Resolution No.: AC/I(19-20).2.RUS11

S.P. Mandali's

RAMNARAIN RUIA AUTONOMOUS COLLEGE

Syllabus for: T.Y.B.Sc.

Program: B.Sc.

Course Code: Statistics (RUSSTA)

(Choice Based Credit System (CBCS) with effect from academic year 2018-19)

Objective of Course

In the third year, there will be two core courses in Statistics per semester and two applied courses in Statistics. The following are the objectives of these courses:

- To understand basic and advance concepts of Probability theory and their applications
- To enable learners to understand Statistical Inference and its applications.
- To teach learners applications of Statistics in Biology, Clinical trials and Bioequivalence, Annuities and Assurance.
- To equip learners with requisite quantitative skills with the use of software.
- To understand and have skill in optimisation techniques and queuing.
- To develop presentation and communication skills

Learning Outcomes

1. Learners will be able to use and apply theory of probability and statistical inference
2. Learners will be able to use statistical techniques in applied fields.
3. Learners will be able to use statistical software tools to solve problems from different fields.
4. Student will be able to engage in interpretation of wide range of information from variety of disciplines including quantitative analysis.

SEMESTER V

Title of the course	PROBABILITYAND DISTRIBUTIONTHEORY			
Course Code	**UNIT**	**TOPICS**	**Credits**	**L / Week**
RUSSTA501	I	Probability	2.5	1
	II	Joint Moment Generating Function Trinomial & Multinomial Distribution		1
	III	Bivariate Normal Distribution		1
	IV	Order Statistics		1
Title of the course	**THEORY OF ESTIMATION**			
RUSSTA502	I	Point Estimation and Properties of Estimator	2.5	1
	II	Methods of Estimation		1
	III	Bayesian Estimation and Confidence Interval		1
	IV	Linear Models		1
Title of the course	**BIOSTATISTICS**			
RUSSTA503	I	Epidemic Models	2.5	1
	II	Bioassay		1
	III	Clinical Trials		1
	IV	Bioequivalence		1
Title of the course	**ELEMENTS OF ACTUARIAL SCIENCE**			
RUSSTA504	I	Mortality Tables	2.5	1
	II	Compound Interest And Annuities Certain		1
	III	Life Annuities		1
	IV	Assurance Benefits		1

Course	PRACTICALS	Credits	L / Week
RUSSTA501	Practicals based on theory Courses	3	8
RUSSTA502	Practicals based on theory Courses	3	8

Course Code: RUSSTA501 PROBABILITYAND DISTRIBUTIONTHEORY

Unit I : PROBABILITY-I: • Basic definitions: Random Experiment, Outcome, Event, Sample Space, Complementary, Mutually Exclusive, Exhaustive and Equally Likely Events. concept of permutation and combination. • Mathematical, Statistical, Axiomatic and Subjective probability. • Sub populations and partitions. • Derivation of a) $A_{r,n}$: Number of distinguishable distributions of putting r indistinguishable balls in n cells; b) Number of distinguishable distributions of putting r indistinguishable balls in n cells such that no cell is empty. • Ordered samples and runs. • Probabilities based on a) Maxwell Boltzmann, Bose Einstein and Fermi Dirac Statistics. • Addition Theorem for (a) two (b) three events. • Theorems on Probability of realization of : (a) At least one (b) Exactly m (c) At least m of N events A_1, A_2, $A_3 \ldots A_N$ • Classical Occupancy problems, Matching problems and Guessing problems (Ref. 1,2,5,7,8)	**15 Lectures**
Unit II: JOINT MOMENT GENERATING FUNCTION, TRINOMIAL AND MULTINOMIAL DISTRIBUTION: • Definition and properties of Moment Generating Function (MGF) of two random variables of discrete and continuous type. Necessary and Sufficient condition for independence of two random variables. ➢ Concept and definition of Multivariate MGF. • **Trinomial distribution:** ➢ Definition of joint probability distribution of (X, Y). Joint moment generating function, moments μ_{rs} where r=0, 1, 2 and s=0, 1, 2. ➢ Marginal & Conditional distributions. Their Means & Variances. ➢ Correlation coefficient between (X, Y). Distribution of the Sum X+Y. • Extension to Multinomial distribution with parameters (n, p_1, p_2,…p_{k-1}) where $p_1+ p_2,+\ldots p_{k-1}+ p_k = 1$. Expression for joint MGF. Derivation of: joint probability distribution of (X_i, Xj). Conditional probability distribution of X_i given $X_j = x_j$ (Ref.2,3,6,7)	**15 Lectures**
<u>Unit III</u> : <u>BIVARIATE NORMAL DISTRIBUTION</u> • Definition of joint probability distribution (X, Y). Joint Moment Generating function, moments μ_{rs} where r=0, 1, 2 and s=0, 1, 2. Marginal & Conditional distributions. Their Means & Variances. • Correlation coefficient between the random variables.	**15 Lectures**

Necessary and sufficient condition for the independence of X and Y. Distribution of aX + bY, where 'a' and 'b' are constants. • Distribution of sample correlation coefficient when $\rho = 0$. Testing the significance of a correlation coefficient. Fisher's z – transformation. Tests for i) H_0: $\rho = \rho_0$ ii) H_0: $\rho_1 = \rho_2$ Confidence interval for ρ. (Ref.1,5)	
Unit IV: ORDER STATISTICS • Definition of Order Statistics based on a random sample. • Derivation of: (a) Cumulative distribution function of r^{th} order statistic. (b) Probability density functions of the r^{th} order statistic. (c) Joint Probability density function of the r^{th} and the s^{th} order statistic ($r<s$) (d) Joint Probability density function of all n ordered statistics. • Probability density function of Median (in the case of odd sample sizes) and Range for Uniform and Exponential distributions. (Ref.2,3,4)	**15 Lectures**

REFERENCES

1. Feller W: An introduction to probability theory and it's applications, Volume: 1, Third edition, Wiley Eastern Limited.
2. Hogg R V. & Craig Allen T.: Introduction to Mathematical Statistics, Fifth edition, Pearson Education (Singapore) Pvt. Ltd.
3. Mood A. M., Graybill F. A., Boes D.C.: Introduction to the theory of statistics, Third edition, Mcgraw- Hill Series.
4. Hogg R. V. and Tanis E.A.: Probability and Statistical Inference, Fourth edition, McMillan Publishing Company.
5. Gupta S C & Kapoor V K: Fundamentals of Mathematical statistics, Eleventh edition, Sultan Chand & Sons.
6. Biswas S.: Topics in Statistical Methodology, First edition, Wiley Eastern Ltd.
7. Kapur J. N. & Saxena H. C.: Mathematical Statistics, Fifteenth edition, S. Chand and Company.
8. Chandra T. K. & Chatterjee D.: A First Course in Probability, Second Edition, Narosa Publishing House.
9. Sheldon M. Ross: Introduction to Probability Models

Course Code RUSSTA502 : THEORY OF ESTIMATION:

Unit I :POINT ESTIMATION AND PROPERTIES OF ESTIMATOR- I: • Notion of a parameter and parameter space. Problem of Estimation, • Definitions of Statistic, Estimator and Estimate. • Properties of a good estimator: • Unbiasedness: Definition of an unbiased estimator, biased estimator, positive and negative bias, illustrations and examples (these should include unbiased and biased estimators for the same parameters). Proofs of the following results regarding unbiased estimators. (i) Two distinct unbiased estimators of $\varphi(\theta)$ give rise to infinitely many unbiased estimators. (ii) If T is an unbiased estimator of θ, then $\varphi(T)$ is unbiased estimator of $\varphi(\theta)$ provided $\varphi(.)$ is a linear function. • Consistency: Consistency: Definition, Proof of the following theorem: An estimator is consistent if its bias and variance both tend to zero as the sample size tends to infinity. • Sufficiency: Concept and definition of Sufficiency, Neymann Factorization Theorem (without proof). Exponential family of probability distributions and Sufficient statistic. • Relative efficiency of an estimator. Illustrative examples. • Minimum variance unbiased estimator (MVUE), Uniqueness property of MVUE. Fisher information function**,** Statement and proof of Cramer-Rao inequality, Cramer–Rao Lower Bound (CRLB), Definition of Minimum Variance Bound Unbiased Estimator (MVBUE) of $\phi(\theta)$.Definition of Efficient estimator using CRLB. (Ref. 1,3,8)	**15 Lectures**
<u>Unit II</u> : <u>PROPERTIES OF ESTIMATOR- II</u> • Minimum variance unbiased estimator (MVUE), Uniqueness property of MVUE. Fisher information function**,** Statement and proof of Cramer-Rao inequality, Cramer–Rao Lower Bound (CRLB), • Definition of minimum variance bound unbiased estimator (MVBUE) of $\phi(\theta)$. Definition of Efficient estimator using CRLB. • Method of Maximum Likelihood Estimation (M.L.E.), Definition of likelihood as a function of unknown parameter, for a random sample from i) discrete distribution ii) continuous distribution. Distinction between likelihood function and joint p.d.f. / p.m.f. • Derivation of Maximum Likelihood Estimator (M.L.E.) for parameters of standard distributions (case of one and two unknown parameters). Properties of M.L.E(without proof) • Method of Moments, Derivation of moment estimators for standard distributions (case of one and two unknown parameters). Illustrations of situations where M.L.E. and Moment Estimators are distinct and their comparison using Mean Square Error. • Method of Minimum Chi-square and Modified Minimum Chi-square.	**15 Lectures**

(Ref: 1,2,3)	
Unit III: BAYESIAN ESTIMATION AND CONFIDENCE INTERVAL • **Bayesian Estimation**: Prior distribution, Posterior distribution, Loss function, Risk function, Bayes' solution under Squared Error Loss Function (SELF) and Absolute Error Loss function. • **Interval Estimation**: Concept of Confidence Interval and Confidence Limits. Definition of pivotal quantity and its use in obtaining confidence limits. Derivation of 100(1-α) % equal tailed confidence interval for the parameters μ, $\mu_1 - \mu_2$ (Population variance(s) known / unknown), σ^2, σ_1^2/σ_2^2 (Normal distribution). Confidence Intervals based on asymptotic property of M.L.E. Confidence interval for the parameters of Binomial, Poisson and Exponential distribution. Equidistant confidence interval for θ based on the random sample from Uniform distribution (0,θ) by using distribution of M.L.E. (Ref: 1, 2, 3)	**15 Lectures**
Unit IV :Linear Models:- Linear Model $Y_{nX1} = X_{nXp}\beta_{pX1} + e_{nX1}$ where e follows N(0, σ^2I). Maximum Likelihood and Least square Estimators of β, and σ^2. Properties of the estimators. Confidence Intervals for β and σ^2. Testing Significance of the β. Best Linear Unbiased Estimator (BLUE). Gauss -Markoff Theorem for Full rank Model. Properties of the Estimator, Estimation of Linear function of parameters $l'\beta$. Its mean and variance. Confidence Interval and Testing of significance of $l'\beta$.	**15 Lectures**

REFERENCES:

1.Hogg R.V., Craig A.T.: Introduction to Mathematical Statistics, Fourth Edition; Collier McMillan Publishers.

2.Hogg R.V., Tannis E. A.: Probability and Statistical Inference, Third Edition; Collier McMillan Publishers.

3. Rohatgi, V. K, Ehsanes Saleh A.K. Md.: An introduction to Probability Theory and Mathematical Statistics, Second Edition, Wiley series in Probability and Statistics.

4.John E. Freund's Mathematical Statistics: I. Miller, M. Miller; Sixth Edition; Pearson Education Inc.

5.Hoe lP.G.: Introduction to Mathematical Statistics; Fourth Edition; John Wiley & Sons Inc.

6.Gupta S.C., Kapoor V.K.: Fundamentals of Mathematical Statistics; Eighth Edition; Sultan Chand & Sons.

7.Kapur J.N., Saxena H.C.: Mathematical Statistics; Fifteenth Edition; S. Chand & Company Ltd.

8.Arora Sanjay and BansiLal : New Mathematical Statistics, Satya Prakashan, New Market, New Delhi,5 (1989)

9.Pawagi V.R. & Ranade Saroj A.: Statistical Methods Using R Software; Nirali Publications.

Course Code RUSSTA503 : BIOSTATISTICS:

Unit I : EPIDEMIC MODELS • The features of Epidemic spread. Definitions of various terms involved. Simple mathematical models for epidemics: Deterministic model without removals, Carrier model. • Chain binomial models. Reed - Frost and Greenwood models. Distribution of individual chains and total number of cases. Maximum likelihood estimator of 'p' and its asymptotic variance for households of sizes up to 4. General Epidemics and Host and Vector model (Ref.1)	**15 Lectures**
Unit II: BIOASSAYS • Meaning and scope of bioassays. Relative potency. Direct assays. Fieller's theorem. • Quantal Response assays. Tolerance distribution. Median effective dose ED50 and LD50. Probit analysis. • Indirect assays. Dose-response relationship .Condition of similarity and Monotony. Linearizing transformations. Parallel line assays. Symmetrical (2, 2) and (3, 3) parallel line assays. Validity tests using orthogonal contrasts. Point Estimate and Interval Estimate of Relative potency. (Ref.2,3)	**15 Lectures**
Unit III: CLINICAL TRIALS: AN INTRODUCTION • Introduction to clinical trials: The need and ethics of clinical trials. Introduction to ICH E9 guidelines. -Common terminology used in clinical trials. Over view of phases (I-IV) Study Protocol, Case record/Report form, Blinding (Single/Double) • Randomized controlled (Placebo/Active controlled), Study Designs (Parallel, Cross Over). Estimation of Sample Size. • Types of Trials: Inferiority, Superiority and Equivalence, Multicentric Trial. Inclusion/Exclusion Criteria. Statistical tools: Analysis of parallel Design using Analysis of Variance. Repeated Measures ANOVA (Concept only) • Concept of odds ratio, Relative Risk. • Introduction to Survival Analysis for estimating Median Survival Time. Kaplan Meier approach of survival Analysis. (Ref. 4,5,6,7,8)	**15 Lectures**
Unit IV: BIOEQUIVALENCE • Definitions of Generic Drug product. Bioavailability, Bioequivalence, Pharmakokinetic (PK) parameters C_{max}, AUC_t, $AUC_{0-\infty}$, T_{max}, K_{el}, T_{half}. • Estimation of PK parameters using 'time vs. concentration' profiles. • Designs in Bioequivalence: Parallel (Analysis), Two Way Crossover, Three Way Crossover, Replicated Crossover (Concept only). Advantages of Crossover design over Parallel design. • Analysis of Parallel design using logarithmic transformation (Summary statistics, ANOVA and 90% confidence interval). • Confidence Interval approach to establish bioequivalence (80/125 rule). (Ref. 9)	**15 Lectures**

REFERENCES:

1. Bailey N.T.J.: The Mathematical theory of infectious diseases, Second edition, Charles Griffin and Co. London.
2. Das M.N and Giri N.C. : Design and Analysis of Experiments, Second edition, Wiley Eastern
3. Finney D.J. : Statistical Methods in Biological Assays, First edition, Charles Griffin and Co. London
4. Sanford Bolton and Charles Bon: Pharmaceutical Statistics, Fourth edition, Marcel Dekker Inc.
5. Zar Jerrold H.: Biostatistical Analysis, Fourth edition, Pearson's education.
6. Daniel Wayne W: Biostatistics- A Foundation for Analysis in the Health Sciences, 7th Edition, Wiley Series in Probability and Statistics.
7. Friedman L. M., Furburg C., Demets D. L.: Fundamentals of Clinical Trials, First edition, Springer Verlag.
8. Fleiss J. L. The Design and Analysis of Clinical Experiments, Second edition, Wiley and Sons
9. Shein-Chung-Chow: Design and Analysis of Bioavailability & Bioequivalence studies, Third Edition, Chapman & Hall/CRC Biostatistics series.
10. Glenwalker: Common Statistical Methods for clinical Research:

Course Code RUSSTA504: ELEMENTS OF ACTUARIAL SCIENCE:

Unit I : MORTALITY TABLES: • Various mortality functions. Probabilities of living and dying. • The force of mortality. Estimation of μ_x from the mortality table. • Central Mortality Rate. Laws of mortality: Gompertz's and Makeham's first law. Select, Ultimate and Aggregate mortality tables. Stationary population. Expectation of life and Average life at death. (Ref.2,3)	**15 Lectures**
Unit II: COMPOUND INTEREST AND ANNUITIES CERTAIN: • Accumulated value and present value, nominal and effective rates of interest. • Varying rates of interest. Equation of value. Equated time of payment. • Present and accumulated values of annuity certain (immediate and due) with and without deferment period. • Present value for perpetuity (immediate and due) with and without deferment Period.	**15 Lectures**

• Present and accumulated values of (i) increasing annuity (ii) increasing annuity when successive instalments form (i) arithmetic progression (ii) Geometric progression (iii) annuity with Frequency different from that with which interest is convertible. Redemption of loan. (Ref.2)	
Unit III: LIFE ANNUITIES: • Present value in terms of commutation functions of Life annuities and Temporary life annuities (immediate and due) with and without deferment period. • Present values of Variable, increasing life annuities and increasing Temporary life annuities (immediate and due). (Ref:1, 2)	**15 Lectures**
Unit IV: ASSURANCE BENEFITS: • Present value of Assurance benefits in terms of commutation functions of : (i) pure endowment assurance (ii) temporary assurance (iii) endowment assurance (iv) whole life assurance (v) special endowment assurance (vi) deferred temporary assurance (vii) Double Endowment • Net premiums: Net level annual premiums (including limited period of payment) for various assurance plans. • Office premiums. (Ref:1,2)	**15 Lectures**

REFERENCES:

1. Neill A. : Life Contingencies, First edition, Heineman educational books London
2. Dixit S.P., Modi C.S., Joshi R.V.: Mathematical Basis of Life Assurance, First edition Insurance Institute of India.
3. Gupta S. C. &. Kapoor V. K.: Fundamentals of Applied Statistics, Fourth edition, Sultan Chand & Sons.
4. Ajaykumar Srivastava and Gorakhnath Agarwal: Mathematical Basis of Life Assurance

DISTRIBUTION OF TOPICS FOR PRACTICALS

SEMESTER-V

COURSE CODE

RUSSTA501(A)

Sr. No.	Practical Topics
5.1.1	Probability-1
5.1.2	Probability -2
5.1.3	Multinomial Distribution
5.1.4	Bivariate Normal Distribution
5.1.5	Test for Significance of Correlation Coefficient
5.1.6	Order Statistics -1
5.1.7	Order Statistics -2

COURSE CODE

RUSSTAP501(B)

Sr. No.	Practical Topics
5.2.1	MVUE and MVBUE
5.2.2	Method of Estimation -1
5.2.3	Method of Estimation -2
5.2.4	Bayes' Estimation
5.2.5	Confidence Interval
5.2.6	Linear Models
5.2.7	Use of R software

COURSE CODE

RUSSTAP502(A)

Sr. No.	Practical Topics
5.3.1	Epidemic models
5.3.2	Direct Assays
5.3.3	Quantal Response Assays
5.3.4	Parallel line Assay
5.3.5	Clinical Trials
5.3.6	Bioequivalence

COURSE CODE

RUSSTAP502(B)

Sr. No.	Practical Topics
5.4.1	Mortality tables 1
5.4.2	Mortality tables 2
5.4.3	Annuities 1
5.4.4	Annuities 2
5.4.5	Life annuities
5.4.6	Assurance benefits

SEMESTER VI

Title of the Course	DISTRIBUTIONTHEORY AND STOCHASTIC PROCESSES			
Course	**UNIT**	**TOPICS**	**Credits**	**L / Week**
RUSSTA601	**I**	**Generating Functions**	**2.5**	**1**
	II	**Stochastic Processes**		**1**
	III	**Queuing Theory-I**		**1**
	IV	**Queuing Theory-II**		**1**
Title of the Course	**TESTING OF HYPOTHESES**			
RUSSTA602	**I**	**Introduction to Testing of Hypothesis**	**2.5**	**1**
	II	**Parametric tests**		**1**
	III	**Likelihood Ratio Test and SPRT**		**1**
	IV	**Non-Parametric tests**		**1**
Title of the Course	**OPERATIONS RESEARCH TECHNIQUES**			
RUSSTA603	**I**	**Inventory Control**	**2.5**	**1**
	II	**Replacement**		**1**
	III	**Simulation**		**1**
	IV	**Mathematical Economics**		**1**
Title of the Course	**FORECASTING & RELIABILITY**			
RUSSTA604	**I**	**Linear Regression-I**	**2.5**	**1**
	II	**Linear Regression-II**		**1**
	III	**Reliability**		**1**
	IV	**Cluster Analysis and Time Series Models**		**1**

Course	PRACTICALS	Credits	L / Week
RUSSTAP601	**Practicals of Course RUSSTA601 & RUSSTA 602**	**3**	**8**
RUSSTAP602	**Practicals of Course RUSSTA603 & RUSSTA 604**	**3**	**8**

Course Code RUSSTA601: DISTRIBUTION THEORY AND STOCHASTIC PROCESSES:

Unit I : GENERATING FUNCTIONS • Definitions of generating function and probability generating function. Expression for mean and variance in terms of generating functions. • Definition of a convolution of two or more sequences. Generating function of a convolution. • Generating functions of the standard discrete distributions. Relation between: i) Bernoulli and Binomial distributions ii) Geometric and Negative Binomial distributions in terms of convolutions. (Ref.1,5)	**15 Lectures**
Unit II: STOCHASTIC PROCESSES • Definition of stochastic process. Postulates and difference differential equations for : (i) Pure birth process (ii) Poisson process with initially 'a' members, for a =0 and a >0 (iii) Yule Furry process (iv)Pure death process (v) Death process with $\mu_n=\mu$ (vi) Death process with $\mu_n=n\mu$ (vii) Birth and death process (viii) Linear growth model. • Derivation of P_n (t), mean and variance where ever applicable. (Ref.1,7,9)	**15 Lectures**
Unit III: QUEUING THEORY -I • Basic elements of the Queuing model. • Roles of the Poisson and Exponential distributions. • Assuming the difference differential equations for birth and death process, derivation of Steady state probabilities for birth and death process. Steady state probabilities and various average characteristics for the following models: (i) (M/M/1) : (GD/ ∞ /∞), Waiting time distributions(M/M/1)(FCFS/ ∞/ ∞) (ii) (M/M/1) : (GD/ N/∞) (Ref.6)	**15 Lectures**
Unit IV: QUEUING THEORY -II Other queuing models i) (M/M/c) : (GD/ ∞/ ∞), ii) (M/M/c):(GD/ N /∞) iii) (M/M/∞) : (GD/ ∞ /∞) (iv) Machine Serving model (M/M/C): (GD/ k /k)	**15 Lectures**

REFERENCES:

1. Feller W: An introduction to probability theory and it's applications, Volume: 1, Third edition, Wiley Eastern Limited.
2. Hogg R. V. & CraigA.T.: Introduction to Mathematical Statistics, Fifth edition, Pearson Education (Singapore) Pvt Ltd.
3. Mood A M, Graybill F A, Bose D C: Introduction to the theory of statistics, Third edition, Mcgraw- Hill Series.
4. Hogg R. V. and Tanis E.A.: Probability and Statistical Inference, Fourth edition, McMillan Publishing Company
5. Gupta S C & Kapoor V K: Fundamentals of Mathematical statistics, Eleventh edition, Sultan Chand & Sons.
6. Taha H.A.: Operations Research: An introduction, Eighth edition, Prentice Hall of India Pvt. Ltd.
7. Medhi J.: Stochastic Processes, Second edition, Wiley Eastern Ltd.
8. Biswas S.: Topics in Statistical Methodology (1992), First edition, Wiley Eastern Ltd.
9. Kapur J. N., Saxena H. C.: Mathematical Statistics, Fifteenth edition, S. Chand and Company

Course Code RUSSTA602 : TESTING OF HYPOTHESES

Unit I : MOST POWERFUL TESTS	**15 Lectures**
• Problem of testing of hypothesis. • Definitions and illustrations of i) Simple hypothesis ii) Composite hypothesis iii)Null Hypothesis iv) Alternative Hypothesis v)Test of hypothesis vi) Critical region vii) Type I and Type II errors viii) Level of significance ix) p-value x) size of the test xi) Power of the test xii) Power function of a test xiii) Power curve. • Definition of most powerful test of size α for a simple hypothesis against a simple alternative hypothesis. Neyman-Pearson fundamental lemma. (Ref. 1,2)	

Unit II : UNIFORMLY MOST POWERFUL & LIKELIHOOD RATIO TESTS • Definition, Existence and Construction of uniformly most powerful (UMP) test. Likelihood ratio principle. • Definition of test statistic and its asymptotic distribution (statement only) • Construction of LRT for the mean of normal distribution for i) known σ^2 ii) unknown σ^2 (two sided alternatives). • LRT for variance of normal distribution for i) known μ ii) unknown μ (two sided alternatives hypotheses) Ref. (1,2,3)	**15 Lectures**
Unit III: SEQUENTIAL PROBABILITY RATIO TEST (SPRT) • Sequential test procedure for testing a simple null hypothesis against a simple alternative hypothesis. Its comparison with fixed sample size (Neyman-Pearson) test procedure. • Definition of Wald's SPRT of strength (α, β). Problems based on Bernoulli, Binomial, Poisson, Normal, Exponential distributions. Graphical /tabular procedure for carrying out the tests. • ASN and OC Function (Ref. 1,6,8,9)	**15 Lectures**
Unit IV: NON-PARAMETRIC TESTS • Need for non parametric tests. • Distinction between a parametric and a non parametric test . • Concept of a distribution free statistic. Nonparametric tests. (i) Sign test (Single and Two samples)(ii) Wilcoxon's signed rank test (iii) Median test (iv) Mann–Whitney test (v) Run test. (Single and Two samples) (vi) Fisher Exact Test (vii) Kruskal Wallis ANOVA (viii) Friedman ANOVA • Assumptions, justification of the test procedure for small & large samples. (Ref.5)	**15 Lectures**

REFERENCES:

1. Hogg R.V. and Craig A.T: Introduction to Mathematical Statistics Fourth edition London Macmillan Co. Ltd.
2. Hogg R.V. and Tanis E.A.: Probability and Statistical Inference. Third edition Delhi Pearson Education.
3. Lehmann, E. L: Testing of Statistical Hypothesis, Wiley &sons
4. Rao, C. R.: Linear Statistical Inference,

5. Daniel W. W.: Applied Non Parametric Statistics First edition Boston-Houghton Mifflin Company.
6. Wald A.: Sequential Analysis First edition New York John Wiley & Sons
7. Biswas S.: Topics in Statistical Methodology. First edition New Delhi Wiley eastern Ltd.
8. Gupta S.C. and Kapoor V.K.: Fundamentals of Mathematical Statistics Tenth edition New Delhi S. Chand & Company Ltd.
9. Sanjay Aroraand BansiLal: New Mathematical Statistics, Satya Prakashan, New Market, New Delhi, 5(1989).
10. Pawagi V. R. and Ranade Saroj A: Statistical Methods Using R Software. Nirali Publications.

Course Code RUSSTA603: OPERATIONS RESEARCH TECHNIQUES

Unit I : INVENTORY CONTROL • Introduction to Inventory Problem • Deterministic Models: Single item static EOQ models for: ➢ Constant rate of demand with instantaneous replenishment, with and without shortages. ➢ Constant rate of demand with uniform rate of replenishment, with and without shortages. ➢ Constant rate of demand with instantaneous replenishment without shortages, with one and two price breaks. • Probabilistic models: Single period with ➢ Instantaneous demand (discrete and continuous) without setup cost. ➢ Uniform demand (discrete and continuous) without set up cost. (Ref. 1,2,3,)	**15 Lectures**
Unit II: **REPLACEMENT** • Replacement of items that deteriorate with time and value of money that remains constant and that change with time. • Replacement of items that fail completely: Individual replacement and Group replacement policies. (Ref. 5)	**15 Lectures**
Unit III: SIMULATION • Scope of simulation applications. Types of simulation. Monte Carlo Technique of Simulation and Bootstrapping. • Elements of discrete event simulation. • Generation of random numbers. Sampling from probability distribution. Inverse method. Generation of random observations from	**15 Lectures**

i) Uniform distribution ii) Exponential distribution iii) Gamma distribution iv) Normal distribution. • Application of Simulation techniques to real life situations. (Ref.4,5)	
Unit IV: Mathematical Economics: • Behaviour of Demand and Supply, Demand functions. Cost and Revenue functions. The elasticity of a function, Elasticity of (i) Demand (ii) Cost. • Normal conditions of (i) demand (ii) cost. Features of prefect competition. • Monopoly (including effects of taxation and subsidy), Duopoly. • Production function. Euler's theorem linear homogenous production functions, Cobb-Douglas production function, CES production function. • The elasticity of substitution. (Ref. 7,8,9)	15 Lectures

REFERENCES:

1. Vora N. D. : Quantitative Techniques in Management, Third edition, McGraw Hill Companies
2. Bannerjee B. : Operation Research Techniques for Management, First edition, Business books
3. Bronson R. : Theory and problems of Operations research, First edition, Schaum's Outline series
4. Kantiswarup, P.K. Gupta, Manmohan : Operations Research, Twelfth edition, Sultan Chand & sons
5. Sharma S. D.: Operations Research, Eighth edition, Kedarnath Ramnath & Co.
6. Taha H.A.: Operations Research An Introduction, Prentice Hall of India
7. Allen R.G.D.: Mathematical Analysis for Economics
8. Henderson J. M. and Quandt R. E.: Micro Economic Theory-A mathematical approach
9. Gupta S.C. and Kapoor V. K.: Fundamentals of Applied Statistics

Course Code RUSSTA604: FORECASTING & RELIABILITY

Unit I: LINEAR REGRESSION I • Linear regression model with one or more explanatory variables. Assumptions of the model, Derivation of Ordinary Least Square (OLS) estimators of regression coefficients, (for one and two explanatory variables models). Properties of least square estimators (without proof). Coefficient of determination R^2 and adjusted R^2. • Procedure of testing : ✓ Overall significance of the model ✓ Significance of individual coefficients • Significance of incremental contribution of explanatory variable for two explanatory variables model. • Confidence intervals for the regression coefficients. • Multiple Linear Regression with Qualitative Independent Variable. (Ref: 8,9)	**15 Lectures**
Unit II: LINEAR REGRESSION II • Autocorrelation: Concept, Detection using Durbin Watson Test, Generalized Least Square (GLS) method. • Heteroscedasticity: Concept, Detection using Breusch-Pagan-Godfrey test. Weighted Least Square (WLS) estimators • Multicollinearity: Concept, Detection using (i) R square & t ratios (ii) Variance Inflation Factor (VIF), • Remedial measures for Multicollinearity: Ridge Regression. • Concept of Statistical Outliers, Detection of Influential Observation. Cook's Distance and Influence Plot. Hold Out method for Model Validation. • Binary Logistic Regression, Concept of Multinomial and ordinal logistic	**15 Lectures**
Unit III : **Unit IV: RELIABILITY** Concept of reliability, Hazard-rate. Bath tub curve. Failure time distributions: (i) Exponential (ii) Gamma (iii) Weibull (iv) Gumbel. Definitions of increasing (decreasing) failure rate. System Reliability. Reliability of (i) series; (ii) parallel system of independent components having exponential life distributions. Mean Time to Failure of a system (MTTF). (Ref 6,7)	**15 Lectures**

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Unit IV: Cluster Analysis and Time Series Models Cluster Analysis: Time Series Models: Concept of stationary time series (graphical and DF test, Methods of converting non-stationary time series into stationary time series by differencing method and detrending method, introduction to Box-Jenkin's ARIMA model (5 steps)	**15 Lectures**

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REFERENCES:

1. Gupta S. C. &. Kapoor V. K.: Fundamentals of Applied Statistics, Fourth edition, Sultan Chand & Sons.
2. Sharma J. K.: Operations Research Theory and Application, Third edition, Macmillan India Ltd.
3. Spiegel M.R. : Theory and Problems of Statistics, Fourth edition, Schaum's Outline Series Tata McGraw Hill
4. Taha Hamdy A. : Operations Research : Eighth edition, Prentice Hall of India Pvt. Ltd
5. VoraN. D.: Quantitative Techniques in Management, Third edition, McGraw Hill Companies
6. Barlow R.E. and Prochan Frank : Statistical Theory of Reliability and Life Testing Reprint, First edition, Holt, Reinhart and Winston
7. Mann N.R., Schafer R.E., Singapurwalla N.D.: Methods for Statistical Analysis of Reliability and Life Data, First edition, John Wiley & Sons.
8. Damodar Gujrathi, Sangetha S: Basic Econometrics,, Fourth edition, McGraw-Hill Companies.
9. Greene William: Econometric Analysis, First edition, McMillan Publishing Company.
10. Johnson and Richen : Applied Multivariate Statistical Analysis

DISTRIBUTION OF TOPICS FOR PRACTICALS

SEMESTER-VI

COURSE CODE RUSSTAP601(A)

Sr. No.	Practical Topics
6.1.1	Generating Function
6.1.2	Stochastic Process
6.1.3	Queuing Theory -1
6.1.4	Queuing Theory -2
6.1.5	Queuing Theory -3

Sr. No	Practical Topics
6.2.1	Testing of Hypothesis 1
6.2.2	Testing of Hypothesis-2
6.2.3	SPRT
6.2.4	Non Parametric test-1
6.2.5	Non Parametric test-2
6.2.6	Use of R software.

COURSE CODE RUSSTAP601(A)

Sr. No.	Practical Topics
6.3.1	Inventory-1
6.3.2	Inventory-2
6.3.3	~~Game Theory~~ Replacement
6.3.4	~~Replacement~~ Reliability
6.3.5	~~Decision Theory-1~~ Mathematical Economics 1
6.3.6	~~Decision Theory-2~~ Mathematical Economics 2

COURSE CODE RUSSTAP601(B)

Sr. No.	Practical Topics
6.4.1	Multiple regression model -1
6.4.2	Multiple regression model- 2
6.4.3	~~Simulation~~ Use of R in MLR, Binary Logistic Regression
6.4.4	~~Reliability~~ Cluster Analysis & Factor Analysis
6.4.5	~~Use of R in MLR, Binary Logistic Regression~~ Time Series Regression-ARMA/ ARIMA

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COURSE CODE RUSSTAP601(B)

THEORY

Internal Assessment of Theory Core Courses Per Semester Per Course

1. One Class Test /Project/Assignment /Presentation: …….20 Marks.
2. One Class Test / Project / Assignment / Presentation: ….20 Marks.

Semester End Examination- THEORY

At the end of the semester, examination of two hours duration and 60 marks based on the four units shall be held for each course.

Pattern of **Theory question** paper at the end of the semester for ***each course***:

There shall be **Four** compulsory Questions of **Fifteen** marks each with internal option. Question1 based on Unit I, Question 2 based on Unit II, Question 3 based on Unit III, Question 4 based on Unit IV.

PRACTICALS

Internal Assessment of Practical Core Courses per Semester per course

1. One Class Test ……. ..15 Marks.
2. Journal ……. ..05 Marks.

Practical Core Courses per Semester per course

1. Practical Examination ……30 Marks.

At the end of the semester, examination of one and half hours duration and 30 marks shall be held for **each course**.

Pattern of **Practical question** paper at the end of the semester for **each theory course**:

Every paper will consist of two parts A and B. Every **part** will consist of two questions of 30 marks each. Learners to attempt one question from each part.

Practical course	Duration	Marks	Will be conducted at the end of
RUSSTAP501(A) & **RUSSTAP501(B)**	3 hours	60	Semester V
RUSSTAP502(A) & **RUSSTAP502(B)**	3 hours	60	Semester V
RUSSTAP601(A) & RUSSTAP601(B)	3 hours	60	Semester VI
RUSSTAP602(A) & RUSSTAP602(B)	3 hours	60	Semester VI

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