SEMESTERWISE BREAK DOWN AND CURRICULUM
FOR
M. Phil MATHEMATICS

WOMEN UNIVERSITY MARDAN

Scheme of Studies for M. Phil (Mathematics)

The M. Phil degree in Mathematics focuses on strengthening of the ability of a student in Mathematical reasoning and logical thinking. Students in this program prepare themselves either for their further development in the field of Mathematics or for jobs in academic, industrial, business and government organizations. The program offers a flexible frame work including scheme of courses covering major areas of Mathematics like Algebra, Analysis, Topology, Computational Mathematics, Foundations of Mathematics and Financial Mathematics.

Admission Criterion

- The applicants must have completed 4-year BS (Mathematics) with CGPA 2.0 out of 4.0; or M.Sc in Mathematics with at least 2nd Division or equivalent grade.
- GAT-General conducted by the National Testing Service with a minimum cumulative score of 50% or GRE (International) Subject Test with 50 % percentile score or GAT subject test with 60 % marks will be required at the time of admission.

The Program

i) The student must complete 24 CH course work with CGPA ≥2.5.
ii) Having obtained CGPA ≥2.5 in course work, the M. Phil student will complete a 6-credit hour thesisand will successfully defend it in order to qualify for the award of M. Phil degree.
iii) Thesis evaluation and viva voce will be conducted by one external examiner (from a universityin Pakistan other than university of enrollment) and one internal examiner.

Semester wise details are given in the following table:

SEMESTER -I

S.No	Course Title	Course Code	Credit Hours
1.	Numerical Solutions of Differential Equations	MTH-720	03
2.	Research Methodology	MTH-721	03
3.	Advance Differential Geometry	MTH-717	03
4.	Graph Theory	MTH-725	03
Total credit hours			**12**

SEMESTER –II

S.No	Course Title	Course Code	Credit Hours
1.	Numerical Solutions of PDEs	MTH-722	03
2.	Mathematical Modeling and Numerical Simulation	MTH-711	03
3.	General Relativity	MTH-718	03
4.	Spectral Theory and Hilbert Spaces	MTH-708	03
Total credit hours			**12**

List of Core Courses for M. Phil Mathematics

Sr. No	Course No.	Title	Credit Hours.
1.	MTH-701	Advanced Calculus	3
2.	MTH-702	Advanced Measure Theory	3
3.	MTH-703	Advanced Topology	3
4.	MTH-704	Field Theory	3
5.	MTH-705	Rings and Categories of Modules	3
6.	MTH-706	Theoretical Astrophysics	3
7.	MTH-707	Advanced Numerical Analysis	3
8.	MTH-708	Spectral Theory in Hilbert Spaces	3
9.	MTH-709	Mathematical logic	3
10.	MTH-710	Computational Fluid Dynamics	3
11.	MTH-711	Mathematical Modeling and Numerical Simulation	3
12.	MTH-712	Advanced Mathematical Methods	3
13.	MTH-713	Computational Geometry	3
14.	MTH-714	Numerical Solutions for Integral Equations	3
15.	MTH-715	Advanced Partial Differential Equations	3
16.	MTH-716	Wavelet Analysis	3
17.	MTH-717	Advanced Differential Geometry	3
18.	MTH-718	General Relativity	3
19.	MTH-719	Mathematical Biology	3
20.	MTH-720	Numerical Solutions of Differential Equations	3
21.	MTH-721	Research Methodology	3
22.	MTH-722	Numerical Solutions of PDEs	3
23.	MTH-723	Regression Analysis	3
24.	MTH-724	Advanced Mathematical Statistics	3
25.	MTH-725	Graph Theory	3
26.	MTH-799	Thesis / Dissertation	6

Note: Overall 24 teaching credit hours for M. Phil program are mandatory. However, the research supervisor of students may recommend additional courses. The department will offer the courses keeping in view the availability of teachers and nature of research to be conducted.

Course Outlines for M. Phil in Mathematics

Course Title: Advanced Calculus

Metric space, limits, continuity, derivatives, applications of the derivatives and mean values theorems, differential.

Definite integral and elementary properties applications. Gamma and Beta functions. Some elementary applications of definite integral (Buffon, s Needle problem, Arc length, Picard existence theorem), Weierstrass approximation theorem..

Differentiation of functions of several variables, partial & directional derivative, differential and differentiability, differentiability in a complex setting, differentiation under integral sign, implicit function theorems and its application, language multilinear, Biochistochrone problem, vibrating string.

Infinite series of number, infinite series of function, Taylor polynomial and Talor expansion, power series, divergent series, infinite series of matrices.

Recommended Books:

1. Bartle, R.G. and Sherbert, D.R. *Introduction to Real Analysis*, Fourth Edition John Wiley & Sons, 2020.
2. Loomis, L. H., Sternberg, S. Z. Advanced Calculus (Revised Edition). Singapore: World Scientific Publishing Company, 2014.
3. Royden, Halsey, and Fitzpatrick, Patrick. Real Analysis. United Kingdom, Pearson, 2017

Course Title: Advanced Measure Theory

Interated integration, Fubini's theorem, Tonelli Hobson Theorem, Vitali's cover of sets. Vitli's Lemma, Lipschutz conditions. Relation between Stieltjes and Lebesgue integral, Riesz Fischer Theorem.
Measure spaces, signed measure, Hahn decomposition, Hahn decomposition theorem, Jordan decomposition, singular measures, Jordan decomposition theorem, Random Nikodym theorem, Random Nikodym derivative. Lebesgue decomposition theorem, Product measure.

Recommended Books:

1. Lee, Tuo Yeong. Henstock-Kurzweil Integration on Euclidean Spaces. Singapore, World Scientific, 2011.
2. Halmos, P. R. *Measure Theory*. New York: Springer-Verlag, 2014.
3. Doob, J.L., Measure Theory. United States, Springer New York, 2012.

Course Title: Advanced Topology

Product Topology, Point-Open Topology, Compact-open topology, Weak Topology-1, Weak Topology-2, Quotient Topology, Identifications, Identification maps, Fundamental Group(first homotopy group), Elementary properties of the fundamental group, Continuous functions and homeomorphisms, Categories and factors, Seifert-Van Kampan Theorem, Direct limits, lifting theorems, regular covering spaces, map lifting, universal covering spaces. 1-manifold on contractibility of S1, Jordan Curve theorem.

Recommended Books:

1. Bradley, Tai-Danae, et al. Topology: A Categorical Approach. United Kingdom, MIT Press, 2020.
2. WEEKS, JEFFREY R.. SHAPE OF SPACE.. N.p., CRC PRESS, 2019.
3. Crossley, Martin D.. Essential topology. Germany, Springer, 2005.

Course Title : Field Theory

Introduction, Field Extensions, Ruler and compass constructions, foundations of Galois Theory, Normality and stability, Splitting fields, Radical Extensions, The Trace and norm Theorems, Finite Fields, Simple Extensions, Cubic and Quadratic Equations.

Separability, Miscellaneous results on Radical extensions, Infinite Algebraic Extensions.

Recommended Books:

1. Prestel, Alexander, and Delzell, Charles. Mathematical Logic and Model Theory: A Brief Introduction. United Kingdom, Springer London, 2011.
2. Roman, Steven. Field Theory. United States, Springer New York, 2013.
3. Francesco, Philippe, et al. Conformal Field Theory. United States, Springer New York, 2012.

Course Title : Rings and Categories of Modules

Rings and Subrings, ring Homomorphism, Ideals and Factor rings, some special rings, polynomial rings, product and functions ring, centre of a ring, the opposite ring of a ring, Matrix ring, endomorphism rings, Idempotents, Nilpotent elements.

Modules and Sub modules, linear combinations and submodules, Factor modules, change

of rings, Annihilators, homomorphism of modules, Epimorphisms and Monomorphisms, Factor theorem, Isomorphism theorem, Exactness, Category of modules, Endomorphism rings, direct Summands, Split Homomorphism, Projections, Idempotents Endomorphisms, Essential and superfluous submodules, Direct sum and product of modules. Direct sums-coproduct, Internal direct sums, decomposition of rings.

Simple modules, Semi simple modules, socle, radical, finitely generated modules, role of radical and socle, artinian, noetherian ring.

Recommended Books :

1. Rings, Modules, Algebras, and Abelian Groups. United Kingdom, CRC Press, 2019.
2. Abelian Groups, Rings, Modules, and Homological Algebra. United States, CRC Press, 2016.
3. Anderson, Frank W., and Fuller, Kent R.. Rings and Categories of Modules. United States, Springer New York, 2012.

Course Title : Theoretical Astrophysics

An approach to astrophysics. The cosmic distance scale. Dynamics and masses of astronomical bodies. Central force. Two body problem with attractive force. Kepler's laws. The concept of mass. The equivalence principle. Random processes. Boltzmann equation and liouville's Theorem. Photons and fast particles. Electromagnetic processes in astrophysics. Quantum processes in astrophysics. Stars. Mathematical formulation of the theory. Equation of the state. Cosmic gas and dust. Shock fronts and Ionization fronts. Structure of the Universe. Dynamics on a cosmic scale. The flow of time. Life in the universe. Dynamics on a cosmic scale. The flow of time. Life in the Universe. Thermodynamics of biological system.

Recommended Books:

1. Zhang, Banggu. Theoretical Astrophysics. N.p., Scientific Research Publishing, Incorporated.
2. Bartelmann, Matthias. Theoretical, Theoretical Astrophysics: An Introduction, Germany, Wiley, 2013..
3. Makarov, Igor Stepanovich. Introduction to Theoretical Astrophysics. Israel, CreateSpaceIndependent Publishing Platform, 2014.

Course Title : Advance Numerical Analysis.

Review of the basic concepts in numerical analysis with convergence and error estimate. Initial value problem, Euler method, multistep methods and their consistency, stability criteria and convergence, system of differential equations, boundary value problems, finite difference methods, collection method, Spline methods, Rayleigh-Ritz methods, Galerikin methods.

RECOMMENDED BOOKS:

1. Advanced Numerical Methods in Applied Sciences. Switzerland, MDPI AG, 2019.

2. Chakraverty, Snehashish, et al. Advanced Numerical and Semi-Analytical Methods for Differential Equations. United Kingdom, Wiley, 2019.
3. Advanced Numerical Methods for Differential Equations: Applications in Science and Engineering. United States, CRC Press, 2021.

Course Title : Spectral Theory in Hilbert Spaces

The Concepts of Hilbert Spaces, Inner Product Spaces, Hilbert Spaces, Bounded Liner operators, Bilinear Forms, Adjoint Operators, Projection Operators, The Fourier-Phincherl Operator. General Theory and Special Analysis of Linear Operators, closed Linear Operators, Invariant Subspaces of a Linear Operator, Eigenvalues and Spectrum of a Linear Operator, The Special Decomposition of a Bounded Self-Adjoint Operator.

Books Recommended:

1. Birman, Michael Sh., and Solomjak, M.Z.. Spectral Theory of Self-Adjoint Operators in Hilbert Space. Netherlands, Springer Netherlands, 2012.
2. Kubrusly, Carlos S.. Spectral Theory of Operators on Hilbert Spaces. Netherlands, Birkhäuser Boston, 2012.
3. Cheverry, Christophe, and Raymond, Nicolas. A Guide to Spectral Theory: Applications and Exercises. Germany, Springer International Publishing, 2021.

Course Title : Mathematical Logic

Introduction, Propositional calculus, Methods of Proof, analysis of Arguments, Predicate Calculus and Quantifiers, Boolean Algebra to Logic, Boolean Functions, Boolean Algebra and propositional Logic. Logic Gates, Combinational Circuits.

Recommended Books:

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1. Monk, J.D.. Mathematical Logic. Germany, Springer New York, 2012.
2. Smullyan, Raymond M.. A Beginner's Guide to Mathematical Logic. United States, Dover Publications, 2014.
3. Leary, Christopher C., and Kristiansen, Lars. A Friendly Introduction to Mathematical Logic. United States, Milne Library, SUNY Geneseo, 2015.

Course Title: Computational Fluid Dynamics

Philosophy of Computational Fluid Dynamics, Computational Fluid Dynamics: Why?,Incompressible plane flows, Stream function and vorticity equations, Conservative form and normalizing systems, Method for solving vorticity transport equation, Basic finite difference forms, Conservative property, Convergence and stability analysis, Explicit and implicit methods, Stream function equation and boundary conditions, Schemes for advective diffusion equation, Upwind differencing and artificial vorticity, Solution for primitive variables.

Recommended Books :

1. Sharma, Atul. Introduction to Computational Fluid Dynamics: Development, Application and Analysis. Switzerland, Springer International Publishing, 2021.
2. Lomax, H., et al. Fundamentals of Computational Fluid Dynamics. Germany, Springer Berlin Heidelberg, 2013.
3. Jayanti, Sreenivas. Computational Fluid Dynamics for Engineers and Scientists. Netherlands, Springer Netherlands, 2018.

Course Title : Mathematical Modeling and Numerical Simulation

Model and its different types, Finite models, Statistical models, Stochastic models, Formulation of a model, Laws and conservation principles, Discrete and continuous models, Manipulation into its most respective form, Evaluation of a model. Case studies, Continuum model, Transport phenomena, Diffusion and air pollution models, Microwave heating, Communication and Information technology.

Recommended Books :

1. Mathematical Modeling and Numerical Simulation of Oil Pollution Problems. Germany, Springer International Publishing, 2015.
2. Sigrist, Jean-François. Numerical Simulation, An Art of Prediction, Volume 2: Examples. United Kingdom, Wiley, 2020.
3. Mathematical Modeling: Problems, Methods, Applications. United States, Springer US, 2013.

Course Title : Advanced Mathematical Methods

General solution of Bessel equation, Recurrence relations, Orthogonal sets of Bessel functions, Modified Bessel functions, Applications. General solution of Legendre equation, Legendre polynomials, Associated Legendre polynomials, Rodrigues formula, Orthogonality of Legendre polynomials, Application. Concept and calculation of Green's function, Approximate Green's function, Green's function method for differential equations, Fourier Series, Generalized Fourier

series, Fourier Cosine series, Fourier Sine series, Fourier integrals. Fourier transform, Laplace transform, Z-transform, Hankel transform, Mellin transform. Solution of differential equation by Laplace and Fourier transform methods.

Recommended Books :

1. Bender, Carl M., and Orszag, Steven A.. Advanced Mathematical Methods for Scientists and Engineers I: Asymptotic Methods and Perturbation Theory. Germany, Springer New York, 2013.
2. Bender, Carl M., and Orszag, Steven A.. Advanced Mathematical Methods for Scientists and Engineers I: Asymptotic Methods and Perturbation Theory. Germany, Springer New York, 2013.
3. Advanced Mathematical Methods: Theory and Applications. N.p., MDPI AG, 2020.

Course Title : Computational Geometry

Introduction to polygonal and polyhedral geometry. Algorithmic design paradigms and data structures for geometric problems. Deterministic and randomized algorithms. Sorting and searching in geometry. Specific construction and computation problems including construction of convex hulls, voronoi diagrams and delaunay triangulation, point location, intersection detection and computation and closest pair computation, Applications to robotic and computergraphics.

Recommended Books :

1. Preparata, Franco P., and Shamos, Michael I.. Computational Geometry: An Introduction. Germany, Springer New York, 2012.
2. de Berg, Mark, et al. Computational Geometry: Algorithms and Applications. Germany, Springer London, Limited, 2013.
3. Devadoss, Satyan L., and O'Rourke, Joseph. Discrete and Computational Geometry. United States, Princeton University Press, 2011.

Course Title : Numerical Solutions of Integral Equations

Linear integral equations of first and second kinds, Solution of integral equations of seconds kind by successive substitutions. The Fredholm theory and its applications Hillbert, Schmidt Theory of Integral Equations.

Recommended Books :

1. Numerical Solution of Integral Equations. Germany, Springer US, 2013.
2. Solution Methods for Integral Equations: Theory and Applications. Germany, Springer US, 2013.
3. Polyanin, Andrei D., et al. Handbook of Integral Equations: Second Edition. United States, CRC Press, 2008.

Course Title: Advanced Partial Differential Equations

Classification of PDEs, canonical form, Laplace, Wave and diffusion equations. PDEs with at least 3 independent variables; non-homogenous problems; green function for time independent problems, infinite domain problems; green function of time dependent problems, wave equation and the method of characteristics.

Recommended Books:

1. Advanced Topics in Computational Partial Differential Equations: Numerical Methods and Diffpack Programming. Germany, Springer Berlin Heidelberg, 2012.
2. Salsa, Sandro, and Verzini, Gianmaria. Partial Differential Equations in Action: Complements and Exercises. Germany, Springer International Publishing, 2015.
3. Shearer, Michael, and Levy, Rachel. Partial Differential Equations: An Introduction to Theory and Applications. United Kingdom, Princeton University Press, 2015.

Course Title : WAVELET ANALYSIS

ELEMENTS OF FOURIER ANALYSIS: Fourier series, Fourier transforms, Inversion formula, Parseval Identity and Plancherel Theorem, Continuous-time convolution and the delta function, Poisson's summable formula, Shanon sampling theorem.

WAVELET TRANSFORMS AND TIME- FREQUENCY ANALYSIS: The Gabor transform, Windowed Fourier transform, uncertainty principle, Integral wavelet transform, Dyadic wavelets, Frames, Wavelet series.

SCALING FUNCTIONS AND MULTI-RESOLUTION ANALYSIS: Multiresolution Analysis, Scaling functions, Wavelets and their duals, linear phase filtering, compactly supported wavelets, orthogonal wavelets.

CARDINAL SPLINE ANALYSIS AND CARDINAL SPLINE WAVELETS : Cardinal spline spaces, B-spline and their properties, computation of cardinal splines, construction of spline approxima- tion formulas and spline interpolation formulas, interpolatory spline wavelets, computation of supported spline wavelets, computation of cardinal spline wavelets, error analysis in spline-wavelet decomposition.

Recommended Books :

1. Debnath, Lokenath, and Shah, Firdous Ahmad. Wavelet Transforms and Their Applications. Bhutan, Birkhäuser Boston, 2014.
2. Bachmann, George, et al. Fourier and Wavelet Analysis. United States, Springer New York, 2012.
3. Wavelets and Their Applications. Germany, Wiley, 2013.

Course Title : Advanced Differential Geometry

Manifolds: Definition, examples, importance and applications, Tensor and its basic algebra, Dimension of manifold, Tangent and cotangent vectors, Sub manifolds, Topology of manifolds. Tensors: Definition, examples, importance and applications, Tensor and its basic algebra, Differential forms, Tensors and a point. Tensor components, Order and rank of tensors, Tensor field. Some fundamental operations with tensors, Cotravariant and covariant tensors. Lie Groups, Geodesics, Curvature, Integration on Manifolds: Orientation of Manifolds, Integrals of forms.

Recommended Books:

1. Kreyszig, Erwin. Differential Geometry. United States, Dover Publications, 2013.
2. Gallier, Jean, and Quaintance, Jocelyn. Differential Geometry and Lie Groups: A Second Course. Germany, Springer International Publishing, 2020.
3. Woods, Frederick. Higher Geometry: An Introduction to Advanced Methods in Analytic Geometry. United States, University of MICHIGAN LIB, 2012.

Course Title : General Relativity

Manifold Theory: Manifolds, Maps of manifolds, Lie Derivatives, Vectors (Tangent vectors), vector field (Tangent field), Vector space (tangent space) at a point, Differentiability of vector fields, Classification of some important tensors: symmetric tensors, Classification of 2 spaces in the tangent space, Bivectors and their classification, Classification of second order symmetric tensors, Classification of the Riemann tensors. Petrov classification of the Weyl tensor, Curvature and curvature Collineations. Derivative operators and parallel transport, curvature of more than 2- dimensional manifolds, geodesics and Geodesics equation, Methods for computing curvature, Symmetries in General Relativity: Killing symmetry, Homothetic symmetry, affine symmetry, conformal symmetry, projective symmetry.

Recommended Books:

1. Wald, Robert M.. General Relativity. United States, University of Chicago Press, 2010.
2. Hartle, James B.. Gravity: An Introduction to Einstein's General Relativity. India, Cambridge University Press, 2021.
3. Bambi, Cosimo. Introduction to General Relativity: A Course for Undergraduate Students of

Physics. Germany, Springer Nature Singapore, 2018.

Course Title : Mathematical Biology

Population dynamics. Growth and spatial spread of organisms. Fisher's equation. Epidemiology the spread of plagues. Reaction-Diffusion models: Turing mechanism for pattern formation. How the leopard got his spots (and sometimes stripes). Enzyme Kinetics and chemical reactions: Michaelis-Menten theory Hormone cycles, neuron-firing. Mass transport; Taylor dispersion.

Recommended Books :

1. Friedman, Avner. Mathematical Biology: Modeling and Analysis. United States, Conference Board of the Mathematical Sciences, 2018.
2. Murray, James D.Mathematical Biology: I. Anintroduction. Germany, Springer New York, 2013.
3. Britton, Nicholas F.. Essential Mathematical Biology. United Kingdom, Springer London, 2012.

Course Title : Numerical Solutions of Differential Equations

- Boundary and initial conditions, Polynomial approximations in higher dimensions.
- **Finite Element Method:** The Galerkin method in one and more dimensions , Error bound on the Galarki method, The method of collocation, Error bounds on the collocation method, Comparison of efficiency of the finite difference and finite element method.
- **Finite Difference Method:** Finite difference approximations.
- Application to solution of linear and non-linear Partial Differential Equations appearing in Physical Problems.
- Euler's Method
- Convergence of Euler's Method
- Runge-Kutta method
- Higher order Runge-Kutta formulas and their applications
- Method of Taylor Expensions and their applications

Recommended Books:

1. Butcher, J. C.. Numerical Methods for Ordinary Differential Equations. United Kingdom, Wiley, 2016.
2. Atkinson, Kendall, et al. Numerical Solution of Ordinary Differential Equations. Germany, Wiley, 2011.
3. Sewell, Granville. Numerical Solution Of Ordinary And Partial Differential Equations, The (3rd Edition). Singapore, World Scientific Publishing Company, 2014.

Course Title : Research Methodology

This module is an introduction to the research methods and methodology generally used in mathematics. This module will enable students to review critically and evaluate the scientific writing from books and research papers (both pure and applied) in the following contents:

- Purpose of Research
- Different types of research (Experimental, non-experimental)
- Sources of data
- Research aims and objectives
- Research design
- Problem identification and hypothesis
- How to review literature and avoid plagiarism
- writing research proposal

Recommended Books:

1. Kothari, C. R.. Research Methodology: Methods and Techniques. India, New Age International (P) Limited, 2004.
2. Research Methodology: A Handbook for Beginners. N.p., Notion Press, 2017.
3. Kumar, Ranjit. Research Methodology: A Step-by-Step Guide for Beginners. India, SAGE Publications, 2019.

Course Title: Numerical Solution of PDE's

Parabolic Equation: Explicit Finite Difference approximation, Crank Nickleson Implicit method:

Derivative Boundary Conditions, The local truncation Errors, Stability. The Necessary and sufficient condition for stability, Finite difference approximation in spherical polar coordinate Hyperbolic equations, Analytical solution of Quasi Linear equations, Finite Difference method on a rectangular mesh for first order equations, Reduction of a first order equation to a system of ordinary differential equation: second order quasi-linear hyperbolic equation; Finite difference method on a rectangular mesh for second order equation ; simultaneous first order equations and Elliptic equation. Finite difference in polar coordinates; formulae for derivatives near curved boundaries; Improvement of the accuracy of the solution ; System iterative method for large linear systems, Jacobian , Gauss and SOR methods, Necessary and Sufficient condition for convergence of iterative methods , methods for acceleration convergence, the Gauss Seidel iteration matrix.

RECOMMENDED BOOKS:

1. Lapidus, Leon, and Pinder, George F.. Numerical Solution of Partial Differential Equations in Science and Engineering. Germany, Wiley, 2011.
2. Deuflhard, Peter, and Weiser, Martin. Adaptive Numerical Solution of PDEs. Germany, De Gruyter, 2012.
3. Thomas, J.W.. Numerical Partial Differential Equations: Finite Difference Methods. Germany, Springer New York, 2013.

Course Title : Advanced Mathematical Statistics.

Univariate probabilistic and deterministic models, Methods of estimation, Composition of confidence intervals and testing, Optimal tests and confidence intervals, Likelihood ratio tests, Linear models, Regression and correlation, Analysis of variance, Analysis of discrete data, Non-parametric models, Decision theory, Markov processes.

Recommended Books:

1. Advanced Mathematical Statistics. India, Advance Learner Press, 2014.
2. Kapadia, Asha Seth, et al. Mathematical Statistics With Applications. United States, Taylor & Francis, 2017.
3. Lauritzen, Steffen. Fundamentals of Mathematical Statistics. United Kingdom, C&H/CRC Press, 2023.

Course Title: Graph theory

Graph, Graphs as Models, sub graph, path and cycle, operations on graph, Matrix representation, bridge, loop, cut- vertex and connectivity, Euler tour, Hamiltonian graphs, Euler formula, trees, properties of trees, distance and centre in a tree, counting trees, spanning trees, isomorphism, 1- isomorphism, 2-isomorphism, planar graph, detection of planarity, platonic bodies, dual graph, geometric and combinatorial dual, Chinese postman problem, travelling salesman problem, marriage problem, personnel

assignment problem, shortest path problem.

Recommended Books:

1. Bollobas, Bela. Modern Graph Theory. Germany, Springer New York, 2013.
2. Bondy, Adrian, and Murty, U.S.R.. Graph Theory. United Kingdom, Springer, 2010.
3. Rahman, Md. Saidur. Basic Graph Theory. Germany, Springer International Publishing, 2017.