commands and using environments to left justify, right justify, center and justify text.

4. Create a document to illustrate LaTeX commands for paper size, font size, font types and styles.

5. Create a document involving mathematical equations to illustrate :
Use of \$ . . . \$ and \$ \$ . . . \$ \$ symbols, use of power and indices (^, _) , Fractions (\frac{ }{ }) , Sum (\sum_{ }^{ }{ }) , Product (\prod_{ }^{ }{ }) , Integral (\int_a^b f(x)dx) within \$ . . . \$ or \$ \$ . . . \$ \$ symbols

6. Create a document involving use of commands for Greek letters and the commands \pm, \mp,\times,\div,\ast,\circ,\vee,\wedge, \cdot,\setminus, \cap,\cup,\leq,\geq,\equiv,\sim, \simeq,\parallel,\subset,\supset,\subseteq, \supseteq,\neq,\in,\approx,\cong,\notin,\perp, \star for mathematical symbols and operations.

7. Create a document involving use of commands \Re,\Im,\prime,\forall,\infty,\emptyset,\exists, \nabla,\surd,\partial,\angle,\backslash,\triangle,\propto,\ldots,\cdots,\hat,\bar,\dot,\ddot, \vec,\imath,\jmath,\tilde for mathematical symbols and operations.

8. Create a document to illustrate the effect of enumerate listing and itemize listing.

9. Create a document to typeset arithmetic operations, subscripts, superscripts, accents, operators, binomial coefficients, congruences, delimiters and integrals.

10. Create a document to illustrate the use of
\begin{matrix} . . . \end{matrix}, \begin{bmatrix} . . . \end{bmatrix},
\begin{Bmatrix} . . . \end{Bmatrix}, \begin{pmatrix} . . . \end{pmatrix},
\begin{vmatrix} . . . \end{vmatrix} and \begin{Vmatrix} . . . \end{Vmatrix}.

11. Create a document involving mathematical symbols, Greek letters and fractions using the environment \begin{equation} . . . \end{equation}. Also illustrare the use of \eqref{ } in the running text.

12. Create a document to write equations using \begin{eqnarray} . . . \end{eqnarray}.

13. Create a document to illustrate the use of \begin{cases} . . . \end{cases}.

14. Create a document to illustrate the use of \begin{align} . . . \end{align}.

15. Create a document to illustrate the use of \begin{array} . . . \end{array}.

16. Create a document to illustrate the use of \begin{table} . . . \end{table} and \begin{tabular} . . . \end{tabular}.

17. Create a document to illustrate the use of \begin{figure} . . . \end{figure}.

18. Create a document to illustrate the use of \begin{thebibliography} . . . \end{thebibliography} and \{cite}{ }.

Books recommended

1. Lamport Leslie, LaTeX, A Document Preparation System, User‘s Guide and Refernce Manual, 2nd Edition, Pearson Education, 1994.

2. Bindner, Donald & Erickson, Martin, A Student‘s Guide to the Study, Practice and Tools of Modern Mathematics, CRC Press, Taylor & Francis Group, LLC, 2011.

CO-PSO matrix for the Course MAT-208: Operations Research Techniques

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	M
CO2	S	M	S	S
CO3	S	S	M	S
CO4	M	S	S	S

CO-PO matrix for the Course MAT-208: Operations Research Techniques

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	M	S	M	M	S	S	M
CO2	M	S	S	S	S	M	S	S	M	S
CO3	S	M	S	S	M	S	M	M	M	M
CO4	S	S	M	S	S	M	S	S	S	S

S=Strong, M=Medium, W=Weak

MAT-208: Operations Research Techniques

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The main role of the paper Operations Research Techniques to enhance the knowledge of students to overcome the problems those have not exact unique solution like inequalities problems with their optimization like transportation and assignment problems. In this paper, students will familiar with overcoming the different types of queuing models, game theory, and job sequencing problems with the different renowned approaches. The inventory control models will develop the learners to establish their business and to override the coming hurdle in their business. Hence after passing the course the students will found more confidence in their life in one or other way.

Course Outcomes: After studying this course, the student will be able to

CO1. Understand the need and origin of Operational Research, Solution of the Linear Programming Problems by graphical, simplex, Big-M and Two-phase methods.

CO2. Learn about the Basic feasible solution, Optimal solution by stepping stone and MODI method of Transportation Problems and Solution of Assignment Problems by Hungarian method.

CO3. Introduce the Queuing theory, Stochastic process, Birth-death process, Markovian queuing models and Sequencing problems.

CO4. Study about the Inventory control models, Economic order quantity model with uniform demand, when shortage are allowed, with uniform replenishment, and Game theory.

Course Contents:

Section-I

Operations Research: Origin, Definition and scope.
Linear Programming: Formulation and solution of linear programming problems by graphical and simplex methods, Big-M and two-phase methods, Degeneracy, Duality in linear programming.

Section-II

Transportation Problems: Basic feasible solutions, Optimum solution by stepping stone and modified distribution methods, Unbalanced and degenerate problems, Transshipment problem.
Assignment problems: Solution by Hungarian method, Unbalanced problem, Case of maximization, Travelling salesman and crew assignment problems.

Section-III

Queuing models: Basic components of a queuing system,Concepts of stochastic processes, Poisson process, Birth-death process. Steady-state solution of Markovian queuing models with single and multiple servers (M/M/1, M/M/C, M/M/1/k, M/MC/k).
Sequencing problems: Solution of sequecing problems, processing n jobs through 2 machines, n jobs through 3 machines, n jobs through m machines, 2 jobs through m machines.

Section-IV

Inventory control models: Economic order quantity(EOQ) model with uniform demand and with different rates of demands in different cycles, EOQ when shortages are allowed, EOQ with uniform replenishment, Inventory control with price breaks.
Game Theory: Two person zero sum game, Game with saddle points, The rule of dominance, Algebraic, Graphical and linear programming methods for solving mixed strategy games.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. H. A. Taha, Operations Research-An Introduction, Prentice Hall, 1997.

2. P. K. Gupta and D.S. Hira, Operations Research, S. Chand and Co. Ltd., 2014.

3. S. D. Sharma, Operations Research, Kedar Nath Ram Nath Publications.

4. J. K. Sharma, Mathematical Models in Operations Research, Tata McGraw-Hill Publishing Company Ltd., 1989.

5. Kanti Swarup, P. K. Gupta and ManMohan, Operations Research, Sultan Chand and Sons, New Delhi, 2005.

CO-PSO matrix for the Course MAT-209: Information Theory

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	M
CO2	S	M	S	S
CO3	S	S	M	S
CO4	M	S	S	S

CO-PO matrix for the Course MAT-209: Information Theory

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	S	S	S	S	S	M	M	S
CO2	S	S	S	M	S	S	M	M	S	S
CO3	M	S	M	S	S	M	S	S	M	S
CO4	S	M	S	S	M	S	S	S	S	M

S=Strong, M=Medium, W=Weak

MAT-209: Information Theory

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: o provide students exposure of axioms for a measure of uncertainty and the Shannon entropy and its properties & characterization. Learn the basic concepts of noiseless coding, channel and channel capacity and relation among them.

Course Outcomes: After studying this course, the student will be able to

CO1. To understand various measures of information with proofs of important properties of information measures.

CO2. To describe the basic concepts of noiseless coding, channel and channel capacity and relation among them.

CO3. Explain important discrete memoryless channels and continuous channels.

CO4. To Analyse information processed by the channels and obtain channel capacity.

Course Contents:

Section-I

Measure of information Axioms for a measure of uncertainty. The Shannon entropy and its properties. Joint and conditional entropies. Trans-information and its properties. Axiomatic characterization of the Shannon entropy due to Shannon and Fadeev.

Section-II

Noiseless coding - Ingredients of noiseless coding problem. Uniquely decipherable codes. Necessary and sufficient condition for the existence of instantaneous codes. Construction of optimal codes.

Section-III

Discrete memoryless channel - Classification of channels. Information processed by a channel. Calculation of channel capacity. Decoding schemes. The ideal observer. The fundamental theorem of information theory.

Section-IV

Continuous channels - The time-discrete Gaussian channel. Uncertainty of an absolutely continuous random variable. The converse to the coding theorem for time-discrete Gaussian channel. The time-continuous Gaussian channel. Band-limited channels.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. R. Ash, Information Theory, Interscience Publishers, New York, 1965.

2. F.M. Reza, An Introduction to Information Theory, MacGraw-Hill Book Company Inc., 1961.

3. J. Aczela dn Z. Daroczy, On Measures of Information and their Characterizations, Academic Press, New York.

Scheme of Examination
M.Sc. Mathematics
Learning Outcomes Based Curriculum Framework (LOCF)
w.e.f. Session 2022-23

Semester-III

Core Courses

Course Code	Title of the Course	Theory Marks	Internal Marks	Practical Marks	Credits L:T:P	Contact hrs per week	Total Credits
MAT-301	Functional Analysis	80	20	-	4:0:0	4	4
MAT-302	Advanced Topology	80	20	-	4:0:0	4	4
MAT-303	Fluid Dynamics	80	20	-	4:0:0	4	4
MAT-304	Mathematical Lab-II	-	-	50	0:0:2	4	2
MAT-305	Seminar	-	-	25	-	-	1
MAT-306	Self Study Paper	-	-	25	-	-	1

Discipline Centric Elective Courses (Any two)

Course Code	Title of the Course	Theory Marks	Internal Marks	Credits L:T:P	Contact hrs per week	Total Credits
MAT-307	Discrete Mathematics	80	20	4:0:0	4	4
MAT-308	Fuzzy Set Theory	80	20	4:0:0	4	4
MAT-309	Mechanics of Solids	80	20	4:0:0	4	4
MAT-310	Analytical Number Theory	80	20	4:0:0	4	4
MAT-311	Partial Differential Equations	80	20	4:0:0	4	4
MAT-312	Difference Equations	80	20	4:0:0	4	4
MAT-313	Mathematical Modeling	80	20	4:0:0	4	4
MAT-314	Computational Fluid Dynamics	80	20	4:0:0	4	4
MAT-315	Cosmology-I	80	20	4:0:0	4	4

Open Elective Course

To be chosen from the pool of open elective courses provided by the University (excluding the open elective course offered by the Department of Mathematics)	Max. Marks 100	Credits 3

Open Elective Course offered by the Department of Mathematics

Course Code	Title of the Course	Theory Marks	Internal Marks	Credits L:T:P	Contact hrs per week	Total Credits
MAT-316	Basics of Vedic Mathematics	80	20	3:0:0	3	3

Total Credits : 27
Total Contact Hours per Week : 27
Max Marks : 700

Note: Optional papers can be offered subject to the availability of requisite resources/faculty.

General Guidelines

1. Seminar

In each semester, there will be a paper on seminar presentation of 25 marks with 01 credit. In this paper, the student will be required to present a seminar of about 15-20 minutes on the theme/topic such as review of research papers/articles published in National/International Journals in his /her area of interest. The topic will be selected by the student in consultation with the teacher alloted to him/her by the department.

An internal committee of two teachers constituted by the Chairperson of the department for each student will evaluate the seminar presentation. The evaluation (Internal evaluation only) will be based on the presentation of student, depth of subject matter and answer to questions. There will be a Coordinator to be nominated by the Chairperson of the Department among the teachers of the Department.

For seminar, the topics should be chosen in the following manner:

1st Semester	Any topic (not related to the syllabi)
2nd Semester	Any Basic Research Paper/Article
3rd Semester	Any National Level Research Paper/Article
4th Semester	Any Foreign Research Paper/Article

2. Self Study Paper

In each semester, there will be a self study paper of 25 marks with 01 credit. The objective of this paper is to create habits of reading books and to develop writing skills in a manner of creativity and originality. The students will select a topic of their own interest in the given area in consulation with their teachers/incharge/mentors. After selecting a suitable title for the paper, the students will be required to prepare a hand written report of about 6-10 pages in his/her own handwritng. The students will be required to submit the report after getting it checked by the concerned teacher and will be asked to re-submit the report after making the required corrections(if any) before the commencment of the examinations of that semester. The structure of the paper will include the following:

- Introduction
- Main Body
- Conclusion

The thoughts presented in the paper must be original work of the students.

The paper will be evaluated by the panel (one external and one internal examiner) to be appointed by the Chairperson of Department from the prescribed panel of the University.

The evaluation of Self Study paper will be done as given below:

- Evaluation of the paper : 15 marks
- Viva-Voce on the paper : 10 marks
- Total : 25 marks

CO-PSO matrix for the Course MAT-301: Functional Analysis

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	M
CO2	S	S	S	M
CO3	S	S	S	M
CO4	S	S	S	M

CO-PO matrix for the Course MAT-301: Functional Analysis

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	M	M	M	M	S	M
CO2	S	S	S	S	M	M	M	M	S	M
CO3	S	M	S	S	S	S	S	M	S	S
CO4	S	M	S	S	S	S	S	M	S	S

S=Strong, M=Medium, W=Weak

MAT-301: Functional Analysis

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The aim of this course is to acquaint the students with normed linear spaces, Banach spaces, four fundamental theorems of Functional Analysis: Hahn-Banach extension theorem, Uniform Bounded Principle, Open Mapping Theorem and Closed Graph Theorem,and some properties of compact operators.

Course Outcomes: After studying this course, the student will be able to

CO1. differentiate between complete and incomplete normed linear spaces.

CO2. understand the concepts of continuity and boundedness of a linear transformation, equivalent formulations of continuiy and Hahn-Banach extension theorem.

CO3. learn Riesz Representation theorem on L^p and $C[a,b]$, Uniform Bounded Principle, Open mapping theorem, Closed graph theorem and their applications.

CO4. distinguish between the concepts of weak and strong convergence and understand several properties of compact operators.

Course Contents:

Section-I

Normed linear spaces, Metric on normed linear spaces, Completion of a normed space, Banach spaces, subspace of a Banach space, Holder's and Minkowski's inequality, Completeness of quotient spaces of normed linear spaces. Completeness of l^p, L^p, R^n, C^n and $C[a, b]$. Incomplete normed spaces.

Section-II

Finite dimensional normed linear spaces and subspaces, Bounded linear transformation, Equivalent formulation of continuity, Spaces of bounded linear transformations, Continuous linear functional, Conjugate spaces, Hahn-Banach extension theorem (Real and Complex form).

Section-III

Riesz Representation theorem for bounded linear functionals on L^p and $C[a, b]$. Second conjugate spaces, Reflexive space, Uniform boundedness principle and its consequences, Open mapping theorem and its application, Projections, Closed Graph theorem.

Section-IV

Equivalent norms, Weak and Strong convergence, their equivalence in finite dimensional spaces.

Compact Operator and its relation with continuous operator, Compactness of linear transformation on a finite dimensional space, properties of compact operators, Compactness of the limit of the sequence of compact operators.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. E. Kreyszig, Introductory Functional Analysis with Applications, John Wiley.

2. H.L. Royden, Real Analysis, MacMillan Publishing Co., Inc., New York, 4th Edition, 1993.

3. George F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Book Company, 1963.

4. A. H. Siddiqi, Khalil Ahmad and P. Manchanda, Introduction to Functional Analysis with Applications, Anamaya Publishers, New Delhi-2006.

5. K.C. Rao, Functional Analysis, Narosa Publishing House, Second edition.

CO-PSO matrix for the Course MAT-302: Advanced Topology

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	M
CO2	S	S	S	M
CO3	S	S	S	M
CO4	S	S	S	M

CO-PO matrix for the Course MAT-302: Advanced Topology

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	S	M	S	M	S	S
CO2	S	S	S	S	S	M	S	M	S	S
CO3	S	S	S	S	S	M	S	M	S	S
CO4	S	S	S	S	S	M	S	M	S	S

S=Strong, M=Medium, W=Weak

MAT-302: Advanced Topology

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The main objective of this course is to familiarize with some advanced topics in topology such as regularity, normality, complete regularity, complete normality, product topology and product invariant properties, embedding and metrization, convergence of nets and filters, paracompactness and its characteriztion.

Course Outcomes: After studying this course, the student will be able to

CO1. know about separation axioms regularity, normality, complete regularity, complete normality; their characterization and basic properties.

CO2. understand the concept of product topology, product topological spaces and their properties, embedding and metrization.

CO3. understand the concepts of nets, filters and their convergence, canonical way of converting nets to filters and vice versa.

CO4. understand the concept of paracompactness and their characterization.

Course Contents:

Section-I

Regular, Normal, T_3 and T_4 separation axioms, their characterization and basic properties, Urysohn's lemma and Tietze extension theorem, Regularity and normality of a compact Hausdorff space, Complete regularity, Complete normality, $T_{3\frac{1}{2}}$ and T_5 spaces, their characterization and basic properties.

Section-II

Product topological spaces, Projection mappings, Tychonoff product topology in terms of standard subbases and its characterization, Separation axioms and product spaces, Connectedness, Locally connectedness and compactness of product spaces, Product space as first axiom space, Tychonoff product theorem.

Embedding and Metrization : Embedding lemma and Tychonoff embedding theorem, Metrizable spaces, Urysohn metrization theorem.

Section-III

Nets : Nets in topological spaces, Convergence of nets, Hausdorffness and nets, Subnet and cluster points, Compactness and nets.

Filters : Definition and examples, Collection of all filters on a set as a poset, Methods of generating filters and finer filters, Ultra filter and its characterizations, Ultra filter principle, Image of filter under a function, Limit point and limit of a filter, Continuity in terms of convergence of filters, Hausdorffness and filters, Canonical way of converting nets to filters and vice versa, Stone-Cech compactification.

Section-IV

Covering of a space, Local finiteness, Paracompact spaces, Michaell theorem on characterization of paracompactness, Paracompactness as regular as well as normal space, A. H. Stone theorem, Nagata- Smirnov Metrization theorem.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. W.J. Pervin, Foundations of General Topology, Academic Press Inc. New York, 1964.

2. K.D. Joshi, Introduction to General Topology, New Age International, 1983.

3. J. L. Kelly, General Topology, Springer Verlag, New York, 2000.

4. J. R. Munkres, Topology, Pearson Education Asia, 2002.

5. Stephen Willard, General Topology, Dover Publications, Inc. Mineola, New York.

6. C. Wayne Patty, Foundations of Topology, Jones and Bartlett Student Edition, 2012.

7. K. Chandrasekhara Rao, Topology, Alpha Science International, 2009.

8. Fred H. Croom, Principles of Topology, Cengage Learning, 2009.

CO-PSO matrix for the Course MAT-303: Fluid Dynamics

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	M
CO2	M	S	S	S
CO3	S	M	M	S
CO4	S	S	S	S

CO-PO matrix for the Course MAT-303: Fluid Dynamics

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	M	M	S	S	M	S	M
CO2	S	M	S	S	M	M	M	S	M	S
CO3	S	S	M	S	S	M	M	S	S	M
CO4	M	M	S	S	S	S	S	M	M	S

S=Strong, M=Medium, W=Weak

MAT-303: Fluid Dynamics

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: This course confines the learner's attention towards the fluid's characteristics like incompressible or compressible, flow of fluids, viscosity, the behavior of fluid during motion, vorticity, pressure at a point in moving fluid, stagnation point. Kinetic energy and its nature with some renowned named theorems, source, sink, doublet, velocity potential, Stoke stream function and their application. Hence, after qualifying the course the learners know the importance of the power of fluid and its works.

Course Outcomes: After studying this course, the student will be able to

CO1. Study about basic behaviour of fluid, velocity potential of fluid, continuity equation and acceleration at a point of the fluid.

CO2. Understand about equation of motion, pressure at a point of fluid, Bernoulli equation and some energy equations of the fluid.

CO3. Learn about the axially symmetric flow, kinetic energy due to impulsive motion, source, sink and doublet.

CO4. Evaluate the Stoke stream function, axisymmetric flow, irrotational motion, complex potential function, and Blasius theorem.

Course Contents:

Section-I

Kinematics - Velocity at a point of a fluid. Eulerian and Lagrangian methods. Stream lines, path lines and streak lines. Velocity potential. Irrotational and rotational motions. Vorticity and circulation. Equation of continuity. Boundary surfaces. Acceleration at a point of a fluid. Components of acceleration in cylindrical and spherical polar co-ordinates.

Section-II

Pressure at a point of a moving fluid. Euler equation of motion. Equations of motion in cylindrical and spherical polar co-ordinates.
Bernoulli equation. Impulsive motion. Kelvin circulation theorem. Vorticity equation. Energy equation for incompressible flow. Kinetic energy of irrotational flow. Kelvin minimum energy theorem. Kinetic energy of infinite fluid. Uniqueness theorems.

Section-III

Axially symmetric flows. Liquid streaming part a fixed sphere. Motion of a sphere through a liquid at rest at infinity. Equation of motion of a sphere. Kinetic energy generated by impulsive motion. Motion of two concentric spheres.
Three-dimensional sources, sinks and doublets. Images of sources, sinks and doublets in rigid impermeable infinite plane and in impermeable spherical surface.

Section-IV

Two dimensional motion; Use of cylindrical polar co-ordinates. Stream function. Axisymmetric flow. Stoke stream function. Stoke stream function of basic flows.
Irrotational motion in two-dimensions. Complex velocity potential. Milne-Thomson circle theorem. Two-dimensional sources, sinks, doublets and their images. Blasius theorem.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. W.H. Besant and A.S. Ramsey, A Treatise on Hydromechanics, Vol.2, CBS Publishers and Distributors, Delhi, 2006.

2. F. Chorlton, Text Book of Fluid Dynamics, C.B.S. Publishers, Delhi, 2004.

3. O'Neill, M.E. and Chorlton, F., Ideal and Incompressible Fluid Dynamics, Ellis Horwood , 1986.

4. R.K. Rathy, An Introduction to Fluid Dynamics, Oxford and IBH Publishing Company, New Delhi, 1976.

5. G.K. Batchelor, An Introduction to Fluid Mechanics, Foundation Books, New Delhi, 1994.

MAT-304: Mathematical Lab-II

Max. Marks : 50
Credits : 0:0:2

Mathematical problem solving techniques based on courses MAT-301 to MAT-303 and two courses from the pool of Discipline Centric Elective Course will be taught. There will be problems based on 5-6 problem solving techniques from each course.

Note: Each student will have to maintain practical record of atleast 25 problems solved during practical class work in a file. Examination will be conducted through a question paper set jointly by the external and internal examiners. The question paper will consists of four questions based on problem solving techniques/algorithm. An examinee will be asked to write the solutions of any two in the answer book. Evaluation will be made on the basis of the examinee's performance in written solutions, practical record and viva-voce.

Practical examination will be conducted as per the following distribution of marks:
Writing solutions of problems : 20 marks
Viva Voce : 20 marks
Practical record : 10 marks.

CO-PSO matrix for the Course MAT-307: Discrete Mathematics

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	S
CO2	S	S	S	S
CO3	S	M	M	S
CO4	S	S	M	S

CO-PO matrix for the Course MAT-307: Discrete Mathematics

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	M	S	M	S	S	S
CO2	S	S	S	S	S	M	S	S	S	M
CO3	S	M	S	S	S	M	S	S	S	S
CO4	S	S	M	S	M	S	M	S	M	M

S=Strong, M=Medium, W=Weak

MAT-307: Discrete Mathematics

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The objective of this course is to get the students familiar with the concepts of Mathematical logic, semigroups, monoids, lattices and its varoius types, Boolean algebras, Finite state machines, Grammars and language.

Course Outcomes: After studying this course, the student will be able to

CO1. Undestand the concept of statement,semigroups and monoids

CO2. Undestand the concept of lattices as partially ordered sets as well as algebraic systems and get familiar with various types of lattices.

CO3. Know about Boolean algebras, evaluate Boolean functions and simplify expressions using properties of Boolean algebras.

CO4. Use finite-state machines to model computer operations and understand the concepts of Language and Grammar.

Course Contents:

Section-I

Statements: Symbolic Representation and Tautologies, Quantifiers, Predicates and validity, Prepositional Logic.
Semigroups and Monoids- Definitions and examples of semigroups and monoids. Homomorphism of semigroups and monoids. Congruence relation and Quotient semigroups. Subsemigroups and submonoids. Direct products. Basic homomorphism theorem. Pigeonhole principle, principle of inclusion and exclusion, derangements.

Section-II

Lattices - Lattices as partially ordered sets, their properties, Lattices as Algebraic systems. Sub lattices, Direct products and Homomorphism, Some special lattices e.g. Complete, Complemented and Distributive Lattices. Join-irreducible elements, Atoms and Minterms.

Section-III

Boolean Algebras- Boolean Algebras as Lattices. Various Boolean Identities. The Switching Algebra example. Subalgebras, Direct Products and Homomorphism, Boolean forms and their equivalence, Minterm Boolean forms, Sum of Products, Canonical forms, Minimization of Boolean functions, Applications of Boolean Algebra to Switching Theory (using AND, OR and NOT gates). The Karnaugh method.

Section-IV

Finite state Machines and their transition table diagrams, Equivalence of Finite State Machines, Reduced Machines, Homomorphism. Finite automata, Acceptors, Non-deterministic Finite Automata and equivalence of its power to that of deterministic Finite automata, Moore and Mealy Machines.
Grammars and Language: Phrase-Structure Grammars, Rewriting rules, Derivations, Sentential forms, Language generated by a Grammar, Regular, Context-free and Context sensitive grammars and Languages, Regular sets, Regular expressions and the Pumping Lemma, Kleene's theorem.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. Kenneth H. Rosen, Discrete Mathematics and its Applications, Tata McGraw-Hill, Fourth Edition.

2. Seymour Lipschutz and Marc Lipson, Theory and Problems of Discrete Mathematics, Schaum Outline Series, McGraw-Hill Book Co., New York.

3. John A. Dossey, Albert D. Otto, Lawrence E. Spence and Charles Vanden Eynden, Discrete Mathematics, Pearson, Fifth Edition.

4. J.P. Tremblay and R. Manohar, Discrete mathematical structures with applications to computer science, Tata-McGraw Hill Education Pvt.Ltd.

5. J. Ullman and J. Hopcroft, Introduction to Automata Theory, Languages and Computation, Addison-Wesley.

6. M. K. Das, Discrete Mathematical Structures for Computer Scientists and Engineers, Narosa Publishing House.

7. C. L. Liu and D. P. Mohapatra, Elements of Discrete Mathematics-A Computer Oriented Approach, Tata McGraw-Hill, Fourth Edition.

CO-PSO matrix for the Course MAT-308: Fuzzy Set Theory

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	M
CO2	S	S	S	M
CO3	S	S	S	M
CO4	S	S	S	M

CO-PO matrix for the Course MAT-308: Fuzzy Set Theory

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	S	S	S	M	S	S
CO2	S	S	S	S	S	S	S	M	S	S
CO3	S	S	S	S	S	S	S	M	S	S
CO4	S	S	S	S	S	S	S	M	S	S

S=Strong, M=Medium, W=Weak

MAT-308: Fuzzy Set Theory

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The main objective of this course is to provide students knowledge of several notions of Fuzzy set theory like fuzzy sets, fuzzy relations, fuzzy graphs and fuzzy numbers which will enable the students to understand its various applications in the fields of algebra, statistics, graph theory and other engineering fields.

Course Outcomes: After studying this course, the student will be able to

CO1. learn about fuzzy sets and some standard operations on fuzzy sets like fuzzy complement, fuzzy union, fuzzy intersection alongwith notions of T-norms and T-conorms.

CO2. acquire the knowledge of various relations like equivalence relation, compatibility relation, pre-order relation, order relation and operations on fuzzy relation, α-cut of fuzzy relation and fuzzy distance between fuzzy sets.

CO3. understand fuzzy graph, α-cut of fuzzy fuzzy graph and various fuzzy relations like fuzzy equivalence relation, fuzzy compatibility relation, fuzzy pre-order relation, fuzzy order relation, fuzzy ordinal relation and fuzzy morphism.

CO4. learn various fuzzy numbers like triangular fuzzy number, trapezoidal fuzzy number, bell shape fuzzy number and operations thereof.

Course Contents:

Section-I

Definition of Fuzzy Set, Expanding Concepts of Fuzzy Set, Standard Operations of Fuzzy Set, Fuzzy Complement, Fuzzy Union, Fuzzy Intersection, Other Operations in Fuzzy Set, T-norms and T-conorms. (Chapter 1, 2 of [1])

Section-II

Product Set, Definition of Relation, Characteristics of Relation, Representation Methods of Relations, Operations on Relations, Path and Connectivity in Graph, Fundamental Properties, Equivalence Relation, Compatibility Relation, Pre-order Relation, Order Relation, Definition and Examples of Fuzzy Relation, Fuzzy Matrix, Operations on Fuzzy Relation, Composition of Fuzzy Relation, α-cut of Fuzzy Relation, Projection and Cylindrical Extension, Extension by Relation, Extension Principle, Extension by Fuzzy Relation, Fuzzy distance between Fuzzy Sets. (Chapter 3 of [1])

Section-III

Graph and Fuzzy Graph, Fuzzy Graph and Fuzzy Relation, α-cut of Fuzzy Graph, Fuzzy Network, Reflexive Relation, Symmetric Relation, Transitive Relation, Transitive Closure, Fuzzy Equivalence Relation, Fuzzy Compatibility Relation, Fuzzy Pre-order Relation, Fuzzy Order Relation, Fuzzy Ordinal Relation, Dissimilitude Relation, Fuzzy Morphism, Examples of Fuzzy Morphism. (Chapter 4 of [1])

Section-IV

Interval, Fuzzy Number, Operation of Interval, Operation of α-cut Interval, Examples of Fuzzy Number Operation, Definition of Triangular Fuzzy Number, Operation of Triangular Fuzzy Number, Operation of General Fuzzy Numbers, Approximation of Triangular Fuzzy Number, Operations of Trapezoidal Fuzzy Number, Bell Shape Fuzzy Number. (Chapter 5 of [1]).

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. Kwang H. Lee, First Course on Fuzzy Theory and Applications, Springer International Edition, 2005.

2. H.J. Zimmerman, Fuzzy Set Theory and its Applications, Allied Publishers Ltd., New Delhi, 1991.

3. John Yen, Reza Langari, Fuzzy Logic - Intelligence, Control and Information, Pearson Education, 1999.

CO-PSO matrix for the Course MAT-309: Mechanics of Solids

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	M	S
CO2	S	M	S	S
CO3	M	S	S	M
CO4	S	S	S	S

CO-PO matrix for the Course MAT-309: Mechanics of Solids

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	S	M	M	S	M	S
CO2	S	S	M	S	S	S	M	M	S	M
CO3	S	S	S	M	M	S	S	S	M	S
CO4	M	S	S	S	S	M	S	M	S	M

S=Strong, M=Medium, W=Weak

MAT-309: Mechanics of Solids

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: Solid mechanics is one of the important branches of physical science concerned with the deformation and motion of continuous solid media under applied external loadings such as forces, displacements, and accelerations that result in inertial force in the bodies, thermal changes, chemical interactions, electromagnetic forces, and so on. In this course the main characteristics of the matters available in the Universe are discussed like; elasticity, rigidity, plasticity, etc. of the matters by introducing the higher dimensions i.e. in tensors form for more accuracy of the matters. Any kind of deformations of the matters can be completely analyzed by knowing the stress or strain at any point of the body by using Hooke's law for different kind of media or matters like; isotropic, anisotropic, monoclinic, orthotropic and some standard results about the behavior of stress and strain have been discussed in this course.

Course Outcomes: After studying this course, the student will be able to

CO1. Know about tensor with its basic properties, symmetric and skew-symmetric tensors, and eigenvalues, eigenvectors of a second order symmetric tensor.

CO2. Understand about stress, stress vector, type of stresses, stress quadric of Cauchy,and Mohar diagram.

CO3. Study about strain, deformation, components of strain, strain quadric of Cauchy, and Saint-Venant conditions of compatibility.

CO4. Learn about generalized Hook's law, Hook's law for different types of media, and Beltrami-Michel compatibility conditions

Course Contents:

Section-I

Cartesian tensors of different orders, Contraction of a tensor, Multiplication and quotient laws for tensors, Substitution and alternate tensors, Symmetric and skew symmetric tensors, Isotropic tensors, Eigenvalues and eigenvectors of a second order symmetric tensor.

Section-II

Analysis of Stress: Stress vector, Normal stress, Shear stress, Stress components, Cauchy equations of equilibrium, Stress tensor of order two, Symmetry of stress tensor, Stress quadric of Cauchy, Principal stresses, Stress invariants, Maximum normal and shear stresses, Mohr diagram.

Section-III

Analysis of Strain: Affine transformations, Infinitesimal affine deformation, Pure deformation, Components of strain tensor and their geometrical meanings, Strain quadric of Cauchy, principal strains, Strain invariants, General infinitesimal deformation, Saint-Venant conditions of compatibility, Finite deformations.

Section-IV

Equations of Elasticity: Generalized Hook's law, Hook's law in an elastic media with one plane of symmetry, Orthotropic and transversely isotropic symmetries, Homogeneous isotropic elastic media, Elastic moduli for an isotropic media, Equilibrium and dynamical equations for an isotropic elastic media, Beltrami - Michell compatibility conditions.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. I.S. Sokolnikoff, Mathematical theory of Elasticity, Tata McGraw Hill Publishing Company Ltd., New Delhi, 1977.

2. Teodar M. Atanackovic and Ardeshiv Guran, Theory of Elasticity for Scientists and Engineers, Birkhausev, Boston, 2000.

3. Saada, A.S., Elasticity-Theory and applications, Pergamon Press, New York.

4. D.S. Chandersekhariah and L. Debnath, Continuum Mechanics, Academic Press, 1994.

5. Jeffreys, H., Cartesian tensors.

6. A.K. Mal and S.J. Singh, Deformation of Elastic Solids, Prentice Hall, New Jersey, 1991.

CO-PSO matrix for the Course MAT-310: Analytical Number Theory

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	S
CO2	S	S	S	M
CO3	S	S	S	M
CO4	M	S	S	S

CO-PO matrix for the Course MAT-310: Analytical Number Theory

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	S	S	S	M	M	S
CO2	S	S	S	S	S	S	S	S	S	S
CO3	S	S	S	S	S	S	S	M	S	S
CO4	S	S	S	S	M	S	M	M	S	S

S=Strong, M=Medium, W=Weak

MAT-310: Analytical Number Theory

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: To provide students exposure of the distribution of primes, irrationality of e and π and the algebraic properties of U_n & Q_n. Also, describe the Arithmetic function, Waring problems and their applicability.

Course Outcomes: After studying this course, the student will be able to

CO1. Describe the classical results related to prime numbers and get familiar with the irrationality of e and π.

CO2. Explain the algebraic properties of U_n and Q_n.

CO3. Describe the Waring's problem and its applicability.

CO4. Know the definition, examples and simple properties of arithmetic functions.

Course Contents:

Section-I

Distribution of primes, Fermat and Mersenne numbers, Farey series and some results concerning Farey series, Approximation of irrational numbers by rationals, Hurwitz's theorem, Irrationality of e and π.

Section-II

The arithmetic in Z_n, The group U_n, Primitive roots and their existence, the group U_{p^n} (p-odd) and U_{2^n}, The group of quadratic residues Q_n, Quadratic residues for prime power moduli and arbitrary moduli, The algebraic structure of U_n and Q_n.

Section-III

Riemann Zeta Function $\zeta(s)$ and its convergence, Application to prime numbers, $\zeta(s)$ as Euler product, Evaluation of $\zeta(2)$ and $\zeta(2k)$.

Diophantine equations $ax+by=c$, $x^2+y^2=z^2$ and $x^4+y^4=z^4$, The representation of number by two or four squares, Waring problem, Four square theorem, The numbers g(k) and G(k), Lower bounds for g(k) and G(k).

Section-IV

Arithmetic functions $\phi(n), \tau(n), \sigma(n)$ and $\sigma_k(n)$, U(n), N(n), I(n). Definitions, examples and simple properties, Perfect numbers, Mobius inversion formula, The Mobius function $\mu(n)$, The order and average order of the function $\phi(n), \tau(n)$ and $\sigma(n)$.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. G. H. Hardy and E. M. Wright, An Introduction to the Theory of Numbers.

2. Gareth A. Jones and J. Mary Jones, Elementary Number Theory, Springer Edition, 1998.

3. D. M. Burton, Elementary Number Theory.

4. N. H. McCoy, The Theory of Numbers, McMillan Company Limited, 1965.

5. I. Niven and H. S. Zuckermann, An Introduction to the Theory of Numbers.

CO-PSO matrix for the Course MAT-311: Partial Differential Equations

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	S
CO2	S	S	S	S
CO3	S	S	S	S
CO4	S	S	S	S

CO-PO matrix for the Course MAT-311: Partial Differential Equations

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	S	M	S	M	S	S
CO2	S	S	S	S	S	M	S	M	S	S
CO3	S	S	S	S	S	M	S	M	S	S
CO4	S	S	S	S	S	M	S	M	S	S

S=Strong, M=Medium, W=Weak

MAT-311: Partial Differential Equations

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The objective of this course is to get the students familiar with the method of separation of variables to solve various boundary value problems associated with heat equation, wave equation and Laplace equation; definition and classification of PDEs, explicit formulas for solutions of four fundamental linear partial differential equations, general non-linear first order PDE and the initial value problem for the Hamilton-Jacobi equation.

Course Outcomes: After studying this course, the student will be able to

CO1. Solve Boundary value problems associated with heat equation, Laplace equation and wave equation by the method of separation of variables.

CO2. Distinguish between linear and nonlinear partial differential equations; solve transport eqation, Laplace equation, Poisson equation; learn properties of harmonic functions and derive Green function.

CO3. Derive explicit formulas for solutions of heat and wave equation.

CO4. Learn to solve general nonlinear first order partial differential equations through envelopes, characteristics and find the weak solution of initial-value problem for the Hamilton-Jacobi equation.

Course Contents:

Section-I

Method of separation of variables to solve Boundary Value Problems (B.V.P.) associated with one dimensional heat equation. Steady state temperature in a rectangular plate, Circular disc, Semi-infinite plate. The heat equation in semi-infinite and infinite regions. Solution of three dimensional Laplace equations, Heat Equations, Wave Equations in cartesian, cylindrical and spherical coordinates. Method of separation of variables to solve B.V.P. associated with motion of a vibrating string. Solution of wave equation for semi-infinite and infinite strings.
(Relevant topics from the book by O'Neil)

Section-II

Partial differential equations: Examples of PDE classification. Transport equation - Initial value problem. Non-homogeneous equations.
Laplace equation - Fundamental solution, Mean value formula, Properties of harmonic functions, Green function.

Section-III

Heat Equation - Fundamental solution, Mean value formula, Properties of solutions, Energy methods.
Wave Equation - Solution by spherical means, Non-homogeneous equations, Energy methods.

Section-IV

Non-linear first order PDE - Complete integrals, Envelopes, Characteristics, Hamilton Jacobi equations.
Calculus of variations, Hamilton ODE, Legendre transform, Hopf-Lax formula, Weak solutions, Uniqueness.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. I.N. Sneddon, Elements of Partial Differential Equations, McGraw Hill, New York.

2. Peter V. O'Neil, Advanced Engineering Mathematics, ITP.

3. L.C. Evans, Partial Differential Equations: (Graduate Studies in Mathematics) 2nd Edition, American Mathematical Society, 2010.

4. H.F. Weinberger, A First Course in Partial Differential Equations, John Wiley and Sons, 1965.

5. M.D. Raisinghania, Advanced Differential equations, S. Chand and Co.

CO-PSO matrix for the Course MAT-312: Difference Equations

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	M	S	S
CO2	S	S	S	M
CO3	M	S	S	S
CO4	S	S	S	S

CO-PO matrix for the Course MAT-312: Difference Equations

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	M	M	S	S	S	M	S
CO2	M	S	S	S	M	S	M	S	S	M
CO3	S	M	S	S	S	S	M	S	S	M
CO4	S	S	M	S	M	M	M	M	S	S

S=Strong, M=Medium, W=Weak

MAT-312: Difference Equations

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The objective of this course includes a basic understanding of mathematical notation and familiarity with reading a mathematical text. After completion of this course students will be able to solve problems based on first order difference equations, difference calculus, and linear algebra and also solve second order linear difference equations and homogeneous and inhomogeneous equations.

Course Outcomes: After studying this course, the student will be able to

CO1. Learn about the difference operator, Summation, Approximate summation and Generating functions.

CO2. Introduce the Linear difference equations, General results for linear equations, Applications, and Z-transform.

CO3. Explore the Stability theory, Stability of linear systems, Phase plane analysis, Stability of Non-linear Systems, and Chaotic Behavior.

CO4. Study about the Asymptotic methods, Asymptotic analysis of sums, Linear equations, and Nonlinear equations.

Course Contents:

Section-I

Difference Calculus: Introduction, The Difference Operator, Summation, Generating functions and Approximate Summation.

Section-II

Linear Difference Equations: First Order Equations, General Results for Linear Equations, Solving Linear Equations, Applications, Equations with Variable Coefficients, Nonlinear Equations that can be Linearized, The z-Transform.

Section-III

Stability Theory: Initial Value Problems for Linear Systems, Stability of Linear Systems, Phase Plane Analysis for Linear Systems, Fundamental Matrices and Floquet Theory, Stability of Nonlinear Systems, Chaotic Behavior.

Section-IV

Asymptotic Methods: Introduction, Asymptotic Analysis of Sums, Linear Equations, Nonlinear Equations.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. Walter Kelley and Allan Peterson, Difference Equations, An Introduction with Applications, Academic Press

2. Calvin Ahlbrant and Allan Peterson, Discrete Hamiltonian Systems, Difference Equations, Continued Fractions and Riccati Equations, Kluwer (1996).

3. Saber Elaydi, An Introduction to Difference Equations, Springer

CO-PSO matrix for the Course MAT-313: Mathematical Modeling

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	M	S
CO2	S	S	S	S
CO3	M	S	S	S
CO4	S	S	S	M

CO-PO matrix for the Course MAT-313: Mathematical Modeling

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	S	S	S	S	M	S	S
CO2	M	S	S	S	M	M	S	S	M	S
CO3	S	S	S	M	S	S	S	S	S	S
CO4	S	M	S	S	S	M	M	M	S	M

S=Strong, M=Medium, W=Weak

MAT-313: Mathematical Modeling

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: Mathematical modeling is commonly regarded as the art of applying mathematics to a real-world problem with a view to better understanding the problem. As such, mathematical modeling is obviously related to problem-solving. However, they may not mean the same thing. In this course, various aspects of mathematical modeling and problem solving will be discussed by using concrete examples, and some of the basic ideas and processes of mathematical modeling will be introduced and described as an approach to problem-solving. The manner of working generates knowledge, and interest in learning mathematics individually and collaboratively, as well as fostering values like punctuality, honesty, responsibility, and respect, to mention only a few, all of which are so necessary for current society.

Course Outcomes: After studying this course, the student will be able to

CO1. Know about basic techniques of mathematical modeling, use of mathematical modeling, and some standard mathematical models.

CO2. Learn about simple epidemics model, SIS model, model with removal, use of mathematical modeling in economics, and mathematical modeling in medicine.

CO3. Study about use of partial differential equations in mathematical modeling, momentum-balance equations and modeling for traffic.

CO4. Understand about stochastic models, linear birth-death process, linear birth-death-immigration process, and non-linear borth-death process.

Course Contents:

Section-I

Introduction and the technique of mathematical modeling, Classification and characteristics of mathematical models. Mathematical modeling through algebra, Finding the radius of the earth, Motion of planets, Motions of satellites. Linear and Non-linear growth and decay models, Population growth models. Effects of Immigration and Emigration on Population size, Decrease of temperature, Diffusion, Change of price of a commodity, Logistic law of population growth. A simple compartment model. Diffusion of glucose or a Medicine in the blood stream.

Section-II

Mathematical modelling of epidemics, A simple epidemics model, A susceptible-infected-susceptible (SIS) model, SIS model with constant number of carriers, Simple epidemic model with carriers, Model with removal, Model with removal and immigration.
Mathematical modelling in economics, Domar macro model, Domar first debt model, Domar second debt model, Samuelson investment model, Stability of market equilibrium. Mathematical modelling in medicine, Arms race and battles: A model for diabetes mellitus, Richardson model for arms race, Lamechester combat model.

Section-III

Mathematical modelling through partial differential equations: Mass-balance Equations, Momentum-balance Equations, Variational principles, Probability generating function, Modelling for traffic on a highway.

Section-IV

Stochastic models of population growth, Need for stochastic models, Linear birth-death-immigration-emigration processes, Linear birth-death process, Linear birth-death-immigration process, Linear birth-death-emigration process, Non-linear birth-death process.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. J.N. Kapur, Mathematical Modeling, New Age International Limited.

2. J.N. Kapur, Mathematical Models in Biology and Medicine, Affiliated East-West Press (P) Ltd.

3. D.N. Burghes and A.D. Wood, Mathematical Models in the Social, Management and Life Sciences, John Wiley and Sons.

4. J.G. Andrews and R.R Mclone, Mathematical Modeling, Butterworths (Pub.) Inc.

CO-PSO matrix for the Course MAT-314: Computational Fluid Dynamics

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	M
CO2	M	S	M	S
CO3	S	S	S	S
CO4	S	M	S	S

CO-PO matrix for the Course MAT-314: Computational Fluid Dynamics

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	M	M	M	S	S	S	M
CO2	S	M	S	S	S	S	M	M	M	M
CO3	M	S	S	S	S	M	S	S	M	S
CO4	S	S	M	S	M	S	M	S	S	S

S=Strong, M=Medium, W=Weak

MAT-314: Computational Fluid Dynamics

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: In continuation of the paper fluid dynamics, this paper is one more advanced step towards the behavior of the fluid that can be observed by mathematical equations like partial differential equations, basic equations of motions, boundary conditions with their classification, maximum principles of boundary layer theory, Navier-Stokes equations, Temporal discretization on a staggered grid or the collocated grid, and with some renowned scheme i.e. Flux splitting, Numerical stability, Jameson Schmidt Turkel scheme, and higher-order schemes. After passing the course successfully the learners become richer to override the day-to-day life problem related to fluid flow exactly and set the new milestone in the development of society.

Course Outcomes: After studying this course, the student will be able to

CO1. Learn about basic equations of fluid dynamics, maximum principle, boundary layer theory, vertex centred discretization, and nonuniform grids.

CO2. Study about finite volume discretization, non-stationary convection diffusion equation, incompressible Navier-Stokes equation, and temporal discretization.

CO3. Understand about iteration methods, Krylov subspace methods, fast Poisson solvers, Shallow water equation, and Godunov order barrier theorem.

CO4. Learn about linear schemes, Osher scheme, Euler equation Flux splitting scheme, higher order schemes, and numerical stability.

Course Contents:

Section-I

Basic equations of Fluid dynamics. Analytic aspects of partial differential equations- classification, Boundary conditions, Maximum principles, Boundary layer theory.
Finite difference and Finite volume discretizations. Vertex-centred discretization. Cell-centred discretization. Upwind discretization. Nonuniform grids in one dimension.

Section-II

Finite volume discretization of the stationary convection-diffusion equation in one dimension. Schemes of positive types. Defect correction. Non-stationary convection-diffusion equation. Stability definitions. The discrete maximum principle.
Incompressible Navier-Stokes equations. Boundary conditions. Spatial discretization on collocated and on staggered grids. Temporal discretization on staggered grid and on collocated grid.

Section-III

Iterative methods. Stationary methods. Krylov subspace methods. Multigrade methods. Fast Poisson solvers.
Iterative methods for incompressible Navier-Stokes equations.
Shallow-water equations One and two dimensional cases. Godunov order barrier theorem.

Section-IV

Linear schemes. Scalar conservation laws. Euler equation in one space dimension analytic aspects. Approximate Riemann solver of Roe.
Osher scheme. Flux splitting scheme. Numerical stability. Jameson Schmidt Turkel scheme. Higher order schemes.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. P. Wesseling, Principles of Computational Fluid Dynamics, Springer-Verlag, 2000.

2. J.F. Wendt, J.D. Anderson, G. Degrez and E. Dick, Computational Fluid Dynamics : An Introduction, Springer-Verlag, 1996.

3. J.D. Anderson, Computational Fluid Dynamics : The basics with applications, McGraw-Hill, 1995.

4. K. Muralidher, Computational Fluid Flow and Heat Transfer, Narosa Pub. House.

5. T.J. Chung, Computational Fluid Dynamics, Cambridge Uni. Press.

6. J.N. Reddy, An introduction to the Finite Element Methods, McGraw Hill International Edition, 1985.

CO-PSO matrix for the Course MAT-315: Cosmology-I

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	S
CO2	S	S	S	S
CO3	S	S	S	S
CO4	S	S	S	S

CO-PO matrix for the Course MAT-315: Cosmology-I

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	S	M	S	M	S	S
CO2	S	S	S	S	S	M	S	M	S	S
CO3	S	S	S	S	S	M	S	M	S	S
CO4	S	S	S	S	S	M	S	M	S	S

S=Strong, M=Medium, W=Weak

MAT-315: Cosmology-I

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: Cosmology deals with the study of the origin, evolution and ultimate fate of the Universe. The course presents the basics of background cosmology for the beginners. This course will serve as a prerequisite for the advanced course on cosmology.

Course Outcomes: This course will enable the students to learn:

CO1. Geometry of the Universe

CO2. Types of energy sources in the Universe

CO3. Evolution of early Universe

CO4. Problems of the standard cosmological model

Course Contents:

Section-I

Brief history of cosmological ideas, In visible light, In other wavebands, Homogeneity and isotropy, The expansion of the Universe, Particles in the Universe, The Friedman equation, Meaning of the expansion, Things that go faster than light, The fluid equation, The acceleration equation, Mass, energy and vanishing factors of c^2 , Flat, Spherical and Hyperbolic geometries, Infinite and observable Universes, Place of Big Bang, Three values of k.

Section-II

Hubble's law, Expansion and redshift, Matter, Radiation, Mixtures, Particle number densities, Evolution including Curvature, Hubble parameter, Density parameter, Deceleration parameter, Cosmological constant, Fluid description, Cosmological models with cosmological constant, Age of the Universe

Section-III

Weighing the Universe through counting stars, nucleosynthesis, galaxy rotation curves, galaxy cluster composition, bulk motions, formation of structure, brightness of supernovae, Nature of dark matter and its searches, Properties of the microwave background, photon to baryon ratio, origin of microwave back- ground, The early Universe, Hydrogen and Helium, Comparing with observations, Contrasting decoupling and nucleosynthesis

Section-IV

Problems with Hot Big Bang: Flatness, horizon and relic particle abundances, Inflationary expansion, Solution of Big Bang problems, Extent of inflation, Inflation and particle physics, The initial singularity, Overview of the standard cosmological model, General relativistic cosmology, Distances and luminosities, Structures in the Universe

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. A. Liddle: An Introduction to Modern Cosmology, Relativity and Cosmology, Wiley (2003).
2. S. Weinberg, Gravitation and Cosmology, John Wiley, New York, (1972).
3. M. Rowan-Robinson, Cosmology, 3rd edition, Oxford University Press (1996).
4. J. A. Peacock: Cosmological Physics, Cambridge University Press (1999).
5. S. Dodelson, Modern Cosmology, Academic Press (2003)

(Open Elective Course offered by Department of Mathematics for students of other Departments)

CO-PSO matrix for the Course MAT-316: Basics of Vedic Mathematics

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	M
CO2	S	S	S	M
CO3	S	S	S	M
CO4	S	S	S	M

CO-PO matrix for the Course MAT-316: Basics of Vedic Mathematics

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	S	M	S	M	S	S
CO2	S	S	S	S	S	M	S	M	S	S
CO3	S	S	S	S	S	M	S	M	S	S
CO4	S	S	S	S	S	M	S	M	S	S

S=Strong, M=Medium, W=Weak

MAT-316: Basics of Vedic Mathematics

Time : 3 hours **Max. Marks : 80**
Credits : 3:0:0

Course Objectives: The aim of this course is to familiarize the students with the mathematical underpinnings and techniques, enhance computation skills, and develop logical and analytical reasoning.

Course Outcomes: After studying this course, the student will be able to

CO1. understand the meaning of mathematical sutras in Sanskrit and perform multiplication using vertically and crosswise.

CO2. understand the concept of multiplication using base and subbase method, squaring using Nikhilam and Duplex method.

CO3. find cube using Nikhilam and Anurupyena Sutra, understand the concept of Meru-prastar and its applications and perform multiplication of algebraic expressions.

CO4. find square and square roots of algebraic expressions, solve simple and miscellaneous simple equations using vedic mathematics techniques.

Course Contents:

Unit-I

- Introduction to Vedic Mathematics
- Importance of Vedic Mathematics
- Number system and its applications in Vedic Mathematics
- Multiplication of any number by numbers containing digit 1 only
- Multiplication of any number by numbers containing digit 9 only
- Multiplication using Sutra-Urdhvatiryagbhyam

Unit-II

- Multiplication using base and sub-base method
- Multiplication using Ekadhikena Sutra
- Sum and Difference of Products
- Square using Nikhilam Sutra
- Square using Duplex Method
- Addition and subtraction of squared and products numbers

Unit-III

- Cube using Nikhilam and Anurupyena Sutra
- Division using Dhwajank Method
- Meru-prastar and their applications
- Square root and cube root
- Algebraic Multiplication

Unit-IV

- Addition and subtraction of algebraic products
- Square and square root of algebraic expressions
- Simultaneous simple equations
- Miscellaneous Simple equations
- Auxiliary fractions
- Triplets

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions from each unit and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Reference Books

1. Bharti Krishan Tirath: Vedic Mathematics, Motilal Banarsidas New Delhi, 2001.

2. Dr. Vyawahare-Chouthaiwale-Borgaonkar : Introduction to Vedic Mathematics, Swadhaya mandal, Kille pardi, Gujarat, 2003.

3. Chouthaiwale-Kolluru: Enjoy Vedic Mathematics, Sri Sri Publications Trust, Banglore, 2010.

4. N. K. Jain, Choudhary: Vedic and Jain Mathematics, Vishwa Punar Nirman, Talangkhedi, Nagpur.

5. V. G. Unkalkar: Magic world of Mathematics, Vandana Publishers Banglore, 2008.

6. V. G. Unkalkar: Excel with Vedic Mathematics, Vandana Publishers Banglore, 2009.

7. V. G. Heroor, The History mathematics and Mathematicians of India, Vidya Bharti, Banglore, 2006.

8. V. G. Heroor, Jyopati, Rajasthan Sanskrit University, Jaipur, 2007.

Scheme of Examination
M.Sc. Mathematics
Learning Outcomes Based Curriculum Framework (LOCF)
w.e.f. Session 2022-23

Semester-IV

Core Courses

Course Code	Title of the Course	Theory Marks	Internal Marks	Practical Marks	Credits L:T:P	Contact hrs per week	Total Credits
MAT-401	Inner Product Spaces and Measure Theory	80	20	-	4:0:0	4	4
MAT-402	Classical Mechanics	80	20	-	4:0:0	4	4
MAT-403	Viscous Fluid Dynamics	80	20	-	4:0:0	4	4
MAT-404	Computing Lab-II (MATLAB)	-	-	50	0:0:2	4	2
MAT-405	Seminar	-	-	25	-	-	1
MAT-406	Self Study Paper	-	-	25	-	-	1

Discipline Centric Elective Courses (Any two)

Course Code	Title of the Course	Theory Marks	Internal Marks	Credits L:T:P	Contact hrs per week	Total Credits
MAT-407	Advanced Complex Analysis	80	20	4:0:0	4	4
MAT-408	Graph Theory	80	20	4:0:0	4	4
MAT-409	Applied Solid Mechanics	80	20	4:0:0	4	4
MAT-410	Bio Mechanics	80	20	4:0:0	4	4
MAT-411	Algebraic Number Theory	80	20	4:0:0	4	4
MAT-412	Algebraic Coding Theory	80	20	4:0:0	4	4
MAT-413	Bio-Fluid Dynamics	80	20	4:0:0	4	4
MAT-414	Fractional Calculus	80	20	4:0:0	4	4
MAT-415	Cosmology-II	80	20	4:0:0	4	4

Total Credits : 24
Total Contact Hours per Week : 24
Max Marks : 600

Total Credits of the Programme : 28 + 26 + 27 + 24 = 105
Max Marks of the Programme : 700 + 650 + 700 + 600 = 2650

Note: Optional papers can be offered subject to the availability of requisite resources/faculty.

CO-PSO matrix for the Course MAT-401: Inner Product Spaces and Measure Theory

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	M
CO2	S	S	S	M
CO3	S	S	S	M
CO4	S	S	S	M

CO-PO matrix for the Course MAT-401: Inner Product Spaces and Measure Theory

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	M	M	M	M	S	M
CO2	S	S	S	S	M	M	M	M	S	M
CO3	S	S	S	S	S	S	S	M	S	S
CO4	S	M	S	S	S	S	S	M	S	S

S=Strong, M=Medium, W=Weak

MAT-401: Inner Product Spaces and Measure Theory

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The aim of this course is to familiarize with Hilbert spaces and some basic tools of Functional Analysis to prove some significant results like Riesz Representation theorem in Hilbert spaces, Spectral theorem on finite dimensional space and to understand the concepts of measure, outer measure, signed measure and several significant results related to signed measure.

Course Outcomes: After studying this course, the student will be able to

CO1. understand Hilbert space as a normed linear space and to prove Projection theorem.

CO2. study orthonormal sets, Riesz Representation theorem, self adjoint operators and positive operators.

CO3. know about projection, normal and unitary operators and understand spectral theorem on finite dimensional space.

CO4. understand the concept of signed measure and some significant theorems like Radon-Nikodym theorem, Lebesgue decomposition theorem and the concepts of Product measure, Baire sets and Baire measure.

Course Contents:

Section-I

Hilbert Spaces: Inner product spaces, Hilbert spaces, Schwarz's inequality, Hilbert space as normed linear space, Convex sets in Hilbert spaces, Projection theorem.

Section-II

Orthonormal sets, Separability, Total Orthonormal sets, Bessel's inequality, Parseval's identity.

Conjugate of a Hilbert space, Riesz representation theorem in Hilbert spaces, Adjoint of an operator on a Hilbert space, Reflexivity of Hilbert space, Self-adjoint operators, Positive operators, Product of Positive Operators.

Section-III

Projection operators, Product of Projections, Sum and Difference of Projections, Normal and unitary operators, Projections on Hilbert space, Spectral theorem on finite dimensional space.
Measure space, Generalized Fatou's lemma, Measure and outer measure, Extension of a measure, Caratheodory extension theorem.

Section-IV

Signed measure, Hahn decomposition theorem, Jordan decomposition theorem, Mutually signed measure, Radon-Nikodym theorem, Lebesgue decomposition, Lebesgue-Stieltjes integral, Product measures, Fubini's theorem, Baire sets, Baire measure, Continuous functions with compact support.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions of 2 marks each without any internal choice covering the entire syllabus.

Books recommended

1. George F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Book Company, 1963

2. H.L. Royden, Real Analysis, MacMillan Publishing Co., Inc., New York, 4th Edition, 1993.

3. E. Kreyszig, Introductory Functional Analysis with Applications, John Wiley (1978).

4. S.K. Berberian, Measure and Integration, Chelsea Publishing Company, New York, 1965.

5. K.C. Rao, Functional Analysis, Narosa Publishing House, Second edition, 2006.

CO-PSO matrix for the Course MAT-402: Classical Mechanics

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	M
CO2	S	S	S	M
CO3	S	S	S	M
CO4	S	S	S	M

CO-PO matrix for the Course MAT-402: Classical Mechanics

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	S	M	S	M	S	S
CO2	S	S	S	S	S	M	S	M	S	S
CO3	S	S	S	S	S	M	S	M	S	S
CO4	S	S	S	S	S	M	S	M	S	S

S=Strong, M=Medium, W=Weak

MAT-402: Classical Mechanics

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The aim of this course is to get the students familiar with the concept of Moments & Products of Inertia and to represent equations of motion for mechanical systems using Lagrangian and Hamiltonian formulations of classical mechanics.

Course Outcomes: After studying this course, the student will be able to

CO1. understand the concepts of Moment of Inertia, momental ellipsoid, equimomental systems and general motion of a rigid body.

CO2. understand free and constrained systems, ideal constraints, generalised coordinates and Lagrange;s equations in independent coordinates.

CO3. understand Hamilton's principle, Poincare-Carton integral invariant and principle of least action.

CO4. become familiar with canonical transformations, conditions of canonicity in terms of Lagrange and Poisson Brackets.

Course Contents:

Section-I

Moments and products of inertia, The theorems of parallel and perpendicular axes, Angular momentum of a rigid body about a fixed point and about fixed axes, Principal axes and principal moments of inertia of a rigid body, Kinetic energy of a rigid body rotating about a fixed point, Momental ellipsoid and equimomental systems, Coplanar mass distributions, General motion of a rigid body. (Relevant topics from the book of Chorlton).

Section-II

Free and constrained systems, Constraints and their classification, Holonomic and non-holonomic systems, Scleronomic and Rheonomic systems, Possible and Virtual Displacements, Possible velocities and possible accelerations, Ideal constraints, The General equation of dynamics, Lagrange's equations of the first kind. The Principle of Virtual Displacements, D' Alembert's Principle.

Independent coordinates and Generalized forces, Lagrange's equations of the second kind in independent coordinates, Generalized velocities and accelerations, Kinetic energy as a function of generalized velocities, Uniqueness of solution, Theorem on Variation of total energy, Potential, Gyroscopic and Dissipative Forces.

Section-III

Lagrange's equations for Potential Forces, The Generalized Potential, Lagrangian and Hamiltonian variables, Donkin's theorem, Hamilton canonical equations, Routh variables and Routh function, Routh's equations, Cyclic or Ignorable coordinates, Poisson Bracket and their simple properties, Poisson identity, Jacobi-Poisson theorem.

Hamilton's principle, Poincare-Carton Integral Invariant, Generalized Conservative Systems, Whittaker's equations, Jacobi's equations, Lagrangian action and the principle of least action. The Universal Integral Invariant of Poincare, Lee Hwa-Chung's Theorem (Statement only).

Section-IV

Canonical transformations, Necessary and sufficient condition for a transformation to be canonical, Univalent canonical transformations, Free canonical transformations, Hamilton-Jacobi equation, Jacobi's theorem, Method of separation of variables in HJ equation.

The Lagrange Brackets, Necessary and sufficient conditions for the canonical character of a transformation in terms of Lagrange Brackets, The Simplicial Nature of the Jacobian Matrix of a canonical transformation, Conditions of canonicity of a transformation in terms of Poisson Brackets, Invariance of the Poisson Brackets in a canonical transformation.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. F. Chorlton, Textbook of Dynamics, CBS Publishers, New Delhi.

2. F. Gantmacher, Lectures in Analytical Mechanics, MIR Publishers, Moscow, 1975.

3. N.C. Rana and P.S. Joag, Classical Mechanics, Tata McGraw- Hill, New Delhi, 1991.

4. P.V. Panat, Classical Mechanics, Narosa Publishing House, New Delhi, 2005.

5. Louis N. Hand and Janet D. Finch, Analytical Mechanics, CUP, 1998.

6. K. Sankra Rao, Classical Mechanics, Prentice Hall of India, 2005.

7. M.R. Speigal, Theoretical Mechanics, Schaum Outline Series.

CO-PSO matrix for the Course MAT-403: Viscous Fluid Dynamics

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	M	S	S
CO2	S	S	M	S
CO3	S	S	S	M
CO4	S	S	S	S

CO-PO matrix for the Course MAT-403: Viscous Fluid Dynamics

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	M	S	S	S	S	M	M	S	M	S
CO2	S	S	M	M	S	S	M	M	S	M
CO3	S	S	S	S	M	S	S	S	S	S
CO4	S	S	S	S	S	S	S	M	M	M

S=Strong, M=Medium, W=Weak

MAT-403: Viscous Fluid Dynamics

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The viscosity is the most important characteristic of the fluid that has been discussed in this course, after completing this course the learners having good knowledge about the vorticity, Karman vortex street, equation of motion of compressible fluid i.e. gas, subsonic, sonic, supersonic flow. Due to the presence of viscosity in the fluid, stress, and strain are developed and play an important role to know about the behavior of fluid flow and the effect of the boundary. Dynamical similarity, Inspection analysis have been discussed to know the physical importance of non-dimensional parameters in two-dimensions. This course will definitely enhance the capacity of learners in the field of fluid dynamics.

Course Outcomes: After studying this course, the student will be able to

CO1. Learn about vorticity and its various types, Motion of vortices, Equation of motion of a Gas, Types of flows and flow through a nozzle.

CO2. Learn properties about stress and strain in a real fluid and relation between them, Newtonian and non-Newtonian fluids, Navier-Stokes equation of motion in Cartesian, cylindrical, and spherical polar co-ordinates.

CO3. Study the fluid flow from between the parallel plates, channels, co-axial circular cylinders, concentric rotation cylinders, tubes of uniform elliptic and equilateral triangular cross-section, and Unsteady flow over a flat plate.

CO4. Introduce the concept of dynamical similarity, Non-dimensional numbers, Buckingham π-theorem and its various applications, Prandtl boundary layer, Blasius theorem, and Kerman integral conditions.

Course Contents:

Section-I

Vorticity in two dimensions, Circular and rectilinear vortices, Vortex doublet, Images, Motion due to vortices, Single and double infinite rows of vortices. Karman vortex street. Wave motion in a Gas. Speed of sound in a gas. Equation of motion of a Gas. Subsonic, sonic and supersonic flows. Isentropic gas flow, Flow through a nozzle.

Section-II

Stress components in a real fluid. Relation between Cartesian components of stress. Translational motion of fluid element. Rates of strain. Transformation of rates of strains. Relation between stresses and rates of strain. The co-efficient of viscosity and laminar flow. Newtonian and non-Newtonian fluids. Navier-Stoke equations of motion. Equations of motion in cylindrical and spherical polar co-ordinates. Equation of energy. Diffusion of vorticity. Energy dissipation due to viscosity. Equation of state..

Section-III

Plane Poiseuille and Couette flows between two parallel plates. Theory of lubrication. Hagen Poiseuille flow. Steady flow between co-axial circular cylinders and concentric rotating cylinders. Flow through tubes of uniform elliptic and equilateral triangular cross-section. Unsteady flow over a flat plate. Steady flow past a fixed sphere. Flow in convergent and divergent chennals.

Section-IV

Dynamical similarity. Inspection analysis. Non-dimensional numbers. Dimensional analysis. Buckingham p-theorem and its application. Physical importance of non-dimensional parameters. Prandtl boundary layer. Boundary layer equation in two-dimensions. The boundary layer on a flat plate (Blasius solution). Characteristic boundary layer parameters. Karman integral conditions. Karman-Pohlhausen method.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. W.H. Besaint and A.S. Ramasey, A Treatise on Hydromechanics, Part II, CBS Publishers, Delhi, 1988.

2. F. Chorlton, Text Book of Fluid Dynamics, C.B.S. Publishers, Delhi, 1985

3. O'Neill, M.E. and Chorlton, F., Ideal and Incompressible Fluid Dynamics, Ellis Horwood Limited, 1986.

4. O'Neill, M.E. and Chorlton, F., Viscous and Compressible Fluid Dynamics, Ellis Horwood Limited, 1989.

5. S.W. Yuan, Foundations of Fluid Mechanics, Prentice Hall of India Private Limited, New Delhi, 1976.

6. H. Schlichting, Boundary-Layer Theory, McGraw Hill Book Company, New York, 1979.

7. R.K. Rathy, An Introduction to Fluid Dynamics, Oxford and IBH Publishing Company, New Delhi, 1976.

8. G.K. Batchelor, An Introduction to Fluid Mechanics, Foundation Books, New Delhi, 1994.

CO-PSO matrix for the Course MAT-404: Computing Lab-II (MATLAB)

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	M
CO2	S	M	S	S
CO3	S	S	M	S
CO4	S	S	S	S

CO-PO matrix for the Course MAT-404: Computing Lab-II (MATLAB)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	M	S	S	S	S	S	S
CO2	M	S	S	S	S	M	S	S	M	S
CO3	S	S	M	S	M	S	M	M	S	M
CO4	S	M	S	S	S	S	S	M	S	S

S=Strong, M=Medium, W=Weak

MAT-404: Computing Lab-II (MATLAB)

Time : 4 hours **Max. Marks : 50**
Credits : 0:0:2

Course Objectives: Introduction to MATLAB introduces students to basic MATLAB programming concepts. Learn features of MATLAB as a programming tool. Promote new teaching model that will help to develop programming skills and technique to solve mathematical problems. Understand MATLAB graphic feature and its applications. Write the programs in MATLAB to solve scientific and mathematical problems.

Course Outcomes: After studying this course, the student will be able to

CO1. Become familiar with MATLAB interface and understand the importance of this software in various fields.

CO2. Learn how to write matrix and perform different algebraic operations, solve system of equations in MATLAB.

CO3. Learn about graph plotting, making programs using conditional statements and loops in MATLAB.

CO4. Explore the various basic concepts of calculus and solution of ordinary differential equations in MATLAB.

Note: **(A)** Each candidate will be provided a question paper of four questions and will be required to attempt two questions. The candidate will first the program in MATLAB of the questions in the answer-book and then run the same on the computer, and then finally add the print-outs of these programs in the answer-book. This work will consist of 30 marks, 15 marks for each question.

(B) The practical file of each student will be checked and Viva-Voce examination based upon the practical file and the theory will be jointly conducted by external and internal examiners. This part of the practical examination shall be of 20 marks.

CO-PSO matrix for the Course MAT-407: Advanced Complex Analysis

COs	PSO1	PSO2	PSO3	PSO4
CO1	M	S	S	S
CO2	S	M	S	M
CO3	S	S	S	M
CO4	S	S	S	M

CO-PO matrix for the Course MAT-407: Advanced Complex Analysis

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	M	S	S	S	M	S	S	M	M	S
CO2	S	S	M	S	S	S	M	S	S	S
CO3	S	M	S	S	M	M	S	S	S	M
CO4	S	S	S	M	M	M	S	M	S	M

S=Strong, M=Medium, W=Weak

MAT-407: Advanced Complex Analysis

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The objective of this course is to explain the fundamental concepts of complex analysis and their role in modern mathematics and applied contexts and understand the concepts of Gamma function and its properties, to demonstrate accurate and efficient use of complex analysis techniques and get familiar with Riemann Zeta function, Riemann functional equation and Mittag Leffler theorem, to demonstrate the idea of Harnack Inequality, Dirichlet region, Green function and its properties, to understand the concept of integral functions, their factorisation, order and exponent of convergence and be familiar with the range of analytic function and proof of related results and to appreciate the existence of special functions and their use in a range of contexts.

Course Outcomes: After studying this course, the student will be able to

CO1. Learn about the Integral Functions, Gamma function, Riemann Zeta function, Weierstrass' factorization theorem, Mittag-Leffler theorem, and Runge theorem.

CO2. Learn Analytic Continuation and its different Uniqueness, Power series method, Schwarz Reflection principle, Germ of an analytic function. Monodromy theorem and its consequences, Dirichlet problem for a unit disc.

CO3. Known about the Harnack inequality, Green function, Poisson-Jensen formula, Hadamard three circles theorem, Growth and order of an entire function, An estimate of number of zeros, and Hadamard factorization theorem.

CO4. Introduce the range of an analytic function, Schottky theorem, Different forms of Picard theorems, Montel Caratheodory theorem, Univalent functions, and the "1/4 theorem".

Course Contents:

Section-I

Integral Functions, Factorization of an integral function, Weierstrass primary factors, Weierstrass factorization theorem, Gamma function and its properties, Stirling formula, Integral version of gamma function, Riemann Zeta function, Riemann functional equation, Mittag-Leffler theorem, Runge theorem(Statement only).

Section-II

Analytic Continuation, Natural Boundary, Uniqueness of direct analytic continuation, Uniqueness of analytic continuation along a curve, Power series method of analytic continuation, Schwarz Reflection principle, Germ of an analytic function. Monodromy theorem and its consequences, Harmonic functions on a disk, Poisson kernel, The Dirichlet problem for a unit disc.

Section-III

Harnack inequality, Harnack theorem, Dirichlet region, Green function, Canonical product, Jensen formula, Poisson-Jensen formula, Hadamard three circles theorem, Growth and order of an entire function, An estimate of number of zeros, Exponent of convergence, Borel theorem, Hadamard factorization theorem.

Section-IV

The range of an analytic function, Bloch theorem, Schottky theorem, Little Picard theorem, Montel Caratheodory theorem, Great Picard theorem, Univalent functions, Bieberbach conjecture (Statement only) and the "1/4 theorem" .

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. H. A. Priestly, Introduction to Complex Analysis, Clarendon Press, Oxford, 1990.

2. S. Ponnusamy, Foundations of Complex Analysis, Narosa Publishing House, 2011.

3. J. B. Conway, Functions of one complex variable, Springer-Verlag, International Student Edition, Narosa Publishing House, 2002.

4. Liang-shin Hann and Bernand E., Classical Complex Analysis, Jones and Bartlett Publishers International, London, 1996.

5. E. T. Copson, An Introduction to the Theory of Functions of a Complex Variable, Oxford University Press, London.

6. E. C. Titchmarsh, The Theory of Functions, Oxford University Press, London.

7. Mark J. Ablowitz and A.S. Fokas, Complex Variables: Introduction and Applications, Cambridge University Press, South Asian Edition, 1998.

8. Ruel V. Churchill and James Ward Brown, Complex Variables and Applications, McGraw-Hill Publishing Company.

9. H.S. Kasana, Complex Variable Theory and Applications, PHI Learning Private Ltd, 2011.

CO-PSO matrix for the Course MAT-408: Graph Theory

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	S
CO2	S	S	S	S
CO3	S	S	S	S
CO4	S	S	S	S

CO-PO matrix for the Course MAT-408: Graph Theory

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	S	M	M	S	S	M	S	S
CO2	S	S	S	S	M	S	S	M	M	S
CO3	S	S	S	S	S	S	S	S	S	S
CO4	S	S	S	S	S	S	S	S	S	S

S=Strong, M=Medium, W=Weak

MAT-408: Graph Theory

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The main objective of this course is to get the students familiar with basic concepts of graph theory and their applications in real life.

Course Outcomes: After studying this course, the student will be able to

CO1. Understand the concept of graph and its various types, applications of graphs, operations on graphs and isomorphism of graphs.

CO2. Get familiar with Eulerian and Hamitonian Graphs.

CO3. Know the concepts of Directed graphs and trees.

CO4. Understand spanning trees, minimal spaning trees and cut sets.

Course Contents:

Section-I

Definition and types of graphs, Walks, Paths and Circuits, Connected and Disconnected graphs, Applications of graphs, operations on Graphs, Graph Representation, Isomorphism of Graphs.

Section-II

Eulerian and Hamiltonian paths, Shortest Path in a Weighted Graph, The Travelling Sales person Problem, Planar Graphs, Detection of Planarity and Kuratowski Theorem, Graph Colouring.

Section-III

Directed Graphs, Trees, Tree Terminology, Rooted Labeled Trees, Prefix Code, Binary Search Tree, Tree Traversal.

Section-IV

Spanning Trees and Cut Sets, Minimum Spanning Trees, Kruskal Algorithm, Prim Algorithm, Decision Trees, Sorting Methods.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. Narsingh Deo, Graph Theory with Applications to Engineering and Computer Science, PHI Pvt. Ltd, 2004.

2. F. Harary: Graph Theory, Addition Wesley, 1969.

3. G. Chartrand and P. Zhang. Introduction to Graph Theory, Tata McGraw-Hill, 2006.

4. Kenneth H. Rosen, Discrete Mathematics and Its Applications, Tata McGraw-Hill, Fourth Edition, 1999.

5. Seymour Lipschutz and Marc Lipson, Theory and Problems of Discrete Mathematics, Schaum Outline Series, McGraw-Hill Book Co, New York, 2007.

6. John A. Dossey, Otto, Spence and Vanden K. Eynden, Discrete Mathematics, Pearson, Fifth Edition, 2005.

7. C. L. Liu and D.P. Mohapatra, Elements of Discrete Mathematics- A Computer Oriented Approach, Tata McGraw-Hill, Fourth Edition.

CO-PSO matrix for the Course MAT-409: Applied Solid Mechanics

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	S
CO2	M	S	S	S
CO3	S	S	M	S
CO4	S	S	S	M

CO-PO matrix for the Course MAT-409: Applied Solid Mechanics

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	S	S	M	S	S	M	S
CO2	S	S	M	M	S	S	S	M	S	S
CO3	S	M	S	S	M	S	M	S	S	S
CO4	S	S	S	S	S	S	S	S	S	M

S=Strong, M=Medium, W=Weak

MAT-409: Applied Solid Mechanics

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: After successful completion of the course Mechanics of Solid in continuation, the students can enjoy the paper Applied Solid Mechanics which has very vast application in engineering and seismology like; to determine the torsion of Beams, Deformation of the thick-walled elastic tube under external and internal pressures, Extension of the beam due to its weight or longitudinal force, bending of the beam due to terminal couple to overcome the problem some variation methods are corporate in this paper for the practical purpose.

Course Outcomes: After studying this course, the student will be able to

CO1. Learn about the strain deformation, Deformation of a thick-walled elastic tube, Airy stress function, Solutions of biharmonic equation using Fourier transform.

CO2. Introduce the concept of Torsion of a beam, rigidity, stress functions, Lines of shearing stress, Torsion of a beam of arbitrary cross-section with some special cases.

CO3. Explore the concept of Bending of beams by terminal couples, transverse load at the centroid of the end section along a principal axis, Ritz method, Galerkin method.

CO4. Asses the Simple harmonic progressive waves, Progressive type solutions, Stationary type solutions, Propagation of waves in an unbounded elastic isotropic media, P-waves, S - waves.

Course Contents:

Section-I

Two dimensional problems: Plane strain deformation, State of plane stress, Generalized plane stress, Airy stress function for plane strain problems, Solutions of a two-dimensional biharmonic equation using Fourier transform as well as in terms of two analytic functions, Expressions for stresses and displacements in terms of complex potentials, Deformation of a thick-walled elastic tube under external and internal pressures.

Section-II

Torsion of Beams: Torsion of a circular cylindrical beam, Torsional rigidity, Torsion and stress functions, Lines of shearing stress, Torsion of a beam of arbitrary cross-section and its special cases for circular, elliptic and equilateral triangular cross-sections, Circular groves in an circular beam.
Extension of Beams: Extension of beams by longitudinal forces, Beams stretched by its own weight.

Section-III

Bending of Beams: Bending of beams by terminal couples, Bending of a beam by transverse load at the centroid of the end section along a principal axis.
Variational Methods: One-dimensional Ritz method, Two - dimensional Ritz method, Galerkin method, Application to torsion of beams.
(Relevant topics from the Sokolnikof book).

Section-IV

Waves: Simple harmonic progressive waves, Plane waves, Progressive type solutions in cartesian coordinates, Stationary type solutions in Cartesian coordinates.
Elastic Waves: Propagation of waves in an unbounded elastic isotropic media, P-waves, S - waves, Wave propagation in two-dimensions, P-SV waves and SH waves.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. I. S. Sokolnikof, Mathematical theory of Elasticity, Tata McGraw Hill Publishing company Ltd. New Delhi, 1977.

2. Teodar M. Atanackovic and Ardeshiv Guran, Theory of Elasticity for Scientists and Engineers, Birkhausev, Boston, 2000.

3. A. K. Mal and S.J. Singh, Deformation of Elastic Solids, Prentice Hall, New Jersey, 1991.

4. C. A. Coluson, Waves.

5. A. S. Saada, Elasticity-Theory and Applications, Pergamon Press, New York, 1973.

6. D. S. Chandersekharian and L.Debnath, Continuum Mechanics, Academic Press.

CO-PSO matrix for the Course MAT-410: Bio Mechanics

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	M	M	M
CO2	M	S	M	M
CO3	S	M	S	S
CO4	S	M	M	S

CO-PO matrix for the Course MAT-410: Bio Mechanics

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	S	S	S	S	M	M	M	S
CO2	S	S	S	M	S	S	S	M	S	S
CO3	M	S	M	S	S	S	S	S	M	S
CO4	S	M	S	S	M	M	S	S	S	M

S=Strong, M=Medium, W=Weak

MAT-410: Bio-Mechanics

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The main objective of the course Bio-Mechanics to enhance the knowledge about Newton equations of motion, Segmental movement and vibrations, Study state aeroelastic problem, Transient fluid dynamics forces due to unsteady motion, Vortex system associated with a finite wing in no steady motion, Blood flow in heat, lungs, arteries, and veins. Rheological properties of blood, pulmonary capillary blood flow, Respiratory gas flow, Law of thermodynamics, Diffusion from the molecular point of view. Tracer motion in a model of pulmonary microcirculation. After passing the course the students can help in Medical labs or as a consultant in one or other ways for any health issue.

Course Outcomes: After studying this course, the student will be able to

CO1. Understand the Mathematical modeling, Lagrange equations, Newton equation of motion, Decoupling of equations of motion, Steady state aeroelastic problems, and Transient fluid dynamics forces due to unsteady motion.

CO2. Learn about the Circulation and vorticity in the wake, Blood flow in heart, lungs, arteries, and veins, Field equations and boundary conditions, Pulsatile flow in arteries, Progressive waves superposed on a steady flow, Reflection and transmission of waves at junctions.

CO3. Explore the Velocity profile of a steady flow in a tube, Reynolds number, Stokes number, and Womersley number, Systematic blood pressure, Respiratory gas flow, Dynamics of the ventilation system.

CO4. Study the Laws of thermodynamics, Diffusion, Filtration, and fluid movement in interstitial space in thermodynamic view, Diffusion from molecular point of view, Indicator dilution method, and peristalsis, and Tracer motion in a model of pulmonary micro-circulation.

Course Contents:

Section-I

Newton equations of motion, Mathematical modeling, Continuum approach, Segmental movement and vibrations, Lagrange equations, Normal modes of vibration, Decoupling of equations of motion. Flow around an airfoil, Flow around bluff bodies, Steady state aeroelastic problems, Transient fluid dynamics forces due to unsteady motion, Flutter.

Section-II

Kutta-Joukowski theorem, Circulation and vorticity in the wake, Vortex system associated with a finite wing in nonsteady motion, Thin wing in steady flow.
Blood flow in heart, lungs, arteries, and veins, Field equations and boundary conditions, Pulsatile flow in arteries, Progressive waves superposed on a steady flow, Reflection and transmission of waves at junctions.

Section-III

Velocity profile of a steady flow in a tube, Steady laminar flow in an elastic tube, Velocity profile of Pulsatile flow, The Reynolds number, Stokes number, and Womersley number, Systematic blood pressure, Flow in collapsible tubes.
Micro- and macro-circulation Rheological properties of blood, Pulmonary capillary blood flow, Respiratory gas flow, Intraction between convection and diffusion, Dynamics of the ventilation system.

Section-IV

Laws of thermodynamics, Gibbs and Gibbs Duhem equations, Chemical potential, Entropy in a system with heat and mass transfer, Diffusion, Filtration, and fluid movement in interstitial space in thermodynamic view, Diffusion from molecular point of view.
Mass transport in capillaries, Tissues, Interstitial space, Lymphatics, Indicator dilution method, and peristalsis, Tracer motion in a model of pulmonary micro-circulation.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. Y.C. Fung, Biomechanics: Motion, Flow, Stress and Growth, Springer-Verlag, New York Inc., 1990.

CO-PSO matrix for the Course MAT-411: Algebraic Number Theory

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	M	S
CO2	S	S	S	M
CO3	S	M	M	S
CO4	S	S	M	S

CO-PO matrix for the Course MAT-411: Algebraic Number Theory

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	S	S	S	M	S	M	M
CO2	S	M	S	S	S	S	S	M	M	S
CO3	S	S	S	S	S	S	S	M	S	M
CO4	S	M	M	S	S	S	M	S	M	S

S=Strong, M=Medium, W=Weak

MAT-411: Algebraic Number Theory

Time : 3 hours

Max. Marks : 80
Credits : 4:0:0

Course Objectives: In this course, students will learn about integers, rational numbers, norm, traces and discriminants, Liouville theorem and find the solution to a given equation using Chinese remainder theorem and Factorization in the ring of algebraic integers.

Course Outcomes: After studying this course, the student will be able to

CO1. To describe the arithmetic of algebraic number fields.

CO2. Prove theorems for integral bases and unique factorization into ideals.

CO3. To Factorize an algebraic integer into irreducibles.

CO4. To understand ramified and unramified extensions and their related results.

Course Contents:

Section-I

Algebraic Number and Integers : Gaussian integers and its properties, Primes and fundamental theorem in the ring of Gaussian integers, Integers and fundamental theorem in Q(ω) where $\omega^3 = 1$, Algebraic fields, Primitive polynomials, The general quadratic field Q($\sqrt{m}$), Units of Q($\sqrt{2}$), Fields in which fundamental theorem is false, Real and complex Euclidean fields, Fermat theorem in the ring of Gaussian integers, Primes of Q($\sqrt{2}$) and Q($\sqrt{5}$).

Section-II

Countability of set of algebraic numbers, Liouville theorem and generalizations, Transcendental numbers, Algebraic number fields, Liouville theorem of primitive elements, Ring of algebraic integers, Theorem of primitive elements.

Section-III

Norm and trace of an algebraic number, Non degeneracy of bilinear pairing, Existence of an integral basis, Discriminant of an algebraic number field, Ideals in the ring of algebraic integers, Explicit construction of integral basis, Sign of the discriminant, Cyclotomic fields, Calculation for quadratic and cubic cases.

Section-IV

Integral closure, Noetherian ring, Characterizing Dedekind domains, Fractional ideals and unique factorization, G.C.D. and L.C.M. of ideals, Chinese remainder theorem, Dedekind theorem, Ramified and unramified extensions, Different of an algebraic number field, Factorization in the ring of algebraic integers.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions each without any internal choice covering the entire syllabus.

Books recommended

1. Esmonde and M Ram Murty, Problems in Algebraic Number Theory, GTM Vol. 190, Springer Verlag, 1999.

2. G.H. Hardy and E.M. Wright, An Introduction to the Theory of Numbers

3. W.J. Leveque, Topics in Number Theory Vols. I, III Addition Wesley.

4. H. Pollard, The Theory of Algebraic Number, Carus Monogrpah No. 9, Mathematical Association of America.

5. P. Riebenboim, Algebraic Numbers Wiley Inter-science.

6. E. Weiss, Algebraic Number Theory, McGraw Hill.

CO-PSO matrix for the Course MAT-412: Algebraic Coding Theory

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	M	S	S
CO2	S	S	M	S
CO3	S	S	S	M
CO4	S	M	S	S

CO-PO matrix for the Course MAT-412: Algebraic Coding Theory

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	S	S	S	M	S	S	M
CO2	S	S	S	M	S	M	S	M	M	S
CO3	S	M	S	S	S	S	M	M	M	S
CO4	S	S	S	S	S	S	S	S	S	M

S=Strong, M=Medium, W=Weak

MAT-412: Algebraic Coding Theory

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The objective of this course is to provide the students exposure of the actual Mathematics used in Coding theory. They will learn the most modern applications and will be able to follow new research in engineering security and coding theory. The course provides an introduction to fundamental concepts of coding theory.

Course Outcomes: After studying this course, the student will be able to

CO1. describe the basic concepts of the coding problem, types of codes, parity check codes and their error-detection & correction capabilities, Hamming distance, decoding syndrome decoding and coset leaders .

CO2. understand linear codes, minimum distances, dimension and polynomial codes, generator and parity check polynomial & matrices.

CO3. learn dual codes, weight distribution of dual of binary linear codes, Macwilliam identity, convolutional codes.

CO4. understand hamming codes and their properties, Bounds on minimum distance for block codes, Plotkin bound, Hamming sphere.

Course Contents:

Section-I

The communication channel, The coding problem, Types of codes, Block codes, Types of codes such as repetition codes, Parity check codes and their error-detection and correction capabilities. Hamming metric, Relationship of error detection/correction with hamming distance, Maximum likelihood decoding procedure, Decoding by syndrome decoding and Coset leaders, Standard array.

Section-II

Linear codes (Binary and non binary), Minimum distance, Dimension, Modular representation of linear codes, Description of linear codes by matrices, Polynomial codes, Generator and parity check polynomials and matrices.

Section-III

Dual codes, Self duality, Weight distribution of dual of binary linear codes, Macwilliam identity (binary case) extending, Expurgating and augmenting a code, Lee metric, Convolutional codes, Description using matrices and polynomials, Encoding using (4,3,2) encoder.

Section-IV

Hamming codes (Binary and non-binary) and their properties, Perfect and quasi-perfect codes. Golay codes as perfect codes, Bounds on minimum distance for block codes, Plotkin bound, Hamming sphere.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. Raymond Hill, A First Course in Coding Theory, Oxford University Press, 1986.
2. Man Young Rhee, Error Correcting Coding Theory, McGraw Hill Inc., 1989.
3. W. W. Peterson and E.J. Weldon, Jr., Error-Correcting Codes. M.I.T. Press, Cambridge Massachuetts, 1972.
4. E. R. Berlekamp, Algebraic Coding Theory, McGraw Hill Inc., 1968.
5. F. J. Macwilliams and N.J.A. Sloane, Theory of Error Correcting Codes, North-Holand Publishing Company.
6. J. H. Van Lint, Introduction to Coding Theory, Graduate Texts in Mathematics, 86, Springer, 1998.
7. L. R. Vermani, Elements of Algebraic Coding Theory, Chapman and Hall, 1996.

CO-PSO matrix for the Course MAT-413: Bio-Fluid Dynamics

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	S
CO2	M	S	S	S
CO3	S	S	M	S
CO4	S	S	S	M

CO-PO matrix for the Course MAT-413: Bio-Fluid Dynamics

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	S	S	S	S	S	M	M	S
CO2	S	S	S	M	S	S	M	M	S	S
CO3	M	S	M	S	S	M	S	S	M	S
CO4	S	M	S	S	M	S	S	S	S	M

S=Strong, M=Medium, W=Weak

MAT-413: Bio-Fluid Dynamics

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The main objective of the course Bio-Mechanics is to enhance the knowledge about Newton equations of motion, Segmental movement and vibrations, Study state aeroelastic problem, Transient fluid dynamics forces due to unsteady motion, Vortex system associated with a finite wing in no steady motion, Blood flow in heat, lungs, arteries, and veins. Rheological properties of blood, pulmonary capillary blood flow, Respiratory gas flow, Law of thermodynamics, Diffusion from the molecular point of view. Tracer motion in a model of pulmonary microcirculation. After passing the course the students can help in Medical labs or as a consultant in one or other ways for any health issue.

Course Outcomes: After studying this course, the student will be able to

CO1. understand the basic concepts of fluid dynamics, Viscosity, Continuity equation, Navier-Stokes equations of motion, and Simplification of basic equations.

CO2. Learn about Blood composition, Blood vessel structure. Diseases related to obstruction of blood flow. Special characteristics of blood flow. Poiseuille flow and its applications.

CO3. Explore the Pulsatile flow in circular rigid tube , Mones-Korteweg expression and its applications. Blood flow through artery with mild stenosis, and Shear stress on stenosis surface.

CO4. Study about the Non-Newtonian fluids and their classification, Power-law model, Herschel-Bulkley model, Casson model. Flow in the renal tubule, and Long- wavelength analysis.

Course Contents:

Section-I

Basic concepts of fluid dynamics. Viscosity. Reynold transport theorem, Rates of change of material integrals, Continuity equation, Navier-Stokes equations of motion, Simplification of basic equations. Reynolds number of flows.
The cardiovascular system. The circulatory system. Systemic and pulmonary circulations. The circulation in the heart. Diseases related to circulation.

Section-II

Blood composition. Structure of blood. Viscosity of blood. Yield stress of blood. Blood vessel structure. Diseases related to obstruction of blood flow.
Flow in pipes and ducts. Developing and fully developed flow. Special characteristics of blood flow. Poiseuille flow and its consequence. Applications of Poiseuille law for the study of blood flow.

Section-III

Pulsatile flow in circular rigid tube and its quantitative aspects. The pulse wave. Mones-Korteweg expression for wave velocity in an inviscid fluid-filled elastic cylindrical tube and its applications in the cardiovascular system. Wave propagation accounting for viscosity and its application to cardiac output determination. Blood flow through artery with mild stenosis, Expressions for pressure drop across the stenosis and across the whole length of artery. Shear stress on stenosis surface.

Section-IV

Non-Newtonian fluids and their classification. Laminar flow of non-Newtonian fluids.
Power-law model, Herschel-Bulkley model, Casson model. Flow in the renal tubule. Solutions when radial velocity at the wall decreases (i) linearly with z (ii) exponentially with z. Peristaltic flows. Peristaltic motion in a channel, Characteristic dimensionless parameters. Long- wavelength analysis.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. Jagan N. Mazumdar; Biofluid Mechanics, World Scientific Pub.

2. J. N. Kapur; Mathematical Models in Biology and Medicine, Affiliated East-West Press Pvt. Ltd.

3. T. J. Pedley; The Fluid Mechanics of Large Blood Vessels, Cambridge Uni. Press, 1980.

4. M. Stanley; Transport Phenomenon in Cardiovascular System, 1972.

5. O'Neill, M. E. and Chorlton, F., Viscous and Compressible Fluid Dynamics, Ellis Horwood Limited, 1989.

6. J. L. Bansal, Viscous Fluid Dynamics, Oxford and IBH Publishing Company, New Delhi, 2000.

CO-PSO matrix for the Course MAT-414: Fractional Calculus

COs	PSO1	PSO2	PSO3	PSO4
CO1	M	S	S	S
CO2	S	S	M	S
CO3	S	M	S	S
CO4	S	S	S	M

CO-PO matrix for the Course MAT-414: Fractional Calculus

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	S	S	M	S	S	S	M
CO2	M	S	S	S	M	S	M	S	M	S
CO3	S	S	S	M	S	M	S	M	S	M
CO4	S	M	S	S	S	S	M	S	M	S

S=Strong, M=Medium, W=Weak

MAT-414: Fractional Calculus

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: The subject of fractional calculus has applications in diverse and widespread fields of engineering and science such as electromagnetic, viscoelasticity, fluid mechanics, electrochemistry, biological population models, optics, and signals processing. It has been used to model physical and engineering processes that are found to be best described by fractional differential equations. In this course, students may familiar with some approaches like Caputos Fractional Derivative, Generalized Functions Approach, Sequential Fractional Derivatives, Left and Right Fractional Derivatives, and many more. Therefore, the course Fractional Calculus becomes increasingly important to be familiar with all traditional and recently developed methods for solving fractional-order PDEs and the implementations of these methods.

Course Outcomes: After studying this course, the student will be able to

CO1. Introduce the first and second type of Eulerian Integrals, Mittag-Leffler function and their different properties to understand the Caputo, Riemann and Liouville's Integrals.

CO2. Learn the different methods of fractional derivatives and integrals such as Grunwaid Letnikov, Riemann and Liouville's.

CO3. Study the Caputo's fractional derivative and different properties of fractional derivative, and Laplace transforms of fractional derivatives.

CO4. Explore the Fourier transformation of fractional derivatives and integrals, Ordinary, and Partial fractional differential equations.

Course Contents:

Section-I

Gamma Function: Definition of the Gamma function, Some properties of the Gamma function, Limit Representation of the Gamma function, Beta Function, Contour Integral Representation, Contour Integral Representation of $\frac{1}{\Gamma(z)}$

Mittag-Leffler Function: Definition and Relation to some other functions, The Laplace transformation of the Mittag-Leffler Function in two parameters, Derivative of the Mittag-Leffler Function, Differential Equations for the Mittag-Leffler Function, Summation Formulas, Integration of the Mittag-Leffler function.

Section-II

The name of the Game, Grunwald Letnikov Fractional derivatives: Unification of Integer-order Derivatives and integrals, Integrals of Arbitrary Order, Derivatives of Arbitrary order, Fractional Derivative of , Composition with integer-order Derivatives, Composition with Fractional Derivatives Riemann Liouville Fractional Derivatives: Unification of integral-order Derivatives and Integrals, Integrals of Arbitrary Order, Derivatives of Arbitrary Order, Fractional Derivative of $(t-a)^{\beta}$, Composition with Integer-Order Derivatives, Composition with Fractional Derivatives, Link of the Grtunwald-letnikov Approach.

Section-III

Some Other Approaches: Caputos Fractional Derivative, Generalized Functions Approach, Sequential Fractional Derivatives, Left and Right Fractional Derivatives.

Properties of fractional Derivatives: Linearity, The Leibniz Rule for Fractional Derivatives, Fractional Derivative of a Composite Function, Riemann Liouville fractional Differentiation of an Integral depending on a Parameter, Behaviour near the Lower terminal, Behaviour far from the Lower terminal.

Laplace transforms of Fractional Derivatives: Basic Facts on the Laplace transform, Laplace Transform of the Riemann-Liouville Fractional Derivatives, Laplace Transform of the Caputo Derivative, Laplace Transform of the Grunwald-Letnikov Fractional Derivative, Laplace transform of the Miller Ross Sequential Fractional Derivative

Section-IV

Fourier transforms of Fractional Derivatives: Basic Facts on the Fourier transform, Fourier Transform of Fractional Integrals, Fourier Transform of Fractional Derivatives.

Linear Fractional Differential Equations, Fractional Differential equation of the General Form, Existence and Uniqueness theorem as a Method of Solution, Dependence of a Solution on Initial Conditions.

Standard Fractional Differential Equations: Ordinary Linear Fractional Differential Equations, Partial Linear Fractional Differential Equations.

Sequential Fractional Differential Equations:Ordinary Linear Fractional Differential Equations,Partial Linear Fractional Differential Equations.

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. K.S. Miller and B. Rose, An Introduction to the Fractional Calculus and Fractional Differential Equations, John Wiley & sons Inc., New York, 1993.

2. Igor Podlubny, Fractional Differential Equations, Academic Press.

3. OLDHAM, Keith B., SPNIER, Jerome. The Fractional Calculus. London: Academic Press c1974. 225p.

4. J. Hadamard. Lectures on Cauchys problem in Linear Partial Fractional Equations. Yale Univ. press, New haven, 1923.

5. A. Carpinteri and F. Mainardi (eds.), Fractals and Fractional Calculus in Continuum Mechanics, Springer verlag, Vienna-New York, 1997.

CO-PSO matrix for the Course MAT-415: Cosmology-II

COs	PSO1	PSO2	PSO3	PSO4
CO1	S	S	S	S
CO2	S	S	S	S
CO3	S	S	S	S
CO4	S	S	S	S

CO-PO matrix for the Course MAT-415: Cosmology-II

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	S	M	S	M	S	S
CO2	S	S	S	S	S	M	S	M	S	S
CO3	S	S	S	S	S	M	S	M	S	S
CO4	S	S	S	S	S	M	S	M	S	S

S=Strong, M=Medium, W=Weak

MAT-415: Cosmology-II

Time : 3 hours **Max. Marks : 80**
Credits : 4:0:0

Course Objectives: Cosmology deals with the study of the origin, evolution and ultimate fate of the Universe. The course deals with the theory of linear perturbations and structure formation in cosmology.

Course Outcomes: This course will enable the students to learn:

CO1. Boltzmann equations

CO2. Linear perturbations in cosmology

CO3. Large-scale anisotropies and acoustic oscillations

CO4. Inhomogeneities to anisotropies

Course Contents:

Section-I

Background Cosmology, The Boltzmann Equations, The Perturbed Ricci Tensor and Scalar, Two Components of the Einstein Equations, Tensor Perturbations, Christoffel Symbols for Tensor Perturbations, Ricci Tensor for Tensor Perturbations, Einstein Equations for Tensor Perturbations, The Decomposition Theorem, From Gauge to Gauge

Section-II

The Einstein-Boltzmann Equations at Early Times, The Horizon, Inflation, A Solution to the Horizon Problem, Negative Pressure, Implementation with a Scalar Field, Gravity Wave Production, Quantizing the Harmonic Oscillator, Tensor Perturbations, Scalar Perturbations, Scalar Field Perturbations around a Smooth Background, Super-Horizon Perturbations, Spatially Flat Slicing

Section-III

Three Stages of Evolution, Large Scales, Super-horizon Solution, Through Horizon Crossing, Small Scales, Horizon Crossing, Sub-horizon Evolution, Numerical Results and Fits, Growth Function, Beyond Cold Dark Matter, Large-Scale Anisotropies, Acoustic Oscillations

Section-IV

Tightly Coupled Limit of the Boltzmann Equations, Tightly Coupled Solutions, Diffusion Damping, Inhomogeneities to Anisotropies, Free Streaming, The Anisotropy Spectrum Today, Sachs-Wolfe Effect, Small Scales, Cosmological Parameters, Curvature, Degenerate Parameters, Distinct Imprints

Note: The question paper will consist of five Sections. Each of the sections I to IV will contain two questions and the students shall be asked to attempt one question from each. Section-V shall be compulsory and will contain eight short answer type questions without any internal choice covering the entire syllabus.

Books recommended

1. A. Liddle: An Introduction to Modern Cosmology, Relativity and Cosmology, Wiley (2003).

2. S. Weinberg, Gravitation and Cosmology, John Wiley, New York, (1972).

3. M. Rowan-Robinson, Cosmology, 3rd edition, Oxford University Press (1996).

4. J. A. Peacock: Cosmological Physics, Cambridge University Press (1999).

5. S. Dodelson, Modern Cosmology, Academic Press (2003)