Revised Syllabi of

T.Y. B.Sc. Statistics (Principal)
(Semester System)

To Be effective from

Academic Year 2010-2011

T.Y. B.Sc. Statistics (Principal)

The code numbers and titles of theory and Practical papers are as follows :

Semester III

ST 331 : Distribution Theory – I

ST 332 : Theory of estimation

ST 333 : Statistical Process Control (On line Methods)

ST 334 : Design of Experiments

ST 335 : C Programming (Turbo C)

ST 336(A) : Operations Management
OR
ST 336(B) : Actuarial Statistics
OR
ST 336(C) : Time Series Analysis

Semester IV

ST 341 : Distribution Theory – II

ST 342 : Testing of Hypotheses

ST 343 : Statistical Process Control (Off line Methods)

ST 344 : Sampling Methods.

ST 345 : Operations Research

ST 346(A) : Medical Statistics
OR
ST 346(B) : Statistical Ecology
OR
ST 346(C) : Statistical Computing Using R software.

Practical Papers

ST 347 : Practical Paper I
ST 348: Practical Paper II
ST 349 : Practical Paper III

University of Pune

Equivalences for the Old Courses(2004-05 to 2009-10) with New Courses (2010 -11 onwards) in Statistics

T. Y. B.Sc. Statistics

Papers in Old Course **(2004-05 to 2009-10)**	Equivalent papers in New Course(2010 -11 onwards)
ST 331: Distribution Theory – I	ST 331 : Distribution Theory – I
ST 332: Theory of estimation	ST 332 : Theory of estimation
ST 333: Statistical Process Control (on line methods)	ST 333 : Statistical Process Control (on line Methods)
ST 334: Sampling Methods.	ST 344 : Sampling Methods.
ST 335: C Programming (Turbo C)	ST 335 : C Programming (Turbo C)
ST 336 A) : Operations Management ST 336 B) : Actuarial Statistics ST 336 C) : Statistical Computing using R software.	ST 336 A) : Operations Management ST 336 B) : Actuarial Statistics ST 346 C) : Statistical Computing using R software
ST 341 : Distribution Theory – II	ST 341 : Distribution Theory – II
ST 342: Testing Hypotheses	ST 342 : Testing of Hypotheses
ST 343 : Statistical Process Control (Off line Methods)	ST 343 : Statistical Process Control (Off line Methods)
ST 344 : Design of Experiments	ST 334 : Design of Experiments
ST 345 : Operation Research	ST 345 : Operation Research
ST 346 A): C++ programming, ST 346 B): Statistical Ecology, ST 346 C): Time Series Analysis.	ST 346 A): No equivalent paper* ST 346 B): Statistical Ecology, ST 336 C): Time Series Analysis
Practicals	
ST 347 : Paper I	ST 347 : Paper I
ST 348 : Paper II	ST 348 : Paper II
ST 349 : Paper III	ST 349 : Paper III

***Since there is no equivalent paper for ST 346 (A) C++ programming , the examination of backlog students will be conducted as per University procedure prescribed in such cases.**

UNIVERSITY OF PUNE
Syllabi for three year Integrated B.Sc. Degree Course
Third Year B.Sc. (Semester System)
(From 2010-2011)
Statistics (Principal)

Note :

1. A student of the three year B.Sc. degree course will not be allowed to offer **Statistics and Statistical Techniques** simultaneously in any of the three years of the course.

2. Students offering **Statistics** at the first year of the three year B.Sc. course may be allowed to offer **Statistical Techniques** as one of their subjects in the second year of the three year B.Sc. course, in place of Statistics.
3. Students offering **Statistical Techniques** at the first year of the three year B.Sc. course may be allowed to offer Statistics as one of their subjects in the second year of the three year B.Sc. course in place of **Statistical Techniques** provided they satisfy other requirements regarding subject combinations, if any.
4. Students must compete all the practicals in each of the practical papers to the satisfaction of the teachers concerned.
5. Students must produce at the time of the practical examination, the laboratory journal along with the completion certificate signed by the Head of the Department.
6. Of the 100 marks for each practical paper, 10 marks shall be reserved for journal and 10 marks for viva. These marks are to be given by concerned teacher in the college. A practical paper shall actually carry 80 marks.
7. In semester III, a student shall offer any one of the following papers.
   ST- 336 (A) : Operation Management
   ST- 336 (B) : Actuarial Statistics
   ST- 336 (C) : Time Series Analysis

8. In semester IV, a student shall offer any one of the following papers.
   ST- 346 (A) : Medical Statistics
   ST- 346 (B) : Statistical Ecology
   ST- 346 (C) : Statistical computing using R

   All other papers of semester III and IV are compulsory.

9. Nature of practical Paper I and II

A) Continuous internal evaluation	**Marks**	**Duration**
i) Journal	10	
ii) Viva-voce	10	
Total of A	20	
B) Annual Practical examination:		
To solve 2 equations out of 4, each of 35 marks	70	3 hours on calculator 2 ½ hours on computer
Viva voce	10	10 minutes
Total of B	80	
Grand Total of A and B	100	3 Hours and 10 minutes

Nature of practical paper III

A) Continuous internal evaluation	**Marks**	**Duration**
i) Journal for C, R or MS Excel/ spreadsheet	5	
ii) Viva for C, R or MS Excel/ spreadsheet	5	
iii) Project Report(Dissertation)	5	
iv) Project viva	5	
Total of A	20	
B) Annual practical examination	**Marks**	
Section I C Programming on computer ,using slips prepared by University. No viva – voce to be conducted for this part.	20	1 Hour and 40 minutes
Section II R or MS Excel/ spreadsheet programming on computer, using slips prepared by University. No viva – voce to be conducted for this part.	20	
Section III Project : Evaluation of Project report(Dissertation) : Viva of individual student	25 15	1 ½ Hour
Total of B	80	3 Hours & 10min.
Total of A and B	100	

Note :

10. Total duration of practical examination will be 3 hours and 10 minutes
11. Batch size should be of maximum 12 students.
12. For Practical papers I and II total time duration using (i) computer is 2 ½ hours (ii) calculator is 3 hours and additional 10 minutes for viva voce in each case.
13. For practical paper III along with internal examination, expert be appointed to find the solution of Section I (C programming part) and Section II (R or MS Excel part)
14. To perform and complete the practicals, it is necessary to have computing facility. So there should be sufficient number of computers, UPS, printer and scientific non programmable calculators in the laboratory.
15. In order to acquaint the students with applications of statistical methods in various fields such as industries, agricultural sectors, government institutes, etc. at least one Study Tour for T.Y. B.Sc. Statistics students must be arranged.
16. For project under practical paper III (ST 349) maximum 5 students are allowed in a group.
17. Copy of the project be made available to the examiner on the first day of practical examination.
18. Use of scientific calculators and statistical tables is allowed for **theory** as well as **practical** examination.
19. **Guidelines for conducting University examination of Paper ST 346 (C) Statistical computing using R software at T.Y. B.Sc. Semester III (as per circular number 61 of 2005)**
    a. The examination will be ON LINE
    b. Provision of at least 15 computers with necessary R software installed should be made available by the centre.
    c. Duration of examination is TWO hours.
    d. Examination will be conducted at the time of theory examination of TY B.Sc. Semester IV. The day ,date and timing of this examination will be same as that of ST346 (A) and ST 346 (B)
    e. The question paper will be printed separately and it is not along with the question papers of ST346 (A) and ST 346 (B)
    f. The examination will be conducted batch wise. A batch will consist of at most 12 candidates.
    g. The batches examined simultaneously will have same question paper. However there will be separate question paper for each batch in case more (than one) batches are required to be formed.
    h. A candidate will solve the question paper given to him/ her on computer and will take a printout of work done by him/her and submit it.

    i. Answer book for this examination will be the answer book which is used at the time of practical examination in other science subject examination.

j. The candidate will have to attach the printout of his/her above referred answer book.
k. The duration of this examination will be extended by 10 minutes for getting printouts.
l. Printouts of Charts, graphs is not required. However they should be shown to the examiner on computer itself.
m. In case of partial power failure proportionate additional time may be given at that center for the concerned batch. In case of total power failure candidates are required to write the answers in the answer book as in the case of regular theory examination.
n. One internal examiner and one external examiner will be appointed for this examination.
o. Examiner for this examination will be from the board of paper setters and examiners of TY B.Sc. / TY B.A. theory examination. The concern the chairman of board of examination will communicate the names of examiners to the University office.
p. Paper setting of this course will be done along with T Y B.Sc. theory examination. Manuscripts of the question papers of 346 (A) will be packed separately and submitted to the University office.
q. University office will prepare 15 copies of that set and send them to concerned centers.
r. External examiner will examine the answer books of candidates immediately after exam is over. He/ She will prepare mark list and send it to the University office / CAP Director. He/ She will send the assessed answer books to the University.
s. For the conduct of this examination the following staff will be appointed at the centre for each batch. Two peons, one junior supervisor, one laboratory supervisor, one laboratory assistant and one machine mechanic.
t. Remuneration to both examiners will be paid at the rate which is prescribed by the University for the examiners of Practical examination of science subjects after the examination work is over.

Semester III

ST : 331 DISTRIBUTION THEORY – I

1. Multinomial Distribution (10 L)

$$P(X_1 = x_1, X_2 = x_2, \cdots, X_k = x_k) = \frac{n!\; p_1^{x_1}\; p_2^{x_2} \cdots p_k^{x_k}}{x_1!\, x_2! \cdots x_k!},$$

$x_i = 0,1,2 \cdots, n;\ i = 1,2 \cdots, k$

$x_1 + x_2 + \cdots x_k = n$

$p_1 + p_2 + \cdots + p_k = 1$

$0 < p_i < 1,\ i = 1,2 \cdots, k$

$= \quad 0 \qquad$ elsewhere.

Notation : $(X_1, X_2, \cdots, X_k) \sim MD(n, p_1, \cdots, p_k)$, $\underline{X} \sim MD(n, \underline{p})$

Where, $\underline{X} = (X_1, X_2, \cdots, X_k)$, $\underline{p} = (p_1, p_2, \ldots, p_k)$

1.1 Joint MGF of $(X_1, X_2, \cdots, X_k)$

1.2 Use of MGF to obtain means, variances, covariances, total correlation coefficients, multiple and partial correlation coefficients for k= 3, univariate marginal distribution, distribution of X_i+X_j. Conditional distribution of X_i given $X_i+X_j = r$

1.3 Variance – covariance matrix, rank of variance – covariance matrix and its interpretation.

1.4 Real life situations and applications.

2. Beta Distribution (8L)

2.1 Beta distribution of first kind

p.d.f. $f(x) = \frac{1}{B(m,n)} x^{m-1} (1-x)^{n-1}, \qquad 0 \le x \le 1, \qquad m,n > 0$

$= 0, \qquad$ elsewhere.

Notation : $X \sim \beta_1(m,n)$

Nature of probability curve, mean, variance, properties, r^{th} raw moment, harmonic mean.

2.2 Relation with U(0,1). The probability distributions of

$\frac{1}{X}$, X+Y, X-Y, XY, $\frac{X}{Y}$, where X and Y are iid $\beta_1(1,1)$

2.3 Beta distribution of second kind

p.d.f. $f(x)=\frac{1}{B(m,n)}.\frac{x^{m-1}}{(1+x)^{m+n}}$, $x \geq 0$, m,n >0

= 0, elsewhere,

Notation : X~ β_2 (m,n)

Nature of probability curve, mean, variance, properties, r^{th} raw moment, harmonic mean.

2.4 Interrelation between β_1(m,n) and β_2 (m,n).

2.5 Distribution of $\frac{X}{Y}$, $\frac{X}{X+Y}$ etc. when X and Y are independent gamma variates.

2.6 Relation between distribution functions of β_1(m,n) and binomial distribution.

2.7 Real life situations and applications .

3. Weibull Distribution **(6 L)**

3.1 p.d.f

$$f(x) = \frac{\beta}{\alpha}\left(\frac{x}{\alpha}\right)^{\beta-1} \exp\left\{-\left(\frac{x}{\alpha}\right)^{\beta}\right\} \qquad x \geq 0,\ \alpha , \beta>0$$

= 0, elsewhere

Notation : X~ W(α , β).

3.2 Probability curve, location parameter, shape parameter, scale parameter, Distribution function, quartiles, mean and variance, coefficient of variation, relationship with gamma and exponential distribution, Hazard rate, IFR and DFR property.

3.3 Real life situations and applications..

4. Order Statistics **(10 L)**

4.1 Order statistics for a random sample of size n from a continuous distribution, definition, derivation of distribution function and density function of the i-th order statistic $X_{(i)}$, particular cases for i=1 and i=n. Distribution of $X_{(i)}$ for random sample from uniform and exponential distributions.

4.2 Derivation of joint p.d.f. of ($X_{(i)}$, $X_{(j)}$), probability distribution of sample range $X_{(n)}$-$X_{(1)}$.

4.3 Distribution of sample median.

4.4 Corr ($X_{(i)}$, $X_{(j)}$), when X_1, X_2 ……X_n are i.i.d. uniform r.v.s ,distribution of $X_{(n)}$ - $X_{(1)}$ and sample median. Comment on unbiased estimator of θ for U(0, θ) and exponential(θ) based on order statistics.

5. Chebychey's Inequality. (6L)

5.1 Chebychev's theorem : If g (x) is a non – negative function of r.v. X such that $E[g(x)] < \infty$, then $P[g(x) \geq k] \leq E[g(X)]/k$,where k is positive real number.

5.2 Chebychev's inequality for discrete and continuous distributions in the forms

$P[|X-\mu| \geq k] \leq \frac{\sigma^2}{k^2}$, k>1 , $P[|X-\mu| \geq k\sigma] \leq \frac{1}{k^2}$

where μ= E(X) and σ^2= Var (X) <∞.

5.3 Applications of Chebychev's inequality in control charts, statistical inference.

6. Central Limit Therom and Weak Law of Large Numbers (8 L)

6.1 Sequence of r.v.s. , convergence of sequence of r.v. in a) probability b) distribution with simple illustrations.

6.2 Statement and proof of the central limit theorem for i.i.d. r.v.s. (proof based on MGF).

6.3 Weak law of large numbers (WLLN).

6.4 Applications of CLT and WLLN..

Books Recommended :

1. H. Cramer : Mathematical Methods of Statistics, Asia Publishing House, Mumbai.
2. Mood, A.M. Graybill, F.Bose, D.C : Introduction to Theory(IIIrd Edition) Mc-Graw Hill Series.
3. B.W. Lindgren : Statistical Theory (IIIrd Edition) Collier Macmillan International Edition, Macmillan Publishing Co.Inc. NewYork.
4. Hogg, R.V. and Craig A.T. : Introduction to Mathematical Statistics (IIIrd Edition), Macmillan Publishing Company, Inc.866 34d Avenue, New York, 10022.
5. Sanjay Arora and Bansi Lal : New Mathematical Statistics (Ist Edition), Satya Prakashan16/17698, New Market, New Delhi,5(1989).
6. S.C. Gupta and V. K. Kapoor : Fundamentals of Mathematical Statistics, Sultan Chand and Sons, 88, Daryaganj, New Delhi, 2.
7. V.K. Rohatgi : An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern Ltd. New Delhi.
8. J. Medhi: Stochastic Processes, Wiley Eastern Ltd…. New Delhi.
9. Hoel, Port and Stone, Introduction to Stochastic Processes, Houghton Miffin.
10. Feller W. : An Introduction of Probability Theory and Its Applications, Vol. I, Wiley Eastern Ltd. Mumbai.
11. Sheldon Ross: A first course in probability (6th edition) : Pearson Education, Delhi.

ST 332 : THEORY OF ESTIMATION

1. Point Estimation (4L)

1.1 Notion of a parameter, parameter space , general problem of estimating an unknown parameter by point and interval estimation.

1.2 Point Estimation : Definition of an estimator, distinction between estimator and estimate , illustrative examples.

2. Methods of Estimation (12L)

2.1 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 p.d.f./ p.m.f.

2.2 **Method of maximum likelihood**: Derivation of maximum likelihood estimator (M.L.E.) for parameters of only standard distributions (case of two unknown parameters only for normal distribution). Use of iterative procedure to derive (M.L.E.). of location parameter μ of Cauchy distribution. Invariance property of (M.L.E.)

2.3 a) M.L.E. of θ in uniform distribution over i) $(0, \theta)$ ii)$(- \theta, \theta)$ iii) $(m\theta, n\theta)$

b) M.L.E. of θ in $f(x ; \theta)= \text{Exp}\{-(x- \theta)\}, x > \theta$.

2.4 Method of Moments : Derivation of moment estimators for standard distributions. Illustrations of situations where M.L.E. and moment estimators are distinct and their comparison using mean square error.

3. Properties of Estimator (20L)

3.1 **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.

a) Two distinct unbiased estimators of $\varphi(\theta)$ give rise to infinitely many estimators.

b) If T is an unbiased estimator of θ , then $\varphi(T)$ is unbiased estimator of $\varphi(\theta)$ provided $\varphi(.)$ is a linear function.

3.2 Notion of the Best Linear Unbiased Estimator and uniformly minimum variance unbiased estimator (UMVUE), uniqueness of UMVUE whenever it exists.

3.3Sufficiency: Concept and definition of sufficiency, statement of Neyman's factorization theorem (Proof for discrete probability distribution.) Pitmann – Koopman form and sufficient statistic; Exponential family of probability distributions and sufficient statistic.

Proofs of the following properties of sufficient statistics.

i) If T is sufficient for θ, then $\varphi(T)$ is also sufficient for θ provided φ is a one to one and onto function.

ii) If T is sufficient for θ then T is also sufficient for $\varphi(\theta)$.

iii) M.L.E. is a function of sufficient statistic.

3.4 Fisher information function: amount of information contained in statistic $T = T(X_1,X_2, \ldots, X_n)$. Statement regarding information in sample and in a sufficient statistic T.

3.5 Cramer- Rao Inequality : Statement and proof of Cramer - Rao inequality, Cramer – Rao Lower Bound(CRLB)definition of minimum variance bound unbiased estimator (MVBUE) of ø (θ) . Proofs of following results:

a). If MVBUE exists for θ then MVBUE exists for φ(θ) where φ(.) is a linear function.

b). If T is MVBUE for θ then T is sufficient for θ.

3.6 Efficiency : Comparison of variance with CRLB, relative efficiency of T_1 w.r.t. T_2 for (i) unbiased (ii) biased estimators. Efficiency of unbiased estimator T w.r.t. CRLB.

Asymptotic Behaviour of an Estimator **(6L)**

3.7 **Consistency** : Definition , proof of the following theorems:

a. An estimator is consistent if its bias and variance both tend to zero as the sample size tends to infinity.
b. If T is consistent estimator of θ and φ (.) is a continuous function, then φ (T) is a consistent estimator of φ (θ).

3.8 Consistency of M.L.E.(Statement only).

4. Interval Estimation **(6L)**

Notion of interval estimation, definition of confidence interval (C.I), length of C.I., confidence bounds. Definition of pivotal quantity and its use in obtaining confidence intervals.

Interval estimation for the following cases.

i) Mean (μ) of normal distribution (σ^2 known and σ^2 unknown).
ii) Variance (σ^2) of normal distribution (μ known and μ unknown).
iii) Median, quartiles using order statistics.

Books Recommended :

1. Lindgren, B.W.: Statistical Theory (third edition) collier Macmillan International Edition, Macmillan publishing Co., Inc. New York.
2. Mood, A.M., Graybill, F. and Bose, D.C. : Introduction to the theory of Statistics (third edition) International Student Edition, McGraw Hill Kogakusha Ltd.
3. Hogg, P.V. and Craig, A.J. : Introduction to Mathematical Statistics (fourth edition), Collier Macmillan International Edition, Macmillan Publishing Co. Inc., New York.
4. Siegel, S. : Nonparametric methods for the behavioral sciences, International Student Edition, McGraw Hill Kogakusha Ltd.
5. Hoel, Port, Stone : Introduction to statistical Theory, Houghton Mifflin Company (International) Dolphin Edition.
6. J.D. Gibbons : Non parametric Statistical Inference, McGraw Hill Book Company, New York.
7. Daniel : Applied Nonparametric Statistics, Houghton Mifflin Company, Roston.
8. V.K. Rohatagi : An introduction to probability theory and mathematical statistics, Wiley Eastern Ltd., New Delhi.
9. Kendall and Stuart : The advanced Theory of Statistics, Vol 1, Charles and company Ltd., London.
10. Dudeweitz and Mishra : Modern Mathematical Statistic, John Wiley and Sons, Inc., New York.

ST 333 : STATISTICAL PROCESS CONTROL (On Line Methods)

1. Introduction (4 L)

Meaning and purpose of Statistical Process Control (SPC), quality of the product, need of process control, statistical process control, on line process control methods (control charts) and offline process control methods (Sampling schemes and plans) as lot control method.

2. Seven Process Control (PC) Tools of SPC (6L)

(i) Check Sheet, (ii) Cause and effect diagram (CED),

(iii) Pareto Diagram, (iv) Histogram,

(v) Control chart, (vi)Scatter Diagram,

(vii) Design of Experiments (DOE).

3. Control Charts (30L)

3.1 Chance causes and assignable causes of variation, statistical basis of control charts, exact probability limits, k -sigma limits, justification for the use of 3- sigma limits for normal distribution and using Chebychev's inequality for non-normal distributions. Criteria for detecting lack of control situations:

(i) A point outside the control limits

(ii) Non random pattern of variation of the following type

(a) A run of seven or more points above or below central line.

(b) Presence of cycle or linear trends etc.

Control chart technique as hypotheses testing problem.

Construction of control charts for (i) standards given, (ii) standards are not given. Uses of control charts.

3.2 **Control charts for Attributes** :

(I) p - chart:

Decisions preparatory to control charts

(i) Size of subgroups

(ii) Frequency of subgroups (periodicity).

Construction and working of p - chart

p-chart when subgroup sizes are same and value of the process fraction defective p is specified : control limits, drawing of control chart, plotting of sample fraction defectives, revision of control limits if necessary, estimation of p for future use. Determination of state of control of the process. Interpretation of high and low spots. Probability of detecting the shift in process fraction defective (or signal) using normal approximation.

P-chart when subgroups sizes are different and value of the process fraction defective p is not specified : different types of control limits:

(i) Separate control limits, (ii) control limits based on average sample size,

(iii) stabilized (standardized P)control limits, drawing of control chart, plotting sample fraction defective, determination of state of control of the process. Identification of real life situations. Limitations of P- chart.

(II) **Confirming run length Chart (CRL)** : Concept, runs formed due to defective and good items, LCL for number of runs. Interpretation. Distinction between CLR and p-chart.

(III) **C chart :** Construction of C-chart when standard is given; control limits justification of 3 sigma limits, drawing of control chart, plotting number of defects per unit. Construction of c-chart when standard is not given; control limits, explanation for the use of 3 sigma limits, drawing of control chart. Plotting number of defects per unit, revision of control limits, if necessary, estimate of process parameter for future use.

Determination of state of control, interpretation of high and low spots in above cases. Identification of real life situations. Probability of detecting shift (or signal) in parameter λ. Comparison between P and C charts. Limitations of C- chart.

3.3 Control charts for variables

(I) Run chart for variable characteristics

(II) Decisions preparatory to control charts :

(i) choice of the variable.

(ii) Basis of subgroups (rational subgroups)

(iii) Size of subgroups

(iv) Frequency of subgroups (periodicity).

(III) R chart and $\overline{X}$ chart

Purpose of R and $\overline{X}$ chart, normal probability plot for checking normality assumption, construction of R chart when the process standard deviation is specified : control limits, drawing of control chart, plotting of sample ranges, drawing conclusion - determination of state of control process, corrective action if the process is out of control.

Construction of $\overline{X}$ chart when the process average is specified: control limits, drawing of control chart, plotting of sample means. Drawing conclusion - determination of state of control process, corrective action if the process is out of control.

(IV) Construction of R chart when the process standard deviation (σ) is not given: control limits, drawing of control chart, plotting sample range values, revision of control limits if necessary, estimate of σ(σ) for future use. Construction of $\overline{X}$ chart when the process average μ is not given : control limits based on σ, drawing of control chart, plotting sample means, revision of control limits of $\overline{X}$ chart, if necessary.

Note : to find revised control limits of any control chart delete the sample points above UCL and points below LCL, in case of R and $\overline{X}$ charts, first of all, revisions of control limits of R is to be completed and then by using the observations for which R chart shows the process is under control, the control limits for $\overline{X}$ chart should be determined. Revision of control limits of $\overline{X}$ chart be continued without revising the value of *R* or σ.

Estimate of μ for further use. Determination of state of control of the process. Identification of real life situations where this technique can be used. Limitations of $\overline{X}$, R charts. Comparison between $\overline{X}$, R, P and C charts.

(V) X-MR chart (individual moving range chart).

4. Capability Studies (8 L)

4.1 Specification limits, natural tolerance limits and their comparisons, decisions based on these comparisons, estimate of percent defective.

4.2 Shift in the process average, evaluation of probability of detecting a shift (or getting signal) on the first sample or on the subsequent samples after the shift (when process standard deviation is fixed). Average Run Length (ARL)for $\overline{X}$ chart, Average Time to Signal (ATS). Operating Characteristic (O.C.) curve for $\overline{X}$ chart, using normality assumption.

4.3 Capability ratio and capability indices (C_p), capability performance indices C_{pk} with respect to machine and process, interpretation, relationship between (i) C_p and C_{pk} (ii) defective parts per million and C_p.

Books Recommended

1. Duncan A.J. : Quality Control and Industrial Statistics, D.B. Taraporewala Sons and Co. Pvt. Ltd., Mumbai.
2. Grant, E. L. and Leavenworth : Statistical Quality Control, Mc-Graw Hill Kogakusha Ltd., New Delhi.
3. Montgomery, D. C. : Statistical Quality Control, John Wiley and Sons, Inc., New York.
4. Kamji and Asher : 100 Methods of TQM, Sage Publishers, Delhi.
5. Johnson and Kotz : Capability Studies, Chapman and Hall Publishers.
6. SP20 : Handbook of SQC, Bureau of Indian Standards.
7. D.H. Besterfield, C.B. Michna etc. Total Quality Management (3rd edition 2009) : Pearson Education, Delhi.

ST 334 : DESIGN OF EXPERIMENTS

1. Design of Experiments (20 L)

1.1 Basic terms of design of experiments : Experimental unit, treatment , layout of an experiment.

1.2 Basic principles of design of experiments : Replication, randomization and local control.

1.3 Choice of size and shape of a plot for uniformity trials, the empirical formula for the variance per unit area of plots.

1.4 Analysis of variance (ANOVA): concept and technique.

1.5 Completely Randomized Design (CRD) : Application of the principles of design of experiment in CRD, Layout, Model: (Fixed effect)

$X_{ij} = \mu + \alpha_i + \varepsilon_{ij}$ i= 1,2, …….t. j = 1,2,………., n_i

assumptions and interpretations. Testing normality by pp plot.

Breakup of total sum of squares into components. Estimation of parameters, expected values of mean sums of squares, components of variance, preparation of (ANOVA) table, testing equality of treatment effects, linear treatment contrast, Hypothesis to be tested

$H_0 : \alpha_1 = \alpha_2 = \ldots = \alpha_t = 0$ and interpretation comparison treatment means using box plot techniques. Statement of Cochran's theorem. F test for testing H_0 with justification (independence of chi- square is to be assumed), test for equality of two specified treatment effects using critical difference (C.D).

1.6 Randomized Block Design (RBD) : Application of the principles of design of experiments in RBD, layout model:

$X_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij}$ i= 1,2, …….t. j = 1,2,………. b,

Assumptions and interpretations.

Breakup of total sum of squares into components. Estimation of parameters, expected values of mean sums of squares, components of variance , preparation of analysis of variance table, Hypotheses to be tested

$H_{01} : \alpha_1 = \alpha_2 = \alpha_3 = \ldots = \alpha_t = 0$

$H_{02} : \beta_1 = \beta_2 = \beta_3 = \ldots = \beta_b = 0$

F test for testing H_{01} and H_{02} with justification (independence of chi-squares is to be assumed), test for equality of two specified treatment effects using critical difference(CD).

1.7 Latin Square Design (LSD): Application of the principles of design of experiments in LSD, layout, Model :

$X_{ij(k)} = \mu + \alpha_i + \beta_j + \gamma_k + \varepsilon_{ij(k)}$ i = 1,2, ⋯m, j = 1,2⋯,m, k=1,2⋯,m.

Assumptions and interpretations.

Breakup of total sum of squares into components. Estimation of parameters, expected values of mean sums of squares, components of variance , preparation of analysis of variance table, hypotheses to be tested.

$H_{01} : \alpha_1 = \alpha_2 = \cdots = \alpha_m = 0$

$H_{02} : \beta_1 = \beta_2 = \cdots = \beta_m = 0$

$H_{03} : \gamma_1 = \gamma_2 = \cdots = \gamma_m = 0$ and their interpretation.

Justification of F test for H_{01}, H_{02} and H_{03} (independence of chi- square is to be assumed). Preparation of ANOVA table and F test for H_{01}, H_{02} and H_{03} testing for equality of two specified treatment effects, comparison of treatment effects using critical difference, linear treatment contrast and testing its significance. .

1.8 Analysis of non- normal data using
- i) Square root transformation for counts.
- ii) Sin^{-1}(.) transformation for proportions.
- iii) Kruskal Wallis H test.

1.9 Identification of real life situations where the above designs are used

2. Efficiency of Design (5L)

2.1 Concept and definition of efficiency of a design.
2.2 Efficiency of RBD over CRD.
2.3 Efficiency of LSD over (i) CRD (ii) RBD.

3. Split Plot Design (4L)

3.1 General description of a split plot design.
3.2 Layout and model.
3.3 Analysis of variance for testing equality of main plot treatments means, sub plot treatment means and interactions.

4. Factorial Experiments (12L)

4.1 General description of m^n factorial experiment, 2^2 and 2^3 factorial experiments arranged in RBD.
4.2 Definitions of main effects and interaction effects in 2^2 and 2^3 factorial experiments.
4.3 Yate's procedure, preparation of ANOVA table, test for main effects and interaction effects.
4.4 General idea of confounding in factorial experiments.
4.5 Construction of layouts in total confounding and partial confounding in 2^2 and 2^3 factorial experiments.
4.6 Total confounding (confounding only one interaction) ANOVA table, testing main effects and interaction effects.
4.7 Partial confounding (confounding only one interaction per replicate); ANOVA table, testing main effects and interaction effects.

5. Analysis of Covariance (ANOCOVA) with One Concomitant Variable (7L)

5.1 Situations where analysis of covariance is applicable.
5.2 Model for covariance in CRD, RBD. Estimation of parameters (derivations are not expected)
5.3 Preparation of analysis of variance – covariance table, test for $\beta=0$, test for equality of treatment effects (computational technique only).

Note : For given data, irrespective of the outcome of the test of regression coefficient (β), ANOCOVA should be carried out.

Books Recommended

1. Federer , W.T. : Experimental Design : Oxford and IBH Publishing Co., New Delhi.
2. Cochran W.G. and Cox, C.M. : Experimental Design, John Wiley and Sons, Inc., New York.
3. Montgomery , D.C.: Design and Analysis of Experiments, and sons, Inc., New York.
4. Dass, M.N. and Giri,N.C. : Design and Analysis of Experiments, Wiley Eastern Ltd., New Delhi.
5. Goulden G.H. : Methods of Statistical Analysis, Asia Publishing House Mumbai
6. Kempthorne, O: Design of Experiments.
   Wiley Eastern Ltd., New Delhi.
7. Snedecor, G.W. and Cochran, W.G. : Statistical Methods, Affiliated East – West Press, New Delhi. (for 1.8)
8. Goon , Gupta,Dasgupta : Fundamentals of Statistics, Vol.II, The world Press Pvt. Ltd. Kolkatta .
9. Gupta S.C. and Kapoor V.K.: Fundamentals of Applied Statistics, S.Chand Sons, New Delhi.
10. C.F. Jeff Wu, Michael Hamda: Experiments, Planning, Analysis and Parameter Design Optimization.
11. Miller and Freund : Probability and Statistics for engineers, Pearson Education, Delhi (for 1.8)

ST 335 : C Programming (Turbo C)

1. Introduction (11 L)

1.1 Algorithms and flowcharts.
1.2 Introduction to procedurals language, middle level language, higher level language, general language structure, character set, keywords, identifiers.
1.3 Data types: Numeric and character data types, Numeric and character constants, string constants, symbolic constants.
1.4 Operators: Numeric, logical, arithmetic, unary, relational, equality, decrement, increment, conditional assignments, precedence of operator expressions and their evaluation.
1.5 Data input/output, numeric and character data, printf ( ), scanf ( ), getchar ( ), putchar ( ), gets ( ), puts ( ).

2 Control Structures (15L)

If, if else, while, do….while, for, switch, goto, break, continue, nested loops, programs using control structures.

3 Arrays (10L)

3.1 Concept, declaration, definition, initialization of array, problem using arrays, passing to function, arrays and string.
Writing C programs using arrays.
3.2 To find mean, median, variance and coefficient of variation of frequency distribution.
3.3 To find correlation coefficient and least square regression lines for a given bivariate data.
3.4 To arrange the given data in increasing/decreasing order of magnitude.
3.5 To obtain median of given n observations.
3.6 To obtain addition of two metrics, multiplication of two matrices.

4 Functions (6L)

Declaration, definition, recursion, user defined functions, library function, by reference, by value, local and global variables.

5 Pointers (4L)

Basic concept, pointer arithmetic, relation to identifier, application to strings, arrays of pointers.

6 Structures and Unions (2L)

Concept and syntax only, (programs using structures and unions are not expected).

List of Simple Programs such as (short programs)

1. Converting °C temperature to °F.
2. To carry out arithmetic calculations.
3. To check whether given number is odd or even.
4. To check whether given number m is divisible by n or not.
5. To find maximum of 2 numbers or 3 numbers.
6. To find area of triangle and circle.

7.To find roots of quadratic equation.
8.To check whether integer is prime or not.
9. To find mean of n numbers.
10. To find sum of digits of a number.
11. To solve simultaneous linear equations. .(two equations in two variables)
12. To evaluate simple and compound interest
13. To solve transcendental equations using Newton- Raphson method.
14. To evaluate exp(x), sin (x), log (x) etc. using Taylor's series expansion.

C programs (long programs)

15. Program in C to prepare a frequency distribution with given class interval from raw data.
16. Program in C to find mean, variance, standard deviation and quartiles for given n observations and frequency distribution.

.

17. Program in C to fit a Binomial distribution to given data.

18. Program in C to evaluate definite integral using trapezoidal rule and Simpson's 1/3 rule .

Books Recommended.

1. Karnighan, B. W. and Ritchi,. M,: The C programming language.
2. Rajaram: Computer programming in C, Prentice Hall (east economy edition).
3. Kanithar, Y.: Let us C, BFB publishers, New Delhi.
4. Gottfried: Programming with C (Schaum Outline series), McGraw Hill co., London.

ST 336 (A): OPERATIONS MANAGEMENT

1) Critical Path Method (CPM) and Project Evaluation and Review Techniques (PERT) (22L)

1.1 Definition of (i) Event,(ii) Node,(iii)Activity,(iv)Critical Activity,(v)Project Duration.

1.2 CPM: Construction of network, Definitions

(i) earliest start time

(ii) earliest finish time

(iii) latest start time

(iii) latest finish fine for an activity.

Critical Path , Types of float , total floats, free float, independent float and their significance. Determination of critical path

1.3 PERT: Construction of network; (i) pessimistic time estimate, (ii) optimistic time estimate (iii) most likely time estimates, Determination of critical path, determination of mean and standard deviation of project duration, computations of probability of completing the project in a specified duration.

1.4 Cost benefit Analysis: Definitions of normal time, crash time, normal cost, crash cost, cost slope, direct cost, indirect cost, project cost, determination of project duration and its associated cost when (i)Normal time are considered,(ii)Crash times are considered. Determination of optimal network.

2) Inventory Models (10L)

2.1 Always Better Control (ABC) analysis; Vital, Essential and Desirable (VED) Analysis; Fast moving, Non moving, Slow moving, Dead (FNSD) Analysis.

2.2 Description of generalized inventory model.

2.3 Types of inventory models:

a) The economic lot size model with uniform demand, instantaneous replenishment rate and no shortage(with derivation)
b) The Economic lot size model with uniform rate of demand, finite replenishment rate and no shortage(with derivation)
c) The economic lot size model with uniform demand, instantaneous replenishment with shortage(without derivation)
d) The economic lot size model with uniform rate of demand, finite replenishment rate with shortage (without derivation).

3) Decision Theory (10L)

3.1 Decision under risk: Expected value criteria

3.2 Decision Trees

3.3 Decision under uncertainty

(a) Laplace criterion

(b) Minimax / Maximax criterion

(c) Savage minimax regret criterion

(d) Hurwitz criterion

4) Replacement Models (6L)

4.1 Introduction

4.2 Replacement of item that deteriorates with time when
(a) value of money remains same during the period (for time as a discrete variable and (continuous variable).
(b)) value of money changes with constant rate during the period.

Books Recommended

1. Gass E.: Linear Programming Method and Applications, Narosa Publishing House, New Delhi.
2. Taha, R. A.: Operation Research – An Introduction, Fifth Edition, Prentice Hall of India, New Delhi.
3. Saceini Yaspan, Friedman : Operation Research Method and Problems, Wiley International Edition.
4. Shrinath L.S.: Linear Programming, AffiliatedEast-West Press Pvt. Ltd. New Delhi.
5. Phillips, D.T., Ravindra, A., Solberg, J. : Operations Research Principles and Practice, John Wiley and Sons Inc.
6. Sharma J. K.: Mathematical Models in Operations Research, Tata McGraw Hill Publishing Company Ltd., New Delhi.
7. Kapoor, V. K.: Operation Research, Sultan Chand and Sons, New Delhi.
8. Gupta, P. K. and Hira, D.S.: Operations Research, S. Chand and company Ltd., New Delhi.
9. Shrinath, L.S.: PERT-CPM Principles and Applications, Affiliated East-West Press Pvt. Ltd., New Delhi.

ST 336 (B): ACTUARIAL STATISTICS

1) Insurance Business (3L)

1.1 Insurance companies as business organizations.

1.2 Role of insurance business in Economy.

1.3 Concept of risk, types of risk, characteristics of insurable risk.

1.4 Working of insurance business, introduction of terms such as premium, policy, Policyholder and benefit.

1.5 Role of Statistics in insurance.

1.6 Insurance business in India.

2) Feasibility of Insurance Business (4L)

2.1 Measurement of adverse financial impact, expected value principle.

2.2 Concept of utility function

2.3 Feasibility of insurance business.

2.4 Illustrative examples.

3) Survival Distribution and Life Tables (12L)

3.1 Time- until death r.v., its d.f. and survival function in actuarial notation.

3.2 Force of mortality.

3.3 Interrelations among d.f., survival function, force of mortality and p.d.f.

3.4 Curtate future life random variable, its d.f. and survival function in actuarial notation.

3.5 Construction of life table using random survivorship approach.

3.6 Uniform distribution assumption for fractional ages.

4) Models for Life Insurance (11 L)

4.1 Theory of compound interest, instantaneous rate of interest, discount factor.

4.2 Insurance payable at the moment of death as well as at the end of the year of death, present value r.v., actuarial present value.

4.3 Derivation of actuarial present value for n-year term life insurance, whole life insurance and Endowment insurance.

5) Annuities (10L)

5.1 Annuities – certain, annuity due, annuity immediate, Life annuities.

5.2 A whole life annuity, present value r.v. of the payment, its actuarial present value using current payment technique.

5.3 n-year temporary life annuity, its present value and actuarial present value.

6) Benefit Premiums (8L)

6.1 Concept of a loss r.v.

6.2 Equivalence principle

6.3 Derivation of fully continuous premium for a unit whole life insurance payable immediately on death.

Books Recommended

1. Actuarial mathematics by N.L. Bowers Jr., H.S.Gerber, J.C. Hickan, D.A.Jones, C.J.Nesbitt, Chapters 1,3,4,5,6. (Publisher: The Society of Actuaries),1997.

2. Lecture notes on Statistics in Insurance and Introduction by Dr. (Mrs.) S.R.Deshmukh.
3. S.R. Deshmukh ,(2010) Actuarial Statistics , Universities Press.

ST 336 (C) : TIME SERIES ANALYSIS

1. Features of Time Series Data **(8L)**

1.1 Trend seasonality, correlation and changing variability
1.2 Test for randomness of a series against trend and seasonality.
1.3 Studying a given series by plots and histograms**.**

2. Population Estimation **(16 L)**

2.1 Moving average and exponential smoothing.
2.2 Forecasting based on smoothing.
2.3 Double exponential smoothing.
2.4 Choosing parameters for smoothing and forecasting.
2.5 Estimating mean square error of forecasting. Prediction Intervals based on normality assumption.

3. Time Series Analysis Through Regression Regression Analysis **(8L)**

3.1 Regression models for trend and seasonality.
3.2 De- trending and de- seasonalizing a series.
3.3 Analysis of residuals

4. Introduction to Box Jenkins Techniques **(8L)**

4.1 Stationary time series : Differing and seasonal differencing.
4.2 Transformation of data : Transformation and differing.
4.3 Simple AR models and forecasts based on AR models, MSE of forecasts.

5. Data Analysis of Real Life Time Series. **(8L)**

5.1 Price index series, share price series, economic time series, Sales tax series, market price of daily consumables.
5.2 Weather related time series: Temperature and rainfall time series, wind speed time series, pollution levels.

Note : Most of the calculations needed are available in MS EXCEL and through regression analysis.

Books Recommended

1. Montgomery , D.C. and Johnson L.A. (1976). Forecasting and Time Series Analysis, McGraw Hill.
2. Farmum, N.R. and Stantorr, L.W. (1989). Quantitative Forecasting Methods, PWS-Kent Publishing Company, Boston.

Semester IV
ST-341 : DISTRIBUTION THEORY -II

1. Cauchy Distribution **(6L)**

1.1 p.d.f. $f(x) = \frac{\lambda}{\pi} \frac{1}{\lambda^2 + (x-\mu)^2}$; $-\infty<x<\infty$, $-\infty<\mu<\infty, \lambda>0$,

= 0 ; elsewhere

Notation : X~ C (μ,λ).

1.2 Nature of the probability curve.

1.3 Distribution function, quartiles, non – existence of moments, distribution of $aX+b.$

Distribution of i) $\frac{1}{X}$, ii) X^2 where X~ C (0,1)

1.4 Additive property for two independent Cauchy variates (statement only), statement of distribution of the sample mean, comment on limiting distribution of $\overline{X}$.

1.5 Relationship with uniform , Student's t and normal distributions.

1.6 Applications of $C(\mu,\lambda)$.

2. Laplace (Double Exponential) Distribution **(6L)**

2.1 p.d.f. $f(x) = \frac{\lambda}{2} \exp(-\lambda|x-\mu|)$, $-\infty < x < \infty$, $-\infty<\mu<\infty, \lambda>0$,

= 0, ; elsewhere

Notation : X~ L (μ,λ).

2.2 Nature of the probability curve.

2.3 Distribution function, quartiles, comment on MLE of μ, λ.

2.4 MGF, CGF, moments and cumulants, β_1, β_2, γ_1, γ_2

2.5 Laplace distribution as the distribution of the difference of two i.i.d. exponential variates with mean $\frac{1}{\lambda}$.

2.6 Applications and real life situations.

3. Lognormal Distribution **(8L)**

3.1 p.d.f.

$$f(x) = \frac{1}{(x-a)\sigma\sqrt{2\pi}} \exp\left\{\frac{-1}{2\sigma^2}[\log_e(x-a)-\mu]^2\right\} , \quad a<x, \ -\infty<\mu<\infty, \ \sigma>0,$$

= 0, ; elsewhere

Notation : X~ LN (a,μ,σ^2).

3.2 Nature of the probability curve.

3.3 Moments (r- th moment of X-a), first four moments , β_1 and γ_1 coefficients, quartiles, mode.

3.4 Relation with N (μ,σ^2) distribution.

3.5 Distribution of ΠX_i , X_i's independent lognormal variates.

3.6 Applications and real life situations

4. Truncated Distributions **(8L)**

4.1 Truncated distribution truncation to the right, left and on both sides.

4.2 Binomial distribution B(n,p) left truncated at X=0,(value zero is discarded),its p.m.f. mean, variance.

4.3 Poisson distribution P(m), left truncated at X=0 ,(value zero is discarded),its p.m.f. mean, variance.

4.4 Normal distribution N (μ,σ^2) truncated i) to the left below a ii) to the right above b iii) to the left below a and to the right above b , (a < b) its p.d.f. and derivation of mean and statement (without derivation)of variance..

4.5 Real life situations and applications.

5. Bivariate Normal Distribution **(10L)**

5.1 p.d.f. of a bivariate normal distribution.

$$f(x) = \frac{1}{2\pi\sigma_1\sigma_2\sqrt{1-\rho^2}} \exp\left\{\frac{-1}{2(1-\rho^2)}\left[\left(\frac{x-\mu_1}{\sigma_1}\right)^2 + \left(\frac{y-\mu_2}{\sigma_2}\right)^2 - 2\rho\left(\frac{x-\mu_1}{\sigma_1}\right)\left(\frac{y-\mu_2}{\sigma_2}\right)\right]-\right\}$$

$-\infty < x, y < \infty$,
$-\infty < \mu_1, \mu_2 < \infty$,
$\sigma_1, \sigma_2 > 0$, $-1 < \rho < +1$

= 0, elsewhere

Notation : (X,Y)~ BN (μ_1, μ_2 , σ_1^2 , σ_2^2 , ρ), $\underline{X} \sim N_p(\underline{\mu}, \Sigma)$, use of matrix algebra is recommended.

5.2 Nature of surface of p.d.f. ,marginal and conditional distributions, identification of parameters, regression of Y on X and of X on Y, independence and uncorrelatedness, MGF and moments. Distribution of aX +bY +c , X/Y.

5.3 Applications and real life situations

6. Finite Markov Chains **(10L)**

6.1 Definition of a sequence of discrete r.v.s. , Markov property, Markov chain, state space and finite Markov chain (M.C.), one step and n step transition probability, stationary transition probability , stochastic matrix P, one step and n step transition probability matrix (t.p.m.) Chapman – Kolmogorov equations, t.p.m. of random walk and gambler's ruin problem.

6.2 Applications and real life situations

Books Recommended

1 H. Cramer : Mathematical Methods of Statistics, Asia Publishing House, Mumbai.
2 Mood, A.M. Graybill, F.Bose, D.C : Introduction to Theory(IIIrd Edition) Mc-Graw Hill Series.
3 B.W. Lindgren : Statistical Theory (IIIrd Edition) Collier Macmillan International Edition, Macmillan Publishing Co.Inc. NewYork.
4 Hogg, R.V. and Craig A.T. : Introduction to Mathematical Statistics (IIIrd Edition), Macmillan Publishing Company, Inc.866 34d Avenue, New York, 10022.
5 Sanjay Arora and Bansi Lal : New Mathematical Statistics (Ist Edition), Satya Prakashan16/17698, New Market, New Delhi,5(1989).

6 S.C. Gupta and V. K. Kapoor : Fundamentals of Mathematical Statistics, Sultan Chand and Sons, 88, Daryaganj, New Delhi, 2.
7 V.K. Rohatgi : An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern Ltd. New Delhi.
8 J. Medhi: Stochastic Processes, Wiley Eastern Ltd…. New Delhi.
9 Hoel, Port and Stone, Introduction to Stochastic Processes, Houghton Miffin.
10 Feller W. : An Introduction of Probability Theory and Its Applications, Vol. I, Wiley Eastern Ltd. Mumbai.
11 Sheldon Ross: A first course in probability (6th edition) : Pearson Education, Delhi.

ST 342 : TESTING OF HYPOTHESES

1. Parametric Tests (15 L)

1.1 (a) Statistical hypothesis, problem of testing of hypotheses. Definition and illustrations of (1) simple hypothesis, (2) composite hypothesis, (3) test of hypothesis, (4) critical region, (5) type I and type II errors. probabilities of type I error and type II error. Problem of controlling the probabilities of errors of two kinds.

(b) Definition and illustrations of (i) level of significance, (ii) observed level of significance (p-value), (iii) size of a test, (iv) power of a test.

1.2 Definition of most powerful(M.P.) level α test of simple null hypothesis against simple alternative. Statement of Neyman - Pearson (N-P) lemma for constructing the most powerful level α test of simple null hypothesis against alternative hypothesis. Illustrations.

1.3 Power function of a test, power curve, definition of uniformly most powerful (UMP) level α test for one sided alternative. Illustrations.

2. Likelihood ratio test : (9L)

Notion of likelihood ratio test (LRT), $\lambda(x)=\text{Sup } L(\theta_0|x) / \text{Sup } L(\theta|x)$ Construction of LRT for $H_0 : \theta \in \Theta$ against $H_1: \theta \notin \Theta$ for the mean of normal distribution for i) known σ^2 ii) unknown σ^2 (one sided and two sided alternatives). LRT for variance of normal distribution for i) known μ ii) unknown μ (one sided and two sided alternatives hypotheses). LRT for parameters of binomial and exponential distribution for two sided alternatives only. LRT as a function of sufficient statistics , statement of asymptotic distribution of
$-2 \log_e \lambda(x)$.

3. Sequential Tests (9 L)

Sequential test procedure for simple null hypothesis against simple alternative hypothesis and its comparison with fixed sample size N-P test procedure. Definition of Wald's SPRT of strength (α, β). Illustration for standard distributions like Bernoulli, Poisson, Normal and Exponential. SPRT as a function of sufficient statistics. Graphical representation of SPRT.

4. Non-parametric Tests (15 L)

4.1 Idea of non- parametric problems. Distinction between a parametric and a non-parametric problem. Concept of distribution free statistic. One tailed and two tailed test procedure of (i) Sign test, ii) Wilcoxon signed rank test (iii) Mann-Whitney U test, (iii) Run test, one sample and two samples problems

4.2 Empirical distribution function $S_n(x)$. Properties of $S_n(x)$ as estimator of F (.). Kolmogorov – Smirnov test for completely specified univariate distribution (one Sample problem only)for two sided alternative hypotheses. Comparison with chi-square test.

Books recommended for

1. Lindgren, B.W.: Statistical Theory (third edition) collier Macmillan International Edition, Macmillan publishing Co., Inc. New York.

2. Mood, A.M., Graybill, F. and Bose, D.C. : Introduction to the theory of Statistics (third edition) International Student Edition, McGraw Hill Kogakusha Ltd.

3. Hogg, P.V. and Craig, A.J. : Introduction to Mathematical Statistics (fourth edition), Collier Macmillan International Edition, Macmillan Publishing Co. Inc., New York.

4. Siegel, S. : Nonparametric methods for the behavioural sciences, International Student Edition, McGraw Hill Kogakusha Ltd.

5. Hoel, Port, Stone : Introduction to statistical Theory, Houghton Mifflin Company (International) Dolphin Edition.

6. J.D. Gibbons : Non parametric Statistical Interence, McGraw Hill Book Company, New York.

7. Daniel : Applied Nonparametric Statistics, Houghton Mifflin Company, Roston.

8. V.K. Rohatgi : An introduction to probability theory and mathematical statistics, Wiley Eastern Ltd., New Delhi.

9. Kendall and stuart : The advanced Theory of Statistics, Vol 1, Charles and company Ltd., London.

10. Dudeweitz and Mishra : Modern Mathematical Statistic, John Wiley and Sons, Inc., New York.
11. Kale, B.K. : A First Course In parametric Inference.
12. Kunte, S ., Purohit, S.G. and Wanjale, S.K. : Lecture Notes On Nonparametric Tests.
13. B.L. Agarwal : Programmed Statistics: New Age International Publications , Delhi.
14. Sanjay Arora and Bansi Lal : New Mathematical Statistics (Ist Edition), Satya Prakashan16/17698, New Market, New Delhi,5(1989).

ST 343 : STATISTICAL PROCESS CONTROL
(Off line Methods)

1. Acceptance of Sampling for Attributes (22L)

1.1 **Introduction :** Concept of sampling inspection plan, comparison between 100% inspection and sampling inspection. Procedures of acceptance sampling with rectification, single sampling plan and double sampling plan. Explanation of the terms: Producer's risk. Consumer's risk, Acceptable Quality Level (AQL). Lot Tolerance Fraction Defective (LTFD), Average Outgoing Quality (AOQ), Average Outgoing Quality Limit (AOQL), Average Sample Number (ASN), Average Total Inspection (ATI), Operating characteristic (OC) curve, AOQ curve.

Note : distinction between type A OC curve and type B OC curve is not expected.

1.2 **Single Sampling Plan** : Evaluation of probability of acceptance using.

(i) Hypergeometric (ii) Binomial (iii) Poisson distributions. Derivation of AOQ and ATI. Graphical determination of AOQL, determination of a single sampling plan by i) lot quality and ii) average quality approaches. Description of Dodge and Roming tables.

1.3 **Double Sampling Plan** : Evaluation of probability of acceptance using Poisson approximation. Derivation of AOQ, ASN and ATI (with complete inspection of second sample). Graphical determination of AOQL. Description of Dodge and Roming Tables. Comparison of single sampling plan and double sample plan.

1.4 Normal, reduced and tightened inspection.

2. Reliability Theory (20 L)

2.1 **Binary Systems of independent compliments** : Block diagrams, fault tree representation. Definition of binary coherent structure and illustrations. Coherent systems of components less than five, (i) Series, (ii) Parallel, (iii) K-out-of-4: Good, (iv) Essentially series, (v) Essentially parallel. Minimal cut, path structure representation of the system.

2.2 **Reliability of Binary Components and Systems** : Reliability of above systems $h(p)$, when components are independent and identically distributed with common probability p of operating.

'S' shaped ness property of h(p) without proof and workout examples to show that using components of low values of reliabilities, i.e. unreliable components, systems with higher reliabilities can be constructed.

2.3 Ageing Properties : Definitions : Hazard rates, hazard function, survival function, concept of distributions with increasing and decreasing failure rate (IFR/DFR), Average Increasing (Decreasing) Failure Rate (IFRA / DFRA).

Relationship between : (i) Survival function and hazard function, (ii) Density function and hazard rate.

Derivations of the following results :

(i) Hazard rate of a series system of components having independent life times is summation of component hazard rates.

(ii) Life time of series system of independent components with independent IFR life times is IFR.

Illustrations : Exponential, gamma, Weibull distributions.

3. Indian Standards (IS) and International Organization for Standardization (ISO) (6L)

Introduction to IS series and ISO 9001 : 2000 (E) series with reference to process control and statistical techniques (History, Organization structure, clauses 5.2+7.2.1+7.2.2+7.2.3,7.4.1, 7.4.2, 7.4.3, 6.3,6.4,7.5.1+ 7.5.2, 8.5.2+8.5.3, 8.5.2, 8.5.3, 8.1 + 8.2.3 + 8.2.4 + 8.4), role of statistical methods.

Note : Use revised clause numbers as and when required.

Books Recommended

1. Duncan, A. J. : Quality Control and Industrial Statistics, D.B. Taraporewalla Sons and Co. Pvt. Ltd., Mumbai.
2. Grant, E.L. and Leavenworth : Statistical Quality Control, Mc-Graw Hill Kogakusha Ltd., New Delhi.
3. Montgomery, D.C. : Statistical Quality Control, John Wiley and Sons, Inc., New York.
4. Kamji and Asher : 100 Methods of TQM, Sage Publishers, Delhi.

5. Johnson and Kotz : Capability Studies, Chapman Hall Pub.
6. SP20 : Handbook of SQC, Bureau of Indian Standards.
7. Dodge and Roming : Sampling Inspection tables, John Wiley and Sons, Inc. New York.
8. Barlow R. E. and Proschan, Frank : Statistical Theory of Reliability and Life Testing, Holt Rinebart and Winston Inc., New York.
9. Sinha, S. K. : Reliability and Life testing, Second Edition, Wiley Eastern Publishers, New Delhi.
10. ISO-9001 : 2000 Quality Management System - Requirements, Bureau of Indian Standards.
11. ISO-9004 : 2000 Quality Management System : Guidelines for Performance Improvement, Bureau of Indian Standards.
12. Trivedi, R. S. : Probability and Statistics with Reliability and Computer Science Applications, Prentice - Hall of India Pvt. Ltd., New Delhi.
13. S. Zacks : Introduction to Reliability Analysis, Probability Models and Statistical Methods, Springer Verlag.
14. D.H. Besterfield, C.B. Michna etc. Total Quality Management (3rd edition 2009) : Pearson Education, Delhi.

ST 344 : SAMPLING METHODS

1. Sampling **(8 L)**

1.1 Concept of distinguishable elementary units, sampling units, sampling frame, random sample, requisites of a good sample. Simple random sampling from finite population of size (N) (i) with replacement (SRSWR) ii) without replacement (SRSWOR) definitions, population mean and population total as parameters, inclusion probabilities.

1.2 (a) Sample mean $\bar{y}$ as an estimator of population mean, derivation of expectation and standard error of $\bar{y}$, confidence interval for population mean, population total standard error.

(b) N$\bar{y}$ as an estimator of population total, derivation of expectation and standard error of N$\bar{y}$

(c) Estimator of above standard errors, both in case of SRSWR and SRSWOR.

1.3 Sampling for proportion as an application of a simple random sampling with Xi as zero or one.

(a) sample proportion as an estimator of population proportion of units possessing a certain attribute, derivation of expectation and standard error of (p).

(b) Np as an estimator of total number of units in the population possessing a certain attribute, derivation of expectation and standard error of Np

(c) Estimator of above standard error both in case of SRSWR and SRSWOR.

2 Determination of Sample Size **(8 L)**

Determination of the sample size for the given :

i) Margin of error and confidence coefficient.

ii) Coefficient of variation of the estimator and confidence coefficient.

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3. Stratified Random Sample Size **(12L)**

3.1 Stratification, basis of stratification, real life situation where stratification can be used.

3.2 Stratified random sampling as a sample drawn from individual strata using SRSWOR in each stratum.

3.3 (a) $\overline{y_{st}} = \frac{\Sigma\ N_i\ \overline{y_i}}{N}$ as an estimator of population mean ($\bar{Y}$),

Derivation of expectation and standard error of $\bar{y}_{st}$

(b) N$\bar{y}_{st}$ as an estimator of population total, derivation of expectation and standard error of N$\bar{y}_{st}$

(c) Estimator of above standard errors.

3.4 Problem of allocation , proportional allocation, Neyman's allocation, derivation of the expressions for the standard errors of the above estimators when these allocations are used.

3.5 Gain in precision due to stratification ,comparison amongst SRSWOR, stratification with proportional allocation and stratification with Neyman's allocation.

3.6 Cost and variance analysis in stratified random sampling, minimization of variance for fixed cost, minimization of cost for fixed variance, optimum allocation, Neyman's allocation as a particular case of optimum allocation in cost and variance analysis.

4. Ratio and Regression Methods of Estimation for SRSWOR (6L)

4.1 Rationale behind using auxiliary variates in estimation.

4.2 Situations where (i) ratio method is appropriate, (ii) regression method is appropriate.

4.3 Ratio and regression estimators of the population mean and population total.

4.4 Comments regarding bias, statement of standard errors of ratio and regression estimators relative efficiency of these estimators, with respect to SRSWOR (Derivations are not expected).

5. Systematic Sampling (Population size divisible by sample size) (6L)

5.1 Real life situations where systematic sampling is appropriate. Techniques of drawing a sample using systematic sampling.

5.2 Estimation of the population mean and population total, standard error of these estimators.

5.3 Comparison of systematic sampling with SRSWOR.

5.4 Comparison of systematic sampling with SRSWOR and stratified sampling in the presence of linear trend.

6. Role of Sample Surveys in Research Methodology (8L)

6.1 Objectives of a sample survey.

6.2 Designing a questionnaire, characteristics of a good questionnaire.

6.3 Planning, execution and analysis of a sample survey, practical problems at each of these stages.

6.4 Sampling and nonsampling errors with illustrations.

6.5 Incomplete samples, Hansen and Hurwitz technique for non response and randomized response technique for intentionally wrong response.

6.6 Study of some surveys illustrating the above ideas, rounds conducted by National Sample Surveys organization.

Books Recommended

1. Cochran, W.G. : Sampling Techniques, Wiley Eastern Ltd., New Delhi.
2. Sukhatme, P.V., Sukhatme, B. V. : Sampling theory of Surveys with Applications, Indian Society of Agricultural Statistics, New Delhi.
3. Murthy, M. N. : Sampling methods, Indian Statistical Institute, Kolkata.
4. Daroga Singh and chaudhary, F. S. : Theory and Analysis of Sample Survey Designs, Wiley Eastern Ltd., New Delhi.
5. Malhotra Naresh : Marketing Research and Applied Orientation (third edition), Prentice Hall of India.
6. Parimal Mukhopadhyay : Sampling theory and methods of survey sampling:

ST 345: OPERATIONS RESEARCH

1) LINEAR PROGRAMMING (24L)

1.1 Statement of the linear Programming Problem (LPP), Formulation of problem as L.P. problem.
Definition of (i) A slack variable, (ii) A surplus Variable.
L.P. Problem in (i) Canonical form ,(ii) standard form.
Definition of i) a slack variable, ii)a surplus variable . L.P.problem in i) canonical form, ii) standard form.
Definition of i) a solution ii) a feasible solution iii) a basic feasible solution, iv) a degenerate and non –degenerate solution v) an optimal solution vi) basic and non-basic variables .

1.2 Solution of L.P.P by
- i) Graphical Method : solution space , unique and non-unique solutions , obtaining an optimal solutions.
- ii) Simplex Method:
  - a) initial basic feasible solution (IBFS) is readily available : obtaining an IBFS, criteria for deciding whether obtained solution is optimal criteria for unbounded solution , no solution , more than one solution .
  - b) IBFS not readily available: introduction of artificial variable, Big-M method, modified objective function, modifications and application of simplex method to L.P.P. with artificial variables.

1.3 Duality Theory: Writing dual of a primal problem, solution of a L.P.P. by using its dual problem.

1.4 Examples and problems.

2) Transportation and Assignment Problem (18L)

2.1 Transportation problem (T.P.), statement of T.P., balanced and unbalanced T.P.

2.2 Methods of obtaining basic feasible solution of T.P. i) North-West corner rule ii) Method of matrix minima (least cost method), iii) Vogel's approximation method (VAM).

2.3 u-v method of obtaining Optimal solution of T.P., uniqueness and non- uniqueness of optimal solutions, degenerate solution.

2.4 Assignment problems: statement of an assignment, balanced and unbalanced problem, relation with T.P., optimal solution of an assignment problem, using Hungarian method.

2.5 Examples and problems.

3) Sequencing (6L)

3.1 Statement of sequencing problem of two machines and n-jobs, three machines and n-jobs (reducible to two machines and n-jobs).

3.2 Calculation of total elapsed time, idle time of a machine, simple numerical problems.

3.3 Examples and problems.

4.Simulation

4.1 Introduction to simulation, merits, demerits, limitations.
4.2 Pseudo random number generates : Linear congruential , mid square method.
4.3 Model sample from normal distribution (using Box- Muller transformation) uniform, exponential distribution.
4.4 Monte Carlo method of simulation.
4.5 Applications of simulations.
4.6 Statistical applications of simulation in numerical integration, queuing theory etc.

Books Recommended

1. Gass,E.: Linear programming method and applications,Narosa Publishing House, New Delhi.
2. Taha, R.A.: Operation research, An Introduction, fifth edition, Prentice Hall of India, New Delhi.
3. Saceini,Yaspan,Friedman : Operation Research methods and problems, Willey International Edition.
4. Shrinath.L.S : Linear Programming ,Affiliated East-West Pvt. Ltd , New Delhi.
5. Phillips,D.T, Ravindra , A, Solberg, I.: Operation Research principles and practice , John Willey and sons Inc.
6. Sharma, J.K.: Mathematical Models in Operation Research , Tata McGraw Hill Publishing Company Ltd., New Delhi.
7. Kapoor,V.K.: Operations Research , Sultan Chand and Sons. New Delhi.
8. Gupta, P.K.and Hira , D.S.: Operation Research, S.Chand and company Ltd., New Delhi.

ST-346(A): MEDICAL STATISTICS

I. Population study **(12L)**

1.1 India's population and census,

1.2 Population growth and models for population growth,

1.3 Birth and death rates,

1.4 Survival function,

1.5 Hazard rate (age specific mortality rate),

1.6 Use of exponential and Weibull distribution for modeling hazard rate.

2. Epidemiology **(12L)**

2.1 Epidemiology.

2.2 Odds, odds ratio, relative risk.

2.3 Estimation of odds ratio (OR), Confidence interval for OR.
Relation with parameter in a log it model.

2.4 Symmetry in square contingency tables, collapsing tables and
Simpson's paradox

3. Clinical trials **(24 L)**

3.1 General information on history of drug discovery including Louis Pasteur (rabies and small pox, Ronald Ross and malaria, Alexander Fleming and penicillin, Jonas Salk and polio, Cholera, asthma, diabetes, blood pressure, heart attack, arthritis.

3.2 Phases of clinical trial, purpose, duration, cost, drug regulatory bodies, ICH, statistical analysis plan, clinical study report

3.3 Parallel designs, case control studies, longitudinal studies, safety studies

3.4 2 treatments, 2 periods cross over design.

3.5 Bioequivalence and bio-availability, non-inferiority trial

3.6 Practice based medical research, evidence based medicine

Books Recommended

1. Course on mathematical and statistical Ecology : Kluwer publishing Holland, A.p .Gore and S. A, Paranjape (200)

2.“ Introduction to Statistical Ecology : M.B. Kulkarni, V.R. Prayag, SIPF Academy, Nasik (2004)

3. Introduction to Categoril Data Analysis : Alan Agrasti John wiley (1996) for part – II epidemiology (mainly odds, odds ratios and inference)

For the more reference books we need to see the books in the department of Stat. Uni,Pune

4. Introduction to Randomized Controlled clinical Trials: J.N.S. Matthews : Chapman and Hall (2006)

5. Statistical Issues in drug Development : Stephen Sann (John Wiley) 2000

6. Clinical Trials – A methodological perpective : Steven Diantadosi (John Wiley 2000)

7. Fundamentals of Clinics Trials: L.M. Friedmon, C.D. Forbes, D.L. Demats (TT) Spinner

8. Epidemiologic Analysis : Steve selvin : (Oxford 200)

9. Statistical Methods for Health Sciences: M.M. Shoukni, C.A. Pavse(1999) CPC Pree.

10. Statistical Analysis of Epidomiologic Data Steve Salvin, Ph.D. : Oxford 1999)

11. Lecture Notes on Medical Statistics : A.P. Gore S.A.Paranjpe and M.B. Kulkarni

ST 346 (B): STATISTICAL ECOLOGY

1) Population Dynamics (16L)

Introduction: Ecology, Statistical Ecology.

1.1. Linear Growth dNt/dt = C, Interpretation and limitation.

1.2. Exponential Model: Solving dNt/dt $= KN_t$, $K > 0$,$K<0$ cases.Properties,Interpretation,Scope and Limitation.

1.3. Logistic growth model :Density dependence, solving differential equation

1.4. $dN_t/dt = a.{}_{Nt}(K-N\ t)$Properties ,carrying Capacity, Interpretation, Scope and Limitation.

1.5. Geompertz Curve: Solving Differential equation $dN_t/dt = a.\log(K/N_t)$, Asymptotically stable Equilibrium ,Properties, Interpretation, Scope and Limitation. Fitting the above growth models to data by linearization and regression.

1.6. **Life tables :** Force of mortality stable population and stationary population. Cohort , columns of life table, interrelation between columns interpretation, construction of life table, uses and application.

1.7. Leslie matrix Models: fecundity and survival matrix, $n_t = M^t n_0$,future projections, stable age distribution, interpretation of largest sign value of M.

2) Smoothing Procedures (16L)

2.1 Poisson forest, Aggregated, Regular spatial point pattern, estimation of population density by quadrate sampling, nearest neighbor distances (Point to individual, individual to individual), i-th order nearest neighbor distance. $\lambda = n/\Pi X^2_i$ mle for Poisson forest, Bias and S.E. of λ estimate.

2.2 Line transect method : Drawing random line transect, exponential detection function, mle of population density, other detection functions.

2.3 Capture –recapture models: Closed population, Open population, Peterson estimator for single recapture, Multiple captures, irative method to find mle of N, Population size.

2.4 Removal method :Zippin's estimator for closed population.

3) Diversity Indices (8L)

3.1 Concept of Biodiversity, need to protect it.

3.2 Richness indices, Simpson's index, Shannon's index.

3.3 Rare fraction Curves, Real life examples for computing these indices.

4) Distribution Models (8L)

4.1 Use of geometric distribution, lognormal distribution in ecology.

Book recommended:

1. Pielou,E.C.(1977):An Introduction to Mathematical Ecology, Wiley.

2. Seber,G.A.F.(1982): The estimation of animal abundance and related parameters, C. Griffin.

3 Ludwig,J.A. and Regnold J.F.: Statistical Ecology, A primer on methods and computing.

4 .Gore,A.P. and Prajpe, S.A. : A First Course on mathematical and Statistical Ecology.

ST – 346 (C) Statistical computing using R software

1. Fundamentals of R **(5L)**

Introduction to R, features of R, installation of R, starting and ending R session, getting help in R, R commands and case sensitivity

Data types : Logical, numeric and complex

Vectors and vector arithmetic

(a)creation of vectors using functions c, assign,seq,rep

(b)Arithmetic operations on vectors using operators +, -, *, /, ^.

(c)Numerical functions: log10,log,sort,max,min, unique, range, length, var, prod, sum, summary, fivenum etc

(d) accessing vectors

(e) alternative ways to create vectors by scan function

1.4 Data frames :creation using data.frame,subset and transform commands.

1.5 Resident data sets : Accession and summary

1.6 Graphics using R :

(a) High level plotting functions

(b) Low level plotting functions

(c) Interactive graphic functions

1.7 Using R as a calculator

The following statistical methods using 'R'

2. Sampling methods (4L)

Drawing a sample from population using SRSWR, SRSWOR, stratified random sampling, systematic sampling

3 Diagrams (4L)

Simple bar diagram, Subdivided bar diagram, multiple bar diagram, Pie diagram, Stem and leaf diagram

4. Graphs (5L)

Box plot,rod or spike plot, histogram (both equal and unequal class intervals), frequency polygon, o give curves, empirical distribution function

5. Measures of central tendency, dispersion, skewness and kurtosis. (6L)

Computations of following measures for all types of data

(a) central tendency: mean,mode,median,quartiles,deciles,percentiles,g.m. and h.m

(b)Dispersion : variance, standard deviation,coefficient of variation, mean deviation

(c)Skewness : Bowley's coefficient and Karl Pearson's coefficient of skewness

(d) Moments : Computations of raw and central moments, measure of skewness and kurtosis based on it.

6 Probability distributions : (6L)

Simulation of random experiment

Hypergeometric distribution : computation of probabilities

Binomial distribution : computation of probabilities, model sampling, fitting

Poisson distribution : computation of probabilities, model sampling, fitting

Normal distribution : computation of probabilities, model sampling, Fitting, testing normality using Anderson- Darling or Wilks- Shapero test

7. Correlation and regression (6L)

Fitting of lines of regression, computation of correlation coefficient, Fitting of parabola

Multiple regression : Fitting of regression plane for trivariate data.

8 Testing of hypotheses (6 L)

Large sample tests for means and proportions, t.test, var.test, chisq.test

9. Analysis of variance: one way, two way (6L)

Books recommended:

S.G. Purohit, S.D. Gore, S.R. Deshmukh : Statistics using R : Narosa Publishing House(Ist edition 2008)

ST 347 : Practical Paper I

Sr. No	Title of the experiment	No.of experiments
1.	Construction of confidence interval for population median and quartiles based on order statistics.	(1)
2.	Testing of hypotheses (Probability of type I and type II errors, power of test etc).	(2)
3.	Construction of most powerful (M.P.) test.	(1)
4.	Construction of uniformally most powerful test (UMP) test plotting of power function.	(1)
5.	Non- parametric tests : Sign test, Wilcoxon's signed rank test , Mann-Whitney U test.	(2)
6.	Non- parametric test : Run test, median test, Kolmogorov- Smirnov test.	(1)
7..	SPRT for Bernoulli, Poisson distribution (graphical representation also)	(1)
8.	SPRT for normal, exponential distribution (graphical representation also)	(1)
9.	p-chart for fixed sample size when standard is (i)given (ii) not given probability of detecting shift	(1)
10.	p-chart for variable sample size based on i) individual control limits ii) Stabilized (standardized p_i) control limits.	(1)
11.	X- MR chart, R , $\overline{X}$ charts. Check normality using normal probability plot.	(2)
12.	R , $\overline{X}$ chart, probability of detecting shift, ARL, OC curve for $\overline{X}$ chart, computations of C_p, C_{pk}.	(1)
13.	Single sampling plan for attributes (OC curve, AOQ, AOQL, ATI using Poisson approximation).	(1)
14.	Determination of single sampling plan for attributes by i) lot quality approach ii) average quality approach	(1)
15.	Double sampling plan for attributes (OC curve, AOQ, AOQL, ATI, ASN using Poisson approximation).	(1)
16.	Determination of minimal i) cut sets ii) path sets for given coherent system. Finding reliability h (p) of coherent system with i.i.d. components each with reliability p. Graph of h (p) against p. S shaped ness property.	(2)
17.	Linear programming problem I (Simplex method)	(1)
18.	Linear programming problem II(Simplex method)	(1)
19.	Transportation problem and assignment problem I	(1)
20.	Transportation problem and assignment problem II	(1)

Note : Answers of experiment No. 17 to 20 are to be verified using TORA package.

ST 348: Practical paper II

Sr. No.	Title of the Experiment	No.of experiments
1.	Analysis of CRD (equal and unequal replications) pairwise comparison of treatments, using critical difference (C.D). Check normality using normal probability plot.	(1)
2.	Analysis of R.B. D. pairwise comparison of treatments using i) C.D ii) Tukey and Scheff's procedure. Efficiency of RBD w.r.t. CRD	(2)
3.	Analysis of L.S.D., pairwise comparison of treatments using C.D. and box plot, efficiency of LSD w.r.t. i) CRD ii) RBD.	(1)
4.	Kruskal Walli H test	(1)
5.	Analysis of covariance in CRD, testing $\beta = 0$, (Carry out ANCOVA even if $\beta=0$ is accepted)	(1)
6.	Analysis of covariance in RBD , testing $\beta= 0$ (Carry out ANCOVA even if $\beta=0$ is accepted).	(1)
7.	Analysis of 2^2 and 2^3 factorial experiments in RBD.	(1)
8.	Analysis of 2^3 factorial experiments in RBD(partial confounding)	(1)
9.	Analysis of 2^3 factorial experiments in RBD.(total confounding)	(1)
10.	Model sampling from Cauchy and Laplace distributions	(1)
11.	Fitting of lognormal distribution.	(1)
12.	Fitting of truncated binomial distribution.	(1)
13.	Fitting of truncated Poisson distribution.	(1)
14.	Applications of bivariate normal distribution	(1)
15.	Simple random sampling (estimation of population mean ,population total with standard error), i) with replacement, ii) without replacement. Confidence interval for population mean and population total.	(2)
16.	Simple random sampling for proportions . Estimation of population proportion , population total with standard errors, confidence interval for population proportion and total.	(1) (1)
17.	Stratified random sampling : Proportional and Neyman allocation, comparison with SRSWOR.	
18.	Stratified random sampling : Cost and variance analysis.	(1)
19.	Ratio and Regression methods of estimation. Comparison with SRSWOR	(2)
20.	Simulation : i) simulation from standard probability distributions a) normal distribution using Box -Muller transformation b) exponential distribution. ii) simulation of M/M/ 1 queue. iii) simulation of approximate integrals to find numerical value of gamma function, beta function with real arguments. etc.	(2)

ST 349 : Practical Paper III

Prerequisites : Knowledge of programming in respective language or software
Equipments : At least 6 computers of latest configuration with necessary software, battery back up, printers scientific calculators, necessary statistical tables, normal probability paper etc.
Preparation by Internal Examiner for section I :
Keep at least 6 computers with latest configuration ready with battery backup, printer and necessary software at the time of examination in statistics laboratory.

Sr. No. **Title of Experiments**
Section : I **C –Programming** (List of programs using C)

1. Miscellaneous problems of following types
   a) Fibonacci series.
   b) Area of circle ,area of triangle by Hero's formula.
   c) Converting Celsius to Fahrenheit and vice versa.

2. Finding maximum , minimum among n numbers.
3. a) Finding whether the integer is i) even or odd ii) divisible by given integer.
   b) Converting a decimal system number to binary system number.
   c) Writing number digit by digit, reversing the same, finding the sum of digits.
   d) Find GCD and LCM of two numbers.
4. Arranging the array in ascending, descending order by i) bubble sort ii) insertion sort , finding median.
5. a) Solving quadratic equation.
   b) Solving two simultaneous linear equations in two variables .
6. a) Finding mean , variance of discrete series.
   b) Finding moving average.
7. Solving transcendental equation by Newton- Raphson method.

Section II : R programming or MS Excel/ Spreadsheet
Note : Practicals based on either R programming or MS Excel**/ Spreadsheet**.
List of Programs based on MS Excel/ Spreadsheet.

8. Descriptive statistics ,ANOVA (one way, two way)
9. Analysis of Latin square design.(LSD)
10. Fitting of lognormal distribution.
11. Fitting of truncated binomial and truncated Poisson distribution.
12. Problems involving computations of probabilities using i) beta distribution. ii) Weibull distribution iii) lognormal distributions iv) truncated normal distribution.
13. Model sample from Cauchy, Laplace distribution, finding MLE of location parameter of Cauchy distribution (Using iterative procedure)
14. Operating characteristic (OC) curve for $\overline{X}$ chart when σ is in control.

List of Programs based on R.

	Sr.no.	**Title of experiment**
8	a	Creation of a vector using seq / c / rep functions
	b	Creation of data frame using data.frame and edit
	c	Accessing elements of a vector/data frame either conditionally or unconditionally
	d	Drawing a histogram and polygon for the given frequency distribution
	e	Drawing a less than and more than ogive curve for the given frequency distribution
9	a	Drawing a simple bar diagram to the given data
	b	Drawing a pie diagram of the given data
	c	Drawing a multiple bar diagram of the given data
	d	Drawing a boxplot for the given data
	e	Drawing a rod plot for the given data
10	a	Computing mean / median /quartile / decile / percentile for n observations
	b	Computing mode of n given observations
	c	Simulating an experiment of tossing a die and preparing its frequency distribution
11	a	Computing mean and variance of given frequency distribution
	b	Computing quartile / decile / percentile for given frequency distribution
12	a	Fitting a line of regression of Y on X / X on Y And finding correlation coefficient for the given data
	b	Computation of probabilities of type $P[a<X<b]$, $P[X>=a]$, $P[X<b]$ etc for standard discrete and continuous distributions (Use all functions starting with d , p , q)
	c	Model sampling from standard discrete and continuous distributions
13	a	Fitting of binomial ,Poisson distribution to the given data
	b	Fitting of normal distribution to the given data
14	a	t - test for testing hypotheses $H_0 : \mu = \mu_0$ $H_0 : \mu_1 = \mu_2$, paired t - test
	b	Testing equality of variances
	c	Fitting of a regression plane to given trivariate data And estimating value of dependent variable for known values of independent variables

Section III

Project : Equivalent to 10 practicals
Data Analysis , report in dissertation form.