

**AC 27/2/13**  
**Item No. 4.8**

**UNIVERSITY OF MUMBAI**



**Syllabus for Sem V & VI**  
**Program: B.Sc.**  
**Course: STATISTICS**

(Credit Based Semester and Grading System with  
effect from the academic year 2013–2014)

**T.Y.B.Sc.**  
**STATISTICS**  
**Credit Based Semester and Grading System**  
**To be implemented from the Academic year 2013-2014**

**SEMESTER V**

**Theory**

<b>Course</b>	<b>UNIT</b>	<b>TOPICS</b>	<b>Credits</b>	<b>L / Week</b>
<b>USST501</b>	<b>I</b>	<b>Probability-I</b>	<b>2.5</b>	<b>1</b>
	<b>II</b>	<b>Probability-II</b>		<b>1</b>
	<b>III</b>	<b>Joint Moment Generating Function Trinomial &amp; Multinomial Distribution</b>		<b>1</b>
	<b>IV</b>	<b>Order Statistics</b>		<b>1</b>
<b>USST502</b>	<b>I</b>	<b>Point Estimation and Properties of Estimator- I</b>	<b>2.5</b>	<b>1</b>
	<b>II</b>	<b>Properties of Estimator- II</b>		<b>1</b>
	<b>III</b>	<b>Methods of Estimation</b>		<b>1</b>
	<b>IV</b>	<b>Bayesian Estimation and Confidence Interval</b>		<b>1</b>
<b>USST503</b>	<b>I</b>	<b>Epidemic Models</b>	<b>2.5</b>	<b>1</b>
	<b>II</b>	<b>Bioassay</b>		<b>1</b>
	<b>III</b>	<b>Clinical Trials</b>		<b>1</b>
	<b>IV</b>	<b>Bioequivalence</b>		<b>1</b>
<b>USST504</b>	<b>I</b>	<b>Mortality Tables</b>	<b>2.5</b>	<b>1</b>
	<b>II</b>	<b>Compound Interest And Annuities Certain</b>		<b>1</b>
	<b>III</b>	<b>Life Annuities</b>		<b>1</b>
	<b>IV</b>	<b>Assurance Benefits</b>		<b>1</b>

<b>Course</b>	<b>PRACTICALS</b>	<b>Credits</b>	<b>L / Week</b>
<b>USSTP05</b>	<b>Practicals of Course USST501 + Course USST502</b>	<b>3</b>	<b>8</b>
<b>USSTP06</b>	<b>Practicals of Course USST503 + Course USST504</b>	<b>3</b>	<b>8</b>

Course Code	Title	Credits
<b>USST501</b>	<b><u>PROBABILITY AND DISTRIBUTION THEORY</u></b>	<b>2.5 Credits (60 lectures )</b>
<b><u>Unit I : PROBABILITY I</u></b>		<b>15 Lectures</b>
<p>(i) Basic definitions: Random Experiment, Outcome, Event, Sample Space, Complementary, Mutually Exclusive, Exhaustive and Equally Likely Events.</p> <p>(ii) Mathematical, Statistical, Axiomatic and Subjective probability.</p> <p>(iii) Sub populations and partitions.  Derivation of a) <math>A_{r,n}</math> : 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.</p> <p>(iv) Ordered samples and runs.</p> <p>(v) Probabilities based on a) Maxwell Boltzmann, Bose Einstein and Fermi Dirac Statistics.</p> <p>(vi) Addition Theorem for (a) two (b) three events.</p> <p style="text-align: right;">(Ref. 1,2,5,7,8)</p>		
<b><u>Unit II : PROBABILITY II</u></b>		<b>15 Lectures</b>
<p>(i) Theorems on Probability of realization of :  (a) At least one (b) Exactly m (c) At least m of N events <math>A_1, A_2, A_3 \dots A_N</math>.  Matching and Guessing problems.</p> <p>(ii) Conditional Probability: Multiplication Theorem for two, three events.  Independence of two/three events - complete and pair wise.</p> <p>(iii) Bayes' theorem. <span style="float: right;">(Ref. 1,2,5,8)</span></p>		
<b><u>Unit III: JOINT MOMENT GENERATING FUNCTION, TRINOMIAL AND MULTINOMIAL DISTRIBUTION</u></b>		<b>15 Lectures</b>
<p>(i) 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.</p> <p><b>(ii) Trinomial distribution:</b>  Definition of joint probability distribution of (X, Y). Joint moment generating function, moments <math>\mu_{rs}</math> where <math>r=0, 1, 2</math> and <math>s=0, 1, 2</math>.  Marginal &amp; Conditional distributions. Their Means &amp; Variances.  Correlation coefficient between (X, Y). Distribution of the Sum X+Y.</p> <p>(iii) Extension to Multinomial distribution with parameters <math>(n, p_1, p_2, \dots, p_{k-1})</math> where <math>p_1 + p_2 + \dots + p_{k-1} + p_k = 1</math>. Expression for joint MGF. Derivation of: joint probability distribution of <math>(X_i, X_j)</math>. Conditional probability distribution of <math>X_i</math></p>		

given $X_j = x_j$	(Ref.2,3,6,7)	
<b>Unit IV: ORDER STATISTICS</b> (i) Definition of Order Statistics based on a random sample. (ii) Derivation of: (a) Cumulative distribution function of $r^{\text{th}}$ order statistic. (b) Probability density functions of the $r^{\text{th}}$ order statistic. (c) Joint Probability density function of the $r^{\text{th}}$ and the $s^{\text{th}}$ order statistic ( $r < s$ ) (d) Joint Probability density function of all $n$ ordered statistics. (iii) Probability density function of Median (in the case of odd sample sizes) and Range for Uniform and Exponential distributions. <div style="text-align: right;">(Ref.2,3,4)</div>		<b>15 Lectures</b>

### **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.

Course Code	Title	Credits
<b>USST502</b>	<b><u>THEORY OF ESTIMATION</u></b>	<b>2.5 Credits (60 lectures )</b>
<p><b><u>Unit I : POINT ESTIMATION AND PROPERTIES OF ESTIMATOR- I</u></b>            Notion of a parameter and parameter space. Problem of Estimation, Definitions of Statistic, Estimator and Estimate.            Properties of a good estimator:            (a) 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 <math>\phi(\theta)</math> give rise to infinitely many unbiased estimators.                (ii) If T is an unbiased estimator of <math>\theta</math> , then <math>\phi(T)</math> is unbiased estimator of <math>\phi(\theta)</math> provided <math>\phi(\cdot)</math> is a linear function.            (b) 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.            (c) Sufficiency: Concept and definition of Sufficiency, Neymann Factorization Theorem (without proof). Exponential family of probability distributions and Sufficient statistic.            (d) Relative efficiency of an estimator. Illustrative examples.  <div style="text-align: right;">(Ref. 1,3,8)</div></p>		<b>15 Lectures</b>
<p><b><u>Unit II : PROPERTIES OF ESTIMATOR- II</u></b>            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 <math>\phi(\theta)</math>. Definition of Efficient estimator using CRLB.  <div style="text-align: right;">(Ref. 1,3,8)</div></p>		<b>15 Lectures</b>
<p><b><u>Unit III : METHODS OF ESTIMATION</u></b>            a) 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)</p>		<b>15 Lectures</b>

<p>b) 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.</p> <p>c) Method of Minimum Chi-square and Modified Minimum Chi-square. (Ref. 1,3,8)</p>	
<p><b><u>Unit IV: BAYESIAN ESTIMATION AND CONFIDENCE INTERVAL</u></b>  <b><u>Bayesian Estimation:</u></b> Prior distribution, Posterior distribution, Loss function, Risk function, Bayes' solution under Squared Error Loss Function (SELF) and Absolute Error Loss function.  <b><u>Interval Estimation:</u></b> Concept of Confidence Interval and Confidence Limits. Definition of pivotal quantity and its use in obtaining confidence limits. Derivation of 100(1-<math>\alpha</math>) % equal tailed confidence interval for the parameters <math>\mu</math>, <math>\mu_1 - \mu_2</math> (Population variance(s) known / unknown), <math>\sigma^2</math>, <math>\sigma_1^2/\sigma_2^2</math> (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 <math>\theta</math> based on the random sample from Uniform distribution (0,<math>\theta</math>) by using distribution of M.L.E. (Ref. 1, 3, 8).</p>	<p><b>15 Lectures</b></p>

**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.Hoel P.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	Title	Credits
<b>USST503</b>	<b><u>BIOSTATISTICS</u></b>	<b>2.5 Credits (60 lectures )</b>
<b><u>Unit I : EPIDEMIC MODELS</u></b> (i) The features of Epidemic spread. Definitions of various terms involved. Simple mathematical models for epidemics: Deterministic model without removals, Carrier model. (ii) 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. (Ref.1 )		<b>15 Lectures</b>
<b><u>Unit II: BIOASSAYS</u></b> i) Meaning and scope of bioassays. Relative potency. Direct assays. Fieller's theorem. ii) Quantal Response assays. Tolerance distribution. Median effective dose ED50 and LD50. Probit analysis. iii) 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)		<b>15 Lectures</b>
<b><u>Unit III: CLINICAL TRIALS: AN INTRODUCTION</u></b> Introduction to clinical trials: The need and ethics of clinical trials. 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). Types of Trials: Inferiority, Superiority and Equivalence, Multicentric Trial. Inclusion/Exclusion Criteria. Statistical tools: Analysis of parallel Design using Analysis of Variance. Concept of odds ratio. Sample size estimation. (Ref. 4,5,6,7,8)		<b>15 Lectures</b>
<b><u>Unit IV: BIOEQUIVALENCE</u></b> Definitions of Generic Drug product. Bioavailability, Bioequivalence, Pharmacokinetic (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, Cross over (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)		<b>15 Lectures</b>

**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 Boltan 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, 7<sup>th</sup> 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.



Course Code	Title	Credits
<b>USST504</b>	<b><u>ELEMENTS OF ACTUARIAL SCIENCE</u></b>	<b>2.5 Credits (60 lectures )</b>
<b><u>Unit I : MORTALITY TABLES:</u></b> Various mortality functions. Probabilities of living and dying. The force of mortality. Estimation of $\mu_x$ 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)		<b>15 Lectures</b>
<b><u>Unit II: COMPOUND INTEREST AND ANNUITIES CERTAIN:</u></b> 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. Present and accumulated values of (i) increasing annuity (ii) increasing annuity when successive installments form arithmetic progression (iii) annuity with Frequency different from that with which interest is convertible. Redemption of loan. (Ref.2 )		<b>15 Lectures</b>
<b><u>Unit III: LIFE ANNUITIES:</u></b> 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 )		<b>15 Lectures</b>
<b><u>Unit IV: ASSURANCE BENEFITS:</u></b> 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 Net premiums: Net level annual premiums (including limited period of payment ) for various assurance plans . Office premiums. (Ref:1,2 )		<b>15 Lectures</b>

**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.

**DISTRIBUTION OF TOPICS FOR PRACTICALS**

**SEMESTER-V**

**COURSE CODE USSTP05**

Sr. No.	Practical Topics (from Course USST501)
5.1.1	Probability-1
5.1.2	Probability -2
5.1.3	Probability -3
5.1.4	Multinomial Distribution
5.1.5	Order Statistics -1
5.1.6	Order Statistics -2

Sr. No.	Practical Topics (from Course USST502)
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	Use of R software

**COURSE CODE USSTP06**

Sr. No.	Practical Topics (from Course USST503)
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

Sr. No.	Practical Topics (from Course USST504)
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

**T.Y.B.Sc. STATISTICS Syllabus**

**Credit Based and Grading System**

**To be implemented from the Academic year 2013-2014**

**SEMESTER VI**

**Theory**

<b>Course</b>	<b>UNIT</b>	<b>TOPICS</b>	<b>Credits</b>	<b>L / Week</b>
<b>USST601</b>	<b>I</b>	<b>Bivariate Normal Distribution</b>	<b>2.5</b>	<b>1</b>
	<b>II</b>	<b>Generating Functions</b>		<b>1</b>
	<b>III</b>	<b>Stochastic Processes</b>		<b>1</b>
	<b>IV</b>	<b>Queuing Theory</b>		<b>1</b>
<b>USST602</b>	<b>I</b>	<b>Introduction to Testing of Hypothesis</b>	<b>2.5</b>	<b>1</b>
	<b>II</b>	<b>Parametric tests</b>		<b>1</b>
	<b>III</b>	<b>Likelihood Ratio Test and SPRT</b>		<b>1</b>
	<b>IV</b>	<b>Non-Parametric tests</b>		<b>1</b>
<b>USST603</b>	<b>I</b>	<b>Inventory Control</b>	<b>2.5</b>	<b>1</b>
	<b>II</b>	<b>Game Theory</b>		<b>1</b>
	<b>III</b>	<b>Replacement</b>		<b>1</b>
	<b>IV</b>	<b>Decision Theory</b>		<b>1</b>
<b>USST604</b>	<b>I</b>	<b>Time Series</b>	<b>2.5</b>	<b>1</b>
	<b>II</b>	<b>Simulation</b>		<b>1</b>
	<b>III</b>	<b>Linear Regression</b>		<b>1</b>
	<b>IV</b>	<b>Reliability</b>		<b>1</b>

<b>Course</b>	<b>PRACTICALS</b>	<b>Credits</b>	<b>L / Week</b>
<b>USSTP07</b>	<b>Practicals of Course USST601 + Course USST602</b>	<b>3</b>	<b>8</b>
<b>USSTP08</b>	<b>Practicals of Course USST603 + Course USST604</b>	<b>3</b>	<b>8</b>

	<b>Title</b>	<b>Credits</b>
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Course Code		
<b>USST601</b>	<b><u>DISTRIBUTION THEORY AND STOCHASTIC PROCESSES</u></b>	<b>2.5 Credits (60 lectures )</b>
<b><u>Unit I : BIVARIATE NORMAL DISTRIBUTION</u></b>		<b>15 Lectures</b>
<p>i) Definition of joint probability distribution (X, Y). Joint Moment Generating function, moments <math>\mu_{rs}</math> where <math>r=0, 1, 2</math> and <math>s=0, 1, 2</math>. Marginal &amp; Conditional distributions. Their Means &amp; Variances. Correlation coefficient between the random variables. Necessary and sufficient condition for the independence of X and Y. Distribution of <math>aX + bY</math>, where 'a' and 'b' are constants.</p> <p>ii) Distribution of sample correlation coefficient when <math>\rho = 0</math>. Testing the significance of a correlation coefficient. Fisher's z – transformation. Tests for i) <math>H_0: \rho = \rho_0</math> ii) <math>H_0: \rho_1 = \rho_2</math> Confidence interval for <math>\rho</math>.</p> <p style="text-align: right;">(Ref. 2,3,5,9)</p>		
<b><u>Unit II : GENERATING FUNCTIONS</u></b>		<b>15 Lectures</b>
<p>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:</p> <p>i) Bernoulli and Binomial distributions ii) Geometric and Negative Binomial distributions in terms of convolutions.</p> <p style="text-align: right;">(Ref.1,5)</p>		
<b><u>Unit III: STOCHASTIC PROCESSES</u></b>		<b>15 Lectures</b>
<p>Definition of stochastic process. Postulates and difference differential equations for : (i) Pure birth process (ii) Poisson process with initially 'a' members, for <math>a = 0</math> and <math>a &gt; 0</math> (iii) Yule Furry process (iv) Pure death process (v) Death process with <math>\mu_n = \mu</math> (vi) Death process with <math>\mu_n = n\mu</math> (vii) Birth and death process (viii) Linear growth model. Derivation of <math>P_n(t)</math>, mean and variance where ever applicable.</p> <p style="text-align: right;">(Ref.1,7,9)</p>		
<b><u>Unit IV: QUEUING THEORY</u></b>		<b>15 Lectures</b>
<p>Basic elements of the Queuing model. Roles of the Poisson and Exponential distributions. Derivation of Steady state probabilities for birth and death process. Steady state probabilities and various average characteristics for the following models:</p> <p>(i) (M/M/1) : (GD/ <math>\infty</math> /<math>\infty</math>)      (ii) (M/M/1) : (GD/ N /<math>\infty</math>) (iii) (M/M/c) : (GD/<math>\infty</math>/<math>\infty</math>)      (iv) (M/M/c) : (GD/ N /<math>\infty</math>) (v) (M/M/<math>\infty</math>) : (GD/ <math>\infty</math> /<math>\infty</math>)</p> <p style="text-align: right;">(Ref.6)</p>		

## **REFERENCES:**

1. Feller W: An introduction to probability theory and its applications, Volume: 1, Third edition, Wiley Eastern Limited.
2. Hogg R. V. & Craig A.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	Title	Credits
<b>USST602</b>	<b><u>TESTING OF HYPOTHESES</u></b>	<b>2.5 Credits (60 lectures )</b>
<p><b><u>Unit I : MOST POWERFUL TESTS</u></b></p> <p>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.</p> <p>Definition of most powerful test of size <math>\alpha</math> for a simple hypothesis against a simple alternative hypothesis. Neyman-Pearson fundamental lemma.</p> <p style="text-align: right;">(Ref. 1,2)</p>		<b>15 Lectures</b>
<p><b><u>Unit II : UNIFORMLY MOST POWERFUL &amp; LIKELIHOOD RATIO TESTS</u></b></p> <p>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 <math>\sigma^2</math> ii) unknown <math>\sigma^2</math> (two sided alternatives). LRT for variance of normal distribution for i) known <math>\mu</math> ii) unknown <math>\mu</math> (two sided alternatives hypotheses).</p> <p style="text-align: right;">Ref. (1,2,3)</p>		<b>15 Lectures</b>
<p><b><u>Unit III: SEQUENTIAL PROBABILITY RATIO TEST (SPRT)</u></b></p> <p>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 <math>(\alpha, \beta)</math>. Problems based on Bernoulli, Binomial, Poisson, Normal, Exponential distributions. Graphical /tabular procedure for carrying out the tests.</p> <p style="text-align: right;">(Ref. 1,6,8,9)</p>		<b>15 Lectures</b>
<p><b><u>Unit IV: NON-PARAMETRIC TESTS</u></b></p> <p>Need for non parametric tests. Distinction between a parametric and a non parametric test .Concept of a distribution free statistic. Single sample and two sample Nonparametric tests. (i) Sign test (ii) Wilcoxon's signed rank test (iii) Median test (iv) Mann-Whitney test (v) Run test.</p> <p>Assumptions, justification of the test procedure for small &amp; large samples.</p> <p style="text-align: right;">(Ref.5)</p>		<b>15 Lectures</b>

## **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 Arora and Bansi Lal: 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	Title	Credits
<b>USST603</b>	<b><u>OPERATIONS RESEARCH TECHNIQUES</u></b>	<b>2.5 Credits (60 lectures )</b>
<b><u>Unit I : INVENTORY CONTROL</u></b>		<b>15 Lectures</b>
<p>Introduction to Inventory Problem</p> <p><u>Deterministic Models:</u></p> <p>Single item static EOQ models for:</p> <p>(i) Constant rate of demand with instantaneous replenishment, with and without shortages.</p> <p>(ii) Constant rate of demand with uniform rate of replenishment, with and without shortages.</p> <p>(iii) Constant rate of demand with instantaneous replenishment without shortages, with at most two price breaks.</p> <p><u>Probabilistic models:</u> Single period with</p> <p>(i) Instantaneous demand (discrete and continuous) without setup cost.</p> <p>(ii) Uniform demand (discrete and continuous) without set up cost.</p> <p style="text-align: right;">(Ref. 1,4,5)</p>		
<b><u>Unit II : GAME THEORY</u></b>		<b>15 Lectures</b>
<p>Definitions of Two person Zero Sum Game, Saddle Point, Value of the Game, Pure and Mixed strategy. Optimal solution of two person zero sum games.</p> <p>Dominance property, Derivation of formulae for (2x2) game.</p> <p>Graphical solution of (2xn) and (mx2) games.</p> <p style="text-align: right;">(Ref. 1 )</p>		
<b><u>Unit III: REPLACEMENT</u></b>		<b>15 Lectures</b>
<p>Replacement of items that deteriorate with time and value of money</p> <p>i) remains constant ii) changes with time.</p> <p>Replacement of items that fail completely: Individual replacement and Group replacement policies.</p> <p style="text-align: right;">(Ref. 5 )</p>		
<b><u>Unit IV: DECISION THEORY</u></b>		<b>15 Lectures</b>
<p>Decision making under uncertainty: Laplace criterion, Maximax (Minimin) criterion, Maximin (Minimax) criterion, Hurwicz <math>\alpha</math> criterion, Minimax Regret criterion.</p> <p>Decision making under risk: Expected Monetary Value criterion, Expected Opportunity Loss criterion, EPPI, EVPI. Bayesian Decision rule for Posterior analysis.</p> <p>Decision tree analysis along with Posterior probabilities.</p> <p style="text-align: right;">(Ref.1)</p>		



**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.

Course Code	Title	Credits
<b>USST604</b>	<b><u>FORECASTING &amp; RELIABILITY</u></b>	<b>2.5 Credits (60 lectures )</b>
<b><u>Unit I : TIME SERIES</u></b> Definition of Time series. Its components. Models of Time Series. Estimation of trend by: (i) Freehand curve method (ii) Method of Semi Averages (iii) Method of Moving Averages (iv) Method of Least Squares. (v) Exponential Smoothing method Estimation of seasonal component by: (i) Method of simple averages (ii) Ratio to moving average method (iii) Ratio to trend method. (Ref.1,2)		<b>15 Lectures</b>
<b><u>Unit II : SIMULATION</u></b> Scope of simulation applications. Types of simulation. Monte Carlo Technique of Simulation. Elements of discrete event simulation. Generation of random numbers. Sampling from probability distribution. Inverse method. Generation of random observations from i) Uniform distribution ii) Exponential distribution iii) Gamma distribution iv) Normal distribution. Simulation techniques applied to inventory and Queuing models. (Ref.4,5)		<b>15 Lectures</b>
<b><u>Unit III: LINEAR REGRESSION</u></b> 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 : (i) overall significance of the model (ii) significance of individual coefficients (iii) Significance of incremental contribution of explanatory variable for two explanatory variables model. Confidence intervals for the regression coefficients. 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) (Ref: 8,9)		<b>15 Lectures</b>
<b><u>Unit IV: RELIABILITY</u></b> Concept of reliability, Hazard-rate. Bath tub curve. Failure time distributions: (i) Exponential (ii) Gamma (iii) Weibull (iv) Gumbel.		<b>15 Lectures</b>

Definitions of increasing (decreasing) failure rate.	
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System Reliability. Reliability of (i) series; (ii) parallel system of independent components having exponential life distributions.	
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Mean Time to Failure of a system (MTTF).	
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(Ref 6,7)	
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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. Vora N. 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.

**DISTRIBUTION OF TOPICS FOR PRACTICALS**

**SEMESTER-VI**

**COURSE CODE USSTP07**

Sr. No.	Practical Topics (from Course USST601)
6.1.1	Bivariate Normal Distribution
6.1.2	Tests for correlation and Interval estimation
6.1.3	Generating Function
6.1.4	Stochastic Process
6.1.5	Queuing Theory -1
6.1.6	Queuing Theory -2

Sr. No.	Practical Topics (from Course USST602)
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 USSTP08**

Sr. No.	Practical Topics (from Course USST603)
6.3.1	Inventory-1
6.3.2	Inventory-2
6.3.3	Game Theory
6.3.4	Replacement
6.3.5	Decision Theory-1
6.3.6	Decision Theory-2

Sr. No.	Practical Topics (from Course USST604)
6.4.1	Time series-1
6.4.2	Time series-2
6.4.3	Simulation
6.4.4	Reliability
6.4.5	Multiple regression model -1
6.4.6	Multiple regression model- 2

**Internal Assessment of Theory Core Courses Per Semester Per Course**

- 1. One Class Test ..... 20 Marks
- 2. One Assignment ..... 10 Marks.
- 3. Active participation in class instructional deliveries .....05 Marks.
- 4. Overall conduct as a responsible student, mannerism etc . .05 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 **Five** compulsory Questions of **Twelve** 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 and Question 5 based on all four Units combined.

**Semester End Examination- PRACTICALS**

At the end of the semester, examination of three hours duration and 100 marks (80+10\* + 10 \*\*) shall be held for **each course** as shown below.

Practical course	Part A	Part B	Duration	Marks out of
USSTP05	Questions from USST501	Questions from USST502	3 hours	80
USSTP06	Questions from USST503	Questions from USST504	3 hours	80
USSTP07	Questions from USST601	Questions from USST602	3 hours	80
USSTP08	Questions from USST603	Questions from USST604	3 hours	80

\* 1. Semester work, Documentation, Journal .....10 Marks.

\*\*2. Viva .....10 Marks.

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

Every paper will consist of two parts A and B. Every **part** will consist of two questions of 40 marks each. Students to attempt one question from each part.

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