

**SCHEME OF STUDIES
AND OUTLINES
FOR
BS 4-YEAR
UNDERGRADUATE PROGRAM IN STATISTICS
(Semester System)**



Session 2024–Onward

**DEPARTMENT OF STATISTICS
GOVERNMENT COLLEGE UNIVERSITY
FAISALABAD**

REVISED SCHEME OF STUDIES FOR BS IN STATISTICS
TO BE IMPLEMENTED FROM FALL SEMESTER 2024

Course Code	Course Title	Credit Hours
Semester - I		
STA-301	Introduction to Statistics	3(3-0)
QTR-421	Quantitative Reasoning-I	3(3-0)
MTH-321	Algebra and Trigonometry	3(3-0)
ENG-321	Functional English	3(3-0)
ISL-321	Islamic Studies	2(2-0)
ISL-322	Ethics (For Non-Muslim only)	2(2-0)
GSC-321	The Science of Global Challenges	3(2-1)
*THQ-311	Teaching of Holy Quran-I	1(1-0)
Total Credit Hours in Semester		17
Semester – II		
STA-302	Fundamentals of Probability and Random Variables	3(3-0)
STA-304	Introduction to Regression Analysis	3(3-0)
STA-306	Applied Statistics	3(3-0)
QTR-422	Quantitative Reasoning-II	3(3-0)
MTH-322	Introduction to Calculus	3(3-0)
ENG-322	Expository Writing	3(3-0)
Total Credit Hours in Semester		18
Semester - III		
STA-401	Introduction to Probability Distributions	3(3-0)
STA-403	Statistics for Society	2(2-0)
STA-405	Fundamentals of Parameter Estimation	3(3-0)
CSI-301	Programming Fundamentals	3(2-1)
ICT-321	Applications of Information and Communication Technologies	3(2-1)
ICP-321	Ideology and Constitution of Pakistan	2(2-0)
PST-321	Pakistan Studies	2(2-0)
*THQ-411		1(1-0)
Total Credit Hours in Semester		18
Semester – IV		

STA-402	Basics of Statistical Hypothesis Testing	3(3-0)
STA-404	Statistical Software	3(0-3)
STA-406	Survey Research Methods	3(3-0)
CCE-421	Civics and Community Engagement	2(2-0)
ENT-422	Entrepreneurship	2(2-0)
	Physical Education and Sports	2(2-0)
MTH-433	Mathematical Methods & Vector Analysis	3(3-0)
Total Credit Hours in Semester		18
Semester – V		
STA-501	Probability and Probability Distributions-I	3(3-0)
STA-503	Sampling Techniques-I	3(3-0)
STA-505	Statistical Methods	3(3-0)
STA-507	Operations Research	3(3-0)
STA-509	Introduction to Data Science	3(3-0)
STA-511	Introduction to Survival Analysis	3(3-0)
*THQ-511	Teaching of Holy Quran-III	1(1-0)
Total Credit Hours in Semester		18
Semester – VI		
STA-502	Probability and Probability Distributions-II	3(3-0)
STA-504	Sampling Techniques-II	3(3-0)
STA-506	Design and Analysis of Experiments-I	3(3-0)
STA-508	Statistical Quality Control	3(3-0)
STA-510	Introduction to Machine Learning	3(3-0)
STA-530	Seminar	1(0-1)
Total Credit Hours in Semester		16
Semester – VII		
STA-601	Econometrics-I	3(3-0)
STA-603	Design and Analysis of Experiments-II	3(3-0)
STA-605	Multivariate Analysis-I	3(3-0)
STA-607	Statistical Inference-I	3(3-0)
STA-609	Statistical Computing –I	3(0-3)
INT-631	Internship/Field Experience	3(0-3)
*THQ-611	Teaching of Holy Quran-IV	1(1-0)
Total Credit Hours in Semester		18

Semester – VIII		
STA-602	Econometrics-II	3(3-0)
STA-604	Statistical Computing –II	3(0-3)
STA-606	Multivariate Analysis-II	3(3-0)
STA-608	Statistical Inference-II	3(3-0)
CAP-630	Capstone Project	3(0-3)
Any One of The Following Optional Courses		
STA-610	Analysis of Time Series and Forecasting	3(3-0)
STA-612	Categorical Data Analysis	3(3-0)
STA-614	Population Studies	3(3-0)
STA-616	Non Parametric Methods	3(3-0)
STA-618	Bayesian Statistics	3(3-0)
Total Credit Hours in Semester		18
Total Credit Hours in BS Statistics Program		141

*No Credit Audit Course



DETAILED COURSE OUTLINES FOR BS STATISTICS

SEMESTER-I

STA-301	Introduction to Statistics	3(3-0)
---------	----------------------------	--------

Meanings of statistics, main branches of statistics, types of variables, measurements scales, errors of measurement, significant digits, statistical data collection, organizing data, classification of data, graphs and charts: stem and leaf diagram, box and whisker plots, bar charts, pie-chart, graphs based on frequency distribution: histogram, frequency polygon, ogive.

Measure of Central Tendency: arithmetic mean, median, mode, geometric mean, harmonic mean, weighted arithmetic mean and its properties, merits and demerits, quantiles, the box plots, empirical relation between mean, median and mode.

Measure of dispersion: absolute and relative measure of dispersion and their properties, merits and demerits, standardized variables, moments, Sheppard's correction, moments ratios, coefficient of kurtosis and skewness, trimmed and Winsorized mean.

Recommended Books:

1. Bluman, G. A. (2023). *Elementary Statistics: A Step by Step Approach*. 11th Ed., McGraw Hill, New York.
2. Walpole, R. E. (2020). *Introduction to Statistics*. 3rd Ed., Macmillan Publishing Company. New York.
3. Chaudhary, S. M., and Kamal, S. (2020). *Introduction to Statistical Theory*. Part-I, 6th Ed., Ilmi Kitab Khana, Lahore, Pakistan.
4. Mcclave, J. T., Benson, P.G., and Snitch, T. (2019). *Statistics for Business & Economics*. 14th Ed., Prentice Hall, New Jersey.
5. Weiss, N. A. (2017). *Introductory Statistics*. 10th Ed., Pearson Education Limited, Essex, England.
6. Schiller, J. L., Sirinivasan, R. L., and Spiegel, M. R. (2012). *Probability and Statistics*. 4th Ed., Schaums Outlines Series. McGraw Hill. New York.
7. Clark, G. M., and Cooke, D. (2011). *A Basic Course in Statistics*. 5th Ed., Arnold, London.
8. Rauf, M. (2001). *Polymer's Modern Statistics*. Polymer Publication, Urdu Bazar, Lahore.

QTR-421	Quantitative Reasoning-I	3(3-0)
---------	--------------------------	--------

Numerical Literacy: Introduction to quantitative reasoning, number system and basic arithmetic operations, unit and their conversions, dimensions, area, perimeter and volume, proportions, rates, ratio and percentages, odds and odds ratio, scale of measurements, tabular and graphical presentation of data, data handling (small and large), data errors, absolute and relative and their applications, quantitative reasoning exercises using number knowledge.

Fundamental Statistical and Mathematical Concepts: Population and sample, descriptive statistics, measures of variability, sets and their operations, rules of counting: multiplication rule, permutation and combination, probability and its application in real life, introduction to random variables and their probability distributions, quantitative reasoning exercises using fundamental statistical and mathematical concepts.

Recommended Books:

1. Bluman, G. A. (2023). *Elementary Statistics: A Step by Step Approach*. 11th Ed., McGraw Hill, New York.
2. de Mesquita, E. B., Fowler, A. (2021). *Thinking Clearly with Data: A Guide to Quantitative Reasoning and Analysis*. Princeton University Press.
3. Walpole, R. E. (2020). *Introduction to Statistics*. 3rd Ed., Macmillan Publishing Company. New York.
4. Zaslow, E. (2020). *Quantitative Reasoning: Thinking in Numbers*. Cambridge University Press.
5. Mclave, J. T., Benson, P.G., and Snitch, T. (2019). *Statistics for Business & Economics*. 14th Ed., Prentice Hall, New Jersey.
6. Weiss, N. A. (2017). *Introductory Statistics*. 10th Ed., Pearson Education Limited, Essex, England.
7. Sevilla, A., and Somers, K. (2013). *Quantitative Reasoning: Tools for Today's Informed Citizens*. 2nd Ed., Wiley Global Education.
8. Schiller, J. L., Sirinivasan, R. L., and Spiegel, M. R. (2012). *Probability and Statistics*. 4th Ed., Schaums Outlines Series. McGraw Hill. New York.
9. Aufmann, R. N., Lockwood, J. S., Nation, R. D., and Clegg, D. K. (2008). *Mathematical Thinking and Quantitative Reasoning*. Houghton Mifflin Company.



SEMESTER-II

STA-302	Fundamentals of Probability and Random Variables	3(3-0)
---------	--	--------

Set theory, counting rules: multiplication, combination, permutation., random experiment, type of events, definitions of probability, laws of probability: complement, addition, multiplication, independence, conditional probability, total probability and Bayes' rule.

Random variable, distribution function, discrete random variable and its probability distribution, continuous random variable and its probability density function, joint distributions: bivariate distribution functions, bivariate probability functions, marginal probability functions, conditional probability functions, independence, continuous bivariate distributions.

Mathematical expectations of random variables, median and mode of continuous random variables, Chebyshev's inequality.

Recommended Books:

1. Bluman, G. A. (2023). *Elementary Statistics: A Step by Step Approach*. 11th Ed., McGraw Hill, New York.
2. Walpole, R. E. (2020). *Introduction to Statistics*. 3rd Ed., Macmillan Publishing Company. New York.
3. Chaudhary, S. M., and Kamal, S. (2020). *Introduction to Statistical Theory*. Part-I, 6th Ed., Ilmi Kitab Khana, Lahore, Pakistan.
4. Mclave, J. T., Benson, P.G., and Snitch, T. (2019). *Statistics for Business & Economics*. 14th Ed., Prentice Hall, New Jersey.
5. Mathai, A. M., and Haubold, H. J. (2018). *Probability and Statistics*. Walter de Gruyter GmbH, Berlin/Boston.
6. Weiss, N. A. (2017). *Introductory Statistics*. 10th Ed., Pearson Education Limited, Essex, England.
7. Schiller, J. L., Sirinivasan, R. L., and Spiegel, M. R. (2012). *Probability and Statistics*. 4th Ed., Schaums Outlines Series. McGraw Hill. New York.
8. Clark, G. M., and Cooke, D. (2011). *A Basic Course in Statistics*. 5th Ed., Arnold, London.
9. Rauf, M. (2001). *Polymer's Modern Statistics*. Polymer Publication, Urdu Bazar, Lahore.

STA-304	Introduction to Regression Analysis	3(3-0)
---------	-------------------------------------	--------

Regression Analysis: concept of regression analysis, scatter diagram, simple and multiple linear regression models: assumptions, model fitting, standard error of estimate, coefficient of determination, fitting of non-linear regression models.

Correlation Analysis: bivariate coefficient of correlation, its properties, rank correlation, multiple and partial correlation coefficients, correlation and causation.

Recommended Books:

1. Bluman, G. A. (2023). *Elementary Statistics: A Step by Step Approach*. 11th Ed., McGraw Hill, New York.
2. Montgomery, D. C., Peck, E. A., and Vining, G. G. (2021). *Introduction to Linear Regression Analysis*. 6th Ed., John Wiley & Sons.
3. Walpole, R. E. (2020). *Introduction to Statistics*. 3rd Ed., Macmillan Publishing Company. New York.
4. Chaudhary, S. M., and Kamal, S. (2020). *Introduction to Statistical Theory*. Part-I, 6th Ed., Ilmi Kitab Khana, Lahore, Pakistan.
5. Mclave, J. T., Benson, P.G., and Snitch, T. (2019). *Statistics for Business & Economics*, 14th Ed., Prentice Hall, New Jersey.
6. Weiss, N. A. (2017). *Introductory Statistics*. 10th Ed., Pearson Education Limited, Essex, England.
7. Clark, G. M., and Cooke, D. (2011). *A Basic Course in Statistics*. 5th Ed., Arnold, London.

STA-306	Applied Statistics	3(3-0)
---------	--------------------	--------

Index Numbers: construction and application of index number. simple and composite index number. fixed based and chain base method. unweighted and weighted index number. theoretical tests for index number. (time reversal tests, factor reversal test, circular test). consumer price index number and sensitive price index number. determination of purchasing power of money, real wages, inflation rate on the basis of index number. limitation of index number.

Time Series Analysis: time series data, components of time series, measurements of systematic components of time series (secular trend, seasonal variation, cyclical fluctuation, irregular), de-trending, deseasonalization of data, forecasting and prediction.

Vital Statistics: meaning of vital statistics, registration of births and deaths in Pakistan. uses of vital statistics, short comings of vital statistics, rates and ratio (sex ratio, child ratio, birth and death ratio, population growth rate, classification of natal rates, death rates or mortality rates, crude death rate, infant mortality rate, specific death rate, case fatality rate, fertility rate, crude birth rate, specific birth rate, standardized death rate, reproduction rate, gross reproduction rate. net reproduction rate, morbidity or sickness rate, marriage rate, divorce rate, etc. general fertility rate, total fertility rate.)

Recommended Books:

1. Mclave, J.T., Benson, P.G., and Snitch, T. (2019). *Statistics for Business & Economics*. 14th Ed., Prentice Hall, New Jersey.
2. Keller, G. (2018). *Statistics for Management and Economics*. Cengage Learning.
3. Ralph, J., O'neill, R., and Winton, J. (2015). *A Practical Introduction to Index Numbers*. John Wiley & Sons, New York.

4. Chaudhary, S. M., and Kamal, S. (2011). *Introduction to Statistical Theory*. Parts I & II, 6th Ed., Ilmi Kitab Khana, Lahore, Pakistan.
5. Rauf, M. (2001). *Polymer's Modern Statistics*. Polymer Publication, Urdu Bazar, Lahore.

QTR-422	Quantitative Reasoning-II	3(3-0)
---------	---------------------------	--------

Statistical and Mathematical Modeling: Introduction to probabilistic and deterministic models, use of linear functions for modeling in real-world situations, bivariate analysis and scatter plots, simple linear regression model and correlation analysis, linear and exponential growth and decay models, basics of estimation and confidence interval (single population mean and proportion), testing of hypothesis (Z-test for single population mean and proportion, t-test for single population mean), statistical inference in decision making, quantitative reasoning exercises using statistical modeling.

Logic, Logical and Critical Reasoning: Introduction and importance of logic, inductive and deductive reasoning, Venn diagrams, predictive modeling to enhance the decision power, quantitative reasoning exercises using logical reasoning concepts and techniques.

Recommended Books:

1. Bluman, G. A. (2023). *Elementary Statistics: A Step by Step Approach*. 11th Ed., McGraw Hill, New York.
2. de Mesquita, E. B., Fowler, A. (2021). *Thinking Clearly with Data: A Guide to Quantitative Reasoning and Analysis*. Princeton University Press.
3. Walpole, R. E. (2020). *Introduction to Statistics*. 3rd Ed., Macmillan Publishing Company. New York.
4. Zaslow, E. (2020). *Quantitative Reasoning: Thinking in Numbers*. Cambridge University Press.
5. McLave, J. T., Benson, P.G., and Snitch, T. (2019). *Statistics for Business & Economics*. 14th Ed., Prentice Hall, New Jersey.
6. Weiss, N. A. (2017). *Introductory Statistics*. 10th Ed., Pearson Education Limited, Essex, England.
7. Sevilla, A., and Somers, K. (2013). *Quantitative Reasoning: Tools for Today's Informed Citizens*. 2nd Ed., Wiley Global Education.
8. Schiller, J. L., Sirinivasan, R. L., and Spiegel, M. R. (2012). *Probability and Statistics*. 4th Ed., Schaums Outlines Series. McGraw Hill. New York.
9. Aufmann, R. N., Lockwood, J. S., Nation, R. D., and Clegg, D. K. (2008). *Mathematical Thinking and Quantitative Reasoning*. Houghton Mifflin Company.

SEMESTER-III

STA-401	Introduction to Probability Distributions	3(3-0)
---------	---	--------

Discrete Probability Distributions: introduction, basic properties (mean and variance) and applications of uniform distribution, Bernoulli distribution, binomial distribution, Poisson distribution, hypergeometric distribution, geometric distribution, negative binomial distribution.

Continuous Probability Distributions: Introduction, properties (mean, median, mode, variance, mean deviation, quartile deviation, skewness and kurtosis) and application of the normal distribution.

Recommended Books:

1. Bluman, G. A. (2023). *Elementary Statistics: A Step by Step Approach*. 11th Ed., McGraw Hill, New York.
2. Walpole, R. E. (2020). *Introduction to Statistics*. 3rd Ed., Macmillan Publishing Company. New York.
3. Chaudhary, S. M., and Kamal, S. (2020). *Introduction to Statistical Theory*. Part-I, 6th Ed., Ilmi Kitab Khana, Lahore, Pakistan.
4. Mcclave, J. T., Benson, P.G., and Snitch, T. (2019). *Statistics for Business & Economics*. 14th Ed., Prentice Hall, New Jersey.
5. Mathai, A. M., and Haubold, H. J. (2018). *Probability and Statistics*. Walter de Gruyter GmbH, Berlin/Boston.
6. Weiss, N. A. (2017). *Introductory Statistics*, 10th Ed., Pearson Education Limited, Essex, England.
7. Schiller, J. L., Sirinivasan, R. L., and Spiegel, M. R. (2012). *Probability and Statistics*. 4th Ed., Schaums Outlines Series. McGraw Hill. New York.
8. Clark, G. M., and Cooke, D. (2011). *A Basic Course in Statistics*. 5th Ed., Arnold, London.

STA-403	Statistics for Society	2(2-0)
---------	------------------------	--------

Statistical concepts and their relevance to social life, health, and physical sciences, humanities, public policy, business; focus on critical approach to statistical evidence, quantitative or formal reasoning.

Basic descriptive skills of quantitative data analysis, how to manipulate variables and how to present statistical information in tabular and graphical form, uses and misuses of Statistics in society. How numbers are deployed in social settings, and how they are used in society to construct and challenge our understanding of the social world, introduce students to quantification in modern societies.

Familiarization with the main instruments for the collection of quantitative data and providing an overview of the methods used to treat such data in contemporary social life, descriptive and explanatory methods and the vision of the social world implicitly associated

with each of the methods we encounter.

Recommended Books:

1. Spiegelhalter, D. (2021). *The Art of Statistics: How to Learn from Data*. Basic Books.
2. Evans, J., Ruane, S., and Southall, H. (2019). *Data in Society: Challenging Statistics in an Age of Globalisation*. Bristol University Press, UK.
3. Chava, F. N., and Anna, L. G. (2018). *Social Statistics for a Diverse Society*. 8th Ed., SAGE Publications Inc.
4. Bennett, J., Briggs, W., and Triola, M. (2017). *Statistical Reasoning for Everyday Life*. 5th Ed., Pearson.
5. Dani, B. Z., Katie, M., and Joan, G. (2017). *International Handbook of Research in Statistics Education*. Springer.
6. Saetnan, A. R., Lomell, H. M., and Hammer, S. (2012). *The Mutual Construction of Statistics and Society*. Routledge.
7. Wasserman, L. (2004). *All of Statistics: A Concise Course in Statistical Inference*. Springer Texts in Statistics.

STA-405	Fundamentals of Parameter Estimation	3(3-0)
---------	--------------------------------------	--------

Sampling: definition, objectives, advantages and disadvantages, types of sampling: probability and non-probability sampling, sampling distribution of mean and difference between means, proportion, difference between two proportions and variance under simple random sampling with and without replacements, central limit theorem.

Point Estimation: point estimators for population mean, difference between two population means, proportion and difference between two population proportions, population variance and their properties (unbiasedness, consistency, efficiency, sufficiency).

Interval Estimation: construction of confidence intervals for population mean, difference between two population means, proportion, difference between two population proportions and population variance, one sided confidence interval.

Recommended Books:

1. Bluman, G. A. (2023). *Elementary Statistics: A Step by Step Approach*. 11th Ed., McGraw Hill, New York.
2. Walpole, R. E. (2020). *Introduction to Statistics*. 3rd Ed., Macmillan Publishing Company. New York.
3. Mclave, J. T., Benson, P.G., and Snitch, T. (2019). *Statistics for Business & Economics*. 14th Ed., Prentice Hall, New Jersey.
4. Weiss, N. A. (2017). *Introductory Statistics*. 10th Ed., Pearson Education Limited, Essex, England.
5. Schiller, J. L., Sirinivasan, R. L., and Spiegel, M. R. (2012). *Probability and Statistics*. 4th Ed., Schaums Outlines Series. McGraw Hill. New York.
6. Chaudhary, S. M., and Kamal, S. (2011). *Introduction to Statistical Theory*. Part-II, 6th Ed., Ilmi Kitab Khana, Lahore, Pakistan.

7. Clark, G. M., and Cooke, D. (2011). *A Basic Course in Statistics*. 5th Ed., Arnold, London.
8. Rauf, M. (2001). *Polymer's Modern Statistics*. Polymer Publication, Urdu Bazar, Lahore.



SEMESTER-IV

STA-402	Basics of Statistical Hypothesis Testing	3(3-0)
---------	--	--------

Hypothesis Testing: Basic definitions, types of error, power of test, OC curve, hypothesis testing for single population mean, difference between two population means (independent and paired samples), proportion, difference between two proportions, variance, ratio of two populations variances.

Chi-square test for independence of attributes, goodness of fit test, hypothesis testing about regression coefficients.

Analysis of Variance (ANOVA): one-way and two-way analysis of variance. Analysis of covariance (ANCOVA).

Recommended Books:

1. Bluman, G. A. (2023). *Elementary Statistics: A Step by Step Approach*. 11th Ed., McGraw Hill, New York.
2. Walpole, R. E. (2020). *Introduction to Statistics*. 3rd Ed., Macmillan Publishing Company. New York.
3. Mclave, J. T., Benson, P.G., and Snitch, T. (2019). *Statistics for Business & Economics*. 14th Ed., Prentice Hall, New Jersey.
4. Weiss, N. A. (2017). *Introductory Statistics*. 10th Ed., Pearson Education Limited, Essex, England.
5. Chaudhary, S. M., and Kamal, S. (2011). *Introduction to Statistical Theory*. Part-II, 6th Ed., Ilmi Kitab Khana, Lahore, Pakistan.
6. Clark, G. M., and Cooke, D. (2011). *A Basic Course in Statistics*. 5th Ed., Arnold, London.
7. Spiegel, M. R. Schiller, J. L., and Sirinivasan, R. L. (2001). *Probability and Statistics*. 4th Ed., Schaums Outlines Series. McGraw Hill. New York.
8. Rauf, M. (2001). *Polymer's Modern Statistics*. Polymer Publication, Urdu Bazar, Lahore.

STA-404	Statistical Software	3(0-3)
---------	----------------------	--------

Statistical Data Analysis using MS Excel

Introduction to Excel software, mathematical functions in Excel and their applications, matrix algebra in Excel, statistical functions in Excel and their applications, graphical analysis by creating graphs like, simple, multiple and clustered bar charts, pie chart, histogram, etc., descriptive statistics (measures of central tendency and dispersion and positions), introduction to data analysis and solver-in option, generation of statistical tables, random number generation through various probability distributions, Monte Carlo simulations.

Regression and Correlation Analysis: Scatter plots, regression analysis (simple and multiple) and its associated statistical inference, handling regression output, residuals analysis and diagnostic checking, bivariate correlation.

Testing of Hypothesis: Testing for single population mean, independent and paired samples tests, Analysis of variance (one-way and two-way), test for population variance and equality of two variances.

Recommended Books:

1. Winston, W. (2019). *Microsoft Excel 2019 Data Analysis and Business Modeling*, 6th Ed., Microsoft Press.
2. David, M. (2017). *Statistics for Managers: Using Microsoft Excel*. Pearson Education India.
3. Humphrey, M. L. (2017). *Excel for Beginners*. Create Space Independent Publishing Platform.
4. Carlberg, C. (2014). *Statistical Analysis: Microsoft Excel 2013*. Que Publishing.
5. Fleming, M. C., and Nellis, J. G. (2000). *Principles of Applied Statistics: An Integrated Approach Using Minitab and Excel*. Cengage Learning EMEA.
6. Levine, D. M., Ramsey, P. R., and Smidt, R. K. (2000). *Applied statistics for engineers and scientists: Using Microsoft Excel & Minitab*. Pearson Education Inc.

STA-406	Survey Research Methods	3(3-0)
---------	-------------------------	--------

The nature of social survey, preliminary study, the main planning problems, pre-test and pilot surveys, the coverage of the surveys, methods of collecting the information: documentary sources, observation, mail questionnaires, interviewing., construction of questionnaires: general principals of design, question content, question wording, open and pre-coded questions, question order., scaling methods: types of scales, rating scales, Thurstone scales, Likert scales, Guttman scales., editing, coding, tabulation, report writing.

Sample Survey Project: Conducting a small scale survey and preparing a comprehensive report.

Recommended Books:

1. Cowels, E. L., and Nelson, E. (2019). *An Introduction to Survey Research, Volume I: The Basics of Survey Research*. 2nd Ed., Business Expert Press, New York.
2. Fowler Jr, F. J. (2014). *Survey Research Methods*. 5th Ed., SAGE Publications, Inc.
3. Punch, K. F. (2003). *Survey Research: The Basics*. SAGE Publications, Inc.
4. Moser, C. A., and Kalton, G. (1971). *Survey Methods in Social Investigation*. 2nd Ed., Heinemann Educational Books Ltd, London.
5. Abrams, M. A. (1951). *Social Surveys and Social Actions*. Heinemann Educational Books Ltd, London.

SEMESTER-V

STA-501	Probability and Probability Distributions-I	3(3-0)
---------	---	--------

Basic Concepts: set theory, definitions and laws of probability, conditional probability, total probability, and Bayes' theorem.

Random Variables: Discrete and continuous probability functions and their distribution functions, mathematical expectation, moment generation function, cumulant generating function and characteristic function, factorial moments, Joint density function, conditional and marginal probability functions, statistical independence and conditional expectation, uniqueness theorem, Inversion theorem, Chebyshev's inequality, laws of large numbers, central limit theorem.

Discrete Probability Distributions: Properties of Bernoulli, binomial, hypergeometric, Poisson, geometric, negative binomial, multinomial distributions and their relationship.

Recommended Books:

1. Gazi, O. (2023). *Introduction to Probability and Random Variables*. Springer Cham.
2. Hogg, R., McKean, J., and Craig, A. (2018). *Introduction to Mathematical Statistics*. 8th Ed., Pearson Education Inc.
3. Mathai, A. M., and Haubold, H. J. (2018). *Probability and Statistics*. Walter de Gruyter GmbH, Berlin/Boston.
4. Thomopoulos, N. T. (2018). *Probability Distributions: With Truncated, Log and Bivariate Extensions*. Springer Cham.
5. Larsen, R., and Marx, M. (2017). *Introduction to Mathematical Statistics and Its Applications*. 6th Ed. Pearson.
6. Bhuyan, K. C. (2010). *Probability Distribution Theory and Statistical Inference*. New Central Book Agency (P) Limited.
7. Hirai, A. S. (1990). *A Course in Mathematical Statistics*. Ilmi Kitab Khana Lahore.
8. Mood, A. M., Graybill, F. A., and Boss, D. C. (1974). *Introduction to the Theory of Statistics*, MacGraw Hill, New York.

STA-503	Sampling Techniques-I	3(3-0)
---------	-----------------------	--------

Basics of Sampling and Sample Survey: Concept of sample and population, Advantages and limitations of sampling, Requirements of a good sample, Bias and its effects, Sampling and non-sampling errors. A survey of sampling design, Steps and problems involved in planning and conduct of census and sample surveys.

Non-Probability Sampling: Non-Probability Sampling Techniques, Quota Sampling, Judgment Sampling etc. Application and Limitations of Non-Probability Sampling Methods.

Probability Sampling: Simple random sampling: Description and properties of simple random sampling. Estimation of population mean, total, proportion, variance and standard errors. Variance and standard error of estimates. Confidence limits and estimation of sample size.

Stratified random sampling: Supplementary information, Stratification, Construction of Strata and Stratified random sampling. Estimation of mean and its standard error. Proportional, Neyman and optimum allocations of sample size. Sampling variance for

proportion and gain in precision in stratified sampling as compared to simple random sampling.

Recommended Books:

1. Lohr, S. S. (2022). *Sampling: Design and Analysis*. 3rd Ed., CRC Press.
2. Arnab, R. (2017). *Survey Sampling: Theory and Application*. Academic Press, Elsevier Limited.
3. Blair, E., and Blair, J. (2014). *Applied survey sampling*. Sage Publications.
4. Mukhopadhyay, P. (2005). *Theory and Methods of Survey Sampling*. Prentice-Hall of India.
5. Singh, R., and Singh, N. (1996). *Elements of Survey Sampling*. Springer Science+Business Media.
6. Cochran, W.G. (1977). *Sampling Techniques*. 3rd Ed., John Wiley & Sons, New York.
7. Murthy, M. N. (1967). *Sampling Theory and Methods*. Statistical Publishing Society, India.

STA-505	Statistical Methods	3(3-0)
---------	---------------------	--------

Statistical Inference: Estimation of parameters and tests of hypotheses, simple and composite hypotheses, Type-I and Type-II errors, level of significance and p-value, power of a test, characteristic function and OC curve, inference about means, proportions, variances and associated power curves, determination of sample size.

Tests based on Chi-square Distribution: Analysis of categorical data, Bartlett test, partitioning of chi-square in a 2×2 table, Fisher's exact test.

Non-parametric Tests: Sign test, run test, test of randomness, Wilcoxon signed-rank and rank-sum tests, Mann-Whitney U-test, Kolmogorov Smirnov's test, Kruskal-Wallis test, Friedman test.

Inference about Regression Model: Test of linearity, testing of hypotheses about simple and multiple regression coefficients, simple correlation, multiple and partial correlations up to three variables, concept of outliers.

Recommended Books:

1. Bluman, G. A. (2023). *Elementary Statistics: A Step by Step Approach*. 11th Ed., McGraw Hill, New York.
2. Heumann, C., Schomaker, M., and Shalabh. (2022). *Introduction to Statistics and Data Analysis: With Exercises, Solutions and Applications in R*. 2nd Ed., Springer.
3. Montgomery, D. C., Peck, E. A., and Vining, G. G. (2021). *Introduction to Linear Regression Analysis*, 6th Ed., John Wiley & Sons.
4. Walpole, R. E. (2020). *Introduction to Statistics*. 3rd Ed., Macmillan Publishing Company. New York.
5. Larsen, R. J., and Marx, M. L. (2018). *An Introduction to Mathematical Statistics and Its Applications*. 6th Ed., Pearson Education, Inc.
6. Kanji, G. K. (2006). *100 Statistical Tests*. 3rd Ed., SAGE Publication.
7. Muhammad. F. (2011). *Statistical Methods and Data Analysis*. Kitab Markaz, Faisalabad.
8. Zar, J. H. (2009). *Biostatistical Analysis*. 5th Edition, Pearson Education, Inc.

STA-507	Operations Research	3(3-0)
---------	---------------------	--------

History and definition of Operations Research, introduction to linear programming, formulation of LP model, matrix form, canonical form, standard form, duality theory, primal and dual form, graphical solution of two variables, simplex method, two-phase method, M-technique, network programming, transportation, assignment and shortest path problems, introduction to CPM and PERT techniques, queuing models.

Recommended Books:

1. Hillier, F. S., and Lieberman, G. J. (2021). *Introduction to Operations Research*. McGraw-Hill Education.
2. Taha, H.A. (2018). *Operations Research: An Introduction*. Global Ed., Pearson Education, Inc.
3. Render, B., Stair Jr, R. M., and Hanna, M. E. (2012). *Quantitative Analysis for Management*. 11th Ed., Pearson Education Inc.
4. Morse, P.M., and Kimball, G. E. (2012). *Methods of Operations Research*. Peninsula Publishing.
5. Panneerselvam, R. (2004). *Operations Research*. Prentice-Hall of India.

STA-509	Introduction to Data Science	3(3-0)
---------	------------------------------	--------

Overview of Data Science: Big data and data science hype, current landscape of perspectives, skill sets needed to be data scientist: data extraction tools, big data management tools, use of various databases to manage big data, data preprocessing.

Data Visualization: basic principles, ideas and tools for data visualization, examples of inspiring projects, overview of machine learning techniques: supervised and unsupervised machine learning algorithms.

Overview of Statistical Software R and Python: strengths and limitations of these analysis tools, data science and ethical issues, discussions on privacy, security, ethics, next generation data scientists.

Recommended Books:

1. Lakshmanan, V. (2022). *Data Science on the Google Cloud Platform*. O'Reilly Media, Inc.
2. Jo, T. (2021). *Machine Learning Foundations*. Springer International Publishing.
3. Martinez, I., Viles, E., and Olaizola, I. G. (2021). *Data Science Methodologies: Current Challenges and Future Approaches*. Big Data Research, 24, 100183.
4. Pierson, L. (2021). *Data Science for Dummies*. John Wiley & Sons.
5. Zumel, N., and Mount, J. (2020). *Practical Data Science with R*, 2nd Ed., Manning Publications Co.
6. Grus, J. (2019). *Data Science from Scratch*. 2nd Ed., O'Reilly Media, Inc.
7. Healy, K. (2018). *Data Visualization: A Practical Introduction*. Princeton University Press.
8. Van Der Aalst, W. (2016). *Process Mining: Data Science in Action* (Vol. 2). Heidelberg: Springer.
9. Zaki, M. J., and Miera, W. (2014). *Data Mining and Analysis: Fundamental Concepts and Algorithms*. Cambridge University Press.

Aims of survival analysis, special Features of survival data: Time to event data and their features, survival function, hazard function, hazard ratio and cumulative hazard functions, censoring and its types.

Estimation of survival function and survival rate, hazard function, median and percentiles of survival times. Confidence interval and comparison of groups, modeling of survival data, sample size requirement for survival study.

Parametric methods of survival analysis: Weibull, Log-normal, Exponential and Gamma distribution.

Nonparametric and Semi-parametric Procedures: Kaplan-Meier estimator, Nelson Aalen estimator, Logrank test.

Recommended Books:

1. Vaman, H. J., and Tattar, P. (2022). *Survival Analysis*. 1st Ed., Chapman and Hall/CRC, New York.
2. Lokhnygina, Y. (2022). *Principles and Practice of Clinical Trials*. Springer, Cham.
3. Moore, D. F. (2016). *Applied Survival Analysis Using R*. Springer International Publishing Switzerland.
4. Hollander, M., Wolfe, D. A., and Chicken, E. (2013). *Nonparametric Statistical Methods*, 3rd Ed., John Wiley
5. Kleinbaum, D. G., and Klein, M. (2012). *Survival Analysis: A Self Learning Text*. 3rd Ed., Springer Science+Business Media.
6. Liu, X. (2012). *Survival Analysis: Models and Applications*. John Wiley & Sons.
7. Guo, S. (2010). *Survival Analysis*. Oxford University Press.
8. Selvin, S. (2008). *Survival Analysis for Epidemiologic and Medical Research*. Cambridge University Press.
9. Lee, E.T., and Wang, J. W. (2003). *Statistical Methods for Survival Data Analysis*. John Wiley & Sons, Inc., New York.
10. Eland-Johnson, R. C., and Johnson, N. L. (1999). *Survival Models and Data Analysis*. John Wiley & Sons, Inc., New York.
11. Parmer, M. K. B., and Macklin, D. (1995). *Survival Analysis: A Practical Approach*. John Wiley & Sons, Inc., New York.
12. Muller, R. G., and Zhou, X. (1996). *Survival Analysis with long-term Survivors*. John Wiley & Sons, Inc., New York.

SEMESTER-VI

STA-502	Probability and Probability Distributions-II	3(3-0)
---------	--	--------

Continuous Probability Distributions: Properties of uniform, normal, negative exponential, gamma, beta, lognormal, Weibull, Rayleigh, Pareto, double exponential, Cauchy distributions, and their relationships among distributions.

Transformation of variables: Transformation of discrete and continuous random variables, change of variable, cumulative distributions function and moment generation function techniques, transformation of two random variables (sum, product and quotient).

Sampling Distributions: Derivation of χ^2 , t and F distributions and their properties, distribution of sample mean, variance and their properties.

Bivariate Normal Distribution: area, moment generating function, marginal and conditional distributions, independence.

Order Statistics: Distribution of r^{th} order statistic, mean and variance of r^{th} order statistic, joint distribution of i^{th} and j^{th} order statistics, distribution of sample range and sample mid-range.

Recommended Books:

1. Gazi, O. (2023). *Introduction to Probability and Random Variables*. Springer Cham.
2. Hogg, R., McKean, J., and Craig, A. (2018). *Introduction to Mathematical Statistics*. 8th Ed., Pearson Education Inc.
3. Mathai, A. M., and Haubold, H. J. (2018). *Probability and Statistics*. Walter de Gruyter GmbH, Berlin/Boston.
4. Thomopoulos, N. T. (2018). *Probability Distributions: With Truncated, Log and Bivariate Extensions*. Springer Cham.
5. Larsen, R., and Marx, M. (2017). *Introduction to Mathematical Statistics and Its Applications*. 6th Ed. Pearson.
6. Bhuyan, K. C. (2010). *Probability Distribution Theory and Statistical Inference*. New Central Book Agency (P) Limited.
7. Hirai, A. S. (1990). *A Course in Mathematical Statistics*. Ilmi Kitab Khana Lahore.
8. Mood, A. M., Graybill, F. A., and Boss, D. C. (1974). *Introduction to the Theory of Statistics*. MacGraw Hill, New York.

STA-504	Sampling Techniques-II	3(3-0)
---------	------------------------	--------

Ratio and product methods of estimation: Need for ratio and product estimation, estimation of population ratio, ratio and product estimators for population mean/total, determining the sample size for ratio, mean/total, separate and combined ratio/product estimators under stratified random sampling.

Regression method of estimation: Need for regression estimation, estimation of mean/total using difference and linear regression estimators, sample size determination for estimating mean/total, separate and combined regression estimators. Systematic sampling: linear and circular systematic sampling, estimation of mean/total, sample size determination for estimating mean/total.

Recommended Books:

1. Lohr, S. S. (2022). *Sampling: Design and Analysis*. 3rd Ed., CRC Press.
2. Arnab, R. (2017). *Survey Sampling: Theory and Application*. Academic Press, Elsevier Limited.
3. Blair, E., and Blair, J. (2014). *Applied survey sampling*. Sage Publications.
4. Mukhopadhyay, P. (2005). *Theory and Methods of Survey Sampling*. Prentice-Hall of India.
5. Singh, R., and Singh, N. (1996). *Elements of Survey Sampling*. Springer Science+Business Media.
6. Cochran, W.G. (1977). *Sampling Techniques*. 3rd Ed., John Wiley & Sons, New York.
7. Murthy, M. N. (1967). *Sampling Theory and Methods*. Statistical Publishing Society, India.

STA-506	Design and Analysis of Experiments-I	3(3-0)
---------	--------------------------------------	--------

Basic Designs: Elementary terms and definition of Design of Experiments, Principals of Design of Experiments. Basic Experimental Designs: Completely Randomized Design (CRD), Randomized Complete Block (RCBD), Latin Square Design, Graeco-Latin Square Design. Analysis of experimental data with missing observations. Relative Efficiency of Designs.

Incomplete Block Designs: Balance Incomplete Block Design BIBD-Lattice Designs, Lattice Square and Youden Squares. Partially Balance Incomplete Block Design PBIBD with Recovery of Intra-Block Information. Generalized Lattices, Cochran's Theorem.

Analysis of Variance and its Assumptions, fixed, random and mixed effects models. analysis of fixed effects models, decomposition of total sum of squares, expected values of mean squares, model adequacy checking, violation of the assumptions and transformations.

Multiple Comparison Tests: Fisher's LSD Test, Duncan's Multiple Range Test (DMRT), Tukey's W-Honestly Significant Difference (HSD) Test, Scheffe's Test.

Contrasts, Orthogonal Contrasts. Testing of Hypotheses Involving Contrasts (Single Degree of Freedom Comparison), Scheffe's Method for comparing all Contrasts, Confidence Intervals.

Recommended Books:

1. Oehlert, G. W. (2022). *A first Course in Design and Analysis of Experiments*. Library of Congress Cataloging-in-publishing data.
2. Montgomery, D. C. (2019). *Design and Analysis of Experiments*. 10th Ed., John Wiley, New York.
3. Boniface, D. R. (2019). *Experimental Design and Statistical Methods for Behavioral and Social Research*. Chapman and Hall/ CRC Press.
4. Cash, P., Stankovic, T., and Storga, M. (2018). *Experimental Design Research: Approaches, Prospective and Applications*. 2nd Ed., Springer International Publisher
5. Dean, A., Voss, D., and Draguljic, D. (2017). *Design and Analysis of Experiments*. 2nd Ed., Springer Cham.
6. Cox, D. R. (2000). *The Theory of Design of Experiments*. Chapman and Hall/ CRC Press.

STA-508	Statistical Quality Control	3(3-0)
---------	-----------------------------	--------

Overview of Basic Concepts: The meaning of quality and quality improvement, dimensions of quality control, traditional and modern definition of quality, total quality managements, statistical methods for quality control and improvement, statistical process control and its tools, chance and assignable causes of quality variation, statistical basis of the control chart, choice of control limits, sample size and sampling frequency, rational subgroup, analysis of patterns on control charts, phases of the control charts.

Control Charts for Variables: $\bar{X}$, R , S and S^2 charts, Shewhart control chart for individual measurements, operating statistic curves associated with control charts.

Control charts for Attributes: p , np , c and u charts.

Other Process Monitoring Schemes: Cumulative sum (CUSUM), exponentially weighted moving average (EWMA) control charts, and moving average (MA) control charts.

Recommended Books:

1. Gupta, B. C. (2021). *Statistical Quality Control: Using Minitab, R, JMP and Python*. John Wiley & Sons.
2. Oakland, J., and Oakland, R. (2018). *Statistical Process Control*. 7th Ed., Routledge, Taylor & Francis Group, New York.
3. Montgomery, D. C. (2018). *Introduction to Statistical Quality Control*. 8th Ed., John Wiley & Sons Inc., New York.
4. Qiu, P. (2013). *Introduction to Statistical Process Control*. CRC Press, Taylor & Francis Group, Boca Raton, Florida.
5. Grant, E. L., and Leavenworth, R. S. (1988). *Statistical Quality Control*. 5th Ed., McGraw-Hill.

STA-510	Introduction to Machine Learning	3(3-0)
---------	----------------------------------	--------

Introduction: Basic concepts of linear and nonlinear Regression models, fundamentals of Artificial intelligence, deep learning and its key terms.

Artificial neural network modeling: introduction to artificial neural network (ANN) modeling, connectivity of ANN with regression modeling, structure of ANN, multilayer perceptron, various Statistical weight initialization methods, guidelines for the determination of hidden layers and hidden neurons, activation functions for both hidden (Linear, logistic, tangent, ReLU, etc.) and output layers, different optimization algorithms for ANN (GD, SGD, RMSprop. etc.), tuning of different hyper-parameters (hidden nodes, hidden layers, batch size, learning rate, epochs, etc.),

Over-fitting and under-fitting: Concepts of over-fitting and under-fitting along with possible solutions including (Drop out, early stopping rule and different Statistical regularization techniques), polynomial approximation orders, various loss functions.

Support vector machines (SVM): Brief introduction, relationship of SVM with regression analysis and ANN modeling, different kernel functions and tuning of hyper-parameters.

Software: R language or Python for the data analysis

Recommended Books:

1. Fieguth, P. (2022). *An Introduction to Pattern Recognition and Machine Learning*. Springer Nature.
2. Stamp, M. (2022). *Introduction to Machine Learning with Applications in Information Security*. CRC Press.
3. Perros, H. G. (2021). *An Introduction to IoT Analytics*. CRC Press.
4. Ertel, W. (2018). *Introduction to Artificial Intelligence*. Springer.
5. Gonzalez, R. C., & Woods, R. E. (2018). *Digital image processing*. 4th Ed, global edition.

STA-530	Seminar	1(0-1)
---------	---------	--------

A special problem given by supervisor.



SEMESTER-VII

STA-601	Econometrics-I	3(3-0)
---------	----------------	--------

Introduction and Basic Concepts: Nature of econometrics, simple linear regression and least squares estimators, properties of linear regression and least square estimators, inference in the least square model, equivalence of three test of regression coefficients, i.e., regression, ANOVA & correlation, tests of equality of regression coefficients and intercepts of the simple linear regression, prediction in simple linear regression model.

General Linear Regression Models (GLM): assumptions, ordinary least squares estimators, properties of least squares estimators, partitioning of the total sum of squares and degrees of freedom, properties of the residual, prediction in GLM, significance tests and confidence intervals, tests of single and set of regression coefficients, least square estimators for partitioned matrix, use of extraneous information in GLM, tests of significance of subset of coefficients, exact linear restrictions, extraneous unbiased restricted estimator for partitioned matrix.

Recommended Books:

1. Greene, W. H. (2018). *Econometric Analysis*. 8th Ed., Pearson Education, Inc.
2. Franses, P. H. (2018). *Enjoyable Econometrics*. Cambridge University Press, UK.
3. Wooldridge, J. M. (2016). *Introductory Econometrics: A Modern Approach*. 7th Ed., Cengage Learning, Inc., Boston, USA.
4. Fox, J. (2016). *Applied Regression Analysis and Generalized Linear Models*. SAGE Publications.
5. Gujarati, D. N., (2015). *Econometrics: By Examples*. 2nd Ed., Palgrave Macmillan Education.
6. Baltagi, B. H. (2011). *Econometrics*. 5th Ed., Springer-Verlag Berlin Heidelberg.
7. Gujarati, D. N., and Porter, D. C. (2009). *Basic Econometrics*. 5th Ed., McGraw-Hill/Irwin.
8. Draper, N.R., and Smith, H. (1998). *Applied Regression Analysis*. John Wiley & Sons, New York.
9. Johnston, J., and DiNardo, J. (1997). *Econometric Methods*. 4th Ed., McGraw-Hill, New York.

STA-603	Design and Analysis of Experiments-II	3(3-0)
---------	---------------------------------------	--------

Factorial Experiments: Difference between factorial design and One-factor-at-a-time design, advantages and disadvantages of factorial experiments. Construction of factorial designs (sign table method, digits method, etc.), 2^k , 3^k series and mixed level factorial experiments and their analyses. Geometrical structure of factorial designs.

Confounding in Factorial Experiments: Complete and partial confounding. Confounding in fractional replications, Split-plot experiments, Split block and Nested design. Missing observations in Split-plot design.

Introduction to Response Surface Methodology: First and 2nd order design, Central Composite design, Fitting of response surface models and estimation of optimum/maximum response.

Recommended Books:

1. Wu, C. F. J., Hamada, M. S. (2021). *Experiments: Planning, Analysis, and Optimization*. 3rd Ed., John Wiley & Sons, New York.
2. Montgomery, D. C. (2019). *Design and Analysis of Experiments*, 10th Ed. John Wiley & Sons, New York.
3. Elser, T. (2017). *Factorial Design: Understanding Design of Experiments (DoE) and Applying it in Practice*, Kindle Edition, Create Space Independent Publishing Platform.
4. Myers, R. H., Montgomery, D. C., and Anderson-Cook, C. M. (2016). *Response Surface Methodology: Process and Product Optimization Using Designed Experiments*, 4th Ed., John Wiley & Sons, New York.
5. Wu, C. F. J., and Mukerjee, R. (2006). *A Modern Theory of Factorial Design*, Springer Series in Statistics.
6. Box, G. E. P., Hunter, J. S., and Hunter, W. G. (2005). *Statistics for Experimenters: Design, Innovation and Discovery*. 2nd Ed. John Wiley & Sons, New York.
7. Mead, R. (1988). *The Design of Experiments*. Cambridge University Press, UK.
8. Das, M. N., and Giri, N. C. (1986). *Design and Analysis of Experiments*. John Wiley & Sons, New York.

STA-605	Multivariate Analysis-I	3(3-0)
---------	-------------------------	--------

Basics: Matrix algebra, introduction to multivariate analysis, linear combinations, Eigen values and Eigen vectors.

Multivariate normal distribution, its mean vector, covariance matrix, moment generating function, marginal and conditional distributions, estimation of mean vector and variance-covariance matrix, correlation matrix, Wishart distribution and its properties.

Hotelling's T^2 distribution and its application, multivariate analysis of variance (MANOVA).

Recommended Books:

1. WU, L., and Qiu, J. (2021). *Applied Multivariate Statistical Analysis and Related Topics with R*. EDP Sciences.
2. Johnson, R.A., and Wichern, D.W. (2018). *Applied Multivariate Statistical Analysis*. 6th Ed. (Classical Version), Pearson Education, Inc.
3. Hair, J. F., Babin, B. J., Anderson, R. E., and Black, W. C. (2018). *Multivariate Data Analysis*. CENGAGE, India.
4. Chatfield, C., and Collins, A. J. (2018). *Introduction to Multivariate Analysis*. Reprint Ed., CRC Press.
5. Anderson, T. W. (2009). *An Introduction to Multivariate Statistical Analysis*. 7th Ed., John Wiley & Sons, New York.
6. Afifi, A. A., and Clark, V. (2004). *Computer Aided Multivariate Analysis*. 4th Ed., Chapman & Hall.

STA-607	Statistical Inference-I	3(3-0)
---------	-------------------------	--------

Properties of Estimators: unbiasedness, consistency, sufficiency, efficiency, completeness,

invariance, Cramer-Rao inequality, Rao-Blackwell theorem, and Lehman-Scheffe theorem.

Methods of Estimation of Parameters: moments, maximum likelihood, least-squares, minimum chi-square, Bayesian and Lyod's.

Recommended Books:

1. Hogg, R.V., McKean, J. W., and Craig, A. T. (2018). *Introduction to Mathematical Statistics*. 8th Ed., Prentice Hall, New Jersey.
2. Rossi, R. J. (2018). *Mathematical Statistics: An Introduction to Likelihood Based Inference*. John Wiley & Sons, New York.
3. Bijma, F., Jonker, M., Van der Vaart, A. (2016). *An Introduction to Mathematical Statistics*. Amsterdam University Press.
4. Wackerly, D. D., Mendenhall III, W., and Scheaffer, R. L. (2008). *Mathematical Statistics with Applications*. 7th Ed., Duxbury, Thomson Learning, Inc.
5. Cox, D. R. (2006). *Principles of Statistical Inference*. Cambridge University Press, UK.
6. Shao, J. (2003). *Mathematical Statistics*. Springer Science+Business Media, LLC.
7. Casella, G., and Berger, R. L. (2002). *Statistical Inference*. 2nd Ed., Duxbury, Thomson Learning, Inc.
8. Mood, A. M., Graybill, F. A., and Boss, D. C. (1997). *Introduction to the Theory of Statistics*. McGraw-Hill, New York.

STA-609	Statistical Computing-I	3(0-3)
---------	-------------------------	--------

Statistical Data Analysis using Minitab and/or SPSS.

Data entering, saving, editing, importing, exporting, and transformation, coding and recoding, graphical analysis by creating graphs like, simple, multiple and clustered bar charts, pie chart, histogram, stem and leaf plot, box-plot, pp-plots etc., descriptive statistics (measures of central tendency and dispersion and positions), random number generation under various probability distributions.

Regression and Correlation Analysis: Scatter plots and matrix plot, regression analysis (simple and multiple) and its associated statistical inference, handling regression output, residuals analysis and diagnostic checking, bivariate, multiple and partial correlation.

Testing of Hypothesis: Testing for single population mean, independent and paired samples tests, Analysis of variance (one-way and two-way), test for population variance and equality of two variances. Chi-square test for independence of attributes.

Design of experiments: Analysis of CRD, RCBD, Latin Squares, Graeco Latin squares designs and multiple comparisons tests.

Statistical Process Control: Construction of attribute and variable control charts.

Non-parametric Tests: Sign test, run test, test of randomness, Wilcoxon signed- rank and rank-sum tests, Mann-Whitney U-test, Kolmogorov Smirnov's test, Kruskal-Wallis test, Friedman test.

Recommended Books:

1. Jasrai., J. (2018). *Data Analysis Using SPSS*. SAGE Publications.
2. Roni, S. M., Djajadikerta, H. G. (2021). *Data Analysis with SPSS for Survey-based Research*. Springer.

3. Khan, R. M. (2013). *Problem Solving and Data Analysis Using Minitab: A Clear and Easy Guide to Six Sigma Methodology*. John Wiley & Sons.
4. Wakefield, D., McLaughlin, K. (2005). *An Introduction to Data Analysis Using Minitab for Windows*. Pearson Education Inc.

INT-631	Internship/Field Experience	3(0-3)
---------	-----------------------------	--------



SEMESTER-VIII

STA-602	Econometrics-II	3(3-0)
---------	-----------------	--------

Multicollinearity: It's nature, OLS estimation in the presence of multicollinearity, consequences of multicollinearity, detection of multicollinearity and the remedial measures, Ridge regression.

Heteroscedasticity: It's nature, OLS estimation in the presence of heteroscedasticity, consequences of using OLS in the presence of heteroscedasticity, detection of heteroscedasticity and the remedial measures.

Autocorrelation: It's nature, OLS estimation in the presence of autocorrelation, the BLUE property in the presence of autocorrelation, consequences of using OLS estimators in the presence of autocorrelation, detection of autocorrelation and remedial measures.

Model Specification and Diagnostic Testing: types of specification errors, consequences, tests of specification errors, errors of measurements.

Simultaneous Equation Models: System of simultaneous linear equations, identification, estimation methods: least variance ratio, two-stage, three-stage and restricted least squares, test of identifying restrictions.

Recommended Books:

1. Greene, W. H. (2018). *Econometric Analysis*. 8th Ed., Pearson Education, Inc.
2. Franses, P. H. (2018). *Enjoyable Econometrics*. Cambridge University Press, UK.
3. Wooldridge, J. M. (2016). *Introductory Econometrics: A Modern Approach*. 7th Ed., Cengage Learning, Inc., Boston, USA.
4. Fox, J. (2016). *Applied Regression Analysis and Generalized Linear Models*. SAGE Publications.
5. Gujarati, D. N., (2015). *Econometrics: By Examples*. 2nd Ed., Palgrave Macmillan Education.
6. Baltagi, B. H. (2011). *Econometrics*. 5th Ed., Springer-Verlag Berlin Heidelberg.
7. Gujarati, D. N., and Porter, D. C. (2009). *Basic Econometrics*. 5th Ed., McGraw-Hill/Irwin.
8. Draper, N.R., and Smith, H. (1998). *Applied Regression Analysis*. John Wiley & Sons, New York.
9. Johnston, J., and DiNardo, J. (1997). *Econometric Methods*. 4th Ed., McGraw-Hill, New York.

STA-604	Statistical Computing-II	3(0-3)
---------	--------------------------	--------

Statistical Data Analysis using R

Introduction to R as a language and environment for statistical computing and graphics, manipulations of numbers, vectors and matrices.

Methods of Data Input: Data input and importing data from different statistical software.

Basic Statistical Analysis in R: getting a random sample from given data, obtaining repeated samples, random number generation for different probability distributions, graphical analysis using R, descriptive statistics using R.

Regression Analysis in R: Regression analysis using matrix approach and using built-in R function, statistical inference, handling regression output in R, binary logistic regression.

Testing of Hypothesis in R: One sample Z and t-test, independent samples Z-test and t-tests, paired samples t-test, one-way ANOVA, test for population variance and equality of two variances, test for equality of several variances. Finding p-values and tabulated values for different probability distributions.

Introduction to programming in R and writing functions for some basic statistical tools.

Recommended Books:

1. Aslam, M., Imdad-Ullah, M. (2023). *Practicing R for Statistical Computing*. Springer Nature Singapore.
2. Long, J. D., and Teetor, P. (2019). *R Cookbook: Proven Recipes for Data Analysis, Statistics, and Graphics*. O'Reilly Media.
3. Lander, J. P. (2017). *R for Everyone: Advanced Analytics and Graphics*. Pearson Education Inc.
4. Crawley, M. J. (2012). *The R Book*, 2nd Ed., Johan Wiley & Sons.
5. Pace, L. (2012). *Beginning R: An Introduction to Statistical Programming*. APress.

STA-606	Multivariate Analysis-II	3(3-0)
---------	--------------------------	--------

Principal Component Analysis: derivation of principal components, principal components from covariance matrix and correlation matrix, advantages and disadvantages of principal component analysis.

Factor Analysis: estimating the factor loadings and error variance, factor rotation, methods of estimation.

Discriminant Analysis: Discrimination rules, classification, calculation of misclassification probabilities.

Canonical Correlation: Derivation of canonical correlations and canonical variables, identifying the canonical variables.

Cluster Analysis: distance measures, linkage techniques.

Recommended Books:

1. WU, L., and Qiu, J. (2021). *Applied Multivariate Statistical Analysis and Related Topics with R*. EDP Sciences.
2. Johnson, R.A., and Wichern, D. W. (2018). *Applied Multivariate Statistical Analysis*. 6th Ed. (Classical Version), Pearson Education, Inc.
3. Hair, J. F., Babin, B. J., Anderson, R. E., and Black, W. C. (2018). *Multivariate Data Analysis*. CENGAGE, India.
4. Chatfield, C., and Collins, A. J. (2018). *Introduction to Multivariate Analysis*. Reprint Ed., CRC Press.
5. Anderson, T. W. (2009). *An Introduction to Multivariate Statistical Analysis*. 7th Ed., John Wiley & Sons, New York.
6. Afifi, A. A., and Clark, V. (2004). *Computer Aided Multivariate Analysis*. 4th Ed., Chapman & Hall.

STA-608	Statistical Inference-II	3(3-0)
---------	--------------------------	--------

Interval Estimation: Pivotal and other methods of finding confidence interval, confidence interval in large samples, shortest confidence interval, optimum confidence interval. Bayes Interval estimation.

Tests of Hypotheses: Simple and composite hypotheses, critical regions, Neyman- Pearson Lemma, power functions, uniformly most powerful tests. Deriving tests of hypothesis concerning parameters in normal, exponential, gamma and uniform distributions. Randomized Tests, Unbiased tests, Likelihood ratio tests and their asymptotic properties. Generalized likelihood-ratio tests.

Sequential Analysis: Introduction to sequential tests, Average sample number and Operating Characteristic functions.

Non-central Distributions: The derivation of Chi-square, t and F and their applications.

Recommended Books:

1. Hogg, R.V., McKean, J. W., and Craig, A. T. (2018). *Introduction to Mathematical Statistics*. 8th Ed., Prentice Hall, New Jersey.
2. Rossi, R. J. (2018). *Mathematical Statistics: An Introduction to Likelihood Based Inference*. John Wiley & Sons, New York.
3. Bijma, F., Jonker, M., Van der Vaart, A. (2016). *An Introduction to Mathematical Statistics*. Amsterdam University Press.
4. Wackerly, D. D., Mendenhall III, W., and Scheaffer, R. L. (2008). *Mathematical Statistics with Applications*. 7th Ed., Duxbury, Thomson Learning, Inc.
5. Cox, D. R. (2006). *Principles of Statistical Inference*. Cambridge University Press, UK.
6. Shao, J. (2003). *Mathematical Statistics*. Springer Science+Business Media, LLC.
7. Casella, G., and Berger, R. L. (2002). *Statistical Inference*. 2nd Ed., Duxbury, Thomson Learning, Inc.
8. Mood, A. M., Graybill, F. A., and Boss, D. C. (1997). *Introduction to the Theory of Statistics*. McGraw-Hill, New York.

STA-630	Capstone Project	3(0-3)
---------	------------------	--------

➤ ANY ONE FROM THE FOLLOWING OPTIONS COURSES

STA-610	Analysis of Time Series and Forecasting	3(3-0)
---------	---	--------

Key Concepts: Time series and its components, stochastic process, stationary time series, purely random processes, non-stationary processes, integrated variables, random walk models, deterministic and stochastic trends, auto- correlation and auto-covariance, correlogram, estimation of the auto- correlation function and partial autocorrelation function, unit root tests.

Forecasting: linear stationary models, autoregressive, moving average and mixed ARIMA models, exponential smoothing techniques, the accuracy of forecasting methods (mean error, mean absolute error, sum of squared error, mean squared errors, percentage error,

mean percentage error, mean absolute percentage error, minimum mean square forecasting, Theil's U-statistic).

Recommended Books:

1. Chatfield, C., and Xing, H. (2019). *The Analysis of Time Series: An Introduction with R*. 7th Ed., CRC Press, Chapman and Hall, London.
2. Box, G. E. P., Jenkins, G. M., Reinsel, G. C., and Ljung, G. M. (2015). *Time Series Analysis: Forecasting and Control*. 5th Ed. John Wiley & Sons Inc., New York.
3. Enders, W. (2015). *Applied Econometric Time Series*. 4th Ed., John Wiley & Sons Inc., New York.
4. Cox, D. R., Hinkley D.V., and Nielsen O. E. B. (1996). *Time Series Models: In Econometrics, Finance and Other Fields*. Chapman & Hall London.
5. Andy, P., West, M., and Harrison, P. J. (1994). *Applied Bayesian Forecasting and Time Series Analysis*. Chapman & Hall, New York.
6. Harvey, A. C. (1990). *Forecasting Structural Time Series Models and the Calamander*. Cambridge University Press, UK.
7. Daggle, P. J. (1990). *Time Series: A Biostatistics Introduction*. Clarendon Press, Oxford.
8. Bovas, A., and Johannes, L. (1983). *Statistical Methods for Forecasting*. John Wiley & Sons. New York.
9. Priestley, M. B. (1981). *Spectral Analysis and Time Series*. Academic Press, London

STA-612	Categorical Data Analysis	3(3-0)
---------	---------------------------	--------

Introduction to Categorical Data: Description of contingency tables and their probability structures, two-way and three-way contingency tables and associated inference, concepts of difference of proportions, odds ratio and relative risk, inference for odds ratios and log odds ratios.

Inference for Discrete Data: Wald test, Score test, LRT with their applications. Pearson residuals analysis, testing independence for nominal and ordinal data, exact inference for small samples, association in three way tables, conditional versus marginal associations, Simpson's Paradox, Conditional and marginal odds ratios, conditional versus marginal independence, Homogeneous association.

Generalized Linear Models: Introduction to generalized linear models and link functions, models for binary response variables, building and applying logistic regression, The Cochran- Mantel-Haenszel test, multcategory logit models. Log-linear models.

Recommended Books:

1. Dunn, P. K., and Smyth, G. K. (2018). *Generalized Linear Models with Examples in R*. 1st Ed., Springer, New York.
2. Agresti, A. (2018). *An Introduction to Categorical Data Analysis*. John Wiley & Sons.
3. Upton, G. J. G. (2016). *Categorical Data Analysis by Example*, John Wiley & Sons.
4. Hosmer Jr, D. W., Lemeshow, S., and Sturdivant, R. X. (2013). *Applied logistic regression*. 3rd Ed., John Wiley & Sons.
5. Agresti, A. (2012). *Categorical Data Analysis*. 3rd Ed., John Wiley & Sons.

STA-614	Population Studies	3(3-0)
---------	--------------------	--------

Sources of Demographic Data: The population census, registration of vital events, housing and demographic surveys. components of population growth, composition of population and vital events. testing the accuracy of demographic data. types and sources of errors, general testing procedures, testing the accuracy of age and sex data.

Basic Demographic Measures: Fertility and mortality measures, mortality rates, total and general fertility rates.

Life Tables: Construction of complete and abridged life tables. different types of life tables. Graphs of L_x , q_x and dx , description and uses of life Table columns, stationary population models, population estimates and projections, inter-censal estimates, population projections through various methods.

Population Models: Theory of demographic transition, consequences of world population growth & population explosion.

State of Population in Pakistan: Development of demographic profile in Pakistan, recent demographic parameters, current and future demographic activities in Pakistan.

Recommended Books:

1. Hinde, A. (2014). *Demographic Methods*. Routledge, Taylor & Francis Group, London.
2. Watcher, K. W. (2006). *Essential Demographic Methods*. University of California.
3. Alho, J. M., Spencer, B. D. (2005). *Statistical Demography and Forecasting*. Springer Science+Business Media, Inc.
4. Keyfitz, N., Caswell, H. (2005). *Applied Mathematical Demography*. 3rd Ed., Springer Verlag, New York.
5. Pollard, A. H., Yousaf, F., and Pollard, G. M. (1982). *Demographic Techniques*. Pergamon Press, Sydney.

STA-616	Non Parametric Methods	3(3-0)
---------	------------------------	--------

The Binomial test, the Quantile test, tests for location parameter: The sign test, modified sign test, Wilcoxon signed rank test, confidence interval based on these tests, Run test for randomness.

Distribution test and rank transformation, Kolmogorov-Smirnov test, Lilliefors's test and Shapiro-Wilks test for normality, Theil's test for linearity of regression.

Tests for Two Samples: the median test, Wilcoxon Mann-Whitney test, Siegal-Tukey and squared rank tests for variance, tests for paired samples.

Tests for K-samples: Kruskal-Wallis test, Friedman test, Multiple comparison with the Friedman test.

Tests for Categorical Data: Cochran's test for binary responses, Spearman's rank correlation coefficient, Kendall's rank correlation coefficient.

Recommended Books:

1. Hollander, M., and Wolfe, A. D. (2013). *Nonparametric Statistics Methods*, 3rd Ed.,

- John Wiley and Sons, New York.
2. Lewis, N. D. (2013). *100 Statistical Tests in R*. 3rd Ed., Heather Hills Press.
 3. Sprent, P., and Smeeton, C. N. (2007). *Applied Nonparametric Statistical Methods*, 4th Edition. CRC Press, Chapman & Hall London.
 4. Kanji, G. K. (2006). *100 Statistical Tests*. 3rd Ed., SAGE Publication.
 5. Maritz, J. S. (1995). *Distribution-Free Statistical Methods*. Chapman & Hall London.
 6. Conover, W. J. (1999), *Practical Nonparametric Statistics*, 3rd Ed., John Wiley & Sons, New York.
 7. Gibbons, L. D., and Chakraborti, S. (1992). *Nonparametric Statistical Inference*. Marcel Decker, New York.

STA-618	Bayesian Analysis	3(3-0)
---------	-------------------	--------

Basic concepts of probability, subjective probability, probability density function and probability density kernel, Bayes theorem, concept of Bayes theorem in Bayesian statistics, application of Bayesian statistics, differences between Bayesian statistics and classical statistics, applications and concepts of non-informative priors (uniform prior and Jeffrey's prior), informative priors, conjugate priors and posterior distributions, selection and formulation of prior distribution for Bayesian analysis, concept of hyper-parameters, different methods for elicitation of hyper-parameter, Bayesian estimation of parameters, Bayes estimator, posterior risk, relationship between Bayesian method of estimation and classical methods of estimation.

Recommended Books:

1. Reich, B. J., and Ghosh, S. K. (2019). *Bayesian Statistical Methods*. CRC Press, Taylor & Francis Group.
2. Turkman, M. A. A., Paulino, C. D., and Müller, P. (2019). *Computational Bayesian Statistics: An Introduction (Vol. 11)*. Cambridge University Press.
3. Hogg, R., McKean, J., and Craig, A. (2018). *Introduction to Mathematical Statistics*. 8th Ed., Pearson Education Inc.
4. Miller, I., Miller, M. (2014). *John E. Freund's Mathematical Statistics with Applications*. 8th Ed., Pearson Education, Inc., Boston.
5. Bolstad, W.M. (2007). *Introduction to Bayesian Statistics*. 2nd Ed., John Wiley, New York.
6. DeGroot, M. H. (2004). *Optimal Statistical Decisions*. John Wiley, New York.
7. Bernardo, J. M., and Smith, A. F. M. (1994). *Bayesian Theory*, John Wiley & Sons, New York.
8. Lee, P. M. (1991). *Bayesian Statistics: An Introduction*. Oxford University Press, New York.
9. Berger, O. J. (1985). *Statistical Decision Theory and Bayesian Analysis*, 2nd Ed., Springer.
10. Ferguson, T. S. (1967). *Mathematical Statistics: A Decision Theoretic Approach*. Academic Press.