

**One year Diploma in**  
**Mathematical Epidemiology and Data Analysis**

**DEPARTMENT OF MATHEMATICS**  
**UNIVERSITY OF KARACHI**

## Program overview

The one year diploma in Mathematical Epidemiology and Data Analysis is designed to provide participants with a comprehensive understanding of the application of mathematical models to study and control of infectious diseases. The program integrates mathematical and statistical methods with epidemiological principles to equip students with the skills necessary for analyzing data, interpreting, and modeling disease dynamics.

## Learning Outcomes

- **Develop Mathematical Models:** Acquire the ability to construct and develop mathematical models for analyzing the spread and dynamics of infectious diseases.
- **Apply Statistical Methods:** Learn to apply statistical methods to epidemiological data, enabling the interpretation and analysis of data patterns and trends.
- **Evaluate Public Health Interventions:** Gain skills in assessing the effectiveness of public health interventions through mathematical modeling and analysis.
- **Utilize Computational Tools:** Develop proficiency in using computational tools and software to simulate and analyze epidemiological scenarios.
- **Interpret Research Findings:** Enhance the capacity to interpret research findings, critically evaluate scientific literature, and contribute to advancements in the field.
- **Communicate Effectively:** Learn to communicate mathematical epidemiological concepts and findings clearly and effectively to diverse audiences, including both technical and non-technical stakeholders.
- **Collaborate in Interdisciplinary Settings:** Develop collaborative skills for working in interdisciplinary settings, collaborating with epidemiologists, public health professionals, and researchers.
- **Contribute to Public Health Policy:** Understand how mathematical modeling can inform public health policy decisions and contribute to disease prevention and control strategies.
- **Address Real-world Challenges:** Apply mathematical epidemiological principles to address real-world challenges in the control and management of infectious diseases.
- **Stay Updated on Emerging Trends:** Stay up-to-date of emerging trends and innovations in the field of mathematical epidemiology through continuous learning and professional development.

**DEPARTMENT OF MATHEMATICS**  
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**Diploma in Mathematical Epidemiology and Data Analysis**

SEMESTER I			SEMESTER II		
DME-500	*Calculus	NC	DME-502	Applied Survival Analysis	3+0
DME-501	Introduction to Software Applications	2+1	DME-504	Mathematical Modeling of Infectious Diseases	3+0
DME-503	Introduction to Mathematical Modeling in Epidemiology	3+0	DME-506	Regression II: Categorical Data Analysis	2+1
DME-505	Regression I: Linear Regression and Modeling	3+0	DME-508	Survey Design, Analysis, and Reporting	3+0
DME-507	Analysis of Epidemiologic Data Using Software	2+1			

*\*The calculus course will only be offered to students with non-mathematics backgrounds*

**DME 500 Calculus (N.C)**

**Introduction to Limits:** Understanding the concept of limits, Evaluating limits algebraically and graphically, One-sided limits and continuity.

**Derivatives and Their Applications:** Definition of derivatives, Basic rules of differentiation, Applications of derivatives in rates of change and optimization.

**Integrals and Their Applications:** Definite and indefinite integrals, Fundamental Theorem of Calculus, Applications of integrals in area and physics problems.

**Techniques of Integration:** Integration by substitution, Integration by parts, Partial fraction decomposition.

**Applications of Integration:** Area between curves, Volumes of solids of revolution, Applications in physics and economics.

**Multivariable Calculus Basics:** Partial derivatives, Multiple integrals, Applications in three-dimensional space.

**Differential Equation:** Introduction of ordinary differential equations.5

**Recommended Books:**

1. Anton, H., Bivens, I. C., & Davis, S. (2012). Calculus, 10<sup>th</sup> edition, Wiley.
2. Erwin Kreyszig. (2019). Advanced Engineering Mathematics, 10<sup>th</sup> edition, Wiley.
3. Hoffmann, L. D., & Bradley, G. L. (2006). Calculus for Business, Economics, and the Social and Life Sciences, McGraw-Hill.
4. Tenenbaum, M., & Pollard, H. (2012). Ordinary Differential Equations, Dover Publications.
5. [Thomas](#).G.B, & [Finney](#).R.L. (1996). Calculus and Analytical Geometry, 9<sup>th</sup> edition, Pearson.

## **DME-501 Introduction to Software Applications (2+1)**

**Introduction to Software Applications:** Overview of popular software applications, Significance of software proficiency in professional settings, Introduction to the Microsoft Office Suite.

**Word Processing with Microsoft Word:** Document creation and formatting, Advanced formatting features, Collaboration tools in Word.

**Spreadsheet Management with Microsoft Excel:** Basic and advanced spreadsheet functions, Data analysis and visualization, Advanced features such as PivotTables and Macros.

**Presentation Design with Microsoft PowerPoint:** Creating effective and engaging presentations, Incorporating multimedia elements, Advanced presentation features.

**Database Fundamentals with Microsoft Access:** Introduction to databases and relational databases, Designing and creating tables, Querying and reporting data.

**Collaboration Tools and Cloud Computing:** Effective use of email and calendars, Introduction to collaborative platforms (e.g., Google Workspace), Online document sharing and collaboration.

**Project Management Tools:** Overview of project management software, Task and project planning, Collaborative project management.

### **Recommended Books:**

1. [Darrell Hajek](#). (2020). Introduction to Office Software: Word - Excel - PowerPoint 2020, Dover Publications.
2. [Edgar McCoy](#). (2023). Microsoft Office 365, Dover Publications.
3. Emergent Lof. (2020). Introduction to Computers and Information Technology, 3<sup>rd</sup> edition, Pearson.
4. [Ian Lamont](#). (2020). The beginner's guide to Microsoft Excel, Excel Online, and Google Sheets, 3<sup>rd</sup> edition, i30 Media.
5. [Tiako.P.Fank](#).(2009). Software Applications: Concepts, Methodologies, Tools, and Applications, 1<sup>st</sup> edition, Information Science Publishing.

## **DME-502 Applied Survival Analysis (3+0)**

**Introduction to Survival Analysis:** Overview of survival analysis, Concepts of survival time, censoring, and truncation, Kaplan- Meier estimator.

**Parametric Survival Models:** Exponential, Weibull, and log-logistic models, Maximum likelihood estimation, Model selection and interpretation.

**Non-parametric Survival Models:** Cox proportional hazards model, Stratified Cox models, Extensions and variations.

**Advanced Topics in Survival Analysis:** Time-dependent covariates, Competing risks, Multistate models.

**Regression Models for Survival Data:** Logistic regression vs. survival regression, Building and interpreting survival regression models.

**Survival Analysis in Practice:** Real-world case studies, Software tools for survival analysis, Ethical considerations in survival analysis research.

**Special Topics and Applications:** Bayesian survival analysis, Machine learning approaches, Survival analysis in healthcare and business.

### **Recommended Books:**

1. Dirk F. Moore. (2016). Applied Survival Analysis Using R, 1<sup>st</sup> edition, Springer.
2. Hosmer.D.W, Lemeshow.S, &May.S. (2011). Applied Survival Analysis: Regression Modeling of Time to Event Data, 2<sup>nd</sup> edition, Wiley.
3. Kleinbaum.D.G, &Mitchel.K. (2012). Survival Analysis: A Self Learning Text, 3<sup>rd</sup> edition, Springer.
4. Melinda Mills. (2011). Introducing Survival and Event History Analysis, 1<sup>st</sup> edition, SAGE Publications Ltd.
5. [Shenyang Guo](#). (2010). Survival Analysis, 1<sup>st</sup> edition, Oxford University Press.

## **DME-503 Introduction to Mathematical Modeling in Epidemiology (3+0)**

**Introduction:** Why use systems models; models of data and models of systems; formulating a model; basic math and statistics review; introduction to coding.

**Introduction to Epidemic Modelling:** Introduction to differential equation modeling and simulation, with examples from infectious and chronic diseases, as well as from basic population dynamics, models of physiological and within-host disease dynamics.

**Infectious Disease Modelling with Demography:** Modelling changing populations; Malthusian model, Logistic model as a model of population growth, simplified logistic model, SIR model with demography.

**Model dynamics:** Steady states, equilibria, stability, introduction to  $R_0$  and its computation by inspection, exploring ODE models of infectious diseases and simulations related to them.

**Vector-Borne diseases:** Introduction to vector-borne diseases, simple models of vector-borne diseases, exploring reproduction number, equilibria and their stability, vector-borne disease model with temporary immunity.

**Techniques for computing  $R_0$ :** Jacobian approach; for  $2 \times 2$  system, Routh-Hurwitz criteria in higher dimensions, failure of Jacobian approach, Next-Generation approach; P. van den Driessche and Watmough approach.

### **Recommended Books:**

1. Brauer.F & Castillo.CC. (2012). Mathematical Models in Population Biology and Epidemiology, 1st edition, Springer.
2. Horst Thieme. (2018). Mathematics in Population Biology, 1st edition, Princeton University Press.
3. [Maia Martcheva](#). (2015). An Introduction to Mathematical Epidemiology, 1st edition, Springer.
4. Michael Y. Li. (2018). An Introduction to Mathematical Modeling of Infectious Diseases, Springer.
5. [Ray M. Merrill](#). (2019). Introduction to Epidemiology, 8th edition, Jones & Bartlett Learning.

## **DME-504 Mathematical Modeling of Infectious Diseases (3+0)**

**Introduction** Categorization of infectious diseases and their definitions, historical perspectives on infectious diseases, and a comprehensive approach to modeling.

**Person-to-Person Transmitted Disease:** Basic models related to airborne transmitted diseases, computation of  $R_0$  for these diseases.

**Vector-Borne Diseases:** Basic models related to the vector-borne diseases, computation of  $R_0$  for these diseases, analysis of the models; local and global stability of DFE.

**Estimating Parameters from Data:** Fitting Epidemic models to data, Model selection criterion.

**Multistrain Disease Dynamics:** Competitive exclusion principle, two-strain epidemic SIR model, Super-infection, Co-infection, Cross-Infection.

**Control Strategies:** Introduction to control strategies related to infectious diseases, modeling vaccination; single strain diseases, modeling quarantine and isolation.

### **Recommended Books:**

1. [William E Schiesser](#). (2018). A Mathematical Modeling Approach to Infectious Diseases, World Scientific.
2. Michael Y. Li, (2018). An Introduction to Mathematical Modeling of Infectious Diseases, Springer.
3. Brauer.F&Chavez.C. (2012). Mathematical Models in Population Biology and Epidemiology, 1st edition, Springer.
4. [Maia Martcheva](#). (2015). An Introduction to Mathematical Epidemiology, 1st edition, Springer.
5. [Ray M. Merrill](#). (2019). Introduction to Epidemiology, 8th edition, Jones & Bartlett Learning.

## **DME-505 Regression 1: Linear Regression and Modeling (3+0)**

**Introduction to Regression Analysis:** Overview of regression analysis, Understanding the role of linear regression in statistical modeling, Introduction to the course objectives and structure.

**Simple Linear Regression:** Basic concepts of simple linear regression, Assumptions and limitations, Practical implementation using statistical software.

**Multiple Linear Regression:** Extending to multiple predictors, Interpretation of coefficients, Model evaluation and diagnostics.

**Model Building and Selection:** Variable selection techniques, Building robust regression models, Cross-validation and model comparison.

**Interaction Effects and Nonlinear Regression:** Introduction to interaction terms, Nonlinear regression models, Practical examples and applications.

**Advanced Topics in Regression Analysis:** Logistic regression, Poisson regression, Time series regression.

**Real-world Applications and Case Studies:** Application of regression in various fields (e.g., economics, biology, social sciences), Analyzing and interpreting real-world data, Presenting results and conclusions.

### **Recommended Books:**

1. Jason W. Osborne. (2016). Regression & Linear Modeling: Best Practices and Modern Methods, 1st edition, SAGE Publications
2. Chatterjee.S, & Ali S. Hadi.A.S. (2013). Regression Analysis by Example, 5th edition, Wiley.
3. George.A. F. & [Alan.J.L.](#) (2012). Linear Regression Analysis, 2nd edition, Wiley.
4. John Fox. (2015). Applied Regression Analysis and Generalized Linear Models, 2nd edition, SAGE publications.
5. Darlington.R.B & Hayes.A.F. (2016). Regression Analysis and Linear Models: Concepts, Applications, and Implementation, 1st edition, The Guilford Press.

## **DME-506 Regression II: Categorical Data Analysis (2+1)**

**Introduction to Categorical Data Analysis** Review of basic regression concepts, Overview of categorical data and its applications, Types of categorical outcomes.

**Binary Logistic Regression** Basics of logistic regression, Model formulation and interpretation, Odds ratios and log-odds.

**Multinomial Logistic Regression** Extending logistic regression to multiple categories, Model interpretation and comparison, Practical examples and applications.

**Ordinal Logistic Regression** Modeling ordinal outcomes, Proportional odds assumption, Applications in social and behavioral sciences.

**Log-linear Models** Extension to contingency tables, Modeling associations between categorical variables, Goodness-of-fit tests.

**Advanced Topics** Generalized estimating equations (GEE), Zero-inflated and overdispersed models, Handling missing data in categorical regression.

**Practical Applications and Case Studies** Real-world examples and case studies, Application of categorical regression in research, Software tools for categorical data analysis.

### **Recommended Books:**

1. Alan Agresti, (2012). Categorical Data Analysis, 3<sup>rd</sup> edition Wiley.
2. Darlington.R.B, &Hayes.A.F. (2016). Regression Analysis and Linear Models: Concepts, Applications, and Implementation, 1<sup>st</sup> edition, The Guilford Press.
3. Hosmer.D.W, Lemeshow.S, &Sturdivant.R.X. (2013). Applied Logistic Regression, 3<sup>rd</sup> edition, Wiley.
4. John Fox, (2015). Applied Regression Analysis and Generalized Linear Models, 2<sup>nd</sup> edition, SAGE publications.
5. Stokes.M.E, Davis.C.S, & Koch.G. (2012). Categorical Data Analysis using SAS, 3<sup>rd</sup> edition, SAS Institute.
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## **DME-507 Analysis of Epidemiological Data Using Software (2+1)**

**Introduction to Epidemiological Data Analysis:** Overview of epidemiological data, Importance of statistical analysis in epidemiology, Introduction to the course objectives and structure.

**Descriptive Statistics and Data Cleaning:** Descriptive statistics for epidemiological data, Data cleaning and preparation, Practical exercises using statistical software.

**Exploratory Data Analysis:** Graphical representation of epidemiological data, Identifying patterns and trends, Outlier detection and handling.

**Measures of Association:** Calculation and interpretation of measures of association, Cross-tabulations and chi-square tests, Introduction to odds ratios and relative risks.

**Regression Analysis in Epidemiology:** Introduction to regression models, Simple and multiple regression in epidemiological studies, Model interpretation and validation.

**Survival Analysis:** Kaplan-Meier survival curves, Log-rank test, Cox proportional hazards model.

**Meta-Analysis in Epidemiology:** Overview of meta-analysis, Effect size estimation and forest plots, Interpreting and reporting meta-analysis results.

### **Recommended Books:**

1. [Maia Martcheva](#), (2015). An Introduction to Mathematical Epidemiology, 1<sup>st</sup> edition, Springer.
2. Mark Woodward. (2013). Epidemiology: Study Design and Data Analysis, 3<sup>rd</sup> edition, Chapman and Hall/CRC.
3. O. S. Miettinen. (2011). Epidemiological Research: Terms and Concepts, 1<sup>st</sup> edition, Springer.
4. Ray M. Merrill. (2015). Introduction to Epidemiology, 8<sup>th</sup> edition, Jones & Bartlett Learning.
5. Rothman.J, Rothman.K.J, &Greenland.S. (2014). Handbook of Epidemiology, Springer.

## **DME-508 Survey Design, Analysis, and Reporting (3+0)**

**Introduction to Survey Research:** Overview of survey research, Types of surveys and their applications, Ethical considerations in survey research.

**Planning and Designing Surveys** Defining survey objectives, Sampling techniques and sample size determination, Developing survey instruments.

**Survey Administration** Modes of survey administration (online, phone, in-person), Pilot testing and pretesting, Managing and monitoring data collection.

**Data Cleaning and Coding** Preparing raw survey data for analysis, Variable coding and recoding, Dealing with missing data.

**Introduction to Survey Analysis** Descriptive statistics for survey data, Weighting and adjustments, Basic inferential statistics.

**Advanced Survey Analysis Techniques** Multivariate analysis of survey data, Regression analysis with survey data, Handling complex survey designs.

**Reporting and Interpreting Survey Results** Visualization of survey data, Report writing and presentation skills, Ethical reporting practices.

### **Recommended Books:**

1. [Anthony Arundel](#). (2023). How to Design, Implement, and Analyze a Survey (How to Research Guides), Edward Elgar Publishing.
2. Floyd J. Fowler, Jr. (2013). Survey Research Methods, 5th edition, SAGE Publications.
3. Graham Kalton. (2020). Introduction to Survey Sampling, 2nd edition, SAGE Publications.
4. Heeringa.S.G, West.B.T, & Berglund.P.A. (2017). Applied Survey Data Analysis, 2nd edition, Chapman and Hall/CRC.
5. Saris.A. (2014). Design, Evaluation, and Analysis of Questionnaires for Survey Research, 2nd edition, Wiley.