DEPARTMENT OF STATISTICS
FACULTY OF MATHEMATICAL SCIENCES
UNIVERSITY OF DELHI, DELHI-110007

Ph.D. COURSE WORK IN STATISTICS

The Ph.D. Programme in Statistics as per the ordinance VI and University letter No. Acad.-I/Ph.D./2025/467, dated 03.09.2025 related to Doctorate of Philosophy (Ph.D.) w.e.f. Academic Year 2025-26.

Course Structure

The total credit requirement for Ph.D. coursework ranges from 12 to 16 credits. Students must complete three compulsory courses; namely Advanced Research Methodology, Research and Publication Ethics, and Research Tools along with one or two discipline-specific elective courses based on the interests of the student.

Courses (i) – (xi):

S.No.	Course Code	Course Name	Credit
(i)	STAT PHD 01	Advanced Research Methodology	4
(ii)	STAT PHD 02	Research and Publication Ethics	2
(iii)	STAT PHD 03	Research Tools	2
(iv)	STAT PHD 04	Design of Experiments	4
(v)	STAT PHD 05	Bayesian Inference	4
(vi)	STAT PHD 06	Order Statistics	4
(vii)	STAT PHD 07	Bio-Statistics	4
(viii)	STAT PHD 08	Reliability and Life Testing	4
(ix)	STAT PHD 09	Industrial Statistics	4
(x)	STAT PHD 10	Survey Sampling	4
(xi)	STAT PHD 11	Statistical Inference	4

Scheme of Evaluation

A student admitted to Ph.D. course work will be evaluated on the basis of final written examination and internal continuous assessment. Continuous assessment will be done through tutorials, assignments, quizzes and group discussion.

STAT PHD 01 **Advanced Research Methodology**

History of Statistics. Statistical Heritage of India, Concept of Research in Statistics.

Selection of Topic for Research, Review of Literature and its role in Designing Research Work, Mode of Literature Survey: Books and Monographs, Journals, Conference proceedings, Abstracting and Indexing Journals, E-Journals/Books. Thesis Writing, Computer Application in Scientific Research, web- Searching, Scientific Articles, Statistical databases.

Scientific Word Processing with LaTeX and MS-Word: Preparation of Articles, Thesis Reports, and Slides; Presentation Tools and Slide Preparation (PowerPoint and Beamer). Statistical Programming with R: Basic Data Types and Structures, Vectors, Matrices, Lists, and Data Frames, Control Structures: Loops and Conditional Statements, User-Defined Functions, Probability Distributions and Statistical Models.

Computer Oriented Numerical Methods-Algorithms for Solving Algebraic and Transcendental Equations, Numerical Integration, Matrix operations.

Suggested Readings:

1. Panneerselvam, R. (2006). Research Methodology. Prentice Hall of India, New Delhi.
2. Beveridge, W. I. B. (1979). The Art of Scientific Investigation. W. E. Norton & Co., New York.
3. Anderson, J., Durston, B. H., & Poole, M. (1970). Thesis and Assignment Writing. Wiley Eastern, New Delhi.
4. Ghosh, J. K., Mitra, S. K., & Parthasarathy, K. R. (1992). Glimpses of India's Statistical Heritage. Wiley Eastern, New Delhi.
5. Hald, A. (1998). A History of Mathematical Statistics from 1750 to 1930. John Wiley & Sons, New York.
6. Lamport, L. (1999). LaTeX: A Document Preparation System (2nd ed.). Addison-Wesley, New York.
7. Dalgaard, P. (2008). Introductory Statistics with R. Springer, New York.
8. Chambers, J. (2008). Software for Data Analysis: Programming with R. Springer, New York.
9. Venkataraman, M. K. (1998). Numerical Methods in Science and Engineering. National Publishing Company, Chennai.

STAT PHD 02 **Research and Publication Ethics**

Introduction to philosophy: definition, nature and scope, concept, branches. Ethics: definition, moral philosophy, nature of moral judgements and reactions

Ethics with respect to science and research, Intellectual honesty and research integrity, Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP), Redundant publications: duplicate and overlapping publications, salami slicing, Selective reporting and misrepresentation of data.

Publication ethics: definition, introduction and importance, best practices / standards setting initiatives and guidelines: COPE, WAME, etc., Conflicts of interest, Publication misconduct: definition, concept, problems that lead to unethical behavior and vice versa, types, Violation of publication ethics, authorship and contributor ship, Identification of publication misconduct, complaints and appeals, Predatory publishers and journals.

Open access publications and initiatives, SHERPA/RoMEO online resource to check publisher copyright & self-archiving policies, Software tool to identify predatory publications developed by SPPU, Journal finder/ journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester etc.

Subject specific ethical issues, FFP, authorship, Conflicts of interest, Complaints and appeals: examples and fraud from India and abroad

Use of plagiarism software like Turnitin, Urkund and other open-source software tools

Indexing databases, Citation databases: Web of Science, Scopus, etc.

Impact factor of journals as per journal citation report, SNIP, SJR, IPP, Cite score, Metrics: h-index, g- index, i10 index, altmetrics.

Suggested Readings:

1. Pruzan Peter (2016). Research Methodology. Springer International Publishing, Switzerland.
2. Jackson, Sherri L. (2010). Research Methods and Statistics. Cengage Learning, INDIA.

STAT PHD 03 **Research Tools**

Use of programming language python for data analysis.

Handling multivariate data using R/Python.

Simulation: Concepts and Advantages of Simulation-Event Type Simulation-Random Variable Generation-U(0,1), Exponential, Gamma and Normal Random Variables–Monte Carlo Integration.

The MCMC Principle, Algorithms and its Variants, Bootstrap Methods.

Suggested Readings:

1. Crewley, M.J. (2007). The R-Book, John Wiley, New York.
2. Dalgaard, P. (2008). Introductory Statistics with R, Springer Science, New York.
3. Robert, C.P. and Casella, G. (2004). Monte Carlo Statistical Methods, Springer Science.
4. McKinney, W. (2022). Python for Data Analysis: Data Wrangling with pandas, NumPy, and Jupyter, O'Reilly Media.
5. Rizzo, M.L. (2019). Statistical Computing with R, Chapman & Hall/CRC Press.
6. Mueller, J. P., & Massaron, L. (2019). Python for data science for dummies. John Wiley & Sons.
7. Hair, J.F., Babin, B.J., Anderson, R.E., & Black, W.C. (2022). *Multivariate Data Analysis*, Cengage Learning.
8. Anderson, T.W. (2003*).* An Introduction to Multivariate Statistical Analysis, Wiley.
9. Ross, S. M. (2022). Simulation. academic press.
10. Ross, S. M. (2014). Introduction to probability models. Academic press.
11. Brooks, S., et al. (2011). Handbook of Markov Chain Monte Carlo. Chapman & Hall/CRC.
12. Efron, B. and Tibshirani, R. (1993). An Introduction to the Bootstrap. Chapman & Hall.

Practice:

- Exploring use of statistical tools and techniques using software taught in class.

STAT PHD 04 **Design of Experiments**

Galois Fields, Quadratic Residues, Hadamard Martices, Plackett Burman Designs and their properties, Orthogonal Arrays and their constructions, Designs for fitting response surfaces, Design criterion involving bias and variance. Mixture Experiments, Constraints on component proportions, Designs for Constrained Mixture Regions, Crossover Designs.

Suggested Readings:

1. Bose, M. and Dey, A. (2009). Optimal Crossover Designs. World Scientific.
2. Cornell, John A. (2002). Experiments with Mixtures, John Wiley & Sons.
3. Dey, A. and Mukerjee, R. (1999). Fractional Factorial Plans, John Wiley & Sons.
4. Hedayat, A. S., Sloane, N. J.A. and Stufken, J. (1999). Orthogonal Arrays: Theory and Applications, Springer.
5. Hinkelmann, K. and Kempthorne, O. (2005). Design and Analysis of Experiments, Vol. 2: Advanced Experimental Design, John Wiley & Sons.
6. Lin, D.K. J. and Draper, N.R. (1999). Projection Properties of Plackett and Burman Designs. Technometrics, 34, 423-428.
7. Myers, R. H. and Montgomery, D. C. (2002). Response Surface Methodology: Process and Product Optimization using Designed Experiments, John Wiley & Sons.
8. Raghavarao, D. (1970). Construction and Combinatorial Problems in Design of Experiments, John Wiley & Sons.

STAT PHD 05 **Bayesian Inference**

Some simple consequences of Axioms of probability, Bayes Theorem. Conjugate analysis for count data, waiting times, Normal likelihood, multivariate normal distribution, normal linear regression model. Behrens-Fisher Controversy.

Informative, non-informative, hybrid and nonparametric priors. Loss functions. Bayes factor, Information theoretic measures for model selection, sensitivity and robust analysis. Bayes point estimation: one parameter, Bayes decisions between k simple hypothesis and between two composite hypothesis. Lindley's method.

Hierarchial models - Poisson-gamma, Gaussian, linear mixed, nonlinear mixed. Empirical Bayes : asymptotic optimality and robustness with respect to prior distribution. Computational Bayesian Statistics.

Suggested Readings

1. Congdon, P. (2003). Applied Bayesian Modelling. Wiley.
2. Congdon, P. (2010). Applied Bayesian Hierarchical Methods. Chapman & Hall.
3. Thompson, J. (2014). Bayesian analysis with STATA. (2014). State Press.
4. Albert, J. (2007). Bayesian Computation with R. Springer.
5. Gelman, A. , Carlin, J. , Stern, H. , Vehtari, D.D.A. and Rubin, D. (2004). Bayesian Data Analysis. Chapman & Hall, 2nd ed.
6. Upadyaya, S.K. , Singh, U. and Dey, D.K. eds. (2007). Bayesian Statistics and its applications. Anamaya, Delhi.
7. Kruschke, J.K. (2015). Doing Bayesian Data Analysis. Elsevier AP.
8. Koch, K. R. (2010). Introduction to Bayesian Statistics, 2nd ed. Springer.
9. French, S. and Smith, J. Q. eds. (1997) The Practice of Bayesian analysis (1997). Arnold Publisher.

STAT PHD 06 **Order Statistics**

Basic distribution theory, conditional distributions, order statistics as a Markov Chain, order statistics for independent non-identically distributed variates; Discrete order statistics, Joint probability mass function, Dependence structure.

Expected values and moments; Order statistics from some specific distributions; Recurrence relations, bounds and approximations for moments of order statistics.

Concomitants of order statistics; Order statistics in statistical inference; Order statistics from a sample containing a single outlier; Asymptotic theory.

Record values; Generalized order statistics.

Suggested Readings:

1. Ahsanullah, M., Nevzorov, V.B. and Shakil, M. (2013). An Introduction to Order Statistics. Atlantis Studies in Probability and Statistics, Vol. 3, Atlantis Press.
2. Arnold, B.C. and Balakrishnan, N. (1989). Relations, Bounds and Approximations for Order Statistics. Lecture Notes in Statistics, Vol.53, Springer-Verlag.
3. Arnold, B.C. Balakrishnan, N. and Nagaraja, H.N. (1992). A first course in Order Statistics, John Wiley.
4. Arnold, B.C., Balakrishnan, N. and Nagaraja, H.N. (1998). Records, John Wiley.
5. David, H.A. and Nagaraja, H.N. (2003). Order Statistics, Third Edition, John Wiley.
6. Galambos, J. (1987). The Asymptotic Theory of Extreme Order Statistics, Second Edition, Krieger, F.L.
7. Kamps, U. (1995). A Concept of Generalized Order Statistics, B.G. Teubner Stuttgart.

STAT PHD 07 **Bio-Statistics**

Nelson-Aalen estimator of cumulative hazard function along with its variance, Its applications in survival analysis, Markov illness death model and epidemic model, Graphical methods for survival distribution fitting and goodness of fit tests, Parametric and non-parametric methods of comparing survival distributions, Mantel - Haenszel test, Estimation of mean residual lifetime with applications, Likelihood construction for

censored and truncated data, Cox PH model along with its likelihood construction, Construction of clinical life table, Carrier Borne epidemic model. Competing risk theory with censoring.

Suggested Readings:

1. Biswas, Suddhendu (1995). Applied Stochastic Processes, New Central Book Agency.
2. Collett, David (2015). Modelling Survival Data in Medical Research, CRC press.
3. Klein, John P., and Moeschberger, Melvin L. (2005). Survival Analysis: Techniques for Censored and Truncated Data, Springer Science & Business Media.
4. Kleinbaum, David G., and Mitchel Klein (2006). Survival Analysis: A Self-learning Text, Springer Science & Business Media.
5. Lee, Elisa T., and Wang, John W. (2003). Statistical Methods for Survival Data Analysis, John Wiley & Sons.
6. Pintilie, Melania (2006). Competing Risks: A Practical Perspective, John Wiley & Sons.

STAT PHD 08 Reliability and Life Testing

Reliability, hazard-rate and mean time to failure and their inter-relationships. Statistical failure models: exponential. Gamma, Weibull, Pareto, normal, lognormal and related distributions. Parametric and Reliability estimation under regression.

Censoring under Type-I, Type-II, and Progressive schemes with applications in life testing. Estimation of parameters of reliability function with complete and censored samples for some selected distributions. Tests of hypotheses and confidence intervals for the reliability function of exponential, gamma,Weibull, normal and lognormal distributions.

Life-time distributions in Reliability analysis, Reliability concepts and measures, Reliability functions, hazard rate functions, Reliability of Series Parallel k-out of- n-systems, coherent systems, standby components, Repairable systems with and without redundancy, preventive maintenance policy. Classes of life distributions: IFR, IFRA, NBU, NBUE and their duals.

Suggested Readings:

1. Bain, L.J. and Engelhardt, M. (1991). Statistical Analysis of Reliability and Life-Testing Models, Marcel Dekker Inc., U.S.A.
2. Hoyland, A. and Rausand, M. (1994). System Reliability Theory: Models and Statistical Theory. Marcel Dekker Inc., New York.
3. Kalbfleisch, J.D. and Prentice, R.L. (1980). The Statistical Analysis of Failure Time Data, John Wiley and Sons, New York.
4. Lawless, J.F. (1982). Statistical Models and Methods for Lifetime Data, John Wiley and Sons Jnc.,.U.S.A.
5. Sinha, S.K. (1986). Reliability and Life-Testing, Wiley Eastern Ltd., New Delhi.
6. Deshpande, J.V. and Puohit, S. (2003). Life-Time Data: Statistical Models and Methods Series on Quality, World Scientific Publishing.
7. Meeker, W.Q., Escobar, L.A. and Pascual, F.G. (2022). Statistical methods for Reliability data. John Wiley and Sons, Inc., New York.

STAT PHD 09 **Industrial Statistics**

Causes of Variation, Warning limits, Average run length, Control Charts for Variables and Attributes, Standardized Control Charts, Statistical process control with auto-correlated process data, Control chart for demerits per unit, Control charts for Individual Units, Cumulative Sum Control Charts, Moving average and Exponentially Weighted Moving Average Control Charts, Multivariate control charts, Process Capability Indices for normal and non-normal Distributions.

Producer's risk, Consumer's risk, Acceptance sampling plan, Single and double sampling plans by attributes, OC, ASN (and ATI), LTPD, AOQ and AOQL curves, Single sampling plan for variables, Lot-by-Lot Attribute Sampling Plans, Acceptance sampling plans. Continuous sampling plans: Bayesian, Multiple, Sequential.

Regression models, Residual Analysis, Transformation of response variable- Box-cox method, Nonlinear regression models, Estimation of parametric functions and related hypotheses testing, Auto-covariance and Autocorrelation functions and their properties, Stationary processes: Moving average (MA) process, Auto-regressive (AR) process, ARMA, ARIMA and SARIMA models.

Suggested Readings:

1. Montgomery, D.C. (2009): Introduction to Statistical Quality Control, Wiley.
2. Wetherill, G.B. and Brown, D.W. (1991): Statistical Process Control: Theory and Practice, Chapman & Hall.
3. Wetherill, G.B. (1977): Sampling Inspection and Quality control, Halsteed Press.
4. Duncan, A.J. (1974): Quality Control and Industrial Statistics, IV Edision, Taraporewala and Sons.
5. Ott, E. R. (1977): Process Quality Control (McGraw Hill)
6. Lawless, J.F. (1982): Statistical model and Methods of Life time data, John Willey.
7. Georg, E.P., Gwilym M. Jenkins and Gregory C. Reinsel (1994): Time series Analysis forecasting and Control, Prentice-Hall International Inc.
8. Brockwell, P.J. and Davis, R.A. (2016): Introduction to Time Series and Forecasting, Springer.

STAT PHD 10 **Survey Sampling**

Fixed population and super-population approaches; Review of various sampling methods with properties; Post and deep stratification; PPSWR/WOR methods, Des Raj and Murthy estimators; Horvitz Thompson Estimator of finite population, IPPS schemes of sampling due to Midzuno-Sen, Rao-Hartley-Cochran and Samphord, Controlled Sampling; randomized response techniques and its various applications.

Resampling Techniques for variance estimation; Ratio Estimation in reference to Jackknife and bootstraps; Relationship between the jackknife and the bootstrap; Successive sampling for two occasions for estimation of population mean/ratio; situation-specific Sampling Schemes: Estimation of mean and variance using ranked set sampling (RSS); RSS in parametric and non-parametric estimation; various versions of RSS; Imperfect ranking; Adaptive Cluster Sampling (ACS); ACS based on order statistics

Design and model based SAE techniques; Direct and Indirect Estimators; Fay-Herriot Model, EBLUP Estimator; Applications in various sectors.

Non-sampling errors, imputation methods for non response, and analysis of survey data. Data integration by combining probability samples with non-probability samples.

Suggested Readings:

1. Chaudhuri, A. and Mukerjee, R. (1988): Randomized Response: Theory and Techniques, New York: Marcel Dekker Inc.
2. Cochran, W.G. (1977): Sampling Techniques. Wiley.
3. Sukhatme, P.V., Sukhatme, B.V. and Ashok A.: Sampling Theory of Surveys with Applications, Indian Society of Agricultural Statistics, New Delhi.
4. Latpate, R., Kshirsagar, Gupta, V.K. and Chandra, G. (2020). Advanced Sampling Methods. Springer
5. Mukhopadhay, P. (2008). Theory and Methods of Survey Sampling, Prentice Hall.
6. Murthy, M. N. (1977): Sampling Theory & Methods, Statistical Publishing Society, Calcutta.
7. Rao, J.N.K. and Molina, I. (2015). Small area estimation, 2nd Edition, Wiley
8. Thompson, S.K. (1996). Adaptive Sampling. John Wiley and Sons
9. Wu and Thompson (2019). Sampling theory and practice. Springer

STAT PHD 11 **Statistical Inference**

Random sample and generation of random sample, Sampling distribution -Z, t, Chi-square, F, Order Statistics, Convergence concepts, Weak and strong laws of large numbers, Central limit theorem, Sufficiency principle, Likelihood principle, Basu's Theorem. Invariance and maximal invariant statistic.

Methods of finding estimators: Method of moments, Maximum likelihood estimators, Methods of evaluating estimators-best unbiased estimator, sufficiency and completeness, Rao-Cramer inequality, Fisher Information, Rao-Blackwell and Lehmann-Scheffe Theorems, Loss and risk functions, admissibility, minimax and Bayes estimators.

Interval estimation: Pivotal quantities, Credible and highest posterior density interval, Coverage probability and Interval length, Expectation-Maximization (EM) algorithm, Bootstrap method: construction of bootstrap confidence intervals.

Neyman-Pearson theory, Most Powerful (MP)Test, UMP Test, Likelihood ratio tests, Wald's Sequential Probability ratio Test (SPRT), Invariant tests. Parametric hypothesis testing methods, One-way and two-way ANOVA, Regression-least square method.

Suggested Readings:

1. Casella, G. and Berger, R.L. (2002) Statistical Inference, Duxbury, USA.
2. Rao, C.R. (1973) Linear Statistical Inference and Its Applications, John Wiley.
3. Kale, B.K. (1999) A First Course on Parametric Inference, Narosa Publishing House, New Delhi.
4. Lehmann, E.L. and Casella, G. (1998) Theory of Point Estimation, Springer.
5. Lehmann, E.L. and Romano, J.P. (2005) Testing Statistical Hypotheses, Springer.
6. Keener R. W. (2010) Theoretical Statistics: Topics for a Core Course, Springer.