UNIVERSITY OF MUMBAI

Syllabus for the S. Y. B.Sc.
Program: B.Sc.
Course : STATISTICS

(Credit Based Semester and Grading System with effect from the academic year 2017–2018)

S.Y.B.Sc. STATISTICS Syllabus
For Credit Based and Grading System
To be implemented from the Academic year 2017-2018
SEMESTER III

Course Code	UNIT	TOPICS	Credits	L / Week
USST301	I	Univariate Random Variables. (Discrete and Continuous)	2	1
	II	Standard Discrete Probability Distributions.		1
	III	Bivariate Probability Distributions.		1
USST302	I	Concepts of Sampling and Simple Random Sampling.	2	1
	II	Stratified Sampling.		1
	III	Ratio and Regression Estimation.		1
USSTP3				6
USSTP3(A)	Practicals based on USST301		1	3
USSTP3(B)	Practicals based on USST302		1	3

SEMESTER IV

Course Code	UNIT	TOPICS	Credits	L / Week
USST401	I	Standard Continuous Probability Distributions.	2	1
	II	Normal Distribution.		1
	III	Exact Sampling Distributions.		1
USST402	I	Analysis of Variance.	2	1
	II	Design Of Experiments, Completely Randomized design & Randomized Block Design.		1
	III	Latin Square Design & Factorial Experiments.		1
USSTP4				6
USSTP4(A)	Practicals based on USST401		1	3
USSTP4(B)	Practicals based on USST402		1	3

Course Code	Title	Credits
USST301	**PROBABILITY DISTRIBUTIONS**	**2 Credits (45 lectures)**
Unit I	**Univariate Random Variables (Discrete and Continuous):**	15 Lectures

Moment Generating Function(M.G.F.):

Definition

Properties:

- Effect of change of origin and scale,

- M.G.F of sum of two independent random variables X and Y ,

- Extension of this property for n independent random variables and for n i.i.d. random variables.

All above properties with proof,

- Uniqueness Property without proof.

- Raw moments using M.G.F: using expansion method and using derivative method.

Cumulant generating Function(C.G.F.):

Definition

Properties:

- Effect of change and origin and scale ,

- Additive Property of C.G.F. and cumulants

Both properties with proof.

Obtaining Cumulants using C.G.F.

Derivation of relationship between moments and cumulants upto order four.

Characteristic Function:

Definition and properties (without Proof)

Examples of obtaining raw moments and central moments up

to order four using M.G.F. and C.G.F. for continuous and

discrete distributions .

Degenerate distribution(One point distribution) P(X=c) =1

Mean, Variance, Use of Degenerate distribution . Discrete Uniform distribution. Mean, Variance, coefficient of skewness using m.g.f., Bernoulli distribution. Mean, Variance, coefficient of skewness using m.g.f. **Binomial distribution :** Mean, Variance, Measures of skewness and Kurtosis based on moments using M.G.F.and C.G.F. , Nature of probability curve, Mode, Additive property , If X follows Binomial, then to find distribution of n-X. Recurrence relation for moments with proof: $\mu'_{r+1} = npq\ \mu'_r + pq\ \frac{d}{dp}\ \mu'r$ $\mu_{r+1} = pq\ [\ nr\ \mu_{r-1} + \frac{d}{dp}\ \mu r\ ]$ Relation between Bernoulli and Binomial using m.g.f. Transformation of random Variable (Univariate) : examples based on it.		
Unit II	**Standard Discrete Probability Distributions**	15 Lectures
Poisson distribution Mean, Variance, Measures of skewness and Kurtosis based on moments using M.G.F.and C.G.F. , Nature of probability distribution with change in the values of parameters, Mode, Additive property. Recurrence relation for moments with proof for μ'_{r+1} ,μ_{r+1} If X and Y are two independent Poisson variables Conditional distribution of X given X+Y with proof Poisson distribution as limiting distribution of Binomial (with proof) Real life examples of Binomial, Poisson distribution. **Geometric Distribution** Definition in terms of No. of failures and No. of trials. Mean, Variance, M.G.F., Mean and Variance using M.G.F., C.G.F., Mean and Variance,μ_3,μ_4 using C.G.F., Coefficients of skewness and		

Kurtosis and nature of probability distribution. Lack of Memory property with proof. If X and Y are two i.i.d. Geometric variables; Conditional distribution of X given X+Y with proof Distribution of sum of k i.i.d. Geometric variables. **Negative Binomial Distribution** Definition, Mean, Variance, M.G.F., Mean and Variance using M.G.F., C.G.F., Recurrence relation for central moments, Mean, Variance,μ_3,μ_4 using C.G.F., Coefficients of skewness and Kurtosis and nature of probability distribution. Lack of Memory property with proof. Recurrence relation for probabilities, Fitting of distribution. Limiting distribution of Negative Binomial distribution (with proof) **Hyper geometric distribution** Definition,Mean,Variance,Limiting distribution of Hyper geometric distribution (with proof) If X and Y are two independent Binomial variables Conditional distribution of X given X+Y (with proof) **Truncated distribution** Definition Truncated Binomial and Truncated Poisson Distribution: (truncated at 0) Probability mass function, mean and variance. Real life situations of Geometric, Negative Binomial, Hypergeometric distributions		
Unit III	**Bivariate Probability Distributions**	**15 Lectures**
Two dimensional Discrete random variables -Joint Probability mass function and its properties -Distribution function of (X,Y) and its properties -Definition of raw and central moments, covariance, correlation coefficient, Independence and correlation between two variables -Marginal and conditional probability distributions		

-Conditional expectation, conditional variance **Continuous bivariate random variables** -Joint Probability density function and its properties -Distribution function of (X,Y) and its properties -Definition of raw and central moments, covariance, correlation coefficient, Independence and correlation between two variables -Marginal and conditional probability distributions -Conditional expectation, conditional variance - Regression Function. Transformation of Random Variables and Jacobian of transformation with illustrations.	

REFERENCES:

1. Introduction to the theory of statistics: A. M. Mood, F.A. Graybill, D. C. Boyes, Third Edition; McGraw-Hill Book Company.
2. Introduction to Mathematical Statistics: R.V.Hogg, A.T. Craig; Fourth Edition; Collier McMillan Publishers.
3. Probability and Statistical Inference: R.V.Hogg, E. A.Tannis, Third Edition; Collier McMillan Publishers.
4. John E. Freund's Mathematical Statistics: I. Miller, M. Miller; Sixth Edition; Pearson Education Inc.
5. Introduction to Mathematical Statistics: P.G. Hoel; Fourth Edition; John Wiley & Sons Inc.
6. Fundamentals of Mathematical Statistics: S.C. Gupta, V.K. Kapoor; Eighth Edition; Sultan Chand & Sons.
7. Mathematical Statistics: J.N. Kapur, H.C. Saxena; Fifteenth Edition; S. Chand & Company Ltd.
8. Statistical Methods: An Introductory Text: J. Medhi; Second edition; Wiley Eastern Ltd.
9. An Outline of Statistical Theory Vol. 1: A.M. Goon, M.K. Gupta, B. DasGupta; Third Edition; The World Press Pvt. Ltd.

Course Code	Title	Credits
USST302	**THEORY OF SAMPLING**	**2 Credits (45 lectures)**
Unit I : Concepts: Population, Population unit, Sample, Sample unit, Parameter, Statistic,Estimator, Bias, Unbi Mean square error & Standard error.Census survey, Sample Survey. Steps in conducting sample survey with examples on designing appropriate Questionnaire. Concepts of S and Non-sampling errors. NSSO, CSO and their functions.Concepts and methods of Pr and Non-Probability Sampling. **Simple Random Sampling:** (SRS). Definition, Sampling with & without replacement (WR/WOR).Lottery method & use of Random numbers to select . Simple random sample. Estimation of population mean & total. Expectation & Variance of the estimators, Unbiased estimator of variance of these estimators. (WR/WOR). Estimation of population proportion. Expectation & Variance of the estimators, Unbiased estimator of variance of these estimators. (WR/WOR). Estimation of Sample size based on a desired accuracy in case of SRS for variables & attributes. (WR/WOR).		15 Lectures
Unit II : Stratified Sampling: Need for Stratification of population with suitable examples. Definition of Stratified Sample. Advantages of stratified Sampling. **Stratified Random Sampling:** Estimation of population mean & total in case of Stratified Random Sampling (WOR within each strata). Expectation & Variance of the unbiased estimators, Unbiased estimators of variances of these estimators. Proportional allocation, Optimum allocation with and without varying costs. Comparison of Simple Random Sampling, Stratified Random Sampling using Proportional allocation and Neyman allocation.		15 Lectures
Unit III : **a. Ratio & Regression Estimation assuming SRSWOR:** Ratio Estimators for population Ratio, Mean & Total. Expectation & MSE of the Estimators. Estimators of MSE. Uses of Ratio Estimator. Regression Estimators for population Mean & Total. Expectation & Variance of the Estimators assuming known value of regression coefficient 'b'. Estimation of 'b'. Resulting variance of the estimators. Uses of regression Estimator. Comparison of Ratio, Regression & mean per Unit estimators.		15 Lectures

b. Introduction to Systematic sampling, Cluster sampling & Two Stage sampling with suitable illustrations.	

REFERENCES:

1. Sampling Techniques: W.G. Cochran; 3rd Edition; Wiley(1978)
2. Sampling Theory and methods: M.N. Murthy; Statistical Publishing Society. (1967)
3. Sampling Theory: Des Raj; McGraw Hill Series in Probability and Statistics. (1968).
4. Sampling Theory of Surveys with Applications: P.V. Sukhatme and B.V. Sukhatme; 3rd Edition; Iowa State University Press (1984).
5. Fundamentals of Applied Statistics: S. C. Gupta and V.K. Kapoor; 3rd Edition; Sultan Chand and Sons (2001).
6. Theory and Analysis of Sample Survey Designs: Daroga Singh, F.S.Chaudhary, Wiley Eastern Ltd. (1986).
7. Sampling Theory and Methods: S. Sampath, Second Edition (2005),Narosa.
8. Theory and Methods of Survey Sampling: Parimal Mukhopadhyay, (1998), Prentice Hall Of India Pvt. Ltd.

DISTRIBUTION OF TOPICS FOR PRACTICALS

SEMESTER-III

COURSE CODE USSTP3

Sr. No	Semester III .Course USSTP3(A)
1	Moment Generating Function, Moments.
2	Cumulant generating Function, Cumulants, Characteristic function.
3	Standard Discrete Distributions.
4	Fitting Standard Discrete Distributions.
5	Bivariate Probability Distributions, Marginal & Conditional distributions, Conditional Mean, Conditional Variance, Correlation.
6	Transformation of discrete & continuous random variables.

Sr. No	Semester III .Course USSTP3(B)
1	Designing of Questionnaire.
2	Simple Random Sampling for Variables.
3	Simple Random Sampling for Attributes.
4	Estimation of Sample Size in Simple Random Sampling.
5	Stratified Random Sampling.
6	Ratio Estimation.
7	Regression Estimation.

USST 303 is a new paper for any student of S.Y.B.Sc. Student must have passed 12th standard with Mathematics. If not then He/She has to complete the required bridge course.

Course Code	Title	Credits
USST303	**OPERATIONS RESEARCH 1**	**2 Credits (45 lectures)**
Unit I : Linear Programming Problem (L.P.P.) : Mathematical Formulation: Maximization & Minimization. Concepts of Solution, Feasible Solution, Basic Feasible Solution, Optimal solution. Graphical Solution for problems with two variables. Simplex method of solving problems with two or more variables. Big M method. Concept of Duality. Its use in solving L.P.P. Relationship between optimum solutions to Primal and Dual. Economic interpretation of Dual.		**15 Lectures**
Unit II : Transportation Problem: Concept, Mathematical Formulation. Concepts of Solution, Feasible Solution. Initial Basic Feasible Solution by North-West Corner Rule, Matrix Minima Method, Vogel's Approximation Method. Optimal Solution by MODI Method. Optimality test, Improvement procedure. Variants in Transportation Problem: Unbalanced, Maximization type.		**15 Lectures**
Unit III :Assignment Problem: Concept. Mathematical Formulation Solution by: Complete Enumeration Method and Hungarian method. Variants in Assignment Problem: Unbalanced, Maximization type. Travelling Salesman Problem **Sequencing :** Processing n Jobs through 2 and 3 Machines & 2 Jobs through m Machines.		**15 Lectures**

REFERENCES

1. Operations Research: Kantiswaroop and Manmohan Gupta. 4th Edition; S Chand & Sons.
2. Schaum Series book in O.R. Richard Broson. 2nd edition Tata Mcgraw Hill Publishing Company Ltd.
3. Operations Research: Methods and Problems: Maurice Sasieni, Arthur Yaspan and Lawrence Friedman, (1959), John Wiley & Sons.
4. Mathematical Models in Operations Research : J K Sharma, (1989), Tata McGraw Hill Publishing Company Ltd.
5. Principles of Operations Research with Applications to Management Decisions: Harvey M. Wagner, 2nd Edition, Prentice Hall of India Ltd.
6. Operations Research: S.D.Sharma.11th edition, Kedar Nath Ram Nath & Company.
7. Operations Research: H. A.Taha.6th edition, Prentice Hall of India.
8. Quantitative Techniques For Managerial Decisions: J.K.Sharma , (2001), MacMillan India Ltd.

PRACTICALS BASED ON USST 303

COURSE CODE USSTP3(C)

Practical Number	Title of Practical
01	Formulation and Graphical Solution of L.P.P.
02	Simplex Method
03	Duality
04	Transportation Problems
05	Assignment Problems
06	Sequencing Problems
07	Problems solving using TORA

SEMESTER IV

Course Code	Title	Credits
USST401	**PROBABILITY AND SAMPLING DISTRIBUTIONS**	**2 Credits (45 lectures)**
Unit I	**Standard Continuous Probability Distributions**	15 Lectures

Rectangular or Continuous Uniform over (a,b) Mean, Median Standard deviation,C.D.F.M.G.F., Mean ,variance,μ_3 using M.G.F., skewness of distribution.

For X following U (0,1), distribution of i) $\frac{X}{1+X}$, ii) $\frac{X}{1-X}$

Triangular distribution

Symmetric and asymmetric over(a, b) with peak at c

-M.G.F. Mean ,Variance , d.f. Median.

Exponential Distribution

Definition, M.G.F.,C.G.F. raw moments and central moments up to order four using M.G.F..and C.G.F.

- Measures of Skewness and Kurtosis ,Nature of Probability curve

- Median and Quartiles and Percentiles

-Forgetfulness Property with proof and examples based on it.

-Distribution of $X_{(1)}$,first order statistic -Distribution of ratio of two i.i.d. Exponential random variables. -Distribution of - $\frac{1}{\lambda}$ ln(1-X) ,if X follows Uniform (0,1). -Distribution of X+Y and $\frac{X}{X+Y}$,for two independent Exponential variables X and Y with mean1.(All with proof.) **Cauchy (with location and scale parameter)** -Properties with proof. Distribution of 1/ x. c.d.f. and percentiles. **Gamma (with Scale and shape parameter)** Expression for r th raw moment Mean, variance, Mode & Standard deviation. M.G.F., Additive property, C.G.F.. raw moments and central moments up to order four using M.G.F.. and C.G.F. Coefficients of skewness and Kurtosis and nature of probability curve. Distribution of sum of independent Exponential random variables. **Beta Distribution: Type I & Type II** Expression for r th raw moment, Mean, Mode and Standard deviation, H.M. If a r.v.X follows Beta of type 1, distribution of 1- X If a r.v. X follows Beta of type 2, distribution of i) $\frac{1}{1+X}$, ii)$\frac{X}{1+X}$ With proof. For two independent Gamma variables X and Y with parameters m and n respectively, distribution of U = $\frac{X}{Y}$ and V= $\frac{X}{X+Y}$ with proof.		
Unit II	**Normal Distribution**	15 lectures
Definition, Derivation of Mean, Median, Mode, Standard deviation, M.G.F. , C,G,F., Moments & Cumulants (up to fourth order). skewness & kurtosis, Nature of Normal curve, Mean absolute deviation. Properties of Normal Distribution. Expression for even order central moments and to show that odd order central moments are zero. Percentiles.		

Distribution of Standard normal variable, Percentiles.

Distribution of linear function of independent Normal variables

(i).aX, (ii). X+b, (iii). aX+bY in particular X+Y and X-Y, (iv) $\sum_{i=1}^{P} a_i x_i$ (all with proof.)

Fitting of Normal Distribution.

Central Limit theorem for i.i.d. random variables.(with proof)

Log Normal Distribution: Derivation of mean & variance.

Mode, Median and relation between them.

Distribution of product of n log normal random variables.

Unit III	**Exact Sampling Distributions**	15 lectures

Chi-Square Distribution:

Derivation of p.d.f. , Concept of degrees of freedom. Mean, Mode & Standard deviation. M.G.F.,C.G.F., Measures of skewness and Kurtosis, Additive property

Distribution of ratio of two independent Chi-square variables

Distribution of $\frac{X}{X+Y}$ if X and Y are two independent Chi-square variables

(All with proof)

Distribution of the sum of squares of independent Standard Normal variables. Sampling distributions of sample mean and sample variance and their independence for a sample drawn from Normal distribution (with proof).

Applications of Chi-Square:

Development of decision criterion with test procedures of

(i) Test of significance for specified value of variance of a Normal population

(ii) Test for goodness of fit,

Test Procedure for independence of attributes.

(i) r × c contingency table,
(ii) 2×2 contingency table, Derivation of test statistic, Yates' correction with proof

Derivation of Confidence interval for the variance of a Normal population when

(i) mean is known, ,
(ii) mean is unknown.

Student's t-distribution:

Derivation of p.d.f. **,** Mean, Median, Mean Deviation & Standard deviation. M.G.F., C.G.F. , Measures of skewness and Kurtosis and Additive property

Limiting distribution of t distribution with proof.

Applications of t:

Development of decision criterion with test procedure of Test of significance for specified value of mean of Normal population.

Test procedure of test of significance for difference between means of

(i) two independent Normal populations with equal variances

(ii) Dependent samples (Paired t test)

Derivation of Confidence intervals for

(i) Mean of Normal population,
(ii) difference between means of two independent Normal populations having the same variance

Snedecor's F-distribution:

Derivation of p.d.f. **,** Expression for r^{th} raw moment, Mean, variance, Mode & Standard deviation

Distribution of Reciprocal of F variable with proof.

Applications of F:

Test procedure for testing equality of variances of two independent Normal populations

i. Mean is known
ii. Mean is unknown

Derivation of confidence interval for ratio of variances of two independent Normal populations.

REFERENCES:

1. Introduction to the theory of statistics: A M Mood, F.A. Graybill, D C Boyes; Third Edition; McGraw-Hill Book Company.
2. Introduction to Mathematical Statistics: R.V.Hogg, A.T. Craig; Fourth Edition; Collier McMillan Publishers.
3. Probability and Statistical Inference: R.V.Hogg, E. A.Tannis, Third Edition; Collier McMillan Publishers.
4. John E. Freund's Mathematical Statistics: I. Miller, M. Miller; Sixth Edition; Pearson Education Inc.
5. Introduction to Mathematical Statistics: P.G. Hoel; Fourth Edition; John Wiley & Sons Inc.
6. Fundamentals of Mathematical Statistics: S.C. Gupta, V.K. Kapoor; Eighth Edition; Sultan Chand & Sons.
7. Mathematical Statistics: J.N. Kapur, H.C. Saxena; Fifteenth Edition; S. Chand & Company Ltd.

8. Statistical Methods- An Introductory Text: J. Medhi; Second edition; Wiley Eastern Ltd.
9. An Outline of Statistical Theory Vol. 1: A.M. Goon, M.K. Gupta, B. DasGupta; Third Edition; The World Press Pvt. Ltd.

Course Code	Title	Credits
USST402	**ANALYSIS OF VARIANCE & DESIGN OF EXPERIMENTS**	**2 Credits** **(45 lectures)**
Unit I : Analysis of Variance: Introduction, Uses, Cochran's Theorem (Statement only). One way classification with equal & unequal observations per class, Two way classification with one observation per cell. Mathematical Model, Assumptions, Expectation of various sums of squares, F-test, Analysis of variance table. Least square estimators of the parameters, Variance of the estimators, Estimation of treatment contrasts, Standard Error and Confidence limits for elementary treatment contrasts.		15 Lectures
Unit II : Design Of Experiments: Concepts of Experiments, Experimental unit, Treatment, Yield, Block, Replicate, Experimental Error, Precision. Principles of Design of Experiments: Replication, Randomization & Local Control. Efficiency of design D1 with respect to design D2. Choice of size, shape of plots & blocks in agricultural & non agricultural experiments. **Completely Randomized Design (CRD) & Randomized Block Design (RBD):** Mathematical Model, Assumptions, Expectation of various sums of squares, F-test, Analysis of variance table. Least square estimators of the parameters, Variance of the estimators, Estimation of treatment contrasts, Standard error and Confidence limits for elementary treatment contrasts. Efficiency of RBD relative to a CRD.		15 Lectures
Unit III : Latin Square Design (LSD): Mathematical Model, Assumptions, Expectation of various sums of squares, F-test, Analysis of variance table. Least square estimators of the parameters, Variance of the estimators, Estimation of treatment contrasts, Standard error and Confidence limits for elementary treatment contrasts. Efficiency of the design relative to RBD, CRD. Missing plot technique for one missing observation in case of CRD, RBD & LSD.		15 Lectures

Factorial Experiments: Definition, Purpose & Advantages. 2^2, 2^3 Experiments. Calculation of Main & interaction Effects. Definition of contrast and orthogonal contrast, Yates' method. Analysis of 2^2 & 2^3 factorial Experiments.	

REFERENCES

1. Experimental Designs: W.G. Cochran and G.M.Cox; Second Edition;John Wiley and Sons.
2. The Design and Analysis of Experiments: Oscar Kempthorne, John Wiley and Sons.
3. Design and Analysis of Experiments: Douglas C Montgomery; 6th Edition;John Wiley & Sons.
4. Design and Analysis of Experiments: M.N.Das and N.C.Giri, 2nd Edition; New Age International (P) Limited;1986.
5. Experimental Design, Theory and Application: Walter T Federer; Oxford & IBH Publishing Co. Pvt. Ltd.
6. Fundamentals of Applied Statistics: S.C.Gupta and V.K.Kapoor; 3rd Edition; Sultan Chand and Sons (2001).
7. Statistical Principles in Experimental Design: B.J. Winer, McGraw Hill Book Company.

DISTRIBUTION OF TOPICS FOR PRACTICALS

SEMESTER-IV
COURSE CODE USSTP4

Sr. No	Semester IV. Course USSTP4(A)
1	Standard Continuous distributions.
2	Normal Distribution.
3	Central Limit Theorem.
4	Chi Square distribution.
5	t distribution.
6	F distribution.

Sr. No	Semester IV .Course USSTP4(B)
1	Analysis of Variance- One Way.
2	Analysis of Variance- Two Way.
3	Completely Randomized Design.
4	Randomized Block Design.
5	Latin Square Design.
6	Missing Observations in CRD, RBD & LSD.
7	Factorial Experiments.

USST 403 is a new paper for any student of S.Y.B.Sc. Student must have passed 12th standard with mathematics. If not then He/She has to complete the required bridge course.

Course Code	Title	Credits
USST403	**Operations Research - 2**	**2 Credits (45 lectures)**
Unit I : CPM and PERT: Objective and Outline of the techniques. Diagrammatic representation of activities in a project: Gantt Chart and Network Diagram. Slack time and Float times. Determination of Critical path. Probability consideration in project scheduling. Project cost analysis. Updating.		**15 Lectures**
Unit II : GAME THEORY Definitions of Two persons Zero Sum Game, Saddle Point, Value of the Game, Pure and Mixed strategy, Optimal solution of two person zero sum games. Dominance property, Derivation of formulae for (2×2) game. Graphical solution of (2×n) and (m×2) games, Reduction of game theory to LPP		**15 Lectures**
Unit III : DECISION THEORY Decision making under uncertainty: Laplace criterion, Maximax (Minimin) criterion, Maximin (Minimax) criterion, Hurwitz α criterion, Minimax Regret criterion. Decision making under risk: Expected Monetary Value criterion, Expected Opportunity Loss criterion, EPPI, EVPI. Bayesian Decision rule for Posterior analysis. Decision tree analysis along with Posterior probabilities.		**15 Lectures**

Sr. No	Semester IV .Course USSTP4(C)
1	CPM-PERT : Construction of Network.
2	Finding Critical Path. Computing Probability of Project completion.
3	Project cost analysis.
4	Updating.
5	Game Theory 1
6	Game Theory 2
7	Decision Theory-1: Decisions Under Uncertainty
8	Decision Theory-2 : Decisions Under Risk
9	Decision Theory-3 : Decision Tree analysis.

REFERENCES

1. PERT and CPM, Principles and Applications: Srinath. 2nd edition, East-West Press Pvt. Ltd.
2. Quantitative Techniques For Managerial Decisions: J.K.Sharma, (2001), MacMillan India Ltd.
3. Mathematical Models in Operations Research: J K Sharma, (1989), Tata McGraw Hill Publishing Company Ltd.

4. Operations Research: S.D.Sharma.11th edition, KedarNath Ram Nath& Company.
5. Operations Research: Kantiswaroop and Manmohan, Gupta. 12thEdition; S Chand & Sons.
6. Schaum Series book in O.R. Richard Bronson. 2nd edition Tata Mcgraw Hill Publishing Company Ltd.
7. Bronson R. : Theory and problems of Operations research, First edition, Schaum's Outline series
8. Operations Research: Methods and Problems: Maurice Sasieni, Arthur Yaspan and Lawrence Friedman,(1959), John Wiley & Sons.
9. Operations Research: H. A.Taha., 6th edition, Prentice Hall of India.
10. Vora N. D. : Quantitative Techniques in Management, Third edition, McGraw Hill Companies.
11. Bannerjee B. : Operation Research Techniques for Management, First edition, Business Books

Semester End Examination

Theory: At the end of the semester, examination of three (3) hours duration and hundred (100) marks based on the three units shall be held for each course.

Pattern of **Theory question** paper at the end of the semester for ***each course*** will be as follows:
Total number of questions five each of twenty marks.
Question one based on all units. Ten sub-questions of two marks each.
Question two, three, four are based on unit I, unit II and unit III respectively.
Question five based on all units: solve two out of three ten marks each.

Practicals: At the end of the semester, examination of two hours duration and 40 marks shall be held for **each course**. Five marks for journal and Five marks for VIVA. (40+10=50)

Pattern of **Practical question** paper at the end of the semester for **each course**:
There shall be Four questions of ten marks each. Students should attempt all questions.
Question 1 based on Unit 1, Question 2 based on Unit II, Question 3 based on Unit III, Question 4 based on all Three Units combined.
Student should attempt **any two** sub questions out of **three** in each question.

Workload

Theory : 3 lectures per week per course.
Practicals: 3 lecture periods per course per week per batch. All three lecture periods of the practicals shall be conducted in succession together on a single day

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