In the **8th semester**, students are usually given an option to choose between **Honours Track** and **Research Track**

**FYUP Course Outline for Semester VIII (For Honours Track)**

| S. No. | Course Code | Course Title | Credits | Category |
|--------|-------------|--------------|---------|----------|
| 1 | MTHS450MJ | Computational Mathematics | 4 | Major |
| 2 | MTHS451MJ | Fourier And Laplace Transform | 4 | Major |
| 3 | MTHS452MJ | Time series Analysis | 4 | Major |
| 4 | MTHS453MJ | Advanced Linear Algebra | 4 | Major |
| 5 | MTHS454MJ | Design of Experiments | 4 | Major |
| 6 | MTHS455MJ | Project | 4 | Major |
| 7 | MTHS450MN | Econometrics | 4 | Minor |

**Note:** Students have to choose **one elective subject from each** basket —

**Basket 1**

| 1. | **Fourier or Laplace Transform (MTHS451MJ)** |
|----|----------------------------------------------|
| 2. | **Time series Analysis (MTHS452MJ)** |

**Basket 2.**

| 1. | **Advanced Linear Algebra (MTHS453MJ)** |
|----|-----------------------------------------|
| 2. | **Design of Experiments (MTHS454MJ)** |

**Course Outline for Semester VIII for ResearchTrack**

| S. No. | Category | Course Code | Course Title | Credits | L | T | P | S | Hours per week |
|--------|----------|-------------|--------------|---------|---|---|---|---|----------------|
| 1 | Major | MTHS456MJ | Research Methodology | 4 | 4 | 0 | 0 | 0 | 4 |
| | | MTHS457MJ | Research Project | 12 | | | | | |
| 2 | Minor 8 | MTHS450MN | Econometrics | 4 | | | | | |

| **Course Title:** Computational Mathematics | **L** | **T** | **P** | **S** | **Semester: 8th** |
|---|---|---|---|---|---|
| **Course Code:** MTHS450MJ | **3** | **x** | **2** | **x** | **Max Marks**: 100 |
| **Credits:** 4 | | | | | |

**Course Objectives**: This programe develops logical skills and basic technical skills so that students should be able to solve basic computing problems. The students should be able to learn the basic of any computer programming language like C, software MATLAB and Scientific documentation using LaTeX.

**Course Outcomes:**
1. Students will be able to apply computational methods and tools to model and solve real-world problems using programming, numerical and statistical techniques.
2. Implement numerical methods and solution for linear algebra problems such as root finding, numerical integration, and numerical linear algebra.

**Prerequisites:** 1. Integrated Computational Lab for Simultaneous Theory and Hands-on Practice
2. Calculus, Differential Equations, Numerical Methods and Basic Programming (Python/Matlab/Mathematica)

**Unit 1:** Evolution of languages: Machine languages, Assembly languages, High-level languages. Software requirements for programming: System software's like operating system, compiler, linker, loader; Application programs like editor. Algorithm, specification of algorithm. Flowcharts. Data Types, Identifiers, Variables Constants and Literals. Arithmetic relational logical operators. Basic input/output statements, Control structures: if-else statement, Nested if statement, Switch statement Loops: while loop, do while, for loop, Nested loops. Arrays: Declaration; initialization.

**Unit 2:** Functions; prototype, passing parameters, identifier visibility. Variable scope, lifetime. Multi-file programming, Introduction to macros. Structures and unions: syntax. Pointers: variables, arrarys. Introduction to object oriented programming, Abstraction, Encapsulation, Introduction to classes and objects; Access specifiers, Constructor; destructor; Function overloading; Operator overloading

**Unit 3:** Introduction to MATLAB, Standard MATLAB windows (Command Window, Figure Window, Editor Window, help window), The semicolon (;), The clc command, Using MATLAB as calculator, Display formats, Elementary math built in functions, The zeroes, ones and eye commands, The transpose operators, Using a colon, Adding elements to existing variables, Deleting elements, Creating arrays (one dimensional & two dimensional), Built in functions for handling arrays, Array multiplication, Inverse of a matrix, Solving three linear equations (array division), Element by element operations, Built in function for analysing arrays.

**Unit 4:** Solving an equation with one variable, Finding a minimum or a maximum of a function, Numerical integration, Ordinary differential equations, Interpolation etc, Symbolic Math: symbolic objects and symbolic expressions, Creating symbolic objects, Creating symbolic expressions, Changing the form of an existing symbolic expression, Integration, Solving an ordinary differential equation, Plotting symbolic expressions, Numerical calculations with symbolic expressions, Examples Of MATLAB applications etc.

**Textbook/ References**
1. E. BALAGURUSWAMI "Programming in ANSI C" Tata McGraw Hill
2. C Programming Absolute Beginner's Guide, Greg Perry ,3rd edition, Que Publishing

3.  BJARNE STROUSTRUP "The C++ programming language" Pearson Education.
4.  Steven C Chapra : Applied Numerical Methods with MATLAB for Engineers and Scientists, McGraw Hill
5.  Amos Gilat: MATLAB-An Introduction and its Application ,Wiley Indian Edition.

| Course Title: Fourier And Laplace Transform | L | T | P | S | Semester: 8th |
|---|---|---|---|---|---|
| Course Code:   MTHS451MJ | 2 | 2 | x | x | Max Marks: 100 |
| Credits: 4 | | | | | |

**Course Objectives:** To develop skill in students about Fourier series, Fourier and Laplace transforms as a tool to solve various problems in the field of applied Mathematics and physics and electronics.

**Course Outcomes:** After the completion of this course, students shall be able to use

1.  Analyze periodic functions and construct their Fourier series representation, including half-range expansions for standard waveforms.

2.  Extend the concept of frequency domain analysis to aperiodic functions using the Fourier Transform and its properties, and relate it to the Discrete Fourier Transform.

3.  Utilize the Laplace Transform and its properties to solve ordinary differential equations and initial value problems, including those with discontinuous forcing functions.

4.  Apply the Laplace Transform technique to solve integral equations, boundary value problems, and fundamental partial differential equations arising in engineering and physics. Fourier and Laplace transforms to solve the differential equations and to understand signal processing in frequency and time domain.

**Unit-I:** Fourier Series: Introduction, Periodic functions: Properties, Even & Odd functions. Special waveforms: Square wave, Sawtooth wave, and Triangular wave. Euler's Formula for Fourier Series, Fourier Series for functions of period $2\pi$, Fourier Series for functions of period 2L, Dirichlet's conditions, Sum of Fourier series. If ( ) is bounded and integrable function on $(-\pi,\pi$ ) and if _n, _n are its Fourier coefficients, then \sum _n,+ _n converges. Half Range Series for sine and cosine functions, examples. Riemann Lebesque theorem.

**Unit II:** The Fourier Transform. Periodic functions, Definition and examples of Fourier seriesDrichlet's conditions, determination of Fourier coefficients, even and odd functions and their Fourier expansion, change of interval, half range series. Fourier transform, inverse Fourier transform, Fourier sine and cosine transforms and their inversion, properties of Fourier transforms Fourier transform of the derivative, convolution theorem, discrete Fourier transform and fast Fourier transform and their properties.

**Unit – III:** Definition, Laplace transform of elementary functions, Properties of Laplace transforms viz Linearity, translation, Change of Scale property etc. Laplace transform as periodic functions, Dirac-Delta function, Inverse Laplace transform. Laplace transform for derivatives, Laplace transform for integrals, Convolution theorem. Solution of ordinary differential equations with constant coefficients. Applications of partial differential equations.

**Unit – IV:** Application of Laplace transform to differential equation and integral equation. Application of Laplace transform to boundary value problems. Electrical circuits, dynamics, Beams, Heat conduction equations and wave equations.

**TextBooks/ References:**

1. Ruel V. Churchill, Fourier Series &amp; Boundary Value Problems, 8th Edition McGraw Hill Education 2011.
2. Davies, Brian, Integral Transforms and Their Applications, Springer, 2002.
3. Erwin, Kreysgiz, Advanced Engineering Mathematics, John Willey & Sons. 10th Edition, 2011.
4. K.S. Rao, Introduction to Partial Differential Equations, K.S. Rao, PHI, India.
5. L. Debnath and D. Bhatta, Integral Transforms and Their Applications, 3rd Edition, CRC Press.

| **Course Title:** Time Series Analysis | **L** | **T** | **P** | **S** | **Semester: 8th** |
|---|---|---|---|---|---|
| **Course Code:** MTHS452MJ | **4** | **x** | **x** | **x** | **Max Marks**: 100 |
| **Credits:** 4 | | | | | |

**Course Objectives:** To provide insights into forecasting techniques, regression frameworks and OLS assumptions; to estimate, interpret, and validate multiple regression models; to understand time series decomposition and its components; and to forecast time series data using appropriate models.

**Course Outcomes:** Students should be able to:
1. Perform Regression analysis on the given dataset using appropriate software.
2. Check and validate all the assumptions of regression analysis.
3. Decompose a time series and estimate its component.
4. Fit an appropriate forecasting model on the given data

**Unit 1:** Simple Linear Regression: Estimation of the model parameters. Least-squares estimates and their properties. Maximum likelihood estimation. Hypothesis testing in simple linear regression. Tests for significance of regression, tests on individual regression coefficients. Confidence intervals in simple linear regression and prediction of new observation. Extension to Multiple linear regression, Residual Analysis, Multicollinearity, Variable selection methods

**Unit 2:** Time Series, Time Series Components, Principle of Decomposition, Moving Average, Exponential Smoothing Methods: Simple exponential smoothing, Holt linear method, Holt – Winter's seasonal method and Pegels classification.

**Unit 3:** The Box-Jenkins Methodology for ARIMA Models: Autoregressive models, Moving Average models, Examining Correlation in Time Series Data, Examining Stationarity in Time Series Data, Non- seasonal/Seasonal ARIMA Models for Time Series Data, Parameter Estimation for ARIMA models, Diagnostic Checking of ARIMA models, Forecasting with ARIMA models

**Unit 4:** Multivariate Time series processes, Moments, Cross Moments and Stationarity, Wold representation, Cross spectrum analysis of bivariate time series processes, cross spectrum, coherency spectrum and squared coherency, amplitude and phase spectrum. Vector ARMA processes, Stationarity and invertibility conditions, Vector moving average processes, Vector Autoregresive (VAR) Processes.

**Text Books/ References**
1. Montgomery D. C, Peck E. A, Vining G. G. (2012). Introduction to Linear Regression Analysis, 5th Edition, Wiley
2. Spyros G. Makridakis, Steven C. Wheelwright, Rob J Hyndman (2015). Forecasting: Methods and Applications, 3rd Edition, Wiley
3. Box George E. P, Jenkins G. M., Reinsel G. C. (2009): Time Series Analysis-Forecasting and Control, 3rd Ed., Pearson Education.
4.Hyndman, R.J., & Athanasopoulos, G. (2018) *Forecasting: principles and practice*, 2nd edition, OTexts: Melbourne, Australia

| **Course Title:** Advanced Linear Algebra | **L** | **T** | **P** | **S** | **Semester:** 8th |
|---|---|---|---|---|---|
| **Course Code:** MTHS453MJ | **4** | **x** | **x** | **x** | **Max Marks**: 100 |
| **Credits:** 4 | | | | | |

**Course Objective:** This course aims to develop a deep understanding of special matrices, their eigenvalues, and related theorems. It focuses on concepts of norms, decompositions, and spectral properties essential for advanced linear algebra. Students will learn to apply these theories to matrix analysis, transformations, and computational methods.

**Course Outcomes:** After studying this course, the student will be able to
1. Analyze eigenvalues, apply diagonalization, and use Schur's and Cayley–Hamilton theorems.
2. Understand norms, inner products, and apply the Gram-Schmidt process in vector spaces.
3. Analyze spectral radius, eigenvalue behavior, and apply SVD and Gersgorin's theorem.
4. Apply matrix decompositions and analyze eigenvalues using Jordan and Courant-Fisher theorems.

**Unit-I:** Special Matrices and their Eigen values, Characteristic Polynomial, Elementary properties of Eigen values, Similarity, Diagonalization, Relation between eigen values of BA and AB, Unitary matrices, properties of unitary matrices, unitary equivalence, Schur's triangularization theorem, Cayley Hamilton theorem and its application.

**Unit-II:** Rank and its properties, introduction to norms and Inner products, Gram-Schmidt algorithm, vector norms and their properties, Applications and equivalence of vector norms, Dual norms, Properties and examples of dual norms, matrix norms and its properties, induced norms and examples, Exploring Rank and Norms using Python.

**Unit-III:** Spectral radius, properties of spectral radius, convergent matrices, Banach lemma, Equivalence of matrix norms and error in inverse of linear systems, errors in inverse of matrices, Eigenvalues: Majorization theorem, Location and perturbance of Eigenvalues, Gersgorin's theorem, singular value definition and singular value decomposition theorem, Exploring spectral radius and singular value decomposition using Python.

**Unit IV:** Normal matrices: Definition and fundamental properties, QR decomposition and canonical form, determining the Jordan form of a matrix, properties of the Jordan canonical form, LU decomposition with pivoting, variational characterization of eigenvalues, Courant-Fisher theorem, positive semidefinite matrix, monotonicity theorem and interlacing theorems.

**Text Books/ Reference Books:**

1. Seymour Lipschutz and Marc Lipson, Schaum's outlines, Linear Algebra, 2017.
2. R. Horn and C. Johnson, Topics in Matrix Analysis, Cambridge University Press, 1991.

3. Richard A. Brualdi, Dragos Cvetkovic, A combinatorial Approach to Matrix Theory and Its Applications, 2008.
4. Carl D. Meyer, Matrix Analysis and Applied Linear Algebra, 2000.
5. Gilbert Strang, Linear Algebra and its applications, Fourth Edition, 2005.

| **Course Title:** Design of Experiments | **L** | **T** | **P** | **S** | **Semester: 8th** |
|---|---|---|---|---|---|
| **Course Code:**   MTHS454MJ | **4** | **x** | **x** | **x** | **Max Marks**: 100 |
| **Credits:** 4 | | | | | |

**Course Objectives:** This course provides the students the ability to understand the design and conduct experiments, as well as to analyze and interpret data.

**Course Learning Outcomes:** After successful completion of this course, student will be able to:
1. Apply ANOVA for two –way classification, fixed effect models with equal, unequal and proportional number of observations per cell, Random and Mixed effect models with m (>1) observations per cell.

2. Design and analyse incomplete block designs, understand the concepts of orthogonality, connectedness and balance.

3. Identify the effects of different factors and their interactions and analyse factorial experiments.
4. Construct complete and partially confounded factorial designs and perform their analysis and apply Split-plot designs and their analysis in practical situations.

**Unit I:** Review of linear estimation and basic designs. Elimination of heterogeneity in two directions. ANOVA: Fixed effect model: Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD), Missing plot technique, General theory and applications, Analysis of Co-variance for CRD and RBD.

**Unit II:** General factorial experiments, factorial effects; best estimates and testing the significance of factorial effects; study of $2^n$ and $3^r$ factorial experiments in randomized blocks; Confounding: complete and partial confounding, construction of symmetrical confounded factorial experiments, fractional replications for symmetrical factorials, split plot experiments.

**Unit III:** Incomplete Block Designs. Concepts of Connectedness, Orthogonality and Balance. Intrablock analysis of General Incomplete Block design. B.I.B designs with and without recovery of interblock information.

**Unit IV:** Application areas: Response surface experiments; first order designs, and orthogonal designs; clinical trials, treatment-control designs; model variation and use of transformation; Tukey's test for additivity.

**References:**.

1. Alok Dey (1986): Theory of Block Designs, Wiley Eastern.

2. Angela Dean and Daniel Voss (1999): Design and Analysis of Experiment, Springer.

3. Cochran, W.G. and Cox, G.M.: Experimental Design, John Wiley and Sons, Inc., New York.
4. Das, M. and Giri, N. (1979): Design and Analysis of Experiments, Wiley Eastern.

5. Montgomery, C.D. (1976): Design and Analysis of Experiment, Wiley, New York.

| Course Title: Project | L | T | P | S | Semester: 8th |
|---|---|---|---|---|---|
| Course Code:  MTHS455MJ | 4 | x | x | x | Max Marks: 100 |
| Credits: 4 | | | | | |

| **Course Title:** Econometrics | **L** | **T** | **P** | **S** | **Semester: 8th** |
|---|---|---|---|---|---|
| **Course Code:**   MTHS450MN | **4** | **x** | **x** | **x** | **Max Marks**: 100 |
| **Credits:** 4 | | | | | |

**Course Objectives:** The course aims to provide knowledge of Econometrics, hands-on experience in regression analysis, and skills to estimate parameters and validate modelling assumptions.

**Course Outcomes:** At the end of the course, the student will be able to
1. Adequate competency in the frontier areas of economic theory and methods, use basic econometric estimation techniques such as ordinary least squares to estimate bivariate and multivariate regression models.
2. Decision about the statistical significance of individual explanatory variable and also over all model.
3. Impacts for the violation of one of the important assumptions for application of ols regression.
4. Acquire additional specialization topics are estimation of system of equations, estimation of panel data models, generalized method of moments, discrete response models, censored regression models and estimation of average treatment effects.

**Unit 1:** Nature of Econometrics and Economic Data Definition of Econometrics – Steps in Empirical Economic Analysis - Econometric Model – The Role of Measurement in Economics – The Structure of Economic Data: Cross-Sectional data, Time Series data, Pooled Cross Section data, Panel Data.

**Unit 2**: Simple Regression Model Two Variable Linear Regression Model: Assumptions, Estimation of Parameters, Tests of Significance and Properties of Estimators – Functional forms of Regression models – Loglinear models, Semi log- models and Reciprocal models – Choice of Functional Form.

**Unit 3:** The General Linear Model Review of Assumptions, Estimation and Properties of Estimators: Un-biasness, BLUEs and Tests of significance of estimates – Analysis of Variance - Dummay variables - Nature of Dummy variables – Use of Dummy Variables – Errors in Variables and its consequences.

**Unit 4:** Auto-regressive and Distributed Lag Models Introduction – Types of Lag schemes - Koyck's lag model, Almon's Lag scheme, Partial Adjustment and Expectations models - Causality in Economics – The Granger Causality Test.

**Text Books:**
1. Johnston,J: Econometric Methods, McGraw-Hill Book Co., New York.
2. Maddala, G.S: Econometrics, McGraw-Hill Book Co., New York, 3rd Rd.
3. Gujarathi, D.N: Basic Econometrics, Fourth Edition, Tata McGraw-Hill, New Delhi.
4. Tintner,G: Econometrics, John Wiley & Sons, New York.
5. Wooldridge, Jeffery M: Econometrics, Cengage Learning India Pvt. Ltd, New Delhi

| **Course Title:** Research Methodology | **L** | **T** | **P** | **S** | **Semester: 8th** |
|---|---|---|---|---|---|
| **Course Code:**  MTHS456MJ | **3** | **x** | **2** | **x** | **Max Marks**: 100 |
| **Credits:** 4 | | | | | |

**Course Objective-** The objective of this course is to equip students with essential knowledge and skills for conducting high-quality mathematical research. The course covers the fundamentals of research methodology, hypothesis testing, scientific writing, and effective presentation. Additionally, it introduces students to computational tools such as LaTeX, R programming, and simulation techniques, fostering the ability to analyze data, simulate models, and prepare professional research documents and presentations.

**Course Outcomes:** After successful completion of this course, student will be able to:

1. Identify and formulate mathematical research problems through effective topic selection and literature review.

2. Demonstrate skills in scientific writing, presentation, and understanding of the publication and funding process.

3. Apply parametric and non-parametric hypothesis tests to analyze statistical data.

4. Interpret test results and understand the limitations of hypothesis testing and measurement scales in research.

5. Create professional research documents and presentations using LaTeX and MS Word.

6. Perform data analysis and implement statistical models using R programming.

7. Apply simulation techniques and random variable generation methods for mathematical modeling.

8. Implement numerical algorithms for solving equations, integration, and matrix operations using computational tools.

**Unit I:** Overview of mathematical research, selection of a research topic and a research problem, literature survey of the topic and problem, writing references and bibliography. Presentations: Importance of effective presentation, how to write good papers, models of the paper writing process, the benefits of targeting good journals, peer review, how to respond to reviewer comments, funding agencies, writing a research grant proposal.

**Unit II:** Basic concepts concerning testing of hypotheses, important parametric and non-parametric tests. Hypothesis testing of means, differences between means, comparing two related

samples, proportions, difference between proportions, comparing a variance to some hypothesized population variance, variances of two normal populations, correlation coefficients. Limitations of tests of hypotheses. Measurement in research, measurement scales.

**Unit III:** Scientific word processing with LaTeX and MS-word: article, thesis report and presentation-power point features, slide preparation. Statistical programming with R: simple manipulations using numbers, vectors, objects & their attributes. Arrays, matrices, lists and data frames. Grouping loops and conditions. User defined functions, probability distributions and statistical models in R.

**Unit IV:** Simulation: Concepts and Advantages of Simulation-Event Type Simulation-Random Variable Generation-U (0,1), Exponential, Gamma and Normal Random Variables–Monte Carlo simulation. The MCMC Principle, Algorithms and its Variants. Computer Oriented Numerical Methods-Algorithms for Solving Algebraic Equations-Numerical Integration-Matrix operations.

**Suggested Readings:**

1. Anderson, J., Durston, B.H., Pooole, M. (1970). Thesis and Assignment Writing, Wiley Eastern. Ltd., New Delhi.

2. Beveridege, B. (1979). The Art of Scientific Investigation, W.E. Norton & Co., New York.

3. Braun, J., Duncan, W. and Murdock, J. (2008). A First Course in Statistical Programming with R, Cambridge University Press, London.

4. Chambers, J. (2008). Software for Data Analysis: Programming with R, Springer, New York.

5. Crewley, M.J. (2007). The R-.Book, John Wiley, New York.

6. Dalgaard, P. (2008). Introductory Statistics with R, Springer Science, New York.

7. Ghosh, J.K., Mitra, S.K. and Parthasarathy, K. R. (1992). Glilmpses of India's Statistical Heritage, Wiley Eastern Limited, New Delhi.

8. Hald, A. (1998). A History of Mathematical Statistics from 1750 to 1930, John Wiley & Sons, New York.

9. Kantiswarup, S., Gupta P.K. and Man Mohan (2008). Operations Research, Sultan Chand & Sons, New Delhi.

10. Kothari, C.R. and Garg, G. (2014). Research Methodology: Methods and Techniques, 3rd Edn., New Age International Publishers.

11. Lamport, L. (1999). LATEX: A Document Preparation System, Addison, Wesley, 2nd edition, New York.

12. Pannerselvan, R. (2006). Research Methodology, Prentice-Hall of India Pvt., New Delhi.

13. Robert, C.P. and Casella, G. (2004). Monte Carlo Statistical Methods, Springer Science, New York.

14. Venkataraman, M.K. (1998). Numerical Methods in Science and Engineering, The National Publishing Company, Chennai.