Department of Statistics
University of Lucknow
Lucknow

Syllabus for UG (STATISTICS)
(National Education Policy-2020)

Academic Session 2021-22
&
onwards

Structure UG Program- Statistics

Year	Semester	Course	Major1		Major 2		Minor		CC/VC		Total Credits	Award
			Statistics	Credits		Credits		Credits		Credits		
I	Semester I	Paper I	**Probability Theory**	4	Paper I	4	Paper I	4	**CC1**	4	24	**Certificate**
		Paper II	**Descriptive Statistics**	4	Paper II	4						
	Semester II	Paper III	**Numerical Analysis and Distributions Theory**	4	Paper III	4	Paper II	4	**VC1**	4	24	
		Paper IV	**Practical**	4	Paper IV	4						
2	Semester III	Paper V	**Inferential Statistics**	4	Paper V	4	Paper III	4	**CC2**	4	24	**Diploma**
		Paper VI	**Sampling Techniques**	4	Paper VI	4						
	Semester IV	Paper VII	**Analysis of Variance and Design of Experiments**	4	Paper VII	4	Paper IV	4	**VC2**	4	24	
		Paper VIII	**Practical**	4	Paper VIII	4						
3	Semester V	Paper IX	**Non-Parametric Methods and Regression Analysis**	4	Paper IX	4			**Internship/ Term Paper**	4	24	**B.A./B.Sc. Degree**
		Paper X	**Statistical Quality Control and Educational Statistics**	4	Paper X	4						
		Paper XI A	**Operations Research**	4								
		Paper XI B	**Programming with C/C++**									
	Semester VI	Paper XII	**Applied Statistics**	4	Paper XI	4			**Minor Project**	4	24	
		Paper XIII	**Practical**	4	Paper XII	4						
		Paper XIV A	**Queueing Theory and Network Analysis**	4								
		Paper XIV B	**Computational Statistics**									
4	Semester VII	Paper XV	**Linear Models and Econometrics**	4					**Research Methodology**	4	24	**B.A./B.Sc. Research**
		Paper XVI	**Multivariate Analysis and Survey Sampling**	4								
		Paper XVII	**Practical**	4								
		Paper XVIII A	**Advanced Inference**	4								
		Paper XVIII B	**Advanced Probability Theory**									
		Paper XIX A	**Stochastic Process**	4								
		Paper XIXB	**Theory of Experimental Designs**									
	Semester VIII								**Major Project**	24	24	
				76		48		16		52	192	

Year-Wise Structure of 4 Year U.G. (B.A./B.Sc.) Statistics Programme (NEP 2020)

Year	Sem.	Paper	Paper type	Theory/Lab work	Title	Credit
1st Year	I	Paper I	Compulsory	Theory	**Probability Theory**	4
		Paper II	Compulsory	Theory	**Descriptive Statistics**	4
	II	Paper III	Compulsory	Theory	**Numerical Analysis and Distributions Theory**	4
		Paper IV	Compulsory	Lab Work	**Practical**	4
2nd Year	III	Paper V	Compulsory	Theory	**Inferential Statistics**	4
		Paper VI	Compulsory	Theory	**Sampling Techniques**	4
	IV	Paper VII	Compulsory	Theory	**Analysis of Variance and Design of Experiments**	4
		Paper VIII	Compulsory	Lab Work	**Practical**	4
3rd Year	V	Paper IX	Compulsory	Theory	**Non-Parametric Methods and Regression Analysis**	4
		Paper X	Compulsory	Theory	**Statistical Quality Control and Educational Statistics**	4
		Paper XI A	Optional	Theory	**Operations Research**	4
		Paper XI B	Optional	Theory	**Programming with C/C++**	4
		Summer Internship/Term Paper				4
	VI	Paper XII	Compulsory	Theory	**Applied Statistics**	4
		Paper XIII	Compulsory	Lab Work	**Practical**	4
		Paper XIV A	Optional	Theory	**Queueing Theory and Network Analysis**	4
		Paper XIV B	Optional	Theory	**Computational Statistics**	4
		Minor Project				4
4th Year	VII	Paper XV	Compulsory	Theory	**Linear Models and Econometrics**	4
		Paper XVI	Compulsory	Theory	**Multivariate Analysis and Survey Sampling**	4
		Paper XVII	Compulsory	Lab Work	**Practical**	4
		Paper XVIII A	Optional	Theory	**Advanced Inference**	4
		Paper XVIII B	Optional	Theory	**Advanced Probability Theory**	4
		Paper XIX A	Optional	Theory	**Stochastic Process**	4
		Paper XIX B	Optional	Theory	**Theory of Experimental Designs**	4
		Research Methodology				4
	VIII	**Major Project**				24

:: Subject Prerequisites::

1. To study this subject a student must had the subject(s) Mathematics in class 12th.
2. Mathematics subject must be compulsory in UG as a combination of Subjects for the candidates offering Statistics.

:: Programme Outcomes (POs) ::

1. Students having Degree in B.Sc. (with Statistics) should have knowledge of different concepts and fundamentals of Statistics and ability to apply this knowledge in various fields of industry. They may pursue their future career in the field of Statistics and Research.
2. Students having Degree in B.A./ B.Sc. (with Statistics) should have knowledge of different concepts and fundamentals of Statistics and ability to apply this knowledge in various fields of industry, monitoring, policy making, administration, government organisations etc. They may pursue their future career in the field of Statistics and Research.

:: Programme Specific Outcomes (PSOs) ::

After completing B.Sc. (with Statistics) the student should have

- Knowledge of different concepts, principles, methodologies and tools (skills) of Statistics.
- Ability to collect, tabulate, represent graphically, analyze and interpret data/information by using appropriate statistical tools.
- Ability to identify and solve a wide range of problems in real life/industry related to Statistics.
- Familiarity with computational techniques and statistical software including programming language (e.g. R) for mathematical and statistical computation.
- Capability to use appropriate statistical skills in interdisciplinary areas such as finance, health, agriculture, government, business, industry, telecommunication and bio-statistics.
- Ability to compete with industrial/private sector demand in the field of data analysis, marketing survey, etc. in professional manner and pursue their future career in the field of Statistics.
- Ability to develop original thinking for formulating new problems and providing their solutions. As a result, they will be able to pursue higher studies or research in the field of Statistics.

SEMESTER I

PAPER I: PROBABILITY THEORY

Credit: 4 **Theory**

Course Outcome:

- ✓ Ability to understand the concept of probability along with basic laws and axioms of probability.
- ✓ Ability to understand the terms mutually exclusive and independence and their relevance.
- ✓ Ability to identify the appropriate method (i.e. union, intersection, conditional, etc.) for solving a problem.
- ✓ Ability to apply basic probability principles to solve real life problems.
- ✓ Ability to understand the concept of random variable (discrete and continuous), concept of probability distribution.

UNIT I

Basic Concepts of probability, Random Experiment, Trial, Sample Point, Sample space, events, Definitions of Mutually Exclusive, Exhaustive and Equally Likely events. Preliminary Notions of Sets: Sets and Elements of Sets, Operations on sets, Algebra of sets. Algebra of Events. Definitions of Probability: Classical, relative frequency and axiomatic approaches and their limitations.

UNIT II

Theorems on Probability: Addition theorem of Probability for n Events, Theorem of Total Probability for n Events, Boole's Inequality, Conditional Probability, Multiplication Theorem of Probability for n events, Independent Events. Bayes' Theorem and its Applications.

UNIT III

Random variables – discrete and continuous, probability mass function (pmf) and probability density function (pdf), Cumulative distribution function (cdf).Joint distribution of two random variables, marginal and conditional distributions. Independence of random variables. Expectation of a random variable and its properties, expectation of sum of random variables and product of independent random variables, conditional expectation and Conditional Variance.

UNIT IV

Moments, moment generating function (m.g.f.) & their properties, continuity theorem for m.g.f. (without proof). Chebyshev's inequality. Weak law of large numbers and Central Limit Theorem for a sequence of independently and identically distributed random variables and their applications.

Suggested Readings:

1. Goon, A.M., Gupta, M.K. & Dasgupta, B.: Fundamentals of Statistics, Volume I.
2. Yule, G.U. and Kendall, M.G.: An Introduction to the Theory of Statistics.

3. Weatherburn, C. E.: Mathematical Statistics.
4. Hogg, R.V., Craig, A.T. and Mckean, J.W.: Introduction to Mathematical Statistics.
5. Parzen, E.S.: Modern Probability Theory and Its Applications.
6. David, S. (1994) : Elementary Probability, Cambridge University Press.
7. Dudewicz, E.J. and Mishra, S.N. (2008). Modern Mathematics Statistics, Wiley.
8. Gupta, S.C. and Kapoor, V.K. (2000). Fundamentals of Mathematical Statistics (10^{th} ed.), Sultan Chand and Sons.
9. Hanagal, D. D. (2009). Introduction to Applied Statistics: A Non-Calculus Based Approach. Narosa Publishing Comp. New Delhi.
10. Johnson, S. and Kotz, S. (1972). Distribution in Statistics Vol. I-II & III, Houghton and Mifflin.
11. Lipschutz, S., Lipson, M. L. and Jain, K. (2010). Schaum's Outline of Probability. 2^{nd} Edition. McGraw Hill Education Pvt. Ltd, New Delhi.
12. Meyer, P. (2017). Introductory Probability and Statistical Applications (2^{nd} ed.), New Delhi, Oxford & IBH Publishing Co. Pvt. Ltd.
13. Mood A.M., Graybill F.A. and Boes D.C. (2007). Introduction to the Theory of Statistics (3^{rd} ed.), New Delhi , Tata McGraw Hill Publishing Co. ltd.
14. Mukhopadhyay, P. (1996). Mathematical Statistics, New Delhi, New Central Book Agency Pvt. Ltd.
15. Parzen, E.S. (1992). Modern Probability Theory and its Applications. Wiley Interscience.
16. Pitman, J. (1993). Probability. Narosa Publishing House.
17. Rao, C.R. (2009). Linear Statistical Inference and its Applications, 2^{nd} Edition, Wiley Eastern.
18. Rohatgi, V.K. and Saleh, A.E. (2008). An introduction to Probability Theory and Mathematical Statistics, Wiley Eastern.

Suggested Online Links/Readings:

http://heecontent.upsdc.gov.in/SearchContent.aspx
https://swayam.gov.in/explorer?searchText=statistics
https://nptel.ac.in/course.html
https://www.edx.org/search?q=statistics
https://www.coursera.org/search?query=statistics&

SEMESTER I

PAPER II: DESCRIPTIVE STATISTICS

Credit: 4 **Theory**

Course Outcome:

- ✓ Knowledge of Statistics, its scope and importance in various fields.
- ✓ Ability to understand concepts of sample vs. population and difference between different types of data.
- ✓ Knowledge of methods for summarising data sets, including common graphical tools (such as boxplots, histograms and stemplots). Interpret histograms and boxplots.
- ✓ Ability to describe data with measures of central tendency and measures of dispersion.
- ✓ Ability to understand measures of skewness and kurtosis and their utility and significance.

UNIT I

Concept of statistical population, Attributes and variables (discrete and Continuous). Different types of scales – nominal, ordinal, ratio and interval. Primary data – designing a questionnaire and schedule, collection of primary data, checking their consistency. Secondary data. Presentation of data: classification, tabulation, diagrammatic & graphical representation of grouped data. Frequency distributions, cumulative frequency distributions and their graphical representations, histogram, frequency polygon and ogives. Stem and Leaf plot. Box Plot.

UNIT II

Measure of central tendency and dispersion, merits and demerits of these measures. Moments and factorial moments. Shephard's correction for moments. Skewness and Kurtosis and their Measures., Measures based on quantiles (Quartiles, Deciles and percentiles).

UNIT III

Bivariate data: Method of least squares for curve fitting. Correlation and regression, Correlation for bivariate frequency distribution, rank Correlation (Spearman's and Kendall's measure), Concepts of Intra-class correlation, correlation ratio. Partial and Multiple Correlation & Multiple Regression for Tri-variate data.

UNIT IV

Attributes- Notion and terminology, contingency table, class frequencies, and ultimate class frequencies, consistency. Association of attributes, Independence, Measure of association for 2x2 table. Chi-square, Karl Pearson's and Tschuprow's coefficient of association. Contingency tables with ordered categories.

Suggested Readings:

1. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2013). Fundamental of Statistics, Vol I, World Press, Kolkata.
2. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2011). Fundamental of Statistics, Vol II, World Press, Kolkata.
3. Gupta, S.C. and Kapoor, V.K. (2000). Fundamentals of Mathematical Statistics (10^{th} ed.), Sultan Chand and Sons.
4. Hanagal, D. D. (2009). Introduction to Applied Statistics: A Non-Calculus Based Approach. Narosa Publishing Comp. New Delhi.
5. Miller, I. and Miller, M. (2006). John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia.
6. Mood, A.M. Graybill, F.A. and Boes, D.C. (2011). Introduction to the Theory of Statistics, 3rd Edn., Tata McGraw-Hill Pub. Co. Ltd.
7. Goon, A.M., Gupta, M.K. & Dasgupta, B.: Fundamentals of Statistics, Volume I.
8. Yule, G.U. and Kendall, M.G.: An Introduction to the Theory of Statistics.
9. Weatherburn, C. E.: Mathematical Statistics.

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https://nptel.ac.in/course.html
https://www.edx.org/search?q=statistics
https://www.coursera.org/search?query=statistics&

SEMESTER II

PAPER III: NUMERICAL ANALYSIS AND DISTRIBUTIONS THEORY

Credit: 4 **Theory**

Course Outcome:

- ✓ Knowledge of discrete distributions. Discuss appropriate distribution: negative binomial, Poisson, etc. with their properties and application of discrete distribution models to solve problems.
- ✓ Knowledge of continuous distributions. Discuss the appropriate distribution (i.e. uniform, exponential, normal, etc.) with their properties and application of continuous distribution models to solve problems.
- ✓ Knowledge of the formal definition of order statistics, derive the distribution function.
- ✓ Knowledge of Numerical Integration.
- ✓ Knowledge of interpolation and extrapolation.

UNIT I

Univariate distributions: Binomial, Poisson, Hypergeometric, Geometric and Negative Binomial, Uniform (discrete &continuous), Normal, Normal and Poisson distributions as limiting case of binomial distribution, Exponential, Gamma, Beta distributions. Cauchy, Laplace, Pareto, Weibull, Log normal Distributions.

UNIT II

Distributions of function of random variables: Distribution of sum, product and quotient of two Variable. χ^2(chi-square), t and F distributions (Central cases only), their relationships and limiting forms. Bivariate normal distribution and its properties.

UNIT III

Calculus of finite differences, operators, separation of symbols, examples and problems. Interpolation formulas with remainder term. Newton's forward and backward formulae. Central difference formulae, Newton's divided difference formulae for interpolation. Lagrange's interpolation formulae.

UNIT IV

Numerical Integration: Derivation of general quadrature formula for equidistant ordinates. Derivation of trapezoidal, Simpson's 1\3rd and 3\8th rules. Weddle's rule.

Suggested Readings:

1. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2013). Fundamental of Statistics, Vol I, World Press, Kolkata.
2. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2011). Fundamental of Statistics, Vol II, World Press, Kolkata.

3. Gupta, S.C. and Kapoor, V.K. (2000). Fundamentals of Mathematical Statistics (10th ed.), Sultan Chand and Sons.
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5. Miller, I. and Miller, M. (2006). John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia.
6. Mood, A.M. Graybill, F.A. and Boes, D.C. (2011). Introduction to the Theory of Statistics, 3rd Edn., Tata McGraw-Hill Pub. Co. Ltd.
7. Weatherburn, C.E. (1961). A First Course in Mathematical Statistics, The English Lang. Book Society and Cambridge Univ. Press.
8. David, S. (1994) : Elementary Probability, Cambridge University Press.
9. David, H.A. (1981). Order Statistics (2nd ed.), New York, John Wiley.
10. Dudewicz, E.J. and Mishra, S.N. (2008). Modern Mathematics Statistics, Wiley.
11. Gupta, S.C. and Kapoor, V.K. (2000). Fundamentals of Mathematical Statistics (10th ed.), Sultan Chand and Sons.
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13. Johnson, S. and Kotz, S. (1972). Distribution in Statistics Vol. I-II & III, Houghton and Mifflin.
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17. Mukhopadhyay, P. (1996). Mathematical Statistics, New Delhi, New Central Book Agency Pvt. Ltd.
18. Parzen, E.S. (1992). Modern Probability Theory and its Applications. Wiley Interscience.
19. Pitman, J. (1993). Probability. Narosa Publishing House.
20. Rao, C.R. (2009). Linear Statistical Inference and its Applications, 2nd Edition, Wiley Eastern.
21. Rohatgi, V.K. and Saleh, A.E. (2008). An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern.

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https://www.coursera.org/search?query=statistics&

SEMESTER II

PAPER IV: PRACTICAL (Lab Work)

Credit: 4 **Practical**

Course Outcome:

After completing this course a student will have:

- ✓ Knowledge of presenting data through graphs and diagrams and interpretations of data.
- ✓ Knowledge of various measures of frequency distributions.
- ✓ Knowledge of curve fitting, regression lines.
- ✓ Knowledge of observing correlation between variables.
- ✓ Knowledge of Numerical Integration.
- ✓ Knowledge of interpolation and extrapolation.

The practical examination will be based on all papers of Semester I and Semester II and will include but not limited to the following experiments.

List of Practical:

1. Graphical representation of data by Histogram, Frequency polygons, frequency curves and Ogives. Stem and Leaf Plot, Box Plot.
2. Calculation of measures of Central Tendency.
3. Calculation of measures of dispersion.
4. Calculation of moments, measures of Skewness and Kurtosis.
5. Fitting of curves by method of least squares.
6. Determination of regression lines and calculation of correlation coefficient – grouped and ungrouped data.
7. Calculation of correlation ratios, rank and intra -class correlation coefficients.
8. Calculation of multiple and partial correlation coefficients for three variables
9. Calculation of measures of association in contingency tables.
10. Construction of forward difference tables and divided difference tables.
11. Interpolation by Newton's forward difference formula for equal intervals and calculation of error.
12. Interpolation by Newton's divided difference formula for unequal intervals. Calculation of error.
13. Interpolation by Lagrange's formula for unequal intervals. Calculation of error.
14. Approximate integration (Trapezoidal rule, Simpson's one-third rules, Simpson's three-eighth rule), Weddle's rule.

SEMESTER III

PAPER V: INFERENTIAL STATISTICS

Credit: 4 **Theory**

Course Outcome:

- ✓ Ability to understand the difference between parameter & statistic and standard error & standard deviation.
- ✓ Knowledge of the sampling distribution of the sum and mean.
- ✓ Knowledge of the concept of Point and Interval Estimation and discuss characteristics of a good estimator.
- ✓ Ability to understand and practice various methods of estimations of parameters.
- ✓ Knowledge of the terms like null and alternative hypotheses, two-tailed and one-tailed alternative hypotheses, significant and insignificant, level of significance and confidence, p value etc.
- ✓ Ability to understand the concept of MP, UMP and UMPU tests
- ✓ Ability to understand under what situations one would conduct the small sample and large sample tests (in case of one sample and two sample tests).

UNIT I

Point estimation. Characteristics of a good estimator: Unbiasedness, consistency, sufficiency and efficiency. Method of maximum likelihood and properties of maximum likelihood estimators (without proof). Method of minimum Chi-square. Method of Least squares and method of moments for estimation of parameters. Problems and examples.

UNIT II

Sufficient Statistics, Cramer-Rao inequality and its use in finding MVU estimators. Statistical Hypothesis (simple and composite). Testing of hypothesis. Type I and Type II errors, significance level, p-values, power of a test. Definitions of Most Powerful (MP), Uniformly Most Powerful (UMP) and Uniformly Most Powerful Unbiased (UMPU) tests.

UNIT III

Neyman-Pearson's lemma and its applications for finding most powerful tests for simple hypothesis against simple alternative. Tests based on t, F and χ^2 distributions.

UNIT IV

Likelihood ratio tests and their reduction to standard tests. Large sample tests, variance – stabilizing transformations. Interval estimation, Pivotal quantity and its use in finding confidence intervals, concept of best confidence intervals.

Suggested Readings:

1. Ferund J.E (2001) : Mathematical Statistics, Prentice Hall of India.
2. Freedman, D., Pisani, R. and Purves, R. (2014). Statistics. 4th Edition. Norton & Comp.
3. Goon, A.M., Gupta, M.K. &Dasgupta, B. (2002). Fundamentals of Statistics, Vol. I. ,Kolkata, The World Press.
4. Gupta, S.C. and Kapoor, V.K. (2000). Fundamentals of Mathematical Statistics (10th ed.), Sultan Chand and Sons.
5. Hanagal, D. D. (2009). Introduction to Applied Statistics: A Non-Calculus Based Approach. Narosa Publishing Comp. New Delhi.
6. Hogg, R.V., McKean, J.W. & Craig, A.T. (2009). Introduction to Mathematical Statistics (6th ed.), Pearson.
7. Kendall, M.G. and Stuart, A. (1979). The Advanced Theory of Statistics, Vol.2. Inference and Relationship. 4th Edition. Charles Griffin & Comp.
8. Kendall, M.G., Stuart, A. and Ord, J.K. (1994). The Advanced Theory of Statistics, Vol. 1. Distribution Theory. 6th Edition. Halsted Press (Wiley Inc.).
9. Kenney, J.F. and Keeping, E.S. (1947). Mathematics of Statistics. Part I. 2nd Edition. Chapman & Hall.
10. Kenney, J.F. and Keeping, E.S. (1951). Mathematics of Statistics. Part II. 2nd Edition. Chapman & Hall.
11. Mood A.M., Graybill F.A. and Boes D.C. (2007). Introduction to the Theory of Statistics (3rd ed.), New Delhi , Tata McGraw Hill Publishing Co. ltd.
12. Tanner, M. (1990). An Investigation for a Course in Statistics. McMillan, New York.
13. Tanur, J.M. (1989) Statistics. A Guide to the Unknown. 3rd Edition, Duxbury Press.
14. Yule, G.U. and Kendall, M.G. (1973). An Introduction to the Theory of Statistics.14th Edition. Charles Griffin & Comp.

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SEMESTER III

PAPER VI: SURVEY SAMPLING

Credit: 4 **Theory**

Course Outcome:

- ✓ Ability to understand the concept of sampling and how it is different from complete enumeration.
- ✓ Knowledge of various probability and non-probability sampling methods along with estimates of population parameters
- ✓ Ability to identify the situations where the various sampling techniques shall be used.
- ✓ Knowledge of sampling and non-sampling errors.
- ✓ Knowledge of regression and ratio methods of estimation in simple random sampling (SRS).

UNIT I

Sampling vs. complete enumeration: sampling units and frame. Precision and efficiency of estimators. Simple Random sampling with and without replacement. Use of random number tables in selection of simple random sample. Estimation of population mean and proportion. Derivation of expression for variance of these estimators. Estimation of variances. Sample size determination.

UNIT II

Stratified random sampling. Problem of allocation, proportional allocation, optimum allocation. Derivation of the expressions for the standard errors of the usual estimators when these allocations are used. Gain in precision due to stratification. Role of sampling cost in the sample allocation. Minimization of variance for fixed cost. Systematic sampling: estimation of population mean and population total, standard errors of these estimators.

UNIT III

Regression and ratio methods of estimation in simple random sampling. Cluster sampling with equal and unequal clusters. Estimators of population mean and their mean square error.

UNIT-IV

Double sampling in ratio method of estimation. Two-stage sampling with equal first stage units: estimator of population mean and its variance, Multi-stage sampling with examples (definition only). Non-sampling errors.

Suggested Readings:

1. Ardilly, P. and Yves T. (2006). Sampling Methods: Exercise and Solutions. Springer.
2. Cochran, W.G. (2007). Sampling Techniques. (Third Edition). John Wiley & Sons, New Delhi.
3. Cochran, W.G. (2008). Sampling Techniques (3rd ed.), Wiley India.

4. Des Raj. (1976). Sampling Theory. Tata McGraw Hill, New York. (Reprint 1979).
5. DesRaj and Chandhok, P. (1998). Sample Survey Theory, Narosa Publishing House.
6. Gupta, S.C. and Kapoor, V.K. (2000). Fundamentals of Mathematical Statistics (10^{th} ed.), Sultan Chand and Sons.
7. Mukhopadyay, P. (2007). Survey Sampling. Narosa Publisher, New Delhi.
8. Murthy, M. N. (1977). Sampling Theory and Statistical Methods. Statistical Pub. Society, Kolkata.
9. Singh, D. and Choudhary, F.S. (1977). Theory and Analysis of Sample Survey Designs. Wiley Eastern Ltd, New Delhi. (Reprint 1986)
10. Sukhatme, P.V. and Sukhatme, B.V. (1970). Sampling Theory Surveys with Applications (Second Edition). Iowa State University Press.
11. Sukhatme, P.V., Sukhatme, B.V., Sukhatme, S. &Asok, C. (1984): Sampling Theories of Survey with Applications, IOWA State University Press and ISAS.
12. Thompson, S.K. (2012). Sampling. John Wiley & Sons.

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https://www.coursera.org/search?query=statistics&

SEMESTER IV

PAPER VII: ANALYSIS OF VARIANCE AND DESIGN OF EXPERIMENTS

Credit: 4 **Theory**

Course Outcome:

After completing this course a student will have:

- ✓ Knowledge of the concept of Analysis of Variance (ANOVA).
- ✓ Ability to carry out the ANOVA for One way and Two way Classification.
- ✓ Ability to carry out the post-hoc analysis.
- ✓ Knowledge of the concept of Design of experiment and its basic principles.
- ✓ Ability to perform the basic symmetric designs CRD, RBD and LSD with and without missing observations.
- ✓ Knowledge of the concept of factorial experiments and their practical applications.

UNIT I

Analysis of Variance. One-way classification. Assumptions regarding model. Two-way classification with equal number of observations per cell. Duncan's multiple comparison test. Analysis of covariance.

UNIT II

Principles of Design of experiments: Randomization, Replication and local control. Choice of size and type of a plot using uniformity trials. CRD, Randomized block design. Concept and definition of efficiency of design. Comparison of efficiency between CRD and RBD.

UNIT III

Latin square design, Lay-out, ANOVA table. Comparison of efficiencies between LSD and RBD; LSD and CRD. Missing plot technique: estimation of missing plots by minimizing error sum of squares in RBD and LSD with one or two missing observations.

UNIT IV

Factorial Experiments: general description of factorial experiments; 2^2, 2^3 and 2^n factorial experiments, definition of main effects and interactions in 2^2 and 2^3 factorial experiments. Preparation of ANOVA by Yates procedure. Estimates and tests for main and interaction effects (Analysis without confounding).

Suggested Readings:

1. Cochran, W. G. and Cox, G. M. (1957). Experimental Design. John Wiley & Sons, New York.
2. Cochran, W.G. and Cox, G.M. (2003). Experimental Design, Asia Publishing House

3. Das, M. N. and Giri, N. S. (1986). Design and Analysis of Experiments (2nd Edition). Wiley.
4. Dean, A. and Voss, D. (1999). Design and Analysis of Experiments. Springer-Verlag, New York.
5. Joshi, D.D. (1987). Linear Estimation and Design of Experiments. New Age International (P) Ltd. New Delhi.
6. Kempthorne, O. (1965). The Design and Analysis of Experiments, John Wiley
7. Montgomery, D.C. (2008). Design and Analysis of Experiments, John Wiley
8. Montgomery, D.C. (2017). Design and analysis of Experiments, 9Th Edition. John Wiley & Sons.

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SEMESTER IV

PAPER VIII: PRACTICAL (Lab Work)

Credit: 4 **Practical**

The practical examination will be based on all papers of Semester I and Semester II and will include but not limited to the following experiments.

PAPER VIII: PRACTICAL (Lab Work)

Practicals will be based on all the papers of Semester III and Semester IV.

SEMESTER V

PAPER IX: NON-PARAMETRIC METHODS AND REGRESSION ANALYSIS

Credit: 4 **Theory**

Course Outcome:

After completing this course a student will have:

- ✓ Ability to understand the basic concepts of vector space and matrices in order to study multivariate distribution.
- ✓ Knowledge of the applications of multivariate normal distribution and Maximum Likelihood estimates of mean vector and dispersion matrix.
- ✓ Ability to apply distribution free tests (Non-parametric methods) for one and two sample cases.

UNIT I

Multivariate normal distributions, marginal and conditional distribution, Moment Generating and Characteristics functions, Maximum likelihood estimation of mean vector and co-variance matrix, Distribution of linear combination of components of multivariate normal.

UNIT II

Linear regression model of full rank, Least squares theory, Estimation of parameters: OLSE and MLE of β and test of hypotheses, R^2 and adjusted R^2, ANOVA table for regression.

UNIT III

Order Statistics, Distributions of minimum, r^{th} and maximum order statistic, Joint distribution of r^{th} and s^{th} order statistics (in continuous case), Distribution of sample range & sample median (for uniform and exponential distributions), Confidence interval for quantiles of order p, tolerance and coverages.

UNIT IV

Non-parametric tests – Tests for randomness, test for goodness of fit, one sample tests: sign test, Wilcoxon signed rank tests, Two sample tests: run test, Kolmogorov – Smirnov's test. Median test and Mann-Whitney U test. Mood tests and Sukhatme test for scale parameter.

Suggested Readings:

1. Anderson, T.W. (2003): An Introduction to Multivariate Statistical Analysis, 3rdEdn., John Wiley
2. Muirhead, R.J. (1982): Aspects of Multivariate Statistical Theory, John Wiley.
3. Kshirsagar, A.M. (1972): Multivariate Analysis, 1stEdn. Marcel Dekker.
4. Johnson, R.A. And Wichern, D.W. (2007): Applied Multivariate Analysis, 6thEdn., Pearson & Prentice Hall
5. Mukhopadhyay, P.: Mathematical Statistics.

6. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2002): Fundamentals of Statistics, Vol. I, 8th Edn. The World Press,Kolkata.
7. Gibbons, J. D. and Chakraborty, S (2003): Nonparametric Statistical Inference. 4th Edition. Marcel Dekker, CRC.
8. Rohatgi, V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics.2nd Edn. (Reprint) John Wileyand Sons.

Suggested Online Links/Readings:

http://heecontent.upsdc.gov.in/SearchContent.aspx
https://swayam.gov.in/explorer?searchText=statistics
https://nptel.ac.in/course.html
https://www.edx.org/search?q=statistics
https://www.coursera.org/search?query=statistics&

SEMESTER V

PAPER X: STATISTICS QUALITY CONTROL AND EDUCATIONAL STATISTICS

Credit: 4 **Theory**

Course Outcome:

- ✓ Familiarity with different aspects of Statistical Quality Control in manufacturing units.
- ✓ Ability to understand the concept of Sampling Inspection plans for products.
- ✓ Knowledge of Statistical tools to be applied in Educational Statistics.
- ✓ Familiarity with various scaling procedures.
- ✓ Knowledge to understand the concept of statistical quality control and different control charts for variables and attributes.

UNIT I

Statistical Quality Control, Process control, different control charts for variables and attributes, modified control charts, group control charts, CUSUM charts, V mask.

UNIT II

Sampling inspection by attributes – single and double sampling plans, Producer's and consumer's risk, OC, ASN, ATI functions AOQL and LTPD for these sampling plans, Sampling inspection by variables – simple cases.

UNIT III

Educational Statistics: Different Scaling procedures: scaling of test items, test scores, rating of qualitative answers and judgements, scaling in terms of normal curve, equivalent scale, percentile scaling, z-scores, t-scores.

UNIT IV

Test theory, linear models, parallel tests, true score, reliability and different methods for assessing it: Parallel test method, test-retest method, split half method, Kuder-Richardson method, Cronbach's α. Validity of tests: Conduct validity, construct validity, criterion validity. Tetra-choric, bi-serial and point bi-serial correlation coefficients.

Suggested Readings:

1. Croxton F.E., Cowden D.J. and Klein, S. (1973). Applied General Statistics(3rd ed.), Prentice Hall of India Pvt. Ltd.
2. Gupta, S.C. and Kapoor, V.K. (2008). Fundamentals of Applied Statistics (4th ed.), Sultan Chand and Sons.
3. Montgomery D.C. (2009) : Introduction to Statistical Quality Control (6th ed.), Wiley India Pvt. Ltd.
4. Mukhopadhyay, P (2011): Applied Statistics, 2nd edition revised reprint, Books and Allied (P) Ltd.

Suggested Online Links/Readings:

http://heecontent.upsdc.gov.in/SearchContent.aspx
https://swayam.gov.in/explorer?searchText=statistics
https://nptel.ac.in/course.html
https://www.edx.org/search?q=statistics
https://www.coursera.org/search?query=statistics&

SEMESTER V

PAPER XI A: OPERATIONS RESEARCH

Credit: 4 **Theory**

Course Outcome:

After completing this course a student will have:

- ✓ An idea about the historical background and need of Operations research.
- ✓ Ability to identify and develop operational research models from the verbal description of the real life problems.
- ✓ Knowledge of the mathematical tools that are needed to solve optimization problems.
- ✓ Ability of solving Linear programming problem, Transportation and Assignment problems, Replacement problems, Job sequencing, etc.

UNIT I

General linear programming problems and their formulations, Method for solving LPP: Graphical Method, Simplex method, Big – M method, Two phase Method, Duality in LPP (introduction only).

UNIT II

Transportation problem, Methods for obtaining IBFS: North-west corner rule, Least cost method, Vogel's approximation method, Methods for determining optimum solution: Stepping stone method, Method of Multipliers (MODI Method). Assignment Problem, Hungarian Algorithm.

UNIT III

Inventory Control, Different costs involved in inventory control, factors affecting inventory control, Deterministic EOQ models, Deterministic EOQ with shortages allowed.

UNIT IV

Job sequencing: n jobs – 2 machines problem, n jobs – K machines problem, 2 jobs – n machines problem. Dynamic Programming Problem, Bellman's optimality Principal.

Suggested Readings:

1. Swarup, K., Gupta P.K. and ManMohan (2007). *Operations Research* (13th ed.), Sultan Chand & Sons.
2. Taha, H.A. (2007). *Operations Research*: *An Introduction, 8th ed.*, Prentice Hall of India.
3. Hadley, G: (2002) : Linear Programming, Narosa Publications
4. Hillier, F.A and Lieberman, G.J. (2010): Introduction to Operations Research- Concepts and cases, 9th Edition, Tata McGraw Hill

Suggested Online Links/Readings:

http://heecontent.upsdc.gov.in/SearchContent.aspx
https://swayam.gov.in/explorer?searchText=statistics
https://nptel.ac.in/course.html
https://www.edx.org/search?q=statistics
https://www.coursera.org/search?query=statistics&

SEMESTER V

PAPER XI B: PROGRAMMING WITH C/C++

Credit: 4 **Theory**

Course Outcome:

After completing this course a student will have:

- ✓ An idea about the historical background and need of Computer Programming.
- ✓ Ability to identify and develop programs through C Language
- ✓ Ability to identify and develop programs through C^{++} Language
- ✓ Knowledge of the C programming tools that are needed to solve optimization problems.
- ✓ Ability of solving various problems relating to applications of Computers.

UNIT I

History and importance of C/C++. Components, basic structure programming, character set, C/C++ tokens, Keywords and Identifiers and execution of a C/C++ program. Data types: Basic data types, Enumerated data types, derived data types. Constants and variables: declaration and assignment of variables, Symbolic Constants, overflow and underflow of data. Operators and Expressions: Arithmetic, relational, logical, assignment, increment/decrement, operators, precedence of operators in arithmetic, relational and logical expression. Implicit and explicit type conversions in expressions, library functions. Managing input and output operations: reading and printing formatted and unformatted data

UNIT II

Decision making and branching - if…else, nesting of if…else, else if ladder, switch, conditional (?) operator. Looping in C/C++: for, nested for, while, do…while, jumps in and out of loops. Arrays: Declaration and initialization of one-dim and two-dim arrays. Character arrays and strings: Declaring and initializing string variables, reading and writing strings from Terminal (using scanf and printf only).

UNIT III

User- defined functions: A multi-function program using user-defined functions, definition of functions, return values and their types, function prototypes and calls. Category of Functions : no arguments and no return values, arguments but no return values , arguments with return values, no arguments but returns a value, functions that return multiple values. Recursion function. Passing arrays to functions, Storage class of Variables.

UNIT IV

Pointers: Declaration and initialization of pointer variables, accessing the address of a variable, accessing a variable through its pointer, pointer expressions, pointer increments/decrement and

scale factor. Pointers and arrays, arrays of pointers, pointers as function arguments, functions returning pointers Structure: Definition and declaring, initialization, accessing structure members, copying and comparison of structure variables, array of structures, structure pointers. Dynamic memory allocation functions: malloc, calloc and free. Pre processors: Macro substitution, macro with argument File inclusion in C/C++: Defining and opening a file (only r, w and a modes), closing a file, I/O operations on files-fscanf and fprintf functions.

Suggested Readings:

1. Kernighan, B.W. and Ritchie, D. (1988): C Programming Language, 2nd Edition, Prentice Hall.
2. Balagurusamy, E. (2011): Programming in ANSI C, Tata McGraw Hill.
3. Gottfried, B.S. (1998): Schaum's Outlines: Programming with C, 2nd Edition, Tata McGraw Hill.

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http://heecontent.upsdc.gov.in/SearchContent.aspx
https://swayam.gov.in/explorer?searchText=statistics
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https://www.coursera.org/search?query=statistics&

SEMESTER VI

PAPER XII: APPLIED STATISTICS

Credit: 4 **Theory**

Course Outcome:

After completing this course a student will have:

- ✓ Familiarity with different aspects of Applied Statistics and their use in real life situations.
- ✓ Ability to understand the concept of Time series along with its different components.
- ✓ Knowledge of Index numbers and their applications along with different types of Index numbers.
- ✓ Familiarity with various demographic methods and different measures of mortality and fertility.
- ✓ Ability to understand the concept of life table and its construction.

UNIT I

Time series, its different components: Trend, Seasonal fluctuation, cyclical fluctuation and Irregular component, additive model, multiplicative models and mixed model (overview), determination of trend: free hand curve fitting method, semi average method, mathematical curve fitting method, method of moving averages, analysis of seasonal fluctuations, Methods for construction of seasonal indices: Ratio to trend method, ration to moving averages method and method of link relatives.

UNIT II

Index number – its definition, its applications, problem involved in computation of index number, price relative and quantity or volume relatives, use of averages, simple aggregative and weighted average method. Laspeyre's, Paashe's, Fisher's and Marshall-Edgeworth's index number, Tests for good index number: Unit test, time reversal test, factor reversal test and circular test, consumer price index number (Overview only)

UNIT III

Demographic methods: Sources of demographic data – census, register, ad-hoc survey, hospital records, Measurement of fertility – crude birth rate, general fertility rate, age-specific birth rate, total fertility rate, gross reproduction rate, net reproduction rate.

UNIT IV

Measurement of mortality: crude death rates, age specific death rates, infant mortality rates, death rate by cause, standardized death rates, Life tables: complete life table, its main features and construction.

Suggested Readings:

1. Croxton F.E. and Cowden D.J. : Applied General Statistics
2. Goon, Gupta and Dasgupta: Fundamentals of Statistics, Vol. I & II

3. Siya Ram : Applied Statistics.
4. Croxton F.E., Cowden D.J. and Klein, S. (1973). Applied General Statistics(3rd ed.), Prentice Hall of India Pvt. Ltd.
5. Gupta, S.C. and Kapoor, V.K. (2008). Fundamentals of Applied Statistics (4th ed.), Sultan Chand and Sons.
6. Mukhopadhyay, P (2011): Applied Statistics, 2nd edition revised reprint, Books and Allied (P) Ltd.

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https://www.edx.org/search?q=statistics
https://www.coursera.org/search?query=statistics&

SEMESTER VI

PAPER XIII: PRACTICAL (Lab Work)

Credit: 4 **Theory**

Practicals based on all the papers of semester V and semester VI.

SEMESTER VI

PAPER XIV A: QUEUEING THEORY AND NETWORK ANALYSIS

Credit: 4 **Theory**

Course Outcome:

After completing this course a student will have:

- ✓ An idea about the historical background and need of Queuing Theory.
- ✓ Ability to identify and develop operational research models from the verbal description of the real life problems.
- ✓ Knowledge of the mathematical tools that are needed to solve optimization problems.
- ✓ Ability of solving Network Analysis models.
- ✓ Knowledge of Project Management.

UNIT I

Queuing Theory: Queuing system and its elements, Distribution of arrivals, Distribution of inter-arrival time, distribution of departures, distribution of service time, classification of queuing models.

UNIT II

Different queuing models with their characteristics: (M|M|1): (∞|FCFS), (M|M|1): (N|FCFS), (M|M|C): (∞|FCFS), Little's formula.

UNIT III

Network Analysis: Minimum spanning tree, Shortest-route problem and Maximal flow model.

UNIT IV

Project Management: PERT/CPM, determination of floats, construction of time chart.

Suggested Readings:

1. Swarup Kanti, Gupta P.K. and Man Mohan: Operations Research, Sultan Chand & Sons.
2. Taha, H.A.: Operations Research, Mac Millan publishing.

Suggested Online Links/Readings:

http://heecontent.upsdc.gov.in/SearchContent.aspx
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https://www.coursera.org/search?query=statistics&

SEMESTER VI

PAPER XIV B: COMPUTATIONAL STATISTICS

Credit: 4 **Theory**

Course Outcome:

After completing this course a student will have:

- ✓ Basic Knowledge of SPSS and R programming with some basic notions for developing their own simple programs and visualizing graphics in R.
- ✓ Ability to perform data analysis for both univariate and multivariate data sets using R as well as SPSS.

UNIT I

Introduction to Computer: Generation of Computer, Basic Structure of Computer, Digital computer and its peripherals, number systems (Binary, Octal, Hexadecimal Systems). Flow chart for simple statistical problems.

Introduction to R Programming and R Studio, Installing R, R as a calculator. Creating a data set, Understanding a data set, Data structure: Vectors, Matrices, Arrays, Data Frames, Factors and Lists. Data inputs: Entering data from the keyboard, Importing Data from Excel, SPSS. SAS, STATA, creating new variables, recoding variable, renaming variables, sorting data, merging and sub setting dataset, Missing values.

UNIT II

Using R: Descriptive Statistics, Graphs, Inferential Statistics- Parametric test: Test for Normality, t-test for single mean, t-test for difference between means, paired t-test. Wilcoxon signed rank sum test, Mann Whitney U test, Kruskal Wallis test, Analysis of Variance (One-way & Two-way ANOVA), measures of association and correlation, Linear Regression: Simple and Multiple regression.

UNIT III

SPSS Environment, entering data, Importing and Exporting data, Data Preparation, Data Transformation. Descriptive Statistics, Explore, Graphs, Inferential Statistics- Parametric test: Test for Normality, t-test for single mean, t-test for difference between means, paired t-test.

UNIT IV

Using SPSS: Non-parametric tests, Analysis of Variance (One-way & Two-way ANOVA), measures of association and correlation, Linear Regression: Simple and Multiple regression.

Suggested Readings:

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

2. Crawley, M.J. (2017). The R Book, John Wiley & Sons.
3. Eckhouse, R.H. and Morris, L.R. (1975). Minicomputer Systems Organization, Programming and Applications, Prentice-Hall.
4. Matloff, N. (2011). The Art of R Programming, No Starch Press, Inc.
5. Eckhouse, R.H. and Morris, L.R. (1975). Minicomputer Systems Organization, Programming and Applications, Prentice-Hall.
6. Margan G A: SPSS for Introductory Statistics; Uses and Interpretation
7. Chambers, J. (2008). Software for Data Analysis: Programming with R, Springer.
8. Crawley, M.J. (2017). The R Book, John Wiley & Sons.
9. Eckhouse, R.H. and Morris, L.R. (1975). Minicomputer Systems Organization, Programming and Applications, Prentice-Hall.
10. Matloff, N. (2011). The Art of R Programming, No Starch Press, Inc.
11. Eckhouse, R.H. and Morris, L.R. (1975). Minicomputer Systems Organization, Programming and Applications, Prentice-Hall.
12.

Suggested Online Links/Readings:

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https://www.coursera.org/search?query=statistics&

SEMESTER VII

PAPER XV: LINEAR MODELS AND ECONOMETRICS

Credit: 4 **Theory**

Course Outcome:

After completing this course a student will have:

- ✓ Use linear and nonlinear models, apply data transformations, and appreciate the need and uses of generalized linear models.
- ✓ Acquire knowledge of various advanced econometric models, estimation methods and related econometric theories.
- ✓ Conduct econometric analysis of data.
- ✓ Apply statistical techniques to model relationships between variables and make predictions.
- ✓ Understand Auto-covariance, auto-correlation function and Vector Auto regression.

UNIT I

Linear models of full rank, Assumptions for linear models, Estimation of model parameters: least squares method, Likelihood method, Properties of the estimators, ANOVA for full rank model distribution of different sum of squares

Linear models not of full rank: Estimation for model parameters: least squares method, Likelihood method, Estimation and error spaces, estimable functions and their BLUE (Gauss-Markov Theorem), ANOVA for not of full rank model, distribution of different sum of squares, test for general linear hypothesis.

UNIT II

Selecting the best regression equation: Forward selection method, backward elimination method and Stepwise regression. Regression Diagnostics: Residuals and their plots, Tests for departure from assumptions of linear models: normality, homogeneity of variances, Multicollienarity and autocorrelation, Transformation: Box - Cox transformation.

UNIT III

Nature of econometrics, review of general linear model (GLM), Generalized least squares (GLS) estimation and prediction, Heteroscedastic disturbances, Pure and mixed estimation, Grouping of observations and equations. Multicollinearity problem, its implications and tools for handling the problem. Auto correlation, its consequences and tests, Linear regression with stochastic regressors, Instrumental variable estimation, Errors in variables, Autoregressive linear regression, Distributed lag models.

UNIT IV

Stationary Processes: Moving average (MA) process, Auto-regressive (AR1 and AR2) process, ARMA and ARIMA models. Vector Auto Regression (VAR), the Granger Causality Test. Ridge regression. Introduction to GARCH model. Simultaneous linear equations model,

Examples, Identification problem, Restrictions on structural parameters - rank and order conditions, Restrictions on variances and covariances.

Suggested Readings:

1. Watherill, G.B. (1986): Regression analysis with applications, Chapman Hall.
2. Theil, H. (1982): Introduction to the theory and practice of Econometrics, john Wiley.
3. Srivastava, V.K. and Giles D.A.E. (1987): Seemingly unrelated regression equations models, Maicel Dekker.
4. Koutsoyiannis, A (1979): Theory of Econometrics, Macmillan Press
5. Johnston, J (1984): Econometric methods, 3rd Ed. Mc Graw Hill.
6. Intrulligator, MD (1980): Econometric models - Techniques and applications, Prentice Hall of India.
7. Gujarathi, D. (1979): Basic Econometrics, McGraw hill.
8. Apte, PG (1990): Text book of Econometrics. Tata McGraw Hill.

Suggested Online Links/Readings:

http://heecontent.upsdc.gov.in/SearchContent.aspx
https://swayam.gov.in/explorer?searchText=statistics
https://nptel.ac.in/course.html
https://www.edx.org/search?q=statistics
https://www.coursera.org/search?query=statistics&

SEMESTER VII

PAPER XVI: MULTIVARIATE ANALYSIS AND SURVEY SAMPLING

Credit: 4 **Theory**

Course Outcome:

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

- ✓ Account for important theorems and concepts in multivariate analysis.
- ✓ Summarize and interpret multivariate data.
- ✓ Appreciate the range of multivariate techniques available.
- ✓ Understand the link between multivariate techniques and corresponding univariate techniques.
- ✓ Conduct statistical inference about multivariate means including hypothesis testing, confidence region calculation, etc.
- ✓ Understand the distinctive features of sampling schemes and its related estimation problems
- ✓ Learn about various approaches (design based and model-based) to estimate admissible parameters; with and without replacement sampling scheme, sampling with varying probability of selection.
- ✓ Learn about the methods of post–stratification (stratified sampling) and controlled sampling and also double sampling procedure with unequal probability of selection.
- ✓ Learn about the applications of sampling methods; systematic, stratified and cluster sampling.
- ✓ Understand the cluster and two stage sampling with varying sizes of clusters/first stage units.

UNIT I

Wishart distribution and its properties, Null and non-null distribution of simple correlation coefficient, Null distribution of partial and multiple correlation coefficient, Distribution of sample regression coefficients, Applications in testing and interval estimation. Hotelling's T^2 statistic and its Null distribution, its application: tests on mean vector for one and more multivariate normal populations, test for equality of the components of a mean vector in a multivariate normal population.

UNIT II

Classification and discrimination procedures for discrimination between two multivariate normal populations-sample discriminant function, test associated with discriminant functions, probabilities of misclassification and their estimation, classification into more than two multivariate normal populations, Fisher Behrens Problem. Canonical variables and canonical correlations: definition, use, estimation and computation. Dimension reduction, Principal components analysis, Factor analysis.

UNIT III

Unequal probability sampling: PPS WR and WOR methods (including Lahiri's scheme) and related estimators of a finite population mean (Hansen-Hurwitz and Desraj estimators for general sample size and Murthy's estimator for a sample of size 2).

UNIT IV

Horvitz-Thompson estimator, its variance and unbiased estimator of variance, IPPS schemes of sampling due to Midzuno-Sen and Rao-Hartley-Cochran. The Jackknife estimation: estimate of bias, estimate of variance; Ratio Estimation in reference to Jackknife. the Bootstrap: estimate of bias, estimate of variance, Relationship between the Jackknife and the bootstrap. Randomized Response techniques (Warner's method: related and unrelated questionnaire methods).

Suggested Readings:

1. Chaudhuri, A. and Mukerjee, R. (1988): Randomized Response: Theory and Techniques, New York: Marcel Dekker Inc.
2. Cochran, W.G.: Sampling Techniques (3rd Edition, 1977). Wiley.
3. Des Raj and Chandak (1998): Sampling Theory, Narosa.
4. Gray, H.L., and Schucany (1972): The generalized jackknife statistic. New York. Marcel Dekker, Inc.
5. Murthy, M. N. (1977): Sampling Theory & Methods, Statistical Publishing Society, Calcutta.
6. Singh, D. and Chaudhary, F.S. (1986): Theory and Analysis of Sample Survey Designs. New Age International Publishers.
7. Sukhatme et al (1984): Sampling Theory of Surveys with Applications. lowa state University Press & IARS.
8. Anderson T.W. (1983): An Introduction to Multivariate Statistical Analysis (Second Edition) Wiley.
9. Giri, N.C. (1977): Multivariate Statistical Inference. Academic Press.
10. Khsirsagar A.M. (1972): Multivariate analysis. Marcel Dekker.
11. Morrison, D.F. (1976): Multivariate Statistical methods. 2nd. Ed. McGRAW Hill.
12. Sharma, S. (1996): Applied multivariate techniques. Wiley.
13. Srivastava M.S. & Khatri C.G. (1979): An Introduction to Multivariate Statistics. North Holland.
14. Johnson, R. and Wychern (1992): Applied multivariate Statistical analysis, prentice-Hall, 3rd. Ed.

Suggested Online Links/Readings:

http://heecontent.upsdc.gov.in/SearchContent.aspx
https://swayam.gov.in/explorer?searchText=statistics
https://nptel.ac.in/course.html
https://www.edx.org/search?q=statistics
https://www.coursera.org/search?query=statistics&

PAPER XVII: PRACTICAL (Lab Work)

The Practicals based on the papers XV and XVI will be done by using Statistical Software R/SPSS.

SEMESTER VII

PAPER XVIII A: ADVANCED INFERENCE

Credit: 4 **Theory**

Course Outcome:

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

- ✓ Apply various estimation techniques and testing procedures to deal with real life problems.
- ✓ Understand consistency, CAN estimator, MLE. Understand UMPU tests UMVU estimators.

UNIT I

Consistency (mean squared and weak). Invariance property of consistency. Asymptotic properties of Consistent estimators: CAN estimators (single as well as multi-parameter cases), invariance of CAN estimators under differentiable transformations, generation of CAN estimators using central limit theorem.

UNIT II

Sufficiency, Factorization Theorem, Minimal sufficient statistic, Completeness and bounded completeness. Distribution admitting sufficient Statistics, Extension of results to multi-parameter case. Bhattacharya's bounds, Rao-Blackwell Theorem, Lehman-Scheffe theorem and their applications.

UNIT III

Minimum Chi square estimators and their modification and their asymptotically equivalence to maximum likelihood estimators. Computational routines: Newton – Raphson method, method of scoring, Consistency and inconsistency, Cramer Huzurbazar Theorem, Asymptotic efficiency of ML estimators, Best Asymptotically normal estimators. Non-randomized and randomized tests. Generalized NP lemma. MLR families. Unbiased tests. UMPU tests against one-sided and two-sided alternatives.

UNIT IV

Locally most powerful unbiased test (type A test). Similar tests. Neymann structure. Confidence set estimation, Relation with hypothesis testing, optimum parametric confidence sets. Large Sample tests: Likelihood ratio (LR) test, asymptotic distribution of LR statistic, Tests based on ML estimators: Pearson's chi-square test for goodness of fit and its relation to LR Test, Test consistency, Asymptotic power of test, Generalized likelihood ratio test, special cases such as multinomial distribution and Bartlett's test for homogeneity of variances.

Suggested Readings:

1. Lehmann, E.L.(1986) : Theory of point. Estimation (Student Edition)
2. Lehmann, E.L.(1986) : Testing statistical hypotheses (Student Edition).
3. Rao, C.R. (1973) : Linear Statistical inference.

4. Dudewicz, E.J. and Mishra, S.N. (1988) : Modern Mathematical Statistics. Wiley Series in Prob. Math. Stat., John Wiley and sons, New York (International Student Edition).
5. Ferguson T. S. (1967) : Mathematical Statistics. Academic press.
6. Zacks, S. (1971) : Theory of statistical Inference, John Wiley & Sons, New York.
7. Kale, B. K.(1999) : A first course on parametric inference, Narosa Publishing House.
8. Rohatagi, V. (1988): An Introduction to probability and mathematical Statistics. Wiley Eastern Ltd. New Delhi (Student Edition).

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http://heecontent.upsdc.gov.in/SearchContent.aspx
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https://www.coursera.org/search?query=statistics&

SEMESTER VII

PAPER XVIII B: ADVANCED PROBABILITY THEORY

Credit: 4 **Theory**

Course Outcome:

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

- ✓ Understand the concepts of random variables, sigma -fields generated by random variables, probability distributions and independence of random variables related to measurable functions.
- ✓ Gain the ability to understand the concepts of measurable functions, sequence of random variables, convergence, modes of convergence.
- ✓ Learn the concepts of weak and strong laws of large numbers and central limit theorem.

UNIT I

Sets and sequences of sets, Rings, Fields, sigma Field and minimal sigma field. Monotone classes. Elements of Measure theory. Probability Measure and properties of measure. Measurable function and their properties.

UNIT II

Sequence of random variables, convergence in probability, almost sure convergence, convergence in distribution and r^{th} mean convergence. Interrelationship among different mode of convergences. Dominated convergence theorem.

UNIT III

Weak and Strong Law of large numbers for independent random variables. Kolmogrov's inequality and theorem. Central Limit Theorem. CLT for i.i.d. random variables, Khinchine's theorem. Central Limit theorem: Lindberg Levy and Liapunoff's form of CLT. Distribution function. Lebsegue and Lebsegue – Stiljes and Riemann Integral.

UNIT IV

Characteristic function. Inversion theorem, continuity theorem and its applications. Product Space, Radon – Nikodymn Theorem (Without proof). Conditional Expectation. Borel – Cantelli Lemma, Borel Zero – One – Law. Signed Measure and Absolute Continuity.

Suggested Readings:

1. Dudewicz, E.J. and Mishra, S.N. (1988): Modern Mathematical Statistics, Wiley, Int'l Students' Edition.
2. Rao C.R. (1973): Linear Statistical Inference and its Applications, 2/e, Wiley Eastern.
3. Rohatgi, V.K. (1984): An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern.

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https://swayam.gov.in/explorer?searchText=statistics
https://nptel.ac.in/course.html
https://www.edx.org/search?q=statistics
https://www.coursera.org/search?query=statistics&

SEMESTER VII

PAPER XIX A: STOCHASTIC PROCESS

Credit: 4 **Theory**

Course Outcome:

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

- ✓ Use notions of long-time behavior including transience, recurrence, and equilibrium in applied situations such as branching processes and random walk.
- ✓ Construct transition matrices for Markov dependent behavior and summarize process information.
- ✓ Use selected statistical distributions for modeling various phenomena.
- ✓ Understand the principles and objectives of model building based on Markov chains, Poisson processes and Brownian motion.

UNIT I

Introduction to stochastic processes (sp's) : Classification of sp's according to state space and time domain, Countable state. Markov chains (MC's), Chapman-Kolmogorov equations, calculation of n-step transition probability and its limit, Stationary distribution, classification of states, transient MC, random walk and gambler's ruin problem

UNIT II

Discrete state space continuous time Markov Chains: Kolmogorov-Feller differential equationsPoisson process, birth and death process, application to queues and storage problems, Wiener process as a limit of random walk, first-passage time and other problems

UNIT III

Renewal theory: Elementary renewal theorem and applications, Statement and uses of key renewal theorem, study of residual life time process, Stationary process, weakly stationary and strongly stationary process, Moving average and auto regressive processes.

UNIT IV

Branching process: Galton-Watson branching process, probability of ultimate extinction, distribution of population size, Martingale in discrete time, inequality, convergence and smoothing properties. Statistical inference in Markov Chains and Markov processes.

Suggested Readings:

1. Adke, S.R. and Munjunath, S.M. (1984): An Introduction to Finite Markov Processes, Wiley Eastern.
2. Bhat, B.R. (2000): Stochastic Models: Analysis and Applications, New Age International, India.

3. Cinlar, E. (1975): Introduction to Stochastic Process, Prentice Hall.
4. Harris, T.E. (1963): The Theory of Branching Processes, Springer - Verlag.
5. Hoel, P.G... Port, S.C. and stone, C.J. (1972): Introduction to Stochastic Process, Houghton Miffin & Co.
6. Jagers, P. (1974): Branching Processes with Biological Applications, Wiley.
7. Medhi, J. (1982): Stochastic Processes, Wiley Eastern.
8. Parzen E. (1962): Stochastic Processes. Holden –Day.

Suggested Online Links/Readings:

http://heecontent.upsdc.gov.in/SearchContent.aspx
https://swayam.gov.in/explorer?searchText=statistics
https://nptel.ac.in/course.html
https://www.edx.org/search?q=statistics
https://www.coursera.org/search?query=statistics&

SEMESTER VII

PAPER XIX A: THEORY OF EXPERIMENTAL DESIGNS

Credit: 4 **Theory**

Course Outcome:

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

- ✓ Design and analyze incomplete block designs, understand the concepts of connectedness, balance, and orthogonality.
- ✓ Understand the analysis of covariance, lattice design, and Split-plot designs and their analysis in practical situations.
- ✓ Identify the effects of different factors and their interactions and analyze factorial experiments.
- ✓ Understand the concepts of finite fields and finite geometries and apply them in construction of MOLS, balanced incomplete block designs, confounded factorial experiments and fractional factorial experiments.

UNIT I

Fixed, random and, mixed effects models; Variance components estimation: study of various methods, Tests for variance components. General block design and its information matrix (C), criteria for connectedness, balance design and orthogonality: Intrablock analysis (estimability, best point estimates/Interval estimates of estimable linear parametric functions and testing of linear hypotheses).

UNIT II

BIBD - recovery of interblock information, Youden design - intrablock analysis, Lattice Design, Split plot design. Analysis of covariance in a general Gauss-Markov model and its applications to standard designs, Missing plot technique - general theory and applications.

UNIT III

Finite group and finite field, Finite geometry: projective and Euclidean, Construction of complete set of mutually orthogonal Latin square (mols), Construction of BIBD's using mols and finite geometries, symmetrically repeated differences, Steiner Triples and their use in construction of BIBD.

UNIT IV

Factorial experiments: analysis of 2^n factorial experiment, complete and partial confounding in case of 2^n, analysis of 3^2, 3^3 and 3^n factorial experiments, complete and partial confounding in case of 3^n factorial experiments, Fractional factorial experiments.

Suggested Readings:

1. Raghava Rao D. (1971): Construction and Combinatorial problems in Design of experiment. Wiley

2. Aloke Dey (1986) : Theory of Block Designs, Wiley Eastern.
3. Angela Dean and Daniel Voss (1999): Design and Analysis of Experiments, Springer.
4. Das, M.N. & Giri, N. (1979): Design and Analysis of experiments, Wiley Eastern.
5. John P.W.M.(1971): Statistical design and analysis of experiments, Mc Millan.
6. Joshi, D.D. (1987) : Linear Estimation and Design of Experiments, Wiley Eastern.
7. Montgomery, C.D.(1976): Design and analysis of experiments, Wiley, New York.
8. Rao, C.R. and Kleffe, J.(1988) : Estimation of Variance Components and applications, North Holland.
9. Searle, S.R., Casella, G. and McCulloch, C.E. (1992) : Variance Components, Wiley.
10. Nigam, Puri & Gupta (1987-88) : Characterisation and Analysis of Block Design, Wiley Eastern.
13. V.K. Gupta & A.K. Nigam (1978-79): Handbook an analysis of Agriculture Experiment, IASRI Publication.

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http://heecontent.upsdc.gov.in/SearchContent.aspx
https://swayam.gov.in/explorer?searchText=statistics
https://nptel.ac.in/course.html
https://www.edx.org/search?q=statistics
https://www.coursera.org/search?query=statistics&

SEMESTER VII

PAPER CC/VC: RESEARCH METHODOLOGY

Credit: 4 **Theory**

Course Outcome:

After successful completion of this program, students will:

- ✓ Have a solid foundation in Statistical Theory and Methodology.
- ✓ be able to communicate the major tenets of statistics, explain their work orally and identify areas of future research areas in statistics.
- ✓ have passed the comprehensive written exams at a superior level based on a summary of required coursework.
- ✓ have designed, carried out and presented an original work of research at the leading edge of the statistics discipline.
- ✓ be able to identify and articulate strategies for dealing with ethical issues that may arise.
- ✓ Attain mastery of broad-based knowledge in social work and specific knowledge relevant to their own research interests, including theories and methods of intervention.
- ✓ be able to explain some elementary statistical courses independently.

UNIT I

Foundations of Research: Meaning, Objectives, Motivation, Utility. Types of research – Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical, concept of applied and basic research process, criteria of good research. Analysis of Literature review – Primary and Secondary Sources, Web sources –critical Literature Review. Development of Working Hypothesis, Research Methods: Scientific method vs Arbitrary Method, Logical Scientific Methods: Deductive, Inductive, Deductive-Inductive, pattern of Deductive –Inductive logical process – Different types of inductive logical methods. Research methods vs. Methodology.

UNIT II

Research design: Meaning, Need, Features of Good Design and Concepts. Research Design types: Survey, Philosophical, Historical, Experimental, Causal Comparative, Genetic, Case Studies. Tools for Data Collection: Collections of Primary Data, Collection of Data through questionnaire and Schedules, other Observation Interview Methods, Collection of Secondary Data, Selection of appropriate method for data collection, Case Study, Focus Group Discussion, Techniques of developing research tools, viz. Questionnaire and rating scales etc. Reliability and validity of Research tools. Sample size determination.

UNIT III

Preparation of Project Proposal - Title, Abstract, Introduction – Rationale, Objectives, Methodology – Time frame and work plan – Budget and Justification – References. Ethical

Issues – Ethical Committees – Commercialization – copy right – royalty – Intellectual Property rights and patent law – Track Related aspects of intellectual property Rights – Reproduction of published material – Plagiarism – Citation and Acknowledgement – Reproducibility and accountability.

UNIT IV

Meaning of Interpretation, Technique of Interpretation, Significance of Report Writing, Different Steps in Writing Report, Layout of the Research Report, Types of Reports, Oral Presentation. Writing Research Project Report: Format and style. Review of related literature its implications at various stages of research. (Formulation of research problem, hypothesis, interpretation and discussion of results). Major findings, Conclusions and suggestions. Citation of references and Bibliography.

Suggested Readings:

1. Garg. B.L., Karadia, R., Agarwal, F. and Agarwal, U.K., 2002. An introduction to Research Methodology, RBSA Publishers.
2. Sinha, S.C. and Dhiman, A.K., 2002. Research Methodology, Vol 2, Ess Publication.
3. Wadehra, B.L.2000. Law relating to patents, trade marks, copyright designs and geographical indications. Universal Law Publishing
4. Fink, A., 2009. Conducting Research Literature Reviews: From the Internet to Paper. Sage Publications
5. Coley, S.M. and Scheinberg, C. A., 1990, "Proposal Writing", Sage Publications.

Suggested Online Links/Readings:

http://heecontent.upsdc.gov.in/SearchContent.aspx
https://swayam.gov.in/explorer?searchText=statistics
https://nptel.ac.in/course.html
https://www.edx.org/search?q=statistics
https://www.coursera.org/search?query=statistics&

SEMESTER VIII

MAJOR PROJECT (24 CREDITS)