Maharaja's College Ernakulam

A GOVERNMENT AUTONOMOUS COLLEGE

Re-Accredited by NAAC with 'A Grade'
Affiliated to Mahatma Gandhi University
Centre of Excellence under Govt. of Kerala
Identified by UGC as College with Potential for Excellence

POST GRADUATE AND RESEARCH
DEPARTMENT OF STATISTICS

Estd. 1875

Post Graduate Curriculum and Syllabus
(Credit Semester System)

M.Sc. STATISTICS

For 2022 Admission Onwards

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POSTGRADUATE & RESEARCH DEPARTMENT OF STATISTICS

Postgraduate Curriculum and Syllabus

M.Sc. - Statistics

For 2022 Admission Onwards

Maharaja's College, Ernakulam

A Government Autonomous College

Affiliated to Mahatma Gandhi University, Kottayam

Masters Degree Programme in Statistics

(w.e.f. 2022 Admission Onwards)

Board of Studies in Statistics

Sl. No.	Name of Member	Designation
1.	**Dr. James Kurian**	Chairman, BoS Statistics
2.	**Dr. P. G. Sankaran**	External Member
3.	**Dr. Sebastian George**	External Member
4.	**Dr. Smitha S.**	External Member [Alumni]
5.	**Sri. Jineesh K James**	External Member [Industry]
6.	**Dr. Jayamol K. V**	Internal Member
7.	**Dr. Angel Mathew**	Internal Member
8.	**Dr. Priya P. Menon**	Internal Member
9.	**Sri. Sujith P**	Internal Member
10.	**Dr. Merlymole Joseph K**	Internal Member
11.	**Dr. Bismi G. Nadh**	Internal Member
12.	**Dr. Maya S. S**	Internal Member

REGULATIONS OF THE

MAHARAJA'S COLLEGE

(Government Autonomous)

POST GRADUATE PROGRAMMES

UNDER CREDIT SEMESTER SYSTEM, 2019

(MC-PGP-CSS2019)

REGULATIONS OF THE POST GRADUATE PROGRAMMES UNDER CREDIT SEMESTER SYSTEM, 2019 (MC-PGP-CSS2019)

1. SHORT TITLE

1.1. These Regulations shall be called Maharaja's College (Government Autonomous) Regulations (2019) governing Post Graduate Programmes under Credit Semester System (MC-PGP-CSS2019)

1.2. These Regulations shall come into force from the Academic Year 2019- 2020.

2. SCOPE

2.1. The regulation provided herein shall apply to all post-graduate programmes from the academic year 2019-2020 admission.

2.2. The provisions herein supersede all the existing regulations for the regular post-graduate programmes conducted in Maharaja's College unless otherwise specified.

3. DEFINITIONS

3.1. **'Academic Committee'** means the Committee constituted by the Principal under this regulation to monitor the running of the Post- Graduate programmes under the Credit Semester System (MC-PGP- CSS2019).

3.2. **'Academic Week'** is a unit of five working days in which distribution of work is organized from day one to day five, with five contact hours of one hour duration on each day. A sequence of minimum of 18 such academic weeks constitutes a semester.

3.3. **'Audit Course'** is a course for which no credits are awarded.

3.4. **'CE'** means Continuous Evaluation (Internal Evaluation)

3.5. **'College Co-Ordinator'** means a teacher from the college nominated by the College Council to look into the matters relating to MC-PGP-CSS 2019 for programmes conducted in the College.

3.6. **'Comprehensive viva-voce'** means the oral examinations conducted by the appointed examiners and shall cover all courses of study undergone by a student for the programme.

3.7. **'Common Course'** is a core course which is included in more than one programme with the same course code.

3.8. **‘Core course’** means a course which cannot be substituted by any other course.

3.9. **‘Course’** means a segment of subject matter to be covered in a semester. Each Course is to be designed variously under lectures / tutorials / laboratory or fieldwork /seminar / project / practical training / assignments / viva-voce etc., to meet effective teaching and learning needs.

3.10. **‘Course Code’** means a unique alpha numeric code assigned to each course of a programme.

3.11. **‘Course Credit’** One credit of the course is defined as a minimum of one hour lecture /minimum of 2 hours lab/field work per week for 18 weeks in a Semester. The course will be considered as completed only by conducting the final examination.

3.12. **‘Course Teacher’** means the teacher of the institution in charge of the course offered in the programme.

3.13. **‘Credit (Cr)’** of a course is a numerical value which depicts the measure of the weekly unit of work assigned for that course in a semester.

3.14. **‘Credit point (CP)’** of a course is the value obtained by multiplying the grade point (GP) by the Credit (Cr) of the course **CP = GP x Cr**.

3.15. **‘Cumulative Grade point average (CGPA)’** is the value obtained by dividing the sum of credit points of all the courses taken by the student for the entire programme by the total number of credits and shall be rounded off to two decimal places. CGPA determines the overall performance of a student at the end of a programme.

(CGPA = Total CP obtained / Total credits of the programme)

3.16. **'Department'** means any teaching Department in the college.

3.17. **'Department Council'** means the body of all teachers of a Department in a College.

3.18. **‘Dissertation’** means a long document on a particular subject in connection with the project /research/ field work etc.

3.19. **‘Duration of Programme’** means the period of time required for the conduct of the programme. The duration of post-graduate programme shall be 4 semesters spread over two academic years.

3.20. **‘Elective course’** means a course, which can be substituted, by an equivalent course from the same subject.

3.21. **'Elective Group'** means a group consisting of elective courses for the programme.

3.22. '**ESE**' means End Semester Evaluation (External Evaluation).

3.23. **'Evaluation'** is the process by which the knowledge acquired by the student is quantified as per the criteria detailed in these regulations.

3.24. **'External Examiner'** is the teacher appointed from other colleges for the valuation of courses of study undergone by the students in a College. The external examiner shall be appointed by the University.

3.25. **'Faculty Advisor'** is a teacher nominated by the Department Council to coordinate the continuous evaluation and other academic activities undertaken in the Department of the College.

3.26. **'Grace Grade Points'** means grade points awarded to course(s), in recognition of the students' meritorious achievements in NSS/ Sports/ Arts and cultural activities etc.

3.27. **'Grade point'** (GP)-Each letter grade is assigned a 'Grade point' (GP) which is an integer indicating the numerical equivalent of the broad level of performance of a student in a course.

3.28. **'Grade Point Average (GPA)'** is an index of the performance of a student in a course. It is obtained by dividing the sum of the weighted grade points obtained in the course by the sum of the weights of the Course **(GPA =ΣWGP / ΣMW).**

3.29. **'Improvement course'** is a course registered by a student for improving his performance in that particular course.

3.30. **'Internal Examiner'** is a teacher nominated by the department concerned to conduct Internalevaluation.

3.31. **'Letter Grade' or 'Grade'** for a course is a letter symbol (A+, A, B+, B, C+, C, D) which indicates the broad level of performance of a student for a course.

3.32. **MC-PGP-CSS2019 means** Maharaja's College (Government Autonomous) Regulations Governing Post Graduate Programmes under Credit Semester System, 2019**.**

3.33. **'Parent Department'** means the Department which offers a particular postgraduate programme.

3.34. **'Plagiarism'** is the unreferenced use of other authors' material in dissertations and assignments and is a serious academic offence.

3.35. **'Programme'** means the entire course of study and examinations.

3.36. **'Project'** is a core course in a programme. It means a regular project work with stated credits on which the student undergoes a project under the supervision of a teacher in the parent department / any appropriate research center in order to submit a dissertation on the project work as specified. It allows students to work more autonomously to construct their own learning and culminates in realistic, student-generated products or findings.

3.37. **'Repeat course'** is a course that is repeated by a student for having failed in that course in an earlier registration.

3.38. **'Semester'** means a term consisting of a minimum of 90 working days, inclusive of examinations, distributed over a minimum of 18 weeks of 5 working days each.

3.39. **'Seminar'** means a lecture given by the student on a selected topic and is expected to train the student in self-study, collection of relevant matter from various resources, editing, document writing and presentation.

3.40. **'Semester Grade Point Average' (SGPA)** is the value obtained by dividing the sum of credit points (CP) obtained by a student in the various courses taken in a semester by the total number of credits for the course in that semester. The SGPA shall be rounded off to two decimal places. SGPA determines the overall performance of a student at the end of a semester **(SGPA = Total CP obtained in the semester / Total Credits for the semester).**

3.41. **'Tutorial'** means a class to provide an opportunity to interact with students at their individual level to identify the strength and weakness of individual students.

3.42. **'University'** means Mahatma Gandhi University, Kottayam, Kerala.

3.43. **'Weight'** is a numeric measure assigned to the assessment units of various components of a course of study.

3.44. **'Weighted Grade Point (WGP)'** is the grade point multiplied by weight.

(WGP = GP x W).

3.45. **'Weighted Grade Point Average (WGPA)'** is an index of the performance of a student in a course. It is obtained by dividing the sum of the weighted grade points by the sum of the weights. WGPA shall be obtained for CE (Continuous Evaluation) and ESE (End Semester Evaluation) separately and then the combined WGPA shall be obtained for each course.

3.46. **'Internship'** means gain a professional work experience

4. ACADEMIC COMMITTEE

4.1. There shall be an Academic Committee constituted by the Principal to manage and monitor the working of MC-PGP-CSS2019.

4.2. The Committee consists of

(a) Principal

(b) Vice-Principal

(c) Secretary, Academic Council

(d) The Controller of Examinations

(e) Two Teachers nominated from among the College Council

4.3. There shall be a subcommittee nominated by the Principal to look after the day-to-day affairs of the Regulations for Post Graduate Programmes under MC-PGP-CSS2019.

5. PROGRAMME STRUCTURE

5.1. Students shall be admitted to post graduate programme under the various faculties. The programme shall include three types of courses, Core Courses, Elective Courses and Common core courses. There shall be a project with dissertation and comprehensive viva-voce as core courses for all programmes. The programme shall also include assignments / seminars / practicals etc.

5.2. No regular student shall register for more than 25 credits and less than 16 credits per semester unless otherwise specified. The total minimum credits, required for completing a PG programme is 80.

5.3. Elective courses and Groups

5.3.1. There shall be at least two and not more than four elective groups (Group A, Group B, Group C, etc.) comprising of three courses each for a programme and these elective courses shall be included either in fourth semester or be distributed among third and fourth semesters. This clause is not applicable for programmes defined by the Expert Committees of Music and Performing Arts.

5.3.2. The number of elective courses assigned for study in a particular semester shall be the same across all elective groups for the programme concerned.

5.3.3. The colleges shall select any one of the elective groups for each programme as per the interest of the students, availability of faculty and academic infrastructure in the institution.

5.3.4. The selection of courses from different elective groups is not permitted.

5.3.5. The elective groups selected by the College shall be intimated to the Controller of Examinations within two weeks of commencement of the semester in which the elective courses are offered. The elective group selected by the college for the students who are admitted in a particular academic year shall not be changed.

5.4. Project work

5.4.1. Project work shall be completed in accordance with the guidelines given in the curriculum.

5.4.2. Project work shall be carried out under the supervision of a teacher of the department concerned.

5.4.3. A candidate may, however, in certain cases be permitted to work on the project in an Industrial/Research Organization on the recommendation of the supervising teacher.

5.4.4. There shall be an internal assessment and external assessment for the project work.

5.4.5. The Project work shall be evaluated based on the presentation of the project work done by the student, the dissertation submitted and the viva-voce on the project.

5.4.6. The external evaluation of project work shall be conducted by two external examiners from different colleges and an internal examiner from the college concerned.

5.4.7. The final Grade of the project (External) shall be calculated by taking the average of the Weighted Grade Points given by the two external examiners and the internal examiner.

5.5. **Assignments:** Every college going student shall submit at least one assignment as an internal component for each course.

5.6. **Seminar Lecture:** Every regular student shall deliver one seminar lecture as an internal component for every course with a weightage of two. The seminar lecture is expected to train the student in self-study, collection of relevant matter from the various resources, editing, document writing, and presentation.

5.7. **Test Papers (Internal):** Every regular student shall undergo at least two class tests as an internal component for each course with a weightage of one each. The best two shall be taken for awarding the grade for class tests.

5.8. No courses shall have more than 5 credits unless otherwise specified.

5.9. **Comprehensive Viva-Voce** -Comprehensive Viva-Voce shall be conducted at the end of fourth semester of the programme and its evaluation shall be conducted by the examiners of the project evaluation.

5.9.1. **Comprehensive Viva-Voce** shall cover questions from all courses in the programme.

5.9.2. There shall be an internal assessment and an external assessment for the comprehensive Viva-Voce.

6. ATTENDANCE

6.1. The minimum requirement of aggregate attendance during a semester for appearing at the end-semester examination shall be 75%. Condonation of shortage of attendance to a maximum of 15 days in a semester subject to a maximum of two times during the whole period of the programme may be granted by the Principal.

6.2. If a student represents his/her institution, University, State or Nation in Sports, NCC, or Cultural or any other officially sponsored activities such as college union / university union etc., he/she shall be eligible to claim the attendance for the actual number of days participated subject to a maximum 15 days in a Semester based on the specific recommendations of the Head of the Department or teacher concerned.

6.3. Those who could not register for the examination of a particular semester due to shortage of attendance may repeat the semester along with junior batches, without considering sanctioned strength, subject to the existing University Rules and Clause 7.2.

6.4. A Regular student who has undergone a programme of study under earlier regulation / Scheme and could not complete the Programme due to shortage of attendance may repeat the semester along with the regular batch subject to the condition that he has to undergo all the examinations of the previous semesters as per the MC-PGP-CSS2019 regulations and conditions specified in 6.3.

6.5. A student who had sufficient attendance and could not register for fourth semester examination can appear for the end semester examination in the subsequent years with the attendance and progress report from the Principal.

7. REGISTRATION / DURATION

7.1. A student shall be permitted to register for the programme at the time of admission.

7.2. A student who has registered for the programme shall complete the programme within a period of four years from the date of commencement of the programme.

8. ADMISSION

8.1. The admission to all regular PG programmes shall be through PG-CAP (Centralized Allotment Process) of the Maharaja's College unless otherwise specified.

8.2. The eligibility criteria for admission to PG Programmes shall be published by the Maharaja's College along with the notification for admission.

9. ADMISSION REQUIREMENTS

9.1 Candidates for admission to the first semester of the PG programme through CSS shall be required to have passed an appropriate Degree Examination recognized by Mahatma Gandhi University as specified or any other examination of any recognized University or authority accepted by the Academic council of Mahatma Gandhi University as eligible thereto.

9.2 Students admitted under this programme are governed by the Regulations in force.

10. PROMOTION

10.1. A student who registers for a particular semester examination shall be promoted to the next semester.

10.2. A student having 75% attendance and who fails to register for examination of a particular semester will be allowed to register notionally and is promoted to the next semester, provided application for notional registration shall be submitted within 15 days from the commencement of the next semester.

10.3. The medium of Instruction shall be English except programmes under faculty of Language and Literature.

11. EXAMINATIONS

11.1. There shall be End Semester Examinations at the end of each semester.

11.2. Practical examinations shall be conducted by the College at the end of each semester or at the end of even semesters as prescribed in the syllabus of the particular programme. The number of examiners for the practical examinations shall be prescribed by the Board of Studies of the programmes subjected to the approval of the Academic Council of the College.

11.3. End-Semester Examinations: The examinations shall normally be conducted at the end of each semester for regular students.

11.4. There shall be one end-semester examination of 3 hours duration for each lecture based and practical courses.

11.5. A question paper may contain short answer type/annotation, short essay type questions/problems and long essay type questions. Different types of questions shall have different weightage.

12. EVALUATION AND GRADING

12.1. **Evaluation**: The evaluation scheme for each course shall contain two parts; (a) End Semester Evaluation (ESE) (External Evaluation) and (b) Continuous Evaluation (CE) (Internal Evaluation). 25% weightage shall be given to internal evaluation and the remaining 75% to external evaluation and the ratio and weightage between internal and external is 1:3. Both End Semester Evaluation (ESE) and Continuous Evaluation (CE) shall be carried out using direct grading system.

12.2. **Direct Grading:** The direct grading for CE (Internal) and ESE (External Evaluation) shall be based on 6 letter grades (A+, A, B, C, D and E) with numerical values of 5, 4, 3, 2, 1 and 0 respectively**.**

12.3. **Grade Point Average (GPA):** Internal and External components are separately graded and the combined grade point with weightage 1 for internal and 3 for external shall be applied to calculate the Grade Point Average (GPA) of each course. Letter grade shall be assigned to each course based on the categorization provided in 12.15.

12.4. **Internal** evaluation for Regular programme: The internal evaluation shall be based on predetermined transparent system involving periodic written tests, assignments, seminars, lab skills, records, viva-voce etc.

12.5. **Components of Internal** (CE) **and External Evaluation (ESE):** Grades shall be given to the evaluation of theory / practical / project / comprehensive viva-voce and all internal evaluations are based on the Direct Grading System.

Proper guidelines shall be prepared by the BoS for evaluating the assignment, seminar, practical, project and comprehensive viva- voce within the framework of the regulation.

12.6. There shall be no separate **minimum grade point for** internal evaluation.

12.7. **The model** of the components and its weightages for Continuous Evaluation(CE) and End Semester Evaluation(ESE) are shown in below:

a) For Theory (CE) (Internal)

	Components	**Weightage**
i.	Assignment	1
ii.	Seminar	2
iii.	Best Two Test papers	2 (1 each)
	Total	**5**

(Grades of best two test papers shall be considered. For test papers all questions shall be set in such a way that the answers can be awarded A+, A, B, C, D and E grade)

b) For theory (ESE) External Evaluation is based on the pattern of questions specified in 12.15.5

c) For Practical (CE) Internal

Components	**Weightage**
Written/Lab test	2
Lab involvement and Record	1
Viva	2
Total	**5**

(The components and the weightage of the components of the practical (Internal) can be modified by the concerned BoS without changing the total weightage 5**)**

d) For Practical (ESE) External

Components	**Weightage**
Written / Lab test	7
Lab involvement and Record	3
Viva	5
Total	**15**

(The components and the weightage of the components of the practical (External) can be modified by the concerned BoS without changing the total weightage 15**)**

e) For Project (CE) Internal

Components	Weightage
Relevance of the topic and analysis	2
Project content and presentation	2
Project viva	1
Total	**5**

(The components and the weightage of the components of the project (Internal) can be modified by the concerned BoS without changing the total weightage 5**)**

A two stage Internal evaluation to be followed for the fruitful completion of the project.

f) For Project (ECE) External

Components	Weightage
Relevance of the topic and analysis	3
Project content and presentation	7
Project viva	5
Total	**15**

(The components and the weightage of the components of the Project (External) can be modified by the concerned BoS without changing the total weightage 15**)**

g) Comprehensive viva-voce

Components	Internal (CE) Weight	External (ESE) Weight
Basic knowledge and Presentation skills	1	3
Topic of interest	1	3
Knowledge of core courses	3	9
Total	**5**	**15**

These basic components can be subdivided if necessary. Total as well as component weightage shall not be changed.

12.8. All grade point averages shall be rounded to two digits.

12.9. To ensure transparency of the evaluation process, the internal assessment grade awarded to the students in each course in a semester shall be published on the notice board at least one week before the commencement of external examination.

12.10. **There shall not be any chance for improvement for internal grade**.

12.11. The course teacher and the faculty advisor shall maintain the academic record of each student registered for the course which shall be forwarded to the University through the

Principal and a copy should be kept in the college for verification for at least two years after the student completes the programme.

12.12. External Evaluation. The external examination in theory courses is to be conducted by the University at the end of the semester. The answers may be written in English or Malayalam except those for the Faculty of Languages. The evaluation of the answer scripts shall be done by examiners based on a well-defined scheme of valuation. The external evaluation shall be done immediately after the examination preferably through Centralized Valuation.

12.13. Photocopies of the answer scripts of the external examination shall be made available to the students on request as per the rules prevailing in the College/University.

12.14. The question paper should be strictly on the basis of model question paper set and directions prescribed by the BoS.

12.15. **Pattern of Questions**

12.15.1. Questions shall be set to assess knowledge acquired, standard, and application of knowledge, application of knowledge in new situations, critical evaluation of knowledge and the ability to synthesize knowledge. Due weightage shall be given to each module based on content/teaching hours allotted to each module.

12.15.2. The question setter shall ensure that questions covering all skills are set.

12.15.3. A question paper shall be a judicious mix of short answer type, short essay type /problem solving type and long essay type questions.

12.15.4. The question shall be prepared in such a way that the answers can be awarded A+, A, B, C, D, E grades.

12.15.5. Weight: Different types of questions shall be given different weights to quantify their range as follows:

Sl. No.	Type of Questions	Weight	Number of questions to be answered
1.	Short Answer type questions	1	8 out of 10
2	Short essay/ problem solving type questions	2	6 out of 8
3.	Long Essay type questions	5	2 out of 4

12.16. **Pattern of question for practical**. The pattern of questions for external evaluation of practical shall be prescribed by the Board of Studies.

12.17. **Direct Grading System.** Direct Grading System based on a 6— point scale is used to evaluate the Internal and External examinations taken by the students for various courses of study.

Grade	Grade Points	Range
A+	5	4.50 to 5.00
A	4	4.00 to 4.49
B	3	3.00 to 3.99
C	2	2.00 to 2.99
D	1	0.01 to 1.99
E	0	0.00

12.18. **Performance Grading.** Students are graded based on their performance (GPA/SGPA/CGPA) at the examination on a 7-point scale as detailed below.

Range	Grade	Indicator
4.50 to 5.00	A+	Outstanding
4.00 to 4.49	A	Excellent
3.50 to 3.99	B+	Very good
3.00 to 3.49	B	Good(Average)
2.50 to 2.99	C+	Fair
2.00 to 2.49	C	Marginal (Pass)
up to 1.99	D	Deficient(Fail)

12.19. **No separate minimum is required for internal evaluation for a pass, but a minimum C grade is required for a pass in an external evaluation. However, a minimum C grade is required for pass in a course.**

12.20. **A student who fails to secure a minimum grade for a pass in a course will be permitted to write the examination along with the next batch.**

12.21. **Improvement of Course-** The candidates who wish to improve the grade / grade point of the external examination of a course / courses he/ she has passed can do the same by appearing in the external examination of the semester concerned along with the immediate junior batch. **This facility is restricted to first and second semesters of the programme.**

12.22. **One Time Betterment Programme -** A candidate will be permitted to improve the CGPA of the programme within a continuous period of four semesters immediately following the completion of the programme allowing only once for a particular semester. The CGPA for the betterment appearance will be computed based on the SGPA secured in the original or betterment appearance of each semester whichever is higher. If a candidate opts for the betterment of CGPA of a programme, he/she has to appear for the external examination of the entire semester(s) excluding practicals / project/ comprehensive viva-voce. One time betterment programme is restricted to students who have passed in all courses of the programme at the regular (First appearance).

12.23. **Semester Grade Point Average (SGPA) and Cumulative Grade Point Average (CGPA)** Calculations. The SGPA is the ratio of sum of the credit points of all courses taken by a student in the semester to the total credit for that semester. After the successful completion of a semester, Semester Grade Point Average (SGPA) of a student in that semester is calculated using the formula given below.

Semester Grade Point Average -SGPA (S_j) = $\Sigma(C_i \times G_i) / \Sigma(C_i$

(SGPA= Total credit Points awarded in a semester / Total credits of the semester)

where 'Sj' is the j semester, 'Gi ' is the grade point scored by the Student in the ‘i' course 'q' is the credit of the i^{th} course.

12.24. **Cumulative Grade Point Average (CGPA)** of a Programme is calculated using the formula:-

Cumulative Grade Point Average (CGPA) = $\Sigma((C_i \times S_i) / \Sigma(C_i$

(CGPA= Total credit points awarded in all semesters / Total credits of the programme)

where 'Ci' is the credits for the ‘i' semester 'Si' is the SGPA for the i^{th} semester. The SGPA and CGPA shall be rounded off to 2 decimal points. For the successful completion of semester, a student shall pass all courses and score a minimum SGPA of 2.0. However, a student is permitted to move to the next semester irrespective of her/his SGPA.

13. GRADE CARD

13.1 The University under its seal shall issue to the students, a consolidated grade card on completion of the programme, which shall contain the following information.

- Name of College
- Title of the PG Programme.
- Name of the Semesters

- Name and Register Number of the student
- Code, Title, Credits and Max GPA (Internal, External & Total) of each course (theory& Practical), project, viva etc. in each semester.
- Internal, external and total grade, Grade Point (G), Letter Grade and Credit Point (P) in each course opted in the semester.
- The total credits and total credit points in each semester.
- Semester Grade Point Average (SGPA) and corresponding Grade in each semester
- Cumulative Grade Point Average (CGPA), Grade for the entire programme.
- Separate Grade card will be issued at the request of candidates and based on University Guidelines issued from time to time.
- Details of description of evaluation process- Grade and Grade Point as well as indicators, calculation methodology of SGPA and CGPA as well as conversion scale shall be shown on the reverse side of the grade card.

14. AWARD OF DEGREE

The successful completion of all the courses with 'C' grade within the stipulated period shall be the minimum requirement for the award of the degree.

15. MONITORING COMMITTEE

There shall be a Monitoring Committee constituted by the Vice- chancellor to monitor the internal evaluations conducted by institutions.

16. RANK CERTIFICATE

The College shall publish the list of top 10 candidates for each programme after the publication of the programme results. Rank certificate shall be issued to candidates who secure positions from 1st to 3rd in the list. Position certificate shall be issued to candidates on their request.

Candidates shall be ranked in the order of merit based on the CGPA secured by them. Grace grade points awarded to the students shall not be counted for fixing the rank/position. Rank certificate and position certificate shall be signed by the Controller of Examinations.

17. GRIEVANCE REDRESSAL COMMITTEE

17.1 **Department level:** The College shall form a Grievance Redressal Committee in each Department comprising of the course teacher and one senior teacher as members and the Head of the Department as Chairperson. The Committee shall address all grievances relating to the internal assessment grades of the students.

17.2 **College level:** There shall be a college level Grievance Redressal Committee comprising of faculty advisor, college coordinator, one senior teacher and one staff council member and the Principal as Chairperson.

18. REPEAL

The Regulations now in force in so far as they are applicable to programmes offered by the College and to the extent they are inconsistent with these regulations are hereby repealed. In the case of any inconsistency between the existing regulations and these regulations relating to the Credit Semester System in their application to any course offered in a College, the latter shall prevail.

19. Credits allotted for Programmes and Courses

19.1 Total credit for each programme shall be 80.

19.2 Semester-wise total credit can vary from 16 to 25

19.3 The minimum credit of a course is 2 and maximum credit is 5.

20. Common Course: If a course is included as a common course in more than one programme, its credit shall be same for all programmes.

21. Course codes: The course codes assigned for all courses (core courses, elective courses, common courses etc.) shall be unique.

22. Models of distribution of courses, course codes, type of the course, credits, teaching hours for a programme are given in the following tables.

Example: Programmes without practical -Total Credits 80- Scheme of the Syllabus

Semester	Course. code	Course. name	Type of the course	Teaching Hours per week	Credit	Total Credits
I	Course.code1	Name 1	core	5	4	20
	Course.code2	Name 2	core	5	4	
	Course.code3	Name 3	core	5	4	
	Course.code4	Name 4	core	5	4	
	Course.code5	Name 5	core	5	4	
II	Course.code6	Name 6	core	5	4	20
	Course.code7	Name 7	core	5	4	
	Course.code8	Name 8	core	5	4	

	Course.code9	Name 9	core	5	4	
	Course.code10	Name 10	core	5	4	
III	Course.code11	Name 11	core	5	4	20
	Course.code12	Name 12	core	5	4	
	Course.code13	Name 13	core	5	4	
	Course.code14	Name 14	core	5	4	
	Course.code15	Name 15	core	5	4	
IV	Course.code16	Name 16	Electi ve	5	3	20
	Course.code17	Name 17	Electi ve	5	3	
	Course.code18	Name 18	Electi ve	5	3	
	Course.code19	Name 19	core	5	4	
	Project-Course.code20	Name 20	core	5	5	
	Comprehensive viva-voce-Course.code21	Name 21	core		2	
	Total					**80**

Appendix

1. **Evaluation first stage – Both internal and external (to be done by the teacher)**

Grade	**Grade Points**	**Range**
A+	**5**	**4.50 to 5.00**
A	**4**	**4.00 to 4.49**
B	**3**	**3.00 to 3.99**
C	**2**	**2.00 to 2.99**
D	**1**	**0.01 to 1.99**
E	**0**	**0.00**

The final Grade range for courses, SGPA and CGPA

Range	Grade	Indicator
4.50 to 5.00	**A+**	**Outstanding**
4.00 to 4.49	**A**	**Excellent**
3.50 to 3.99	**B+**	**Very good**
3.00 to 3.49	**B**	**Good**
2.50 to 2.99	**C+**	**Fair**
2.00 to 2.49	**C**	**Marginal**
Upto 1.99	**D**	**Deficient(Fail)**

Theory External (ESE)

Maximum weight for external evaluation is 30. Therefore, maximum Weighted Grade Point (WGP) is 150.

Type of Question	Qn. No's	Grade Awarded	Grade point	Weights	Weighted Grade Point
Short Answer	1	A+	5	1	5
	2	-	-	-	-
	3	A	4	1	4
	4	C	2	1	2
	5	A	4	1	4
	6	A	4	1	4
	7	B	3	1	3
	8	A	4	1	4
	9	B	3	1	3
	10	-	-	-	
Short Essay	11	B	3	2	6
	12	A+	5	2	10
	13	A	4	2	8
	14	A+	5	2	10
	15	-	-	-	-
	16	-	-	-	-

	17	A	4	2	8
	18	B	3	2	6
Long Essay	20	A+	5	5	25
	21	-	-	-	-
	22	-	-	-	-
	23	B	3	5	15
			TOTAL	**30**	**117**
Calculation : Overall Grade of the theory paper = Sum of Weighted Grade Points /Total weight 117/30 = 3.90 = Grade B					

Theory – Internal (CE)

Maximum Weight for internal evaluation is 5. *ie*., maximum WGP is 25

Components	Weight (W)	Grade Awarded	Grade Point (GP)	WGP =W *GP	Overall Grade of the course
Assignment	1	A	4	4	**WGP/Total weight = 24/5 =4.80**
Seminar	2	A+	5	10	
Test paper 1	1	A+	5	5	
Test paper 2	1	A+	5	5	
Total	**5**			**24**	**A+**

Practical-External-ESE

Maximum weight for external evaluation is 15. Therefore, Maximum Weighted Grade Point (WGP) is 75.

Components	Weight (W)	Grade Awarded	Grade Point(GP)	WGP=W *GP	Overall Grade of the course
Written/Lab test	7	A	4	28	**WGP/Total weight = 58 / 15 = 3.86**
Lab involvement & record	3	A+	5	15	
viva	5	B	3	15	
Total	**15**			**58**	**B**

Practical-Internal-CE

Maximum weight for internal evaluation is 5. Therefore Maximum Weighted Grade point (WGP) is 25.

Components	Weight (W)	Grade Awarded	Grade Point(GP)	WGP=W *GP	Overall Grade of the course
Written/ Lab test	2	A	4	8	**WGP/Total weight =17/5=3.40**
Lab involvement & record	1	A+	5	5	
viva	2	C	2	4	
Total	**5**			**17**	**B**

Project-External-ESE

Maximum weight for external evaluation is 15. Therefore Maximum Weighted Grade Point (WGP) is 75.

Components	Weight (W)	Grade Awarded	Grade Point(GP)	WGP=W *GP	Overall Grade of the course
Relevance of the topic & Analysis	2	C	2	4	**WGP/Total weight = 59/15= 3.93**
Project content & presentation	8	A+	5	40	
Project viva-voce	5	B	3	15	
Total	**15**			**59**	**B**

Project-Internal-CE

Maximum weight for internal evaluation is 5. Therefore Maximum Weighted Grade Point (WGP) is 25.

Components	Weight (W)	Grade Awarded	Grade Point(GP)	WGP=W *GP	Overall Grade of the course
Relevance of the topic & Analysis	2	B	3	6	**WGP/Total weight = 21/5 = 4.2**
Project content & presentation	2	A+	5	10	
Project viva-voce	1	A+	5	5	
Total	**5**			**21**	**A**

Comprehensive viva-voce-External-ESE.

Maximum weight for external evaluation is 1.5. Therefore Maximum Weighted Grade Point (WGP) is 75.

Comprehensive viva voce-Internal-CE

Maximum weight for internal evaluation is 5. Therefore Maximum Weighted Grade Point (WGP) is 25.

Components	Internal (CE) Weight	External (ESE) Weight
Basic knowledge and Presentation skills	1	3
Topic of interest	1	3
Knowledge of core courses	3	9
Total	**5**	**15**

These basic components can be subdivided if necessary.

2. **Evaluation - second stage -**

Consolidation of the Grade (GPA) of a Course PC-I.

The End Semester Evaluation (ESE) (External evaluation) grade awarded for the course PC-I is A and its Continuous Evaluation (CE) (Internal Evaluation) grade is A. The consolidated grade for the course PC-I is as follows:

Evaluation	Weight	Grade awarded	Grade Points awarded	Weighted Grade Point

External	3	A	4.20	12.6
Internal	1	A	4.40	4.40
Total	**4**			**17**
Grade of a course.	GPA of the course =Total weighted Grade Points/Total weight **17/4 =4.25 = Grade A**			

3. **Evaluation -Third Stage**

Semester Grade Point Average (SGPA).

Course code	Title of the course	Credits (C)	Grade Awarded	Grade Points(G)	Credit Points (CP=C X G)
01	**PC-1**	**5**	**A**	**4.25**	**21.25**
02	**-----**	**5**	**A**	**4.00**	**20.00**
03	**-----**	**5**	**B+**	**3.80**	**19.00**
04	**-----**	**2**	**A**	**4.40**	**8.80**
05	**-----**	**3**	**A**	**4.00**	**12.00**
TOTAL		**20**			**81.05**
SGPA	**Total credit points / Total credits = 81.05/20 = 4.05 = Grade- A**				

4. **Evaluation - fourth Stage -**

Cumulative Grade Point Average (CGPA)

If a candidate is awarded three A+ grades in semester 1 (SGPA of semester 1), semester 2 (SGPA of semester 2) and semester 4 (SGPA of semester 4) and a B grade in semester 3 (SGPA of semester 3). Then the CGPA is calculated as follows:

Semester	Credit of the Semesters	Grade Awarded	Grade point (SGPA)	Credit points
I	20	A+	4.50	90
II	20	A+	4.60	92
III	20	B	3.00	60
IV	20	A+	4.50	90
TOTAL	**80**			**332**
CGPA= Total credit points awarded / Total credit of all semesters **= 332 / 80 = 4.15 (Which is in between 4.00 and 4.49 in 7-point scale)** **Therefore, the overall Grade awarded in the programme is A**				

Masters of Science in Statistics

Programme Structure& Syllabi for MSc. Statistics

(With effective from the academic year 2022 admission onwards)

Overview

M.Sc. Statistics is a Postgraduate degree course focusing on developing data analysis skills and theoretical knowledge in all of the core areas of statistics. It is designed to achieve broad knowledge in theoretical statistics and wide range of skills in statistical applications. These highly sought after skills in statistics are currently in demand in government agencies, IT/consulting firms and industry. The Master degree in Statistics is intended for quantitatively oriented Mathematics/Statistics students with bachelor's degrees in related field.

Duration

The duration of PG program shall be 4 semesters. The duration of each semester shall be 90 working days. A student may be permitted to complete the program, in a period of 4 continuous semesters from the date of commencement of the first semester of the programs.

Program Structure

The programme shall include two types of courses, Program Core (PC) courses and Program Elective (PE) Courses. There shall be a Program Project (PP) with dissertation to be undertaken by all students. The Programme will also include assignments, seminars / practical, viva etc., if they are specified in the Curriculum. In the third and the fourth semesters the students can choose electives that will suit the needs of students, from the electives specified in the syllabus. There shall also be a Program Project or dissertation to be undertaken by all students. Every program conducted under Credit Semester System.

Viva Voce

Comprehensive Viva-voce shall be conducted at the end semester of the program and it shall cover questions from all courses in the program.

Project work

Project work shall be completed by working outside the regular teaching hours under the supervision of a teacher in the concerned department. There should be an internal assessment and external assessment for the project work. The external evaluation of the Project work is followed by presentation of work including dissertation and Viva-Voce.

Examinations

There shall be end-semester examination at the end of each semester. Project evaluation and Viva -Voce shall be conducted at the end of the program only. Project evaluation and Viva-Voce shall be conducted by external examiner and one internal examiner. There shall be one end-semester examination of 3 hours duration in each lecture based course and practical course. The examinations for which computers are essential should be conducted in the computer lab supervised by an external examiner.

SYLLABUS – M.Sc. STATISTICS

Semester	Course Code	Course Name	Credit	Hours
I	PG1STAC01	MEASURE AND PROBABILITY THEORY	4	5
	PG1STAC02	DISTRIBUTION THEORY	4	5
	PG1STAC03	ANALYTICAL TOOLS FOR STATISTICS	4	5
	PG1STAC04	SAMPLING THEORY	4	5
	PG1STAC05	STATISTICAL COMPUTING USING R	4	5
		Total	**20**	**25**
II	PG2STAC06	OPERATIONS RESEARCH	4	5
	PG2STAC07	PROBABILITY AND MULTIVARIATE DISTRIBUTIONS	4	5
	PG2STAC08	THEORY OF ESTIMATION	4	5
	PG2STAC09	STOCHASTIC PROCESSES	4	5
	PG2STAC10	STATISTICAL COMPUTING USING PYTHON	4	5
		Total	**20**	**25**
III	PG3STAC11	TESTING OF STATISTICAL HYPOTHESES	4	5
	PG3STAC12	DESIGN AND ANALYSIS OF EXPERIMENTS	4	5
	PG3STAC13	MULTIVARIATE ANALYSIS	4	5
	PG3STAC14	STATISTICAL COMPUTING USING SPSS	4	5
	PG3STAE01	STATISTICAL QUALITY ASSURANCE	3	5
	PG3STAE02	CATEGORICAL DATA ANALYSIS		
		Total	**19**	**25**
IV	PG4STAC15	ECONOMETRIC METHODS	4	5
	PG4STAC16	STATISTICAL COMPUTING USING SAS	4	5
	PG4STAE03	TIME SERIES ANALYSIS	3	5
	PG4STAE04	POPULATION DYNAMICS	3	5
	PG4STAE05	SURVIVAL ANALYSIS		
	PG4STAPD	PROJECT/ DISSERTATION	5	5
	PG4STAPV	VIVA-VOCE	2	
		Total	**21**	**25**

TOTAL CREDITS: 80

PROGRAM SPECIFIC OUTCOME (PSO)

PSO1. Students will acquire both a conceptual and operational understanding of the core areas of statistics.

PSO2. Students will acquire both a conceptual and operational understanding in the applied fields like sample surveys, time series analysis, multivariate statistics, optimization, experimental design and analysis, quality control/reliability analysis, econometrics, demography, population dynamics/categorical data analysis, etc.

PSO3. Students will achieve the qualities of precision and clarity in the communication of statistical ideas, effective use of non-classroom resources to gain knowledge. Proficiency in the formulation and construction of statistical results, practice in analyzing, formulating, modeling, testing, and interpretation of the results.

PSO4. Students shall acquire effective skills in reasoning and report writing. They will be capable of using computer technologies and statistical software like SPSS, R, PYTHON and SAS.

FIRST SEMESTER

Sl. No.	Course Code	Course Name
1	PG1STAC01	MEASURE AND PROBABILITY THEORY
2	PG1STAC02	DISTRIBUTION THEORY
3	PG1STAC03	ANALYTICAL TOOLS FOR STATISTICS
4	PG1STAC04	SAMPLING THEORY
5	PG1STAC05	STATISTICAL COMPUTING USING R

COURSE CODE : **PG1STAC01**

COURSE TITLE : **MEASURE AND PROBABILITY THEORY**

CREDITS : **4**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	**Course Outcome (Expected)**	**Cognitive Level**	**PSO No.**
1	Learn the basics of Set theory and integration	U, Ap	1
2	Understand the concepts of random variables, sigma-fields generated by random variables, probability distributions and independence of random variables related to measurable functions.	U, Ap	1, 2
3	Develop probabilistic concepts (random variables, expectation and limits) within the framework of measure theory	U, Ap, C	1, 2
4	Gain the ability to understand the concepts of measurable functions, sequence of random variables, convergence, modes of convergence.	U, Ap, E	1, 2, 3
5	The inequalities and theorems will boost the students/researchers to develop their own inequalities/theorems of need	R, Ap, C	1, 2

PSO – Programme Specific Outcome, CO-Course Outcome;

Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create.

Course Content:

Module	**Course Description**		**Hours**	**CO No.**
I	1.1	Algebra of sets	25	1, 2
	1.2	Limit of a sequence of sets		1, 2
	1.3	Fields, Sigma fields, Borel field		1, 2
	1.4	Definition of Lebesgue measure and Counting measure.		2, 3
	1.5	Measurable functions and their properties		2, 3
	1.6	Integrals of indicator function, simple function and measurable functions, basic integration theorems		1, 3, 4
	1.7	Monotone convergence theorem		1, 4, 5
	1.8	Fatou's Lemma		1, 4, 5
	1.9	Bounded convergence theorem and Lebesgue dominated convergence theorem.		1, 4, 5

II	2.1	Probability space and elementary properties of probability measure.	20	2, 3
	2.2	Discrete and Continuous Probability Space		2
	2.3	Monotone and continuity property of probability measures.		2, 3
	2.4	Independence of finite number and sequence of events.		1, 2
	2.5	Borel-Cantelli Lemma, Borel 0-1 criterion		3, 5
	2.6	Conditional probability and Baye's theorem		3, 5
III	3.1	Random variables		2, 3
	3.2	Properties of random variables		2, 3
	3.3	Distribution function and its properties		2, 3
	3.4	Jordan decomposition theorem		2, 5
	3.5	Correspondence theorem (statement only).		2, 5
	3.6	Mathematical expectation and its properties		4
	3.7	Basic, Chebyshev's, Markov's, Liaponov's, Jensen's, Cr, Cauchy-Swartz's, Holder's, Minkowski's inequalities		2, 5
	3.8	Independence of random variables.		2
IV	4.1	Convergence almost sure	20	4
	4.2	Convergence in probability		4
	4.3	Convergence in distribution		4
	4.4	Convergence in r^{th} mean		4
	4.5	Inter relationship between modes of convergence		4
	4.6	Komogorov's inequality for i.i.d random variables		
	4.7	Helly-Bray Lemma (Statement Only)		2, 5

Reference books

1) Basu A.K. (2012). Measure Theory and Probability, Second Edition, PHI Learning Pvt. Ltd, New Delhi.
2) Bhat B.R (1999) Modern Probability theory, Third Edition, Wiley Eastern Ltd, New Delhi.
3) Laha R.G. and Rohatgi V.K. (1979) Probability theory, John Wiley
4) Rao C.R. (2009) Linear Statistical Inference and its Applications, Second edition, Wiley Eastern
5) Robert G. Bartle (2001) A Modern Theory of Integration, American Mathematical Society (RI)
6) Rohatgi V.K. and SalehM. (2015) An introduction to probability and statistics, Third edition, Wiley.

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Module	**Part A** (Weight 1) 8/10	**Part B** (Weight 2) 6/8	**Part C** (Weight 5) 2/4
I	2	2	1
II	3	2	1
III	2	2	1
IV	3	2	1
Total	**10**	**8**	**4**

MODEL QUESTION PAPER

First Semester

Programme – M.Sc. Statistics

PG1STAC01 - MEASURE AND PROBABILITY THEORY

(2022 Admission – Regular)

Time: Three Hours Maximum Weight: 30

Part A

Short Answer Questions

*(Answer any **eight** questions. Each question carries Weight **1**)*

1. Define limit superior of a sequence of sets, and find the same of the sequence of intervals $\{A_n\} = \{(5 - \frac{1}{n}, 8)\}$.
2. State Lebesgue dominated convergence theorem.
3. State the monotone property of probability measure, and show that for any event A, $0 \leq P(A) \leq 1$.
4. Obtain the equations defining the independence of a class of three events.
5. State the law of total probability.
6. Show that $\text{Min}(X_1, X_2, \ldots X_n)$ is a random variable, if $X_1, X_2, \ldots X_n$ are random variables.
7. State the necessary and sufficient conditions for a function to be the distribution function of a random variable.
8. Give a necessary and sufficient condition for convergence in probability of a sequence of random variables.
9. Define convergence in law of a sequence of random variables.

10. What is the implication between convergence in probability and that in distribution of a sequence of random variables?

(8x1=8 Weights)

Part B
Short Essay Questions/Problems
*(Answer any **six** questions. Each question carries Weight **2**)*

11. Show that the union of a sequence of arbitrary events can be expressed as the union of a sequence of mutually exclusive events.
12. Describe the Constructive definition of measurable function.
13. Find the probability of observing the pattern THH when a coin is tossed indefinitely. State the result you used.
14. State and prove Liaponov's inequality on absolute moments.
15. State and prove a necessary and sufficient condition for convergence almost surely of a sequence of random variables.
16. State and prove Baye's theorem.
17. Show that $F_X(x) = P(X \leq x)$ is a distribution function.
18. Verify the Statement "Convergence in probability implies convergence in distribution".

(6x2=12 Weights)

Part C
Long Essay Questions
*(Answer any **two** questions. Each question carries Weight **5**)*

19. State and prove Fatou's Lemma.
20. State and prove Borel zero-one criterion.
21. State and prove Jordan decomposition theorem on distribution functions.
22. State and prove Kolmogorov's inequality on the convergence of a sequence of random variables.

(2x5=10 Weights)

COURSE CODE : **PG1STAC02**

COURSE TITLE : **DISTRIBUTION THEORY**

CREDITS : **4**

Course Outcome:

Upon the successful completion of the course students will be able to accomplish the following:

CO No.	Course Outcome (Expected)	Cognitive Level	PSO No.
1	Provide a solid and well based introduction to various discrete distributions and investigate their important properties.	U , Ap	1,2,4
2	Provide a solid and well based introduction to various absolutely continuous distributions and investigate their important properties.	U, Ap	1,2,4
3	Enables to cover foundations in sampling distributions and order statistics	U	1,2
4	Enables to understand some bivariate distributions	U, Ap	1,2,3

PSO – Programme Specific Outcome, CO-Course Outcome;
Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create.

Course Content:

Module	Course Description	Hours	CO No.
I	1.1. Discrete Distributions	25	1
	1.2. Bernoulli distribution		1
	1.3. Binomial distribution		1
	1.4. Poisson distribution		1
	1.5. Negative binomial distribution		1
	1.6. Geometric distribution		1
	1.7. Hyper geometric distribution		1
	1.8 Power series distributions–definition, member identification		1
II	2.1. Continuous Distributions	25	2
	2.2. Rectangular distribution		2
	2.3. Exponential distribution		2
	2.4. Weibull distribution		2
	2.5. Beta distribution		2
	2.6. Gamma distribution		2
	2.7. Pareto distribution		2
	2.8. Normal distribution		2
	2.9. Lognormal distribution		2
	2.10. Cauchy distribution		2
	2.11. Laplace distribution		2
	2.12. Logistic distribution		2

	2.13. Inverse Gaussian distribution		2
III	3.1. Sampling distributions	20	3
	3.2. Chi-square distribution		3
	3.3. *t* distribution		3
	3.4 *F* distribution		3
	3.5. Non-central Chi-square distribution		3
	3.6. Non-central *t* distribution		3
	3.7. Non-central *F* distribution		3
	3.8. Order statistics		3
	3.9. Joint and marginal distributions of Order statistics		3
IV	4.1. Multinomial distribution	20	4
	4.2. Bivariate Normal distributions		4
	4.3. Bivariate Exponential distribution		4

Reference Books

1) Arnold B.C, Balakrishnan N. and Nagaraja H.N. (1992) A first Course in Order Statistics.
2) Gupta S.C. and Kapoor V.K. (2000) Fundamentals of Mathematical Statistics, S. Chand & Co, New Delhi.
3) Hogg R.V and Craig A.T. (2013) Introduction to Mathematical Statistics, Macmillian publishing company.
4) Johnson N.L, Kotz S. and Balakrishnan N. (1991) Continuous Univariate distributions I & II, Wiley.
5) Johnson N.L, Kotz S. and Kemp A.W. (1992) Univariate discrete distributions, Wiley.
6) Johnson N.L, Kotz S. and Kemp A.W. (1992) Multivariate discrete distributions, Wiley.
7) Kotz S, Balakrishnan N. and Johnson N.L. (2000) Continuous Multivariate distributions, Wiley.
8) Rohatgi V.K. and Saleh M. (2015) An introduction to probability and statistics, Third edition, Wiley

Question Paper Blue Print

Module	**Part A** (Weight 1) 8/10	**Part B** (Weight 2) 6/8	**Part C** (Weight 5) 2/4
I	3	2	1
II	3	2	1
III	2	2	1
IV	2	2	1
Total	**10**	**8**	**4**

MODEL QUESTION PAPER

First Semester

Programme – M.Sc. Statistics

PG1STAC02 - DISTRIBUTION THEORY

(2022 Admission – Regular)

Time: Three Hours | Maximum Weight: 30

Part A

Short Answer Questions

*(Answer any **eight** questions. Each question carries Weight **1**)*

1. Define probability generating function. Deduce variance from pgf
2. Derive the recurrence relation for central moments of Binomial distribution
3. Derive the moment generating function of Poisson distribution.
4. Find Characteristic function of Beta distribution
5. Let X_1 and X_2 be two independent exponential rvs with parameter θ. Find the distribution of $X_1 + X_2$
6. Let Xfollows N(0,1). Find the distribution of X^2
7. Define multinomial distribution.
8. Define r^{th}order statistic. Find the pdf of $X_{(r)}$
9. Obtain the moment generating function of χ^2 distribution
10. Let F follows F (m,n). Find the distribution of (1+ (m/n)F)

(8x1=8 Weights)

Part B

Short Essay Questions/Problems

*(Answer any **six** questions. Each question carries Weight **2**)*

11. Let X_1 follows G (α_1,θ) and X_2 follows G (α_2,θ). Find the distribution of X_1 / X_2
12. Find the characteristic function of Cauchy distribution
13. If X_1 follows Uniform(0,1) and conditional distribution of X_2 / X_1 follows follows Binomial (n, x). Find the distribution of X_2
14. Define the power series distribution. Show that Binomial is a particular case of power series distribution
15. Derive the joint pdf of $r^{th}$and s^{th}order statistics, Derive the distribution of range.
16. Derive mean and mode of F distribution
17. State the properties of bivariate exponential distribution.
18. State and prove the interrelationship between χ^2 ,t and F distribution.

(6x2=12 Weights)

Part C

Long Essay Questions

*(Answer any **two** questions. Each question carries Weight **5**)*

19. Let $X_1, X_2, \ldots, X_n$ be random sample of size n from exponential distribution with pdf

    $f(x) = \theta e^{-\theta x} \quad x \geq 0$

    i)Find the pdf of r^{th} order statistic ii) Show that $X_{(r)}$ and $X_{(r)} - X_{(s)}$ are independent

20. State and prove bivariate lack of memory property.

21. Derive the mgf of Power series distribution. Find the mgf of Poisson from the mgf of Power series distribution. Derive the recurrence relation for cumulants of Power series distribution.

22. Let X_1 and X_2 be two independent χ^2rvs with parameters $n_1$and n_2 respectively.

    i) Find the distribution of $X_1 + X_2$, X_1 / X_2

    ii) Show that X_1+X_2 and X_1/ X_1+X_2 are independent

(2x5=10 Weights)

COURSE CODE : **PG1STAC03**

COURSE TITLE : **ANALYTICAL TOOLS FOR STATISTICS**

CREDITS : **4**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	Course Outcome (Expected)	Cognitive Level	PSO No.
1	Solve the problems related to convergence of sequence and series of real valued functions and maxima-minima of functions of several variables.	Ap	1,2
2	Explain the concepts vector and matrix algebra, including linear independence, basis and dimension of a subspace, rank and nullity of matrices.	U	1,4
3	Understand and solve systems of linear equations and interpret their results	U, Ap	1,3,4
4	Introduce and analyse the concepts in linear algebra like characteristic roots and vectors, generalized inverses.	U, An	1,2
5	Apply the concepts of quadratic forms and spectral decomposition of matrices useful in multivariate statistical analysis.	Ap	1,3,4

PSO – Programme Specific Outcome, CO-Course Outcome;
Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create.

Course Content:

Module	Course Description	Hours	CO No.
I	1.1. Sequence and series of real numbers*	20	1
	1.2. Convergence of sequence and series of real numbers*		1
	1.3. Continuity and uniform continuity*		1
	1.4. Differentiability*		1
	1.5. Functions of several variables: maxima and minima		1
	1.6. Method of Lagrangian multipliers		1
	1.7. Laplace transform and its application to Differential equations		1
	1.8. Fourier transform (Basic concepts)		1
II	2.1. Vector spaces and Subspaces	20	2
	2.2. Linear independence of vectors		2
	2.3. Basis and dimension of a vector space		2

	2.4. Inner product and orthogonal vectors		2
	2.5. Orthonormal basis		2
	2.6. Gram-Schmidt orthogonalization process		2
	2.7. Matrix and its properties		2
	2.8. Rank of a matrix		2
	2.9. Partitioned matrices		2
III	3.1. Linear equations	25	3
	3.2. Rank-Nullity theorem		3
	3.3. Characteristic roots and vectors		4
	3.4. Characteristic subspaces of a matrix		4
	3.5. Nature of characteristic roots of s special types of matrices		4
	3.6. Algebraic and geometric multiplicity of a characteristic root		4
	3.7. Cayley-Hamilton theorem		4
	3.8. Generalized inverse and its properties		4
	3.9. Moore-Penrose inverse and its computations		4
IV	4.1. Quadratic forms	25	5
	4.2. Congruent transformations		5
	4.3. Congruence of symmetric matrices		5
	4.4. Canonical reduction of real quadratic forms		5
	4.5. Orthogonal reduction of real quadratic forms		5
	4.6. Nature of quadratic forms		5
	4.7. Simultaneous reduction of quadratic forms		5
	4.8. Similarity of matrices		5
	4.9. Spectral decomposition of real symmetric matrices		5
	4.10. Singular value decomposition		5

*Definition and Problems only

Reference Books

1) Apostol T.M. (1996) Mathematical Analysis, Second edition, Narosa Publishing House, New Delhi.
2) Gilbert Strang (2014) Linear Algebra and its Applications, 15th Re-Printing edition, Cengage Learning.
3) Hoffman K. and Kunze R. (2014) Linear Algebra, Second edition, Phi Learning.
4) Malik S.C. and Arora S. (2014) Mathematical analysis, Fourth edition, New age international.
5) Rao A.R. and Bhimasankaram P. (2000) Linear Algebra, Second edition, Hindustan Book Agency.
6) Rao C.R. (2009) Linear Statistical Inference and its Applications, Second edition, Wiley Eastern.

Question Paper Blue Print

Module	**Part A** (Weight 1) 8/10	**Part B** (Weight 2) 6/8	**Part C** (Weight 5) 2/4
I	2	2	1
II	3	2	1
III	3	2	1
IV	2	2	1
Total	**10**	**8**	**4**

MODEL QUESTION PAPER

First Semester

Programme – M.Sc. Statistics

PG1STAC03 - ANALYTICAL TOOLS FOR STATISTICS

(2022 Admission – Regular)

Time: Three Hours Maximum Weight: 30

Part A

Short Answer Questions

*(Answer any **eight** questions. Each question carries Weight **1**)*

1. Distinguish between continuity and uniform continuity of a function.
2. If $L\{F(\text{t})\} = f(\text{s})$, then find $L\{F(\text{at})\}$.
3. Define (i) Vector space and (ii) Basis of a vector space.
4. Give two definitions of rank of a matrix.
5. Define linear independence of vectors.
6. Define algebraic multiplicity and geometric multiplicity of characteristic roots.
7. Show that two similar matrices have the same characteristic roots.
8. Define a g-inverse.
9. Write down the symmetric matrix associated with the quadratic form $x^2 - xy + 3y^2$.
10. Define (i) Index of a quadratic form and (ii) signature of a quadratic form.

(8x1=8 Weights)

Part B

Short Essay Questions/Problems

*(Answer any **six** questions. Each question carries Weight **2**)*

11. Test for convergence of the infinite series $\sum_{n\geq 1} \frac{n+1}{n^p}$.

12. Using Laplace transform solve $y''+2y'+y=6te^{-t}$, given that $y(0)=2, y'(0)=5$.

13. If S and T are two subspaces of a vector space V, then show that $S\cap T$ and $S+T$ are subspaces of V.

14. Determine whether or not the following set of vectors is linearly independent {(1, 2, 6), (-1, 3, 4), (-1, -4, -2)}.

15. State and prove a necessary and sufficient condition for the system $AX = B$ to be consistent.

16. State and Prove Cayley-Hamilton theorem.

17. Show that every square matrix is unitary similar to a triangular matrix.

18. Explain the spectral decomposition of real symmetric matrices and prove its properties.

(6x2=12 Weights)

Part C
Long Essay Questions
*(Answer any **two** questions. Each question carries Weight **5**)*

19. (i) State the conditions under which a function of several variables has a maximum or minimum at a point.

    (ii) Find maxima and minima of the function $f(x,y)=x^3+y^3-3x-12y+20$.

20. Explain Gram-Schmidt method of constructing an orthonormal basis of a finite dimensional vector space. Illustrate it using an example.

21. State and prove rank-nullity theorem.

22. State and prove a necessary and sufficient condition for positive definiteness of a quadratic form.

(2x5=10 Weights)

COURSE CODE : **PG1STAC04**

COURSE TITLE : **SAMPLING THEORY**

CREDITS : **4**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	Course Outcome (Expected)	Cognitive Level	PSO No.
1	Understand the principles underlying sampling as a means of making inferences about a population and the estimation methods for population mean, total and proportion under various sampling schemes.	U	1,2
2	Apply various sampling procedures like SRS, Stratified, systematic, Cluster etc., and estimate the population parameters for attributes and variables;	Ap	1,2
3	Learn about various approaches to estimate admissible parameters; with and without replacement sampling scheme, sampling with varying probability of selection.	U, Ap	1,2,3
4	Use practical applications of ratio and regression methods of estimation	Ap	2,3
5	Apply various sampling methods to real world problems	Ap, An	2,3,4

PSO – Programme Specific Outcome, CO-Course Outcome;
Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create.

Course Content:

Module	Course Description	Hours	CO No.
I	1.1. Census and sampling methods, Sampling & Non sampling errors, methodologies in sample surveys by NSSO	25	1
	1.2. Probability sampling and non-probability sampling		1
	1.3. Simple random sampling with (SRSWR) and without replacement (SRSWOR)		1, 2
	1.4. Estimation of the population mean, total and proportions,		1
	1.5. Properties of the estimators, variance and standard error of the estimators, confidence intervals		1, 2
	1.6. Sample size determination under SRS		2
	1.7. Stratified random sampling		2, 5
	1.8. Estimation of the population mean, total and proportion & their properties under Stratified sampling		2
	1.9. Optimum allocation, other types of allocation		1, 2
	1.10 Comparison of the precisions of estimators		2
II	2.1. Systematic sampling: Linear & Circular	25	1, 2
	2.2 Estimation of mean and variance		1, 2
	2.3. Comparison of systematic sampling with SRS and stratified sampling		2

	2.4. Comparison with populations having a linear trend		2
	2.5. Cluster sampling, single stage cluster sampling with equal and unequal cluster sizes		2, 5
	2.6. Estimation of the population mean and its standard error		2
	2.7. Multistage and multiphase sampling		2, 5
	2.8. Two-stage cluster sampling with equal and unequal cluster sizes		2, 5
	2.9. Estimation of the population mean and its standard Error (Equal sizes only)		2
	2.10. Comparison of cluster sampling with SRS and stratified sampling		2
	2.11. Concept of Interpenetrating sub-sampling.		2
III	3.1. Unequal probability sampling	20	3, 5
	3.2. PPS sampling with and without replacement		3
	3.3. Inclusion probabilities		3
	3.4. Cumulative total method, Lahiris method		3, 5
	3.5. Midzuno-Zen method		3, 5
	3.6. Estimation of the population total and its estimated variance under PPSWR sampling		3
	3.7. Ordered and unordered estimators of the population total under PPSWOR		3
	3.8. Horwitz–Thomson estimator and its estimated SE		3
	3.9. Des-Raj's ordered estimator & its properties for n=2		3
	3.10. Murthy's unordered estimator & its properties for n=2		3
IV	4.1. Inference in survey sampling -fixed population and super population approach	20	4
	4.2. Ratio method of estimation		4
	4.3. Estimation of the population ratio, mean and total, Comparison with SRS		4
	4.4. Hartly-Ross estimator		4
	4.5. Regression method of estimation		4
	4.6. Large sample comparison with mean per unit estimator and ratio estimators		4
	4.7. Basic ideas of Quota sampling; Network sampling and Adaptive sampling.		5

Reference Books

1) Ardilly P., Tille' Y. (2006). Sampling Methods: Exercises and Solutions, Springer.
2) Cochran W. G. (1999) Sampling Techniques, 3rd edition, John Wiley and Sons.
3) George A. F. Seber, Mohammad M. Salehi (2013). Adaptive Sampling Designs Inference for Sparse and Clustered Populations, Springer.

4) Mukhopadyay P. (2009) Theory and Methods of Survey Sampling, 2nd edition, PHL, NewDelhi.

5) Sampath S. C. (2001) Sampling Theory and Methods, Alpha Science International Ltd., India.

6) Sarinder Singh (2003) Advanced Sampling Theory with Applications, Springer-Sciences Business media B V

7) Singh D. and Choudhary F. S. (1986) Theory and Analysis of Sample Survey Designs, Wiley Eastern Ltd.

Question Paper Blue Print

Module	**Part A** (Weight 1) 8/10	**Part B** (Weight 2) 6/8	**Part C** (Weight 5) 2/4
I	3	2	1
II	3	2	1
III	2	2	1
IV	2	2	1
Total	**10**	**8**	**4**

MODEL QUESTION PAPER

First Semester

Programme – M.Sc. Statistics

PG1STAC04 - SAMPLING THEORY

(2022 Admission – Regular)

Time: Three Hours — Maximum Weight: 30

Part A

Short Answer Questions

*(Answer any **eight** questions. Each question carries Weight **1**)*

1. What is meant by sampling error?
2. When do you make use of Stratified Sampling?
3. What are the advantages of systematic sampling?
4. Define regression estimator.
5. What is the second order inclusion probability with Zen –Midzuno scheme of sampling?
6. Define network sampling
7. Name any two methods of selecting a PPS Sample.
8. What is Multiphase sampling?

9. What is Des-Raj's ordered estimator?
10. What do you mean by ratio estimator of population mean?

(8x1=8 Weights)

Part B

Short Essay Questions/Problems

*(Answer any **six** questions. Each question carries Weight **2**)*

11. What is stratified random sampling? Explain any two methods of allocation of sample sizes in strata.
12. Derive Hartley-Ross unbiased ratio type estimator of population total
13. Distinguish between linear and circular systematic sampling.
14. Derive Murthy's unordered estimator in PPS sampling
15. Prove that if N = nk, with usual notations, systematic sample mean $\bar{y}_{sy}$ is an unbiased estimator of population mean. Also find its variance.
16. What do you mean by PPS sampling? Explain any one procedure of drawing a PPS sample with replacement. Give an example.
17. Give the method of estimating the population proportion in a finite population using SRSWOR.What is its variance?
18. Find the variance of the ratio estimator of population total.

(6x2=12 Weights)

Part C

Long Essay Questions

*(Answer any **two** questions. Each question carries Weight **5**)*

19. (a) Carry out a comparison between SRSWOR and SRSWR.

    (b) Prove that in stratified random sampling with a linear cost function, $V(\bar{y}_{st})$ is minimum for a fixed cost C and the cost is minimum for a fixed $V(\bar{y}_{st})$ when $n_h \propto \frac{W_h S_h}{\sqrt{C_h}}$
20. Derive the variance of the ratio estimator of population total. Also find an upper limit of its bias
21. Explain cluster sampling. Show that the mean of cluster means in the sample is an unbiased estimate of population mean if clusters are of equal size. Also derive its variance.
22. (a) Distinguish between ordered and unordered estimators.

    (b) Define Horvitz Thompson estimator for population total in varying probability sampling. Show that it is unbiased.

(2x5=10 Weights)

COURSE CODE : **PG1STAC05**

COURSE TITLE : **STATISTICAL COMPUTING USING R**

CREDITS : **4**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	Course Outcome (Expected)	Cognitive Level	PSO No.
1	Understand basics of R programming and perform various operations on data in R.	U, An	1,4
2	Apply the principles of statistical distributions to solve problems	Ap	2,3,4
3	Solve the problems related to linear algebra like system of linear equations, characteristic roots and vectors, generalized inverses, classification of quadratic forms, and spectral decomposition.	Ap	2,3,4
4	Solve the problems related to Simple random sampling, Stratified random sampling, Systematic sampling, Ratio & Regression methods of estimation, Cluster sampling and Unequal probability sampling	Ap.	2,3,4
5	Equips the student with the intellectual apparatus and cognitive skills with which theoretical learning is applied to analyse and solve both social behavioural patterns and statistical problems.	Ap	2,3,4

PSO – Programme Specific Outcome, CO-Course Outcome;
Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create.

Course Content:

Module	Course Description	Hours	CO No.
I	1.1. Introduction to electronic spread sheets	15	1,5
	1.2. Working with work books, excel functions		1,5
	1.3. Charts and Pivot Tables		1,5
	1.4. Basics of R and R-Studio, R Sessions and Functions		1,5
	1.5. Basic math, variables, data types, vectors, data frames, lists		1,5
	1.6. Matrices, Arrays, Classes, Importing data files		1,5
	1.7. Control Statements, Loops		1.5
	1.8. Simple R programs based on following modules		1,5
	2.1. Fitting of Binomial distribution	25	1,2,5

II	2.2. Fitting of Poisson distribution		1,2,5
	2.3. Fitting of Negative Binomial distribution		1,2,5
	2.4. Fitting of Geometric distribution		1,2,5
	2.5. Fitting of Exponential distribution		1,2,5
	2.6. Fitting of Normal distribution		1,2,5
	2.7. Fitting of log normal distribution		1,2,5
	2.8. Goodness of fit		1,2,5
III	3.1. Linear independence of set of vectors	25	1,3,5
	3.2. Construction of orthonormal basis		1,3,5
	3.3. Determination of null Space and nullity of a matrix		1,3,5
	3.4. Solution of system of linear equations		1,3,5
	3.5. Computation of characteristics roots and vectors		1,3,5
	3.6. Computation of the inverse of matrix by partitioning.		1,3,5
	3.7. Computation of g-inverse		1,3,5
	3.8. Computation of Moore Penrose g-inverse		1,3,5
	3.9. Identification of nature of quadratic forms		1,3,5
	3.10. Canonical reduction of quadratic forms		1,3,5
	3.11. Orthogonal reduction of quadratic forms		1,3,5
	3.12. Spectral decomposition of real symmetric matrices		1,3,5
IV	4.1. Estimator of population mean, total, proportion Confidence interval of population mean, total proportion and estimator of variances under SRS	25	1,4,5
	4.2. Estimator of population parameters and their variances under stratified random sampling and the comparison of efficiency with SRS		1,4,5
	4.3. Estimation of population parameters under systematic sampling and their efficiency with SRS		1,4,5
	4.4. Estimation using ratio and regression methods and their variances		1,4,5
	4.5. Estimation of population parameters under cluster sampling and their efficiency with SRS		1,4,5
	4.6. Sample selection procedures under PPS sampling and estimation of population parameters using PPSWR, DesRaj ordered estimator, Murthy’s estimator, Horvits-Thompson estimator and comparison of these procedures		1,4,5

Question Paper Blue Print

Total No. of Questions	**Module I** (R Programming)	**Module II** (Distribution Theory)	**Module III** (Analytical Tools for Statistics)	**Module IV** (Sampling Theory)
9	**2**	**2**	**2**	**3**

__Nine__ numeric questions, each having __six__ weights, are to be asked. __Two__ questions from __modules I, II, and III,__ and __Three__ questions from __module IV__ must be asked. The student is expected to answer __five__ questions, and __at least one question from each of the modules__ must be answered. The use of R and MS Excel packages is permitted for answering questions. An examination of 3 hours duration must be conducted in the computer lab under the supervision of an external examiner appointed by the Controller of Examinations.

Students are provided lab training in R programming and MS Excel to equip them to apply the tools mentioned in the paper.

MODEL QUESTION PAPER

First Semester

Programme – M.Sc. Statistics

PG1STAC05 - STATISTICAL COMPUTING USING R

(2022 Admission – Regular)

Time: Three Hours Maximum Weight: 30

(Answer any __five__ questions without omitting any section.
Each question carries Weight __6__)

Section I

1. The following are five measurements on the variables x_1, x_2, and x_3:

x_1	9	2	6	5	8
x_2	12	8	6	4	10
x_3	3	4	0	2	1

   a. Write the steps to create 3 vectors x_1, x_2, and x_3.

   b. Write the steps to construct a matrix ***X***, combining the above vectors $\mathbf{X} = \begin{bmatrix} 9 & 12 & 3 \\ 2 & 8 & 4 \\ 6 & 6 & 0 \\ 5 & 4 & 2 \\ 8 & 10 & 1 \end{bmatrix}$

   c. Find the arrays $\bar{\mathbf{x}}, \mathbf{S_n}, \mathbf{R}$ using R

2. Consider the vectors x_1 and x_2 created in problem 1. (a) Create and R function to test the equality of means of x_1 and x_2 assuming that the variances of the populations are equal. (b) Conduct the test and report the results in (a).

Section II

3. Fit a normal distribution to the following data in heights in cm of 200 Indians. Also test the goodness of fit.

Heights	144-150	150-156	156-162	162-168	168-174	174-180	180-186
Frequencies	3	12	23	52	61	39	10

4. A die was thrown 180 times. The following results were obtained

No. turning up	1	2	3	4	5	6
Frequencies	25	35	40	22	32	26

Fit appropriate distribution to the data and test whether the die is unbiased.

Section III

5. a) Determine whether or not the following set of vectors is linearly independent
{(1, 2, 6), (-1, 3, 4), (-1, -4, -2)}.

b) Determine a basis for the null space of $\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 2 & 1 & 2 \\ 3 & 4 & 3 & 4 \end{bmatrix}$.

6. a) Find a g-inverse of the Matrix $\begin{pmatrix} 8 & 7 & 9 & 11 \\ 11 & 9 & 7 & 3 \\ 6 & 11 & 8 & 9 \end{pmatrix}$

b) Determine the Moore-Penrose g-inverse of the matrix, $A = \begin{bmatrix} 2 & -1 \\ -2 & 1 \\ 4 & -2 \end{bmatrix}$.

Section IV

7. Using the data given below and considering the size classes a stratum, compare the efficiencies of the following alternative allocations of a sample of 3000 factories for estimating the total output. The sample is to be selected with SRSWOR, within each stratum.

(a) Proportional allocation

(b) Allocation proportional to total output

(c) Optimum allocation

Sl. No	Size class no of works	No of factories	Output per factory (1000 Rs)	Standard deviation (1000 Rs)
1	1-49	18260	100	80
2	50-99	4315	250	200
3	100-249	2233	500	600
4	250-999	1057	1760	1900
5	1000 and above	567	2250	2500

8. An experienced farmer makes an eye estimate of the weight of peaches x_i in an orchid of N=200 trees. He finds the total weight of X=11,600 lb. The peaches are packed and weighted on a sample of 10 trees, with the following results

Tree No	Actual wt. (Yi)	Est.wt. (xi)
1	61	59
2	42	47
3	50	52
4	58	60
5	67	67
6	45	48
7	39	44
8	57	58
9	71	76
10	53	58

Estimate the actual weight using (a) Ratio method (b) Regression method (c) Simple mean per element method. Compare their efficiencies.

9. A sample of 8 villages were selected using probability proportional to size sampling without replacement, the probability being proportional to the number of families. The number of children of school going age in these families are given for selected villages: -

No of families	5557	862	2532	3523	8368	7357	1146	1645
# of children school going	482	95	196	302	768	55	41	400

The total number of families in the district is 41,61,598. Estimate the total no of children of school going age in the district and estimate its standard error.

b) The following data relates to a sample of factories drawn using SRSWOR. Using Ratio method, estimate the total absentees in the population, given its size to be 43256 workers. Also estimate its standard error. X – Total workers in the sample factory and Y – Total absentees in the factory:

X	75	64	69	63	43	53	148	132	47	43	116	65	103	67	95	79	30	45	28	142	125
Y	6	6	8	5	6	2	16	13	4	9	12	8	9	14	9	7	3	2	3	8	9

Total number of factories in the population is 350.

(5x6=30 Weights)

SECOND SEMESTER

Sl. No.	Course Code	Course Name
1	PG2STAC06	OPERATIONS RESEARCH
2	PG2STAC07	PROBABILITY AND MULTIVARIATE DISTRIBUTIONS
3	PG2STAC08	THEORY OF ESTIMATION
4	PG2STAC09	STOCHASTIC PROCESSES
5	PG2STAC10	STATISTICAL COMPUTING USING PYTHON

COURSE CODE : **PG2STAC06**

COURSE TITLE : **OPERATIONS RESEARCH**

CREDITS : **4**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	Course Outcome (Expected)	Cognitive Level	PSO No.
1	Learn the basics of linear programming	U, R	2, 3
2	Solve any type of linear programming problems (transportation, assignment etc) using appropriate techniques and interpret the results obtained.	U, Ap	2, 3, 4
3	Conduct and interpret post-optimal and sensitivity analysis and explain the primal-dual relationship.	Ap, An	1, 2, 3, 4
4	Gain the ability to solve Nonlinear programming and Quadratic programming problem.	U, Ap, An	2, 3, 4
5	Choose the appropriate inventory model for a given practical application	Ap	2, 3, 4
6	Able to find the shortest time for a sequence of jobs to be done.	An, Ap	2, 3, 4
7	Understand and study the strategic relation between rational players through game theory	U, Ap	1, 2, 3, 4

PSO – Programme Specific Outcome, CO-Course Outcome;
Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create.

Module		Course Description	Hours	CO No.
I	1.1	Convex sets and associated theorems	25	1
	1.2	Graphical method, Simplex method		2
	1.3	Artificial variables Technique-Big M method, Two phase method		2
	1.4	Dual simplex method		2, 3
	1.5	Concept of duality and sensitivity analysis		2, 3
	1.6	Transportation problems, Assignment problems, Travelling Salesman Problem		2
II	2.1	General non-linear programming problem, Dynamic and Quadratic programming	20	4
	2.2	Kuhn-Tucker conditions for QPP		4
	2.3	Constrained optimization with equality constraints - necessary conditions for a generalized NLPP		4

	2.4	Sufficient conditions for a general NLPP with one constraint, sufficient conditions for a general problem with *m* (< *n*) constraints		4
III	3.1	Deterministic inventory models -general inventory model, Static economic-order quantity (EOQ) models	25	5
	3.2	Classic EOQ model, EOQ with price breaks, multi-item EOQ with storage limitation		5
	3.3	Introduction to Sequencing Problems		5
	3.4	Solution to Sequencing Problem - Processing n-jobs through two machines		6
	3.5	Processing n-jobs through three Machines Processing two jobs through m machines, processing n-jobs through m-machines		6
	3.6	Processing two jobs through m machines		6
	3.7	Processing n-jobs through m-machines		6
IV	4.1	Two person zero sum games	20	7
	4.2	Fundamental theorem of matrix games		7
	4.3	Solution 2 x 2 game without saddle point		7
	4.4	Graphical Method for solving 2 x n and m x 2 games without saddle point		7
	4.3	Rectangular games as a Linear programming problem		2, 7

Reference Books

1) Kanti Swarup, Gupta, P.K. and Man Mohan (2001) Operations Research, Ninth edition, Sultan Chand & Sons.
2) Paneerselvam, R. (2008) Operations Research, Second edition, Prentice Hall of India Pvt. Ltd., New Delhi.
3) Ravindran A, Philips D.T and Soleberg J.J. (1997) Operation Research-Principles and Practice, John Wiley & Sons.
4) Sharma J.K. (2013) Operations Research: Theory and Applications, Fifth edition, Laxmi Publications-New Delhi.
5) Taha H.A. (2007) Operations Research -An introduction, Eighth edition, Prentice-Hall of India Ltd.

Question Paper Blue Print

Module	**Part A** (Weight 1) 8/10	**Part B** (Weight 2) 6/8	**Part C** (Weight 5) 2/4
I	3	2	1
II	2	2	1
III	3	2	1
IV	2	2	1
Total	**10**	**8**	**4**

MODEL QUESTION PAPER

Second Semester

Programme – M.Sc. Statistics

PG2STAC06 - OPERATIONS RESEARCH

(2022 Admission – Regular)

Time: Three Hours | Maximum Weight: 30

Part A

Short Answer Questions

(Answer any ***eight*** *questions. Each question carries Weight* ***1****)*

1. Define (i) Surplus (ii) Slack variable.
2. Describe travelling salesman problem.
3. Describe an unbiased Assignment problem.
4. Solve the game with pay off matrix $P = \begin{bmatrix} 5 & 12 \\ 3 & 6 \end{bmatrix}$.
5. What is the difference between a game with a saddle point and without a saddle point?
6. State the General Non-linear programming.
7. Define (i) Total Elapsed time (ii) Idle time of a machine.
8. State the basic features of Dynamic Programming.
9. Explain the meaning of EOQ.
10. What are the various cost involved in the inventory model?

(8x1=8 Weights)

Part B

Short Essay Questions/Problems

(Answer any ***six*** *questions. Each question carries Weight* ***2****)*

11. Describe a transportation problem as an LPP. Discuss any method of finding an initial basic feasible solution to a transportation problem.
12. Discuss Wolf's modified Simple method of solving a quadratic programming problem.
13. Explain the Hungarian method for solving an Assignment problem.
14. Explain EOQ with price breaks.
15. Derive the Kuhn-Tucker first order necessary optimality conditions.
16. The payoff matrix of a game is given below

	B_1	B_2	B_3	B_4
A_1	5	-10	9	0
A_2	6	7	8	1
A_3	8	7	15	1
A_4	3	4	-1	4

Find the best strategy of each player and value of the game.

17. Explain the theory of dominance in the solution of rectangular games.
18. How can we solve a sequencing problem with n jobs and 3 machines?

(6x2=12 Weights)

Part C
Long Essay Questions

*(Answer any **two** questions. Each question carries Weight **5**)*

19. Describe the step by step for solving a transportation problem.
20. What is Quadratic Programming? Describe Beal's method for solving the same.
21. Discuss and derive the EOQ formula for an inventory model with shortage cost, instantaneous replenishment and constant rate of demand.
22. State and prove the fundamental theorem of game.

(2x5=10 Weights)

COURSE CODE : **PG2STAC07**

COURSE TITLE : **PROBABILITY AND MULTIVARIATE DISTRIBUTIONS**

CREDITS : **4**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	Course Outcome (Expected)	Cognitive Level	PSO No.
1	Learn the concepts of laws of large numbers and its applications.	U, Ap	1,2,3
2	Illustrate the concepts of central limit theorem and its applications.	U, Ap	1,2,3
3	Explain the properties of characteristic functions and apply the inversion formula and uniqueness theorem.	U, Ap	1,3
4	Understand the properties of multivariate normal distribution and Wishart distribution, and their real-life applications.	U, Ap	1,2,4
5	Derive the distribution of quadratic forms and understand simple, partial and multiple correlations.	U, Ap	1,2,4

PSO – Programme Specific Outcome, CO-Course Outcome;
Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create.

Course Content:

Module	Course Description	Hours	CO No.
I	1.1. Law of large numbers	25	1
	1.2. Weak law of large numbers		1
	1.3. Necessary and sufficient condition for WLLN		1
	1.4. Bernoulli's WLLN, Poisson WLLN		1
	1.5. Chebychev's WLLN, Khinchine's WLLN		1
	1.6. Strong law of large numbers		1
	1.7. Kolmogorov's SLLN for independent and i.i.d. random variables		1
	1.8. Central limit theorem		2
	1.9. Demoivre-Laplace central limit theorem		2
	1.10. Lindberg-Levy central limit theorem		2
	1.11. Liaponov's central limit theorem		2
	1.12. Lindberg-Feller central limit theorem (without proof)		2
II	2.1. Characteristic functions: Definition and simple properties	20	3
	2.2. Uniform continuity and non-negative definiteness		3
	2.3. Bochner's Theorem (without proof)		3
	2.4. Characteristic function and moments		3
	2.5. Convex combinations of characteristic functions		3
	2.6. Inversion Formula		3

	2.7. Fourier Inversion theorem		3
	2.8. Continuity theorem		3
	2.9. Characteristic function of a vector random variable		3
III	3.1. Multivariate normal distribution (singular and non-singular)	20	4
	3.2. Characteristic function of multivariate normal distribution		4
	3.3. Marginal and conditional distributions		4
	3.4. Characterization properties		4
	3.5. Estimation of mean vector and dispersion matrix		4
	3.6. Independence of sample mean vector and dispersion matrix		4
IV	4.1. Wishart distribution and its basic properties	25	4
	4.2. Characteristic function of Wishart distribution		4
	4.3. Quadratic forms and their distributions		5
	4.4. Independence of quadratic forms		5
	4.5. Cochran's Theorem		5
	4.6. Simple, partial and multiple correlations (Definitions)		5
	4.7. Properties and their inter-relationships		5

Reference Books

1) Anderson T.W (1984) An introduction to multivariate statistical analysis, Second Edition, John Wiley.
2) Bhat B.R (1999) Modern Probability theory, Third Edition, Wiley Eastern Ltd, New Delhi.
3) Kotz S, Balakrishnan N, and Johnson N.L. (2000) Continuous Multivariate Distributions, Volume 1, Models and Applications, Second Edition, John Wiley.
4) Laha R.G and Rohatgi V.K (1979) Probability theory, Wiley.
5) Rao. C. R (2009) Linear statistical inference and its applications, Second Edition, Wiley Eastern.

Question Paper Blue Print

Module	**Part A** (Weight 1) 8/10	**Part B** (Weight 2) 6/8	**Part C** (Weight 5) 2/4
I	3	2	1
II	2	2	1
III	2	2	1
IV	3	2	1
Total	**10**	**8**	**4**

MODEL QUESTION PAPER

Second Semester

Programme – M.Sc. Statistics

PG2STAC07 - PROBABILITY AND MULTIVARIATE DISTRIBUTIONS

(2022 Admission – Regular)

Time: Three Hours | Maximum Weight: 30

Part A

Short Answer Questions

*(Answer any **eight** questions. Each question carries Weight **1**)*

1. Distinguish between WLLN and SLLN.
2. State Poisson WLLN.
3. State Lindberg-Feller Central limit theorem.
4. State Bochner's theorem and give one application of Bochner's theorem.
5. Examine whether $\phi(t) = (1+t^4)^{-1}$ is a characteristic function.
6. Define the singular multivariate normal distribution.
7. Derive the characteristic function of a non-singular multivariate normal distribution.
8. Show that Wishart distribution is a matrix variate generalization of the Chi-Square distribution.
9. If $X \sim N_p(0, I)$ then show that a quadratic form $X'AX$ and the linear form $B'X$ are independent if and only if $AB = 0$.
10. Distinguish between partial and multiple correlation.

(8x1=8 Weights)

Part B

Short Essay Questions/Problems

*(Answer any **six** questions. Each question carries Weight **2**)*

11. Examine whether SLLN holds for the sequence $\{X_n\}$ of independent random variables where $P(X_n = \pm n^\alpha) = \frac{1}{2n^2}$, $P(X_n = 0) = 1 - \frac{1}{n^2}$.
12. State and prove Lindberg -Levy form of Central limit theorem.
13. Show that characteristic function of a random variable is non-negative definite.
14. Show that the characteristic function is real if and only if the corresponding probability distribution is symmetric about the origin.
15. Let $X = \begin{pmatrix} X^{(1)} \\ X^{(2)} \end{pmatrix}$ be a p-variate normal random vector. Obtain the necessary and sufficient condition for the independence of $X^{(1)}$ and $X^{(2)}$.

16. Show that $\bar{X}$ and S are independently distributed when sampling from a multivariate normal population.
17. Derive the distribution of the sample dispersion matrix when sampling from a multivariate normal population.
18. Let X$\sim N_p(0, \sum)$, then write the necessary and sufficient condition for the independence of the quadratic forms $X'AX$ and $X'BX$ where A and B are real symmetric matrices.

(6x2=12 Weights)

Part C

Long Essay Questions

(Answer any ***two*** *questions. Each question carries Weight* ***5****)*

19. State and prove Kolmogrov strong law of large numbers for i.i.d. random variables.
20. State and prove Fourier inversion theorem.
21. Obtain the MLE of μ and $\sum$ when sampling from Multivariate Normal population with parameters μ and $\sum$.
22. State and prove the Cochran's theorem for the independence of quadratic forms.

(2x5=10 Weights)

COURSE CODE : **PG2STAC08**

COURSE TITLE : **THEORY OF ESTIMATION**

CREDITS : **4**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	Course Outcome (Expected)	Cognitive Level	PSO No.
1	Understand and analyze desirable properties of estimators	Ap	1,2,3
2	Understand how to construct different confidence intervals and evaluate their properties.	U	1,2,3
3	Apply methods of estimation in inferential problems.	U, Ap	1,3
4	Understand how to solve for parameters using iterative methods	U, An	1,2,4
5	Understand theoretical support for Bayesian analysis and applications in inferential problems.	Ap	1,2,4

PSO – Programme Specific Outcome, CO-Course Outcome;
Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create.

Course Content:

Module	Course Description	Hours	CO No.
	1.1. Criteria for estimators - unbiasedness, consistency, efficiency, sufficiency,	20	1
	1.2. Minimal sufficiency, likelihood equivalence		1
	1.3. Fisher-Neyman factorization theorem ,		1
	1.4. Completeness, bounded completeness		1
	1.5. Exponential families		1
	1.6. Ancillary statistics, Basu's Theorem		1
II	2.1. UMVUE and their characterization, BLUE,	25	2
	2.2. Rao-Black well theorem, Lehmann-Scheffe theorem		2
	2.3. Fisher information measure and its properties.		2
	2.4. Cramer-Rao inequality, Chapman-Robbins inequality		2
	2.5. Bhattacharyya's bounds (concept only). Equivariance.		2
	2.6. Pitman estimator.		2
III	3.1. Methods of estimation: method of moments, method of Maximum likelihood & their properties	25	3
	3.2. Cramer-Huzurbazar theorem		3
	3.3. Iterative methods, EM Algorithm		
	3.4. Fisher's scoring method, multiple roots,		4
	3.5. Method of minimum chi-square		4
	3.6. Method of modified minimum chi-square		4

IV	4.1. Bayes Theorem, Bayes risk, Non-parametric inference	20	5
	4.2. Bayes principle, Bayes estimators		5
	4.3. Admissible decision rules		5
	4.4. Prior-Posterior analysis for normal, binomial and Poisson processes.		5

Reference books

1) Berger J.O. (1993) Statistical Decision Theory and Bayesian Analysis, Third Edition, Springer.
2) Casella, G and Berger, R.L (2007) Statistical Inference, Second Edition, Cengage Learning.
3) Hogg R. V. and Craig A. T. (2013) Introduction to Mathematical Statistics, Pearson
4) Kale B. K. (2005) A First Course on Parametric Inference, Alpha Science International.
5) Lehmann E.L. (1983) Theory of point estimation – Wiley, New York.
6) Lindgren B.W (1976) Statistical Decision Theory (3rd Edition), Collier Macmillian, New York.
7) Rao C.R (2009) Linear Statistical Inference and its Applications, John Wiley, New York.
8) Rohatgi V.K. and Saleh A.K. (2015) An Introduction to Probability Theory and Mathematical Statistics, Wiley.

Question Paper Blue Print

Module	**Part A** (Weight 1) 8/10	**Part B** (Weight 2) 6/8	**Part C** (Weight 5) 2/4
I	3	2	1
II	3	2	1
III	2	2	1
IV	2	2	1
Total	**10**	**8**	**4**

MODEL QUESTION PAPER

Second Semester

Programme – M.Sc. Statistics

PG2STAC08 - THEORY OF ESTIMATION

(2022 Admission – Regular)

Time: Three Hours | Maximum Weight: 30

Part A

Short Answer Questions

*(Answer any **eight** questions. Each question carries Weight **1**)*

1. What do you mean by Fisher Information?
2. Give an example to show that unbiased estimator of a parameter need not exist.
3. Is M.L.E unique? Justify.
4. Define UMVUE and give an example.
5. Define an ancillary statistic and give an example of it with proper justification.
6. Define an exponential family of distributions. Verify whether Poisson distribution is a member of this family.
7. What do you mean by minimax estimator?
8. Distinguish between randomized and non-randomized decision rule.
9. Describe the method of moments.
10. Define loss function. Give 2 examples of the same.

(8x1=8 Weights)

Part B

Short Essay Questions/Problems

*(Answer any **six** questions. Each question carries Weight **2**)*

11. Explain the minimum chi square method of estimation of parameters
12. Let $X_1, X_2, ...X_n$ be a random sample from Poisson population with parameter λ. Find the UMVUE of $e^{-\lambda}$.
13. Let $X_1, X_2...X_n$ be a random sample of size 2 from $P(\lambda)$. Show that $X_1 + \alpha X_2$, $\alpha>1$ is not sufficient for λ.
14. State and prove Fisher- Neymann factorization theorem.
15. Let $X_1,X_2...X_n$ be iid observations from a population with pdf $f(x;\theta)= \theta(1-\theta)^x$, $x=0,1,2......$, $0<\theta<1$. Find Cramer Rao lower bound for the variance of an unbiased estimator of θ.
16. State and prove Basu's theorem. What is its application in Statistics?
17. State and prove Lehmann- Scheffe theorem
18. Explain the terms (a) Bayes risk (b) loss function (c) Posterior distribution.

(6x2=12 Weights)

Part C

Long Essay Questions

*(Answer any **two** questions. Each question carries Weight 5)*

19. Define MLE of a parameter. Prove that MLE's are asymptotically normal.
20. (a) State and prove Rao-Blackwell theorem.

    (b) Define UMVUE and give one example.
21. State and prove Cramer- Huzurbazar theorem.
22. Define minimax estimator. Let X follows B(n,θ) using the loss function L(θ, d) = $(\theta - d)^2/\theta(1-\theta)$. Find the minimax estimator of θ.

(2x5=10 Weights)

COURSE CODE : **PG2STAC09**

COURSE TITLE : **STOCHASTIC PROCESSES**

CREDITS : **4**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	Course Outcome (Expected)	Cognitive Level	PSO No.
1	Understand the concepts of Stochastic processes & its various classifications	U	1,2
2	Understand the concepts of Markov chains, classification of its states and limiting probabilities & to solve problems related to it.	U & Ap	1,2
3	Explain continuous time Markov chains, Poisson processes and its generalizations & Apply birth-death methodology for solving queueing problems;	U & Ap	1,2,3
4	Explain renewal process, Brownian motion, Weiner Process and some properties associated with it	U	1,2
5	Describe and use the recurrence relation for generation sizes in a Branching Process and determine the probability of ultimate extinction	U &An	1,2,3

PSO – Programme Specific Outcome, CO-Course Outcome;

Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create.

Course Content:

Module	Course Description	Hours	CO No.
I	1.1. Introduction to Stochastic Processes	25	1
	1.2. Classification of Stochastic Processes according to state space and time domain		1
	1.3. Finite and countable state Markov Chain		2
	1.4. Transition probability matrix		1
	1.5. Chapman-Kolmogorov equation		1
	1.6. First passage probabilities		1
	1.7. Classification of states and of Markov chains		2
	1.8. Basic limit theorems of MCs		2
	1.9. Mean ergodic theorem		2
	1.10. Stationary distributions, limiting probabilities		2
	1.11. Random walk & Gambler's ruin problem		2
II	2.1. Continuous time MC	25	3
	2.2. Poisson processes and its properties		3
	2.3. Pure birth process and Yule processes		3
	2.4. Birth and Death process		3

	2.5. Kolmogorov forward and backward differential equations		3
	2.6. Linear growth with immigration		3
	2.7. Stationary solutions of queuing models – M/M/1, M/M/s, M/M/∞		3
	2.8. M/G/1 que and Pollazcek-Khinchine result		3
III	3.1. Renewal process, concepts, examples	20	4
	3.2. Poisson process viewed as renewal process		4
	3.3. Renewal equation		4
	3.4. Stopping time		4
	3.5. Wald's equation		4
	3.6. Elementary renewal theorem		4
	3.7. Central limit theorem for renewals		4
	3.8. Key renewal theorem (statement)		4
	3.9. Delayed renewal processes.		4
IV	4.1. Branching process, discrete time branching processes-examples	20	5
	4.2. Generating function relations		5
	4.3. Mean and variance functions		5
	4.4. Extinction probabilities, criteria for extinction		5
	4.5. Total population size and its generating function relations		5
	4.6. A brief introduction to Brownian motion and Weiner process.		4

Reference Books

1) Basu A.K. (2003) Introduction to Stochastic Processes, Narosa, New-Delhi.
2) Bhat B.R. (2010) Stochastic Models: Analysis and Applications, First edition, New Age International.
3) Cinlar E. (2013) Introduction to Stochastic Processes, Dover Publications, NewYork.
4) Feller W. (1968) Introduction to Probability Theory and its Applications, Vols. I & II, John Wiley, New York.
5) Karlin S. and Taylor H.M. (1975) A First Course in Stochastic Processes, Second edition, Academic Press, New-York.
6) Medhi J. (2014) Stochastic Processes. Third Edition, New Age International.
7) Ross S.M. (2014) Introduction to Probability models, Eleventh edition, Academic Press.

Question Paper Blue Print

Module	**Part A** (Weight 1) 8/10	**Part B** (Weight 2) 6/8	**Part C** (Weight 5) 2/4
I	3	2	1
II	2	2	1
III	3	2	1
IV	2	2	1
Total	**10**	**8**	**4**

MODEL QUESTION PAPER

Second Semester

Programme – M.Sc. Statistics

PG2STAC09 - STOCHASTIC PROCESSES

(2022 Admission – Regular)

Time: Three Hours | Maximum Weight: 30

Part A

Short Answer Questions

*(Answer any **eight** questions. Each question carries Weight **1**)*

1. Define a stochastic process and classify it.
2. Bring out the relation between exponential distribution and a Poisson process.
3. Discuss the concept of periodicity of a state in a Markov chain.
4. State Chapman-Kolmogorov equation in the case of Continuous Process.
5. Define an ergodic Markov Chain
6. Define delayed renewal process.
7. State the key renewal theorem.
8. Describe Galton- Watson Branching Process.
9. If the distribution of offspring distribution is B (n, p), then find the pgf of offspring distribution.
10. Explain Birth and Death process.

(8x1=8 Weights)

Part B

Short Essay Questions/Problems

*(Answer any **six** questions. Each question carries Weight **2**)*

11. Explain renewal process. For a renewal process $\{(N(t); t > 0)\}$, find the renewal

function.

12. Establish the condition for recurrence of a Markov Chain.
13. Derive the stationary distribution for M|M|1 queue.
14. In. usual notation, Show that $P_n\ (s)\ =\ P_{n-1}\ (P(s))$
15. Show that the probability of ultimate extinction is given by the smallest root of the equation $s\ =\ P(s)$ where $P(s)$ denote the pgf of offspring distribution.
16. Define irreducible Markov chain. Show that for an irreducible Markov chain all states are of same nature.
17. Describe Gambler's ruin problem. Find the probability of ultimate ruin of the Gambler.
18. Explain how Poisson process is related to binomial and uniform distribution.

(6x2=12 Weights)

Part C
Long Essay Questions

(Answer any ***two*** *questions. Each question carries Weight* ***5****)*

19. State and prove Basic Limit theorem of Markov chains.
20. State and prove central limit theorem of renewal process.
21. Obtain ultimate extinction probabilities of a Galton-Watson branching process.
22. (a) Derive briefly the various components of a queuing system.

    (b) Derive the differential difference equations for a simple birth process, stating the assumptions.

(2x5=10 Weights)

COURSE CODE : **PG2STAC10**

COURSE TITLE : **STATISTICAL COMPUTING USING PYTHON**

CREDITS : **4**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	Course Outcome (Expected)	Cognitive Level	PSO No.
1	Understand basics of Python programming and perform various operations on data in Python.	U, An	2,4
2	Solve the problems related to linear, Quadratic programming, sequencing problem. Also able to decide the best strategies through game theory and choose appropriate inventory models.	Ap	2,3,4
3	Solve practical problems related to estimation of sample mean vector and variance-covariance matrix of multivariate normal data, finding the means, variances and covariances of the normal variates expressed in the quadratic forms, finding the distribution of the linear combinations of the components, conditional and marginal distribution of the components given the multivariate normal random vector, solving problems on simple , partial , multiple correlations and testing of hypotheses in multivariate normal populations.	Ap	2,3,4
4	Solve for the estimates of unknown parameters using different methods such as the method of moments, method of maximum likelihood and various iterative methods like method of minimum chi square and method of modified chi square.	Ap	2,3,4
5	Solve the problems related to transition probability, first passage transition probability, limiting probability of Markov Chains (MC), classification of states of a MC, stationary distributions of a MC, Poisson process, different queuing models like M/M/1, M/M/S, mean and variance of branching process (BP), extinction probability of BP.	Ap	2,3,4
6	Equips the student with the intellectual apparatus and cognitive skills with which theoretical learning is applied to analyse and solve both social behavioural patterns and statistical problems.	Ap	3,4

PSO – Programme Specific Outcome, CO-Course Outcome;
Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create.

Course Content:

Module	Course Description	Hours	CO No.
I	1.1. Solving LPP, Transportation problem	22	1,2,6
	1.2. Solving Assignment Problem, Travelling Salesman problem		1,2,6
	1.3. Solving Quadratic Programming problem		1,2,6
	1.4. Solve by dual simplex method		1,2,6
	1.5. Finding Economic Order Quantity		1,2,6
	1.6. Choosing best strategies using game theory		1,2,6
	1.7. Find total elapsed time of sequencing problem		1,2,6
II	2.1. Estimation of sample mean vector and variance -covariance matrix of multivariate normal data	22	1,3,6
	2.2. Evaluating the means, variances and covariances of the normal variates expressed in the quadratic forms,		1,3,6
	2.3. Given the multivariate normal random vector, finding the distribution of the linear combinations of the components.		1,3,6
	2.4. Given the multivariate normal random vector finding the marginal and conditional distribution of the components		1,3,6
	2.5. Solving problems on simple correlation		1,3,6
	2.6. Solving problems on partial correlation		1,3,6
	2.7. Solving problems on multiple correlation		1,3,6
	2.8. Testing of hypothesis on population mean vector when the population variance -covaraiance matrix is given.		1,3,6
	2.9. Testing the equality of mean vectors of two multivariate normal normal populations		1,3,6
III	3.1 Estimation of parameters	24	1,4,6
	3.2 Method of moments		1,4,6
	3.3 Method of maximum likelihood		1,4,6
	3.4 Fisher's Scoring method		1,4,6
	3.5 Method of minimum chi square		1,4,6
	3.6 Method of modified minimum chi square		1,4,6
	3.7 Uniformly Minimum Variance Unbiased Estimates		1,4,6
IV	4.1. Calculation of transition probabilities of a MC	22	1,5,6
	4.2. Calculation of first passage transition probabilities of a MC		1,5,6
	4.3. Classification of states of a MC		1,5,6
	4.4. Stationary distributions of MCs.		1,5,6
	4.5. Determination of various characteristics of different queuing models like M/M/1 & M/M/2		1,5,6
	4.6. Determination of mean & variance of a BP		1,5,6
	4.7. Determination of extinction probabilities of BP		1,5,6

Question Paper Blue Print

Total No. of Questions	Module I (Operations Research)	Module II (Probability And Multivariate Distributions)	Module III (Theory of Estimation)	Module IV (Stochastic Processes)
9	**2**	**2**	**3**	**2**

Nine *numeric questions, each having* ***six*** *weights, are to be asked.* ***Two*** *questions from* ***modules I, II and IV*** *and* ***three*** *question from* ***module III*** *must be asked. The student is expected to answer* ***five*** *questions, and* ***at least one question from each of the modules*** *must be answered. The use of Python, R, and MS Excel packages is permitted for answering questions. An examination of 3 hours duration must be conducted in the computer lab under the supervision of an external examiner appointed by the Controller of Examinations.*

MODEL QUESTION PAPER

Second Semester

Programme – M.Sc. Statistics

PG2STAC10 - STATISTICAL COMPUTING USING PYTHON

(2022 Admission – Regular)

Time: Three Hours Maximum Weight: 30

(Answer any ***five*** *questions without omitting any section.*
Each question carries Weight ***6****)*

Section I

1. Use Wolfe's method to solve the following quadratic programming problem:
   Maximize $z = 4x_1 + 6x_2 - 2x_1^2 - 2x_1x_2 - 2x_2^2$
   Subject to $x_1 + 2x_2 \leq 2, x_1 \geq 0, x_2 \geq 0$
2. A company manufacturing air-coolers has plants located at Mumbai and Kolkata with a weakly capacity of 200 units and 100 units, respectively. The company supplies air-coolers to its 4 showrooms situated at Ranchi, Delhi, Lucknow and Kanpur which has a demand of 75, 100, 100 and 30 units, respectively. The cost of transportation per unit (in Rs.) is shown in the following table.

	Ranchi	**Delhi**	**Lucknow**	**Kanpur**
Mumbai	90	90	100	100

Kolakata	50	70	130	85

Section II

3. The mean vector and dispersion matrix of 4 anthropometric characteristics for a district are given below. Find the marginal distribution of (i) X_3 (ii) (X_1, X_2) (iii) $3X_2 + 5X_3 + X_4$ and (iv) the conditional distribution of X_2 given $X_1 = 4, X_3 = 5, X_4 = 4$.

Characteristics= $\begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \end{bmatrix}$ Mean Vector = $\begin{bmatrix} -6 \\ 1 \\ 0 \\ 3 \end{bmatrix}$ Dispersion matrix= $\begin{bmatrix} 2 & 0 & 3 & 0 \\ 0 & 5 & 0 & 2 \\ 3 & 0 & 5 & 0 \\ 0 & 2 & 0 & 1 \end{bmatrix}$

4. (a) A random sample of size 72 from a 4 variate Normal distribution gave the sample mean vector (22.3 14.5 7.9 12.8)' and sample dispersion matrix as:

$$\begin{bmatrix} 13.0552 & 4.1740 & 8.9620 & 2.7332 \\ & 4.8250 & 4.0500 & 2.0190 \\ & & 10.8200 & 3.8520 \\ & & & 1.1962 \end{bmatrix}$$

Test whether the population mean vector is (20 15 8 14)' at 1% level.

(b) Obtain $R_{1.23}$ and $r_{12.3}$ for the following data.

Profit(in lakhs):	2	6	4	3	7	5	9
Production(in 1000 units):	16	14	18	21	15	14	23
Sales(in 1000 units):	13	11	14	18	13	10	17

Also write the regression equation of Profit on production and Sales. Estimate the Profit when production =30 and Sales = 25.

Section III

5. Obtain the MLE of θ and its standard error from the following.

Class	AB	Ab	aB	ab
Frequency	204	34	72	10
Expected proportions	$\frac{2+\theta}{4}$	$\frac{1-\theta}{4}$	$\frac{1-\theta}{4}$	$\frac{\theta}{4}$

6. The frequency distribution of accidents in a factory over a specified period of time is given below.

No of accidents	0	1	2	3	4 or more
Frequency	405	126	41	22	06

Assume that the above dataset is a sample from a Poisson population with parameter λ. Obtain the estimate of λ by minimum chi square method.

7. The number of words Y in a sentence of a certain book is a random variable which has log normal distribution with parameters μ and σ. A sample of 10 sentences from the book gives the following number of words: 7, 11, 15, 22, 40, 60, 13, 20, 56, 25. Find the estimates of μ and σ^2.

Section IV

8. A Markov Chain has states $(0,1,2,3)$ with transition probability matrix.

$$P = \frac{1}{24}\begin{bmatrix} 12 & 7 & 4 & 1 \\ 4 & 11 & 4 & 5 \\ 12 & 7 & 4 & 1 \\ 4 & 5 & 4 & 11 \end{bmatrix}$$

(i) Find $P(X_4 = 1 | X_1 = 3, X_2 = 0, X_3 \neq 2)$.

(ii) Find the stationary distribution and the mean recurrence times for the various states.

9. Given the following transition probability matrix of a Markov chain with states 0, 1, 2, 3. Classify the states of the Markov chain as ergodic or absorbing.

$$P = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1/3 & 1/3 & 1/3 \\ 0 & 1/3 & 1/3 & 1/3 \\ 0 & 1/3 & 1/3 & 1/3 \end{bmatrix}$$

(5x6=30 Weights)

THIRD SEMESTER

Sl. No.	Course Code	Course Name
1	PG3STAC11	TESTING OF STATISTICAL HYPOTHESES
2	PG3STAC12	DESIGN AND ANALYSIS OF EXPERIMENTS
3	PG3STAC13	MULTIVARIATE ANALYSIS
4	PG3STAC14	STATISTICAL COMPUTING USING SPSS
5	PG3STAE01	STATISTICAL QUALITY ASSURANCE
6	PG3STAE02	CATEGORICAL DATA ANALYSIS

COURSE CODE : **PG3STAC11**

COURSE TITLE : **TESTING OF STATISTICAL HYPOTHESES**

CREDITS : **4**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	Course Outcome (Expected)	Cognitive Level	PSO No.
1	Understand about formulation of hypothesis, properties of different test and application.	Ap	1,2,3
2	Understand how to construct different confidence intervals and evaluate their properties.	U	1,2,3
3	Acquire theoretical background for likelihood ratio test and its applications in inference.	U, Ap	1,3
4	Understand Sequential probability ratio tests, Construction of sequential probability ratio tests, Wald's fundamental equation. Wald's identity, OC and ASN functions, Properties of SPRT.	U, An	1,2,4
5	Acquire theoretical support for Non-parametric test and apply them in real life problems of testing.	Ap	1,2,4

PSO – Programme Specific Outcome, CO-Course Outcome;
Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create.

Course Content:

Module	Course Description	Hours	CO No.
I	1.1. Tests of hypotheses	20	1
	1.2. Formulation of problem, Simple and composite hypotheses, Null and alternative hypotheses		1
	1.3. Size and power of a test		1
	1.4. Randomized and non-randomized tests		1
	1.5. Most Powerful test, Neyman-Pearson lemma and its generalization		1
	1.6. Monotone likelihood ratio property, UMP tests		1
	1.7. Unbiased tests and UMPU tests, Unbiased critical regions		1
	1.8. Basic concepts of Symmetry and invariance, maximal invariance, most powerful invariant tests.		
	1.9. Similar regions and Neyman structure tests.		1
II	2.1. Confidence interval estimation	20	2
	2.2. Relationship between confidence interval estimation and testing of hypothesis.		2
	2.4. UMA and UMAU confidence intervals.		2
	2.5. Shortest confidence intervals.		2

	2.6. Construction of confidence intervals using pivots.		2
	2.7. Large sample confidence interval based on maximum likelihood estimator.		2
III	3.1. Likelihood ratio tests and their properties	25	3
	3.2. Testing mean and variance of a normal population		3
	3.3. Testing equality of means and variances of two normal populations		4
	3.4. Sequential probability ratio tests		4
	3.5. Construction of sequential probability ratio tests		4
	3.6. Wald's fundamental equation.		4
	3.7. Wald's fundamental identity		4
	3.8. OC and ASN functions and curves		4
	3.9. Properties of SPRT.		4
IV	4.1. Non-parametric inference	25	5
	4.2. Goodness of fit tests- Chi square test and Kolmogorov-Smirnov test for one and two sample problems		5
	4.3. Sign test, Wilcoxon signed-rank test		5
	4.4. Wald-Wolfowitz run test		5
	4.5. Median test, Man-Whitney U-test		5
	4.6. Chi-Square tests for independence and homogeneity		5
	4.7. One way layout-Kruskal Wallis test, Friedman test.		5

Reference books

1) Casella, G and Berger, R.L (2007) Statistical Inference, Second Edition, Cengage Learning.

2) Gibbons, J.K. (1971) Non-Parametric Statistical Inference, McGraw Hill.

3) Kale, B.K. (2005) A First Course in Parametric Inference, Second Edition, Alpha Science International Ltd.

4) Lehmann, E.L. (1998) Testing Statistical Hypothesis, John Wiley.

5) Rohatgi V.K. and Saleh M. (2015) An introduction to probability and statistics, Third Edition, Wiley.

6) Srivastava M.K. and Srivastava N. (2009) Statistical Inference: Testing of Hypotheses, PHI.

7) Wald, A. (1947) Sequential Analysis, Doves.

Question Paper Blue Print

Module	**Part A** (Weight 1) 8/10	**Part B** (Weight 2) 6/8	**Part C** (Weight 5) 2/4
I	3	2	1
II	2	2	1
III	2	2	1
IV	3	2	1
Total	**10**	**8**	**4**

MODEL QUESTION PAPER

Third Semester

Programme – M.Sc. Statistics

PG3STAC11 - TESTING OF STATISTICAL HYPOTHESES

(2022 Admission – Regular)

Time: Three Hours | Maximum Weight: 30

Part A

Short Answer Questions

*(Answer any **eight** questions. Each question carries Weight **1**)*

1. Define two types of errors and power of a test.
2. Explain how the best critical region is determined.
3. Obtain the MP test for testing the mean $\mu = \mu_0$ against $\mu = \mu_1$, $\mu_1 > \mu_0$ when $\sigma^2=1$ is normal population.
4. Give an example of a family of distributions with MLR property and justify it.
5. Define Unbiased Confidence Interval.
6. Describe Wald's SPRT. Derive the approximate expression for the O.C. function.
7. Derive the relation connecting the boundary values A, B and strength (α,β) of an SPRT.
8. Explain Wilcoxon signed rank test.
9. Describe Kolmogorov–Smirnov two sample test statistic.
10. Explain the test procedure for testing the equality of means of two normal populations.

(8x1=8 Weights)

Part B

Short Essay Questions/Problems

*(Answer any **six** questions. Each question carries Weight **2**)*

11. (a) State and prove Neyman-Pearson lemma.

(b) Show that if a sufficient statistic T exists for a family, then Neyman-Pearson MP test is a function of T.

12. State and prove a set of sufficient conditions for a similar test to have Neyman structure.
13. Define M.P region and U.M.P region. Show that a M.P. region is necessarily unbiased.
14. Establish the connection between UMA confidence set and UMP tests.
15. Show that the LR test for testing the equality of variances of two normal populations is the usual F-test.
16. Using Walds fundamental identity,derive the ASN function when E(z) = 0.
17. (a) Describe median test.

    (b) What are the advantages and drawbacks of non-parametric methods over parametric methods?
18. Explain Chi-Square tests for independence and homogeneity.

(6x2=12 Weights)

Part C
Long Essay Questions
*(Answer any **two** questions. Each question carries Weight 5)*

19. Given a random sample of size n from the distribution with p.d.f $(x, \theta) = \theta e - \theta x$, $x > 0$. Show that there exists no UMP test for testing $H_0 : \theta = \theta_0$ against $H_1 : \theta \neq \theta_0$
20. Establish the connection between UMAU confidence set and UMPU tests.
21. Describe the general method of construction of Likelihood Ratio test. Discuss the properties of the test.
22. (a) Compare Chi-square test and Kolmogorov-Smirnov Test.

    (b) Explain Kruskall–Wallis one-way analysis of variance and Friedman's two-way analysis of variance.

(2x5=10 Weights)

COURSE CODE : **PG3STAC12**

COURSE TITLE : **DESIGN AND ANALYSIS OF EXPERIMENTS**

CREDITS : **4**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	Course Outcome (Expected)	Cognitive Level	PSO No.
1	To develop a deeper understanding about the linear models, parametric estimation, tests of hypotheses regarding the model parameters.	U	1,2,3
2	Understand and apply the basic principles while designing an experiment, ANOVA of one way, two way and three-way classification models along with Analysis of covariance. Identify the common and important types of experimental designs with respective advantages and disadvantages.	U, Ap	1,2,4
3	Learn tests for comparing pairs of treatment means, factorial experiments, Confounding, fractional factorial experiments, Incomplete block designs, BIBD, PBIBD, Split plot and Strip plot designs by solving real life examples.	U, An, Ap	1,3
4	Understand and differentiate between connectedness, orthogonality and balanced designs.	An, Ap	1,2,3
5	To suggest appropriate experimental designs suitable for real life situations so as to minimise the experimental error.	C, An, Ap	1,2,4

PSO – Programme Specific Outcome, CO-Course Outcome;

Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create.

Course Content:

Module	Course Description	Hours	CO No.
I	1.1. Gauss Markov setup, Estimability of parameters	20	1
	1.2. Method of least squares, Variance and covariances of the estimates		1
	1.3. Gauss- Markov theorem		1
	1.4. Tests of linear hypotheses		1
	1.5. Analysis of variance		1
	1.6. ANOVA – One way, two way and three way classification models		2
II	2.1. Basic principles of experimental designs	25	2
	2.2 Uniformity trials		2
	2.3. Completely randomised design (CRD) and its analysis		2,5
	2.4. Randomised block design(RBD) and its analysis		2,5
	2.5. Missing plot technique		2

	2.6. RBD with missing plots		2
	2.7. Efficiency comparison of RBD with CRD		2
	2.7. Latin square design(LSD) and its analysis		2,5
	2.8. LSD with missing plots		2
	2.9. Efficiency comparison of LSD with RBD		2
	2.10. Greaco Latin square design and analysis		2,5
	2.11. Analysis of covariance technique in CRD and RBD		2
III	3.1. Incomplete block design, Balanced incomplete block design (BIBD).	20	3,4,5
	3.2. Intra block analysis of BIBD		3
	3.3. Incidence matrix , Parametric relationships in BIBD		3
	3.4. Partially balanced Incomplete block design with m associate classes		3
	3.5. Lattice designs basic concepts		3
	3.6. Connectedness		3,4
IV	4.1. Factorial experiments, Main effects, Interaction effects	25	3,5
	4.2. Analysis of 2^n and 3^n factorial experiments		3,5
	4.3. Yates method for the computation of factorial effect totals		3
	4.4. Confounding in 2^n and 3^n factorial experiments		3
	4.5. Construction of confounded scheme		3
	4.5. Fractional factorial Designs		3,5
	4.6. Split plot Design and its analysis.		3,5
	4.7. Strip plot design		3.5

Reference books

1) Agarwal B.L (2010) Theory and Analysis of Experimental Designs, CBS Publishers & Distributers

2) Das M.N. and Giri N.C. (1994) Design and analysis of experiments, Wiley Eastern Ltd.

3) Dean A. and Voss D. (1999) Design and Analysis of Experiments, Springer Texts in Statistics

4) Dey A. (1986) Theory of Block Designs, Wiley Eastern, New Delhi.

5) Gomez K.A. and Gomez A.A. (1984) Statistical Procedures for Agricultural Research,Wiley.

6) Joshi D.D. (1987) Linear estimation and Design of Experiments, Wiley Eastern.

7) Montgomery C.D. (2012) Design and Analysis of Experiments, John Wiley, New York.

Question Paper Blue Print

Module	**Part A** (Weight 1) 8/10	**Part B** (Weight 2) 6/8	**Part C** (Weight 5) 2/4
I	2	2	1
II	3	2	1
III	3	2	1
IV	2	2	1
Total	**10**	**8**	**4**

MODEL QUESTION PAPER

Third Semester

Programme – M.Sc. Statistics

PG3STAC12 - DESIGN AND ANALYSIS OF EXPERIMENTS

(2022 Admission – Regular)

Time: Three Hours Maximum Weight: 30

Part A

Short Answer Questions

*(Answer any **eight** questions. Each question carries Weight **1**)*

1. Develop the procedure to test the general linear hypothesis based on a linear model, stating clearly the assumptions.
2. Explain fixed effect and random effect models with examples.
3. Explain Yates procedure for obtaining various effect totals in a 2^3 factorial experiment.
4. Derive the expression to estimate one observation missing in RBD with k treatments and r replications.
5. Given three independent stochastic variables Y_1, Y_2, Y_3 having common variance σ^2 such that $E(Y_1)=\theta_1+\theta_2$ $E(Y_2)=\theta_1+\theta_3$ $E(Y_3)=\theta_1+\theta_2$. Show that $C_1\theta_1+C_2\theta 2+C_3\theta_3$ is estimable if and only if $C_1 = C_2 + C_3$.
6. State and prove Fisher's inequality.
7. Explain Graeco Latin square design with an example.
8. Explain the concept of split plot design with an example.
9. What do you understand by missing plot in a design of experiment? Discuss Yates' method of estimation of a missing plot value.
10. Explain strip plot design.

(8x1=8 Weights)

Part B

Short Essay Questions/Problems

*(Answer any **six** questions. Each question carries Weight **2**)*

11. Develop the analysis of Completely Randomised Design with k observations per cell.
12. Give the layout of a partially confounded design in 2^3 factorial in which the effects ABC, AC and BC are confounded in three replicates.
13. Derive the expression to estimate one observation missing in LSD with k treatments and r replications.
14. If $e^{'}\beta$ and $m^{'}\beta$ are estimable, find $V(e^{'}\beta^{\wedge})$ and $Cov(e^{'}\beta^{\wedge}, m^{'}\beta^{\wedge})$, where $\beta^{\wedge}$ is the least square estimate of β.
15. What are main effects and interaction effects of a factorial design? Express these in a 2^3 factorial experiment, in terms of treatment means.
16. Define BIBD. State the important relations among the parameters of a BIBD and prove any two of them.
17. Explain the basic principals in field experimentation.
18. Explain the basic concepts of PBIBD with m associate classes.

(6x2=12 Weight)

Part C

Long Essay Questions

*(Answer any **two** questions. Each question carries Weight **5**)*

19. Define BIBD and develop intra block analysis of BIBD.
20. What do you understand by ‘analysis of covariance’? Describe the analysis of covariance for a one way (CRD) lay out (with one concomitant variable only).
21. Develop the analysis of split plot design with RBD layout for main plot treatments.
22. Explain Yates’ procedure for obtaining various effect total in 2^3 factorial experiment. Obtain the ANOVA table and carry out its statistical analysis.

(2x5=10 Weights)

COURSE CODE : **PG3STAC13**

COURSE TITLE : **MULTIVARIATE ANALYSIS**

CREDITS : **4**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	Course Outcome (Expected)	Cognitive Level	PSO No.
1	Understand Hotelling's T^2 and Mahalanobis D^2 statistics and analyse multivariate data with mean vectors.	U, Ap	1,2,4
2	Implement dimension reduction techniques like principal component analysis and factor analysis on real life problems.	Ap	1,3,4
3	Demonstrate knowledge and understanding of the basic ideas behind discriminant analysis and clustering analysis techniques with applications.	U, Ap	1,2,4
4	Understand MANOVA and analyse multivariate data with several mean vectors.	U, An	1,3,4

PSO – Programme Specific Outcome, CO-Course Outcome;
Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create.

Course Content:

Module	Course Description	Hours	CO No.
I	1.1. Notion of likelihood ratio tests	25	1
	1.2. Hotelling's T^2 statistic and its properties		1
	1.3. Null distributions (one sample and two sample cases)		1
	1.4. Applications of Hotelling's T^2 statistic		1
	1.5. Mahalnobis D^2 statistic and its properties		1
	1.6. Testing equality of mean vectors		1
	1.7. Multivariate Fisher-Behrens problem		1
	1.8. Profile Analysis		1
II	2.1. Dimension Reduction methods	20	2
	2.2. Principal component analysis		2
	2.3. PCA: Method of extraction and properties		2
	2.4. Hoteling's iterative procedure		2
	2.5. Factor Analysis		2
	2.6. Orthogonal factor model		2
	2.7. Estimation of loading matrix		2
	2.8. Canonical variates and canonical correlation		2
III	3.1. Classification problems	20	3
	3.2. Discriminant Analysis-Baye's procedure		3
	3.3. Classification into one of the two populations		3
	3.4. Classification into several populations		3

	3.5. Fishers' linear discriminant function and its associated tests		3
	3.6. Canonical discriminant analysis (Basic concepts)		3
IV	4.1. Cluster Analysis	25	3
	4.2. Similarity measures		3
	4.3. Hierarchical clustering methods		3
	4.4. Non-hierarchical clustering methods: K-Means		3
	4.5. Multivariate General linear models		4
	4.6. MANOVA (one way and two way)		4
	4.7. Wilk's λ		4
	4.8. Test for independence of sets of variates		4
	4.9. Test for equality of dispersion matrices		4
	4.10. Sphericity test		4

Reference Books

1) Anderson T. W. (2003) An Introduction to Multivariate Statistical Analysis, Third edition, John Wiley.
2) Bryan, F.J (2004) Multivariate Statistical Methods: A Primer, Third Edition, Chapman & Hall.
3) Everitt, B and Hothorn, T. (2011) An introduction to Applied Multivariate Analysis with R, Springer
4) Johnson R.A. and Wichern D.W. (2007) Applied Multivariate Statistical Analysis. Sixth Edition, Pearson.
5) Kachigan, S.K. (1991) Multivariate Statistical Analysis: A Conceptual Introduction, Hawthorne Academic
6) Kshirasagar, A.M. (1972) Multivariate Analysis, Marcel-Dekker.
7) Rencher, A. C. (1995) Methods of Multivariate Analysis. John Wiley.
8) Seber G. F. (1983) Multivariate Observations, John Wiley.

Question Paper Blue Print

Module	**Part A** (Weight 1) 8/10	**Part B** (Weight 2) 6/8	**Part C** (Weight 5) 2/4
I	3	2	1
II	2	2	1
III	2	2	1
IV	3	2	1
Total	**10**	**8**	**4**

MODEL QUESTION PAPER

Third Semester

Programme – M.Sc. Statistics

PG3STAC13 - MULTIVARIATE ANALYSIS

(2022 Admission – Regular)

Time: Three Hours Maximum Weight: 30

Part A

Short Answer Questions

*(Answer any **eight** questions. Each question carries Weight **1**)*

1. What are the uses of Hotelling's T^2 statistic.
2. Establish the relation between Hovelling's T^2 and Mahalnobis D^2.
3. Distinguish between Principal Component analysis and Factor analysis.
4. Define canonical correlation.
5. What do you mean by Fisher's Linear Discriminant function.
6. Explain the problem of classification.
7. What is profile Analysis
8. Explain the Wilk's λ statistic useful in the likelihood ratio tests.
9. What is the divisive method of clustering.
10. Distinguish between Monothetic and Polythetic methods of clustering.

(8x1=8 Weights)

Part B

Short Essay Questions/Problems

*(Answer any **six** questions. Each question carries Weight **2**)*

11. Explain the Fisher-Behren problem.
12. What are the uses of Hotelling's T^2 in analyzing a multivariate data.
13. Describe the orthogonal factor model in factor analysis.
14. Show that canonical correlation coefficient is the non-zero root of a determinantal equation.
15. Describe the Bayes' classification procedure.
16. Explain the test for discrimination while discriminating between two populations.
17. Explain the sphericity test.
18. Distinguish between hierarchical and non-hierarchical clustering methods.

(6x2=12 Weights)

Part C

Long Essay Questions

*(Answer any **two** questions. Each question carries Weight **5**)*

19. Obtain the distribution of Hotelling's T^2 statistic.
20. Explain the role of eigenvalues and eigenvectors in principal component analysis. Describe the Hotelling's iterative procedure to find the principal components.
21. Discuss the problem of assigning an observation of unknown origin to one of the three *p*-variate normal populations having the same unknown dispersion matrix based on samples taken from these populations.
22. Explain the Agglomerative methods in Cluster analysis.

(2x5=10 Weights)

COURSE CODE : **PG3STAC14**

COURSE TITLE : **STATISTICAL COMPUTING USING SPSS**

CREDITS : **4**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	Course Outcome (Expected)	Cognitive Level	PSO No.
1	Understand basics of SPSS and perform various analysis on data in SPSS.	U, An	1,4
2	Calculate the size and power of a test, find the confidence intervals for parameters, test mean and variance of a normal population, equality of means and variances of two normal populations, obtain SPRT for parameters using tabular and graphical procedures and the corresponding OC and ASN, different non-parametric tests such as goodness of fit tests-chi square and KS tests, Sign test, Wilcoxon signed-rank test, Wald-Wolfowitz run test, Median test, Man-Whitney U-test, Chi-Square tests for independence and homogeneity.	Ap	1,2,4
3	Perform the Analysis of variance (ANOVA) of the data corresponding to various designs like completely randomised design (CRD), Randomised block design (RBD), Latin square design (LSD), Greaco Latin square design (GLSD), Balanced incomplete block design (BIBD), Analysis of covariance (ANACOVA), Factorial experiments and Split plot experiments.	Ap	1,3,4
4	Solve the problems related to multivariate analysis like testing equality of mean vectors or dispersion matrices, principal component analysis, factor analysis, canonical correlation analysis, discriminant analysis and cluster analysis.	Ap	1,2,4
5	Illustrate Statistical Quality control concepts using various control charts and curves. Calculate and Interpret process capability and calculate ARL and AOQL of control charts	Ap	1,3,4
6	Compute and interpret Relative risk, Odds ratio, sensitivity, specificity etc. of the data sets. Apply suitable statistical analysis techniques to different categorical data sets and assess the model reliability.	Ap, An, E	1,3,4

7	Equips the student with the intellectual apparatus and cognitive skills with which theoretical learning is applied to analyse and solve both social behavioural patterns and statistical problems.	Ap	1,3,4

PSO – Programme Specific Outcome, CO-Course Outcome;
Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create.

Course Content:

Module	Course Description	Hours	CO No.
I	1.1. Size and power of a test	24	1,2,7
	1.2. Confidence intervals for parameters		1,2,7
	1.3. Testing mean and variance		1,2,7
	1.4. Testing equality of means and variances		1,2,7
	1.5. Most Powerful and Uniformly Most Powerful Test		1,2,7
	1.6. SPRT for unknown parameters		1,2,7
	1.7. OC and ASN of SPRT		1,2,7
	1.8. Non parametric tests		1,2,7
II	2.1. ANOVA of one way classified data.	22	1,3,7
	2.2. ANOVA of two way classified data.		1,3,7
	2.3. ANOVA of CRD.		1,3,7
	2.4. ANOVA of RBD.		1,3,7
	2.5. ANOVA of RBD with missing observations.		1,3,7
	2.6. ANOVA of LSD.		1,3,7
	2.7. ANOVA of LSD with missing observations.		1,3,7
	2.8. ANOVA of GLSD.		1,3,7
	2.9. ANOVA of BIBD.		1,3,7
	2.10. ANOVA of 2^n and 3^n factorial experiments.		1,3,7
	2.11. ANOVA of totally and partially confounded 2^n factorial experiments.		1,3,7
	2.12. ANACOVA of RBD with one concomitant variable.		1,3,7
	2.13. ANOVA of Split plot design with main plots laid out in RBD.		1,3,7
III	3.1. Testing of hypothesis related to mean vectors (One sample and two sample cases)	22	1,4,7
	3.2. Construction of confidence region for the mean vector.		1,4,7
	3.3. Profile Analysis		1,4,7
	3.4. Principal component analysis		1,4,7
	3.5. Factor analysis		1,4,7
	3.6. Canonical correlation analysis		1,4,7
	3.7. Classification into one of the two populations		1,4,7
	3.8. Classification into several populations		1,4,7
	3.9. Cluster analysis		1,4,7
	3.10. Testing independence of sets of variables		1,4,7
	3.11. Testing equality of dispersion matrices		1,4,7
	3.12. Sphericity test		1,4,7

IV_A	4_A.1. Construction of different charts ($\bar{x}$-chart, median chart, R-chart, S-chart etc.)	22	1,5,7
	4_A .2. OC & ASN curves of different sampling plans		1,5,7
	4_A .3. Calculation & Interpretation of process capability		1,5,7
	4_A .4. Calculation of ARL, AOQL		1,5,7
IV_B	4_B.1. Odds ratio, Relative risks, Sensitivity and specificity	22	1,6,7
	4_B.2. MNemar's test, Fisher's Exact test, Chi-square test		1,6,7
	4_B.3. Logistic regression, Multinomial logistic regression		1,6,7
	4_B.4. Poisson regression, Negative Binomial Regression		1,6,7
	4_B.5. Proportional hazards regression		1,6,7
	4_B.6. Bayesian statistics using simulations		1,6,7
	4_B.7. Markov Chain Monte Carlo		1,6,7
	4_B.8 The Gibbs sampler		1,6,7
	4_B.9 The Metropolis-Hastings algorithm		1,6,7

Question Paper Blue Print

Total No. of Questions	**Module I** (Testing of Statistical Hypothesis)	**Module II** (Design and Analysis of Experiments)	**Module III** (Multivariate Analysis)	**Module IV_A** (Statistical Quality Assurance)	**Module IV_B** (Categorical Data Analysis)
9 (11)	**3**	**2**	**2**	**2**	**2**

Nine *numeric questions, each having* ***six*** *weights, are to be asked.* ***Three*** *questions from* ***module I*** *and* ***Two*** *questions from* ***modules II, III, IV_A and IV_B*** *must be asked. The student is expected to answer* ***five*** *questions,* ***selecting at least one question from each of the modules I, II & III and at least one question from either of module IV_A OR IV_B****. The use of Python, R, and SPSS packages is permitted for answering questions. An examination of 3 hours duration must be conducted in the computer lab under the supervision of an external examiner appointed by the Controller of Examinations.*

MODEL QUESTION PAPER

Third Semester

Programme – M.Sc. Statistics

PG3STAC14 - STATISTICAL COMPUTING USING SPSS

(2022 Admission – Regular)

Time: Three Hours Maximum Weight: 30

(Answer any ***five*** *questions without omitting any section.*
Each question carries Weight ***6****)*

Section I

1. Given a sample of size 9 from $N(\theta, 1)$ in order to test the hypothesis H_0: $\theta=10$, the critical region was $\bar{X} < 9$ and $\bar{X} > 10.3$, where $\bar{X}$ is the sample mean. Calculate the power at $\theta = 11$ and size of the test.
2. Assuming that the observations 1.5, 2.5, 2, 3, 4.3, 3.5, 3.85, 4.5, 1.2 and 3.75 are drawn from a normal population with mean θ and standard deviation .5. Test $H_0: \theta = 1.5$ aganist $H_1: \theta = 3$ using SPRT with α=0.01 and β=0.05. Setup a graphical procedure too. Draw the OC and ASN curves.
3. The following data gives the service time for 30 persons in a queue. Test whether it is exponentially distributed with mean service of 20 minutes using KS test.
   0.6, 1.6, 3.2, 3.2, 3.5, 3.8, 5.9, 6.2, 6.8, 11.3, 11.9, 13.5, 15.1, 15.7, 16.2, 16.3, 18.6, 18.7, 20.7, 22, 23.1, 23.8, 23.9, 26.4, 27.9, 37.4, 39.6, 40, 60, 62.

Section II

4. In the table given below are the yields of 6 varieties of 4 replicates of an experiment in which two values are missing. Estimate the missing values and analyze the data.

Blocks	Treatments					
	1	2	3	4	5	6
1	18.4	15.4	9.6	13.6	17.1	14.6
2	11.7	---	12.8	15.7	16.4	11.9
3	13.4	16.5	17.3	18.4	---	22.6
4	16.5	13.6	12.6	15.7	16.3	17.9

5. The following data gives the yields of potatoes in a manurial experiment with 3 manures each at 2 levels along with the layout of the design. Analyze the data.

	Replicate 1			
Block 1	npk 33.9	n 27.3	p 33.4	k 30.9
Block 2	np 26.5	pk 26.6	nk 33.5	(1) 33.9

	Replicate2			
Block1	npk 27.9	np 22.4	k 32.5	(1) 32.3
Block2	pk 34.8	nk 27.1	n 34.1	p 30.7

Section III

6. Two samples each of size 50 taken from two MVN populations gave the following results.

$$\bar{X}_1 = \begin{pmatrix} 3.90 \\ 3.97 \\ 4.33 \\ 4.40 \end{pmatrix} \quad \bar{X}_2 = \begin{pmatrix} 4.72 \\ 4.63 \\ 4.83 \\ 3.80 \end{pmatrix} \quad \text{and } A = \begin{pmatrix} 28.42 & 18.62 & -4.90 & -8.33 \\ & 28.91 & -4.41 & -7.84 \\ & & 22.54 & 20.58 \\ & & & 22.54 \end{pmatrix}$$

a) Test whether the two populations have the same mean vector assuming the two groups have the same dispersion matrix at 1% level of significance.

b) Find the 99% confidence region for the difference of mean vectors.

7. Two samples of sizes 15 and 25 from two normal populations $N_4(\mu^{(1)}, \Sigma)$ and $N_4(\mu^{(2)}, \Sigma)$ respectively gave the following:

$$\bar{X}^{(1)} = (16.43\ 12.56\ 14.89\ 9.56)' \ , \bar{X}^{(2)} = (14.41\ 10.51\ 13.12\ 8.11)' \text{ and}$$

$$S = \begin{pmatrix} 57.375 & 47.940 & 36.414 & 17.230 \\ & 69.003 & 37.638 & 13.005 \\ & & 59.925 & 13.311 \\ & & & 29.580 \end{pmatrix}$$

i) Construct the best linear discriminant function

ii) Classify the observation $(15.24\ 11.83\ 14.25\ 9.01)$

iii) Test whether only X_1 and X_2 are sufficient for the purpose of discrimination (α = 0.05).

iv) Can the linear function $Y = X_1 - X_2 + X_3 + X_4$ be suggested as best discriminant function?

Section IV_A

8. A double sampling plan is given by n=2000, n_1=100, n_2=150, c_1=1, c_2=4. The lots rejected by the plan are 100% inspected and all the defectives found are replaced by good ones.

(a) Draw OC curve for this plan, calculating at least 8points and state the approximation used if any.

(b) Draw the ASN curve for the same plan.

9. Control charts for $\bar{X}$ and R are maintained for an important quality characteristics. The sample size is n=7; $\bar{X}$ and R are computed for each sample. After 35 samples, we have found that $\sum \bar{X}_i$=7805 and $\sum$Ri=1200.

(a) Set up $\bar{X}$ and R charts using these data.

(b) Assuming both charts exhibit control, estimate the process mean and SD

(c) If the quality characteristic is normally distributed and if the specification are 220±35, can the process meet the specifications? Estimate the fraction non-conforming.

Section IV_B

10. A study on the effect of vitamin C on catching a cold was conducted and the results where summarized in the following table

	Outcome		
Treatment	Cold	No Cold	Total
Vitamin C	17	122	139
No vitamin C	31	109	140
Total	48	231	279

(a) Test the significance of Vitamin C on catching a cold

(b) Compute the relative risk and Odds ratio

(c) Construct a 99% confidence interval for the OR

11. Whyte, et al 1987 (Dobson, 1990) reported the number of deaths due to AIDS in Australia per 3 month period from January 1983 –June 1986.

y_i = number of deaths

x_i = time point (quarter)

x	y	x	y
1	0	8	18
2	1	9	23
3	2	10	31
4	3	11	20
5	1	12	25
6	4	13	37
7	9	14	45

Fit a suitable GLM for the following data and interpret the results

(5x6=30 weights)

COURSE CODE : **PG3STAE01**

COURSE TITLE : **STATISTICAL QUALITY ASSURANCE**

CREDITS : **3**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	Course outcome (expected)	Cognitive Level	PSO No.
1	Acquire and understand about basic concepts of quality, methods of quality assurance and statistical quality control techniques, since quality has become a major business strategy.	U	1,2,3
2	Understand acceptance sampling for attributes, Single sampling, Double Sampling, Multiple sampling and sequential sampling plans and measuring the performance of these plans.	U	1,2,3
3	acquire proficiency in control charts, basic ideas and designing of control charts using mean charts, median charts, R charts, S charts and economic design of Schewart control charts	U, Ap	1,3
4	To understand the concepts of acceptance sampling by variables, sampling plans with single and double specification limits and also about continuous sampling plans	An	1,2,4
5	To get deeper understanding on process capability studies and about six sigma philosophy , CUSUM Charts, EWMA Charts and also about performance measures-OC and ARL for control charts, Taguchi philosophy, Orthogonal arrays and linear graph.	An	1,2,4

PSO – Programme Specific Outcome, CO-Course Outcome;
Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create

Course Content

Module	Course Description	Hours	CO No.
I	1.1. Quality and quality assurance	20	1
	1.2. Methods of quality assurance.		1
	1.3. Introduction to TQM and ISO Standards		1
	1.4. Statistical Quality Control		1
	1.5. Acceptance sampling for attributes.		2
	1.6. Single sampling and double sampling		2
	1.7. Multiple and sequential sampling		2
	1.8. Measuring the performance of the plans.		2

II	2.1. Control charts, basic ideas	20	3
	2.2. Designing of control charts for the number of of non-conformities and fraction non conformities.		3
	2.3. Mean charts		3
	2.4. Median charts		3
	2.5. Extreme value charts		3
	2.6. R charts		3
	2.7. S charts		3
	2.8. Economic design of Schewart control chart		3
III	3.1. Acceptance sampling by variables	25	4
	3.2. Sampling plans for a single specification limit with known variance		4
	3.3. Sampling plans for a single specification limit with unknown variance		4
	3.4. Sampilng plans with double specification limits		4
	3.5. Comparison of sampling plans by variables.		4
	3.6. Comparison of sampling plans by attributes		4
	3.7. Continuous sampling plan I		4
	3.8. Continuous sampling plan II		4
	3.9. Continuous sampling plan III		4
IV	4.1. Process capability studies	25	5
	4.2. Statistical aspect of Six sigma philosophy		5
	4.3. Control charts with memory		5
	4.4. CUSUM Charts		5
	4.5. EWMA Charts		5
	4.6. OC and ARL for control charts		5
	4.7. The Taguchi method & Experimental design in Taguchi methods		5
	4.8. Taguchi philosophy of quality and Loss functions		5
	4.9. SN ratios and performance measures		5
	4.10. Orthogonal arrays and linear graph, Estimation of effects and parameter design.		5

Reference Books

1) Amitava Mitra- Fundamentals of Quality Control and improvement-Pearson Education Asia 2001- Chapter 12 (relevant Parts)
2) Chin-KneiCho (1987) Quality Programming, John Wiley.
3) Duncan, A.J. (1986)Quality Control and Industrial Statistics
4) Grant E.L. and Leaven Worth, R.S. (1980) Statistical Quality Control, McGraw Hill.
5) Mittag, H.J.&Rinne, H. (1993) Statistical methods for quality assurance, Chapman& Hall, Chapters 1,3 and 4
6) Montgomery R.C.(1985).Introduction to Statistical Quality Control, Fourth edition , Wiley
7) Schilling, E.G.(1982) Acceptance Sampling in Quality Control, Marcel Dekker

8) The ISO 9000 book, Second edition , Rabbit, J T and Bergle, PA Quality resources, Chapter 1

Question Paper Blue Print

Module	**Part A** (Weight 1) 8/10	**Part B** (Weight 2) 6/8	**Part C** (Weight 5) 2/4
I	2	2	1
II	2	2	1
III	3	2	1
IV	3	2	1
Total	**10**	**8**	**4**

MODEL QUESTION PAPER

Third Semester

Programme – M.Sc. Statistics

PG3STAE01 - STATISTICAL QUALITY ASSURANCE

(2022 Admission – Regular)

Time: Three Hours Maximum Weight: 30

Part A

Short Answer Questions

*(Answer any **eight** questions. Each question carries Weight **1**)*

1. Distinguish between process control and product control in SQC.
2. Justify the 3σ limits as control limits in any control chart.
3. Distinguish between chance causes and assignable causes.
4. Define the terms: Producers risk, consumers risk.
5. Define operating characteristic function of a control chart. What is its importance in process control?
6. What is a *c* – chart. When and where it is used.
7. Explain *CUSUM* charts.
8. Define the terms: *AQL and LTPD*.
9. Distinguish between multiple sampling plans and sequential sampling plans.
10. Explain the technique of curtailed inspection.

(8x1=8 Weights)

Part B

Short Essay Questions/Problems

*(Answer any **six** questions. Each question carries Weight **2**)*

11. Explain the terms: control limits, tolerance limits and specification limits.
12. What is meant by Average Sample Number ASN and ASN curve?
13. Distinguish between defects and defectives. Explain the construction and operation of a *p* chart.
14. What are acceptance sampling plans? Explain the *SSP*.
15. Describe a procedure to derive a SSP using attributes with a specified α and β.
16. What is meant by rectifying inspection? Obtain the *AOQ* function of a *SSP*.
17. Explain the method of construction of the *O. C.* curves for an attribute *DSP*.
18. Explain V-Mask procedure.

(6x2=12 Weights)

Part C

Long Essay Questions

*(Answer any **two** questions. Each question carries Weight **5**)*

19. Explain the construction and interpretation of mean chart and range chart.
20. How will you study the process capability of a production process? What are the important indices for measuring the process capability?
21. Derive the *ASN* and *ATI* functions for a *DSP* and draw their general shapes.
22. Explain the double sampling inspection plan.

(2x5=10 Weights)

COURSE CODE : **PG3STAE02**

COURSE TITLE : **CATEGORICAL DATA ANALYSIS**

CREDITS : **3**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	Course Outcome (Expected)	Cognitive Level	PSO No.
1	Remember the definitions Odds ratio, Relative risk, Sensitivity and Specificity. Understand the association between attributes, categorical variables and their applications in generalized linear models	R, U	1,2
2	Understand different probability models and GLMs. Applications of such models in real life situations are also introduced and familiarized.	U, Ap	2,3,4
3	Apply techniques of constructing the Poisson, Proportional hazards regression and Negative Binomial regression models and apply them in real life situations. Evaluate the strengths and weakness of these models	Ap, An, E	2,3,4
4	Apply techniques of random number generation, simulation to MCMC and Gibbs sampler. Evaluate different random number techniques. Create logic for generating random numbers from any statistical distribution	Ap, An, E, C	2,3,4

PSO – Programme Specific Outcome, CO-Course Outcome;

Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create.

Course Content:

Module	Course Description	Hours	CO No.
I	1.1. Data measurement levels and types of statistical studies	20	1
	1.2. Categorical variables and categorical data analysis		1
	1.3. Distributions for categorical data and inference for categorical data		1
	1.4. Introduction to Binary data and the latent variable approach		1
	1.5. Odds ratio, Relative risk, Sensitivity and Specificity, ROC curves		1

	1.6. Fishers exact test and McNemar's test		1
	1.7. Inference for contingency table, Chi-square test		1
	1.8. Binomial response models and Likelihood ratio		1
II	2.1. Linear probability models	20	2
	2.2. Link functions for categorical data		2
	2.3. General form of GLM		2
	2.4. Logistic Regression Analysis		2
	2.5.Logit and Probit Models with Categorical Predictors		2
	2.6. Multiple logistic regression		2
	2.7. Inference for logistic Regression		2
	2.8. Interpreting parameters in logistic Regression		2
	2.9. Regression diagnostics, Predictions		2
	2.10. Multinomial logistic regression		
III	3.1. Poisson regression models	25	3
	3.2. Negative Binomial Regression Models		3
	3.3. Proportional hazards regression models		3
	3.4. Estimation and Interpretations of coefficients		3
	3.5. Regression diagnostics		3
	3.6. Predictions		3
IV	4.1. Principles of Bayesian statistics	25	4
	4.2. Bayesian Inference for Categorical Data		4
	4.3. Inference using simulations from Standard distributions		4
	4.4. Markov Chain Monte Carlo (MCMC)		4
	4.5. The Gibbs sampler		4
	4.6. The Metropolis-Hastings algorithm		4

Reference books

1) Agresti, A. (2002) Categorical Data Analysis. New York: John Wiley.
2) Agresti, A. (2007) Introduction to Categorical Data Analysis 2nd edn, New York: John Wiley
3) Carlin, B.P. and Louis, T.A. (2000) Bayes and Emperical Bayes Methods for Data Analysis, Second Edition
4) Congdon P. (2006) Bayesian Statistical Modelling, Second Edition, John Wiley & Sons, Ltd. ISBN: 0-470-01875-5
5) Ntzoufras I. (2009) Bayesian Modeling using WinBUGS John Wiley & Sons Inc.
6) Powers D.A. (1999) Statistical methods for Categorical data analysis. Academic press Inc.
7) Shewhart, W.A. and Wilks, S.S. (2013) Case Studies in Bayesian Statistical Modelling and Analysis. Wiley.

Question Paper Blue Print

Module	**Part A** (Weight 1) 8/10	**Part B** (Weight 2) 6/8	**Part C** (Weight 5) 2/4
I	2	2	1
II	3	2	1
III	2	2	1
IV	3	2	1
Total	**10**	**8**	**4**

MODEL QUESTION PAPER

Third Semester

Programme – M.Sc. Statistics

PG3STAE02 - CATEGORICAL DATA ANALYSIS

(2022 Admission – Regular)

Time: Three Hours　　　　Maximum Weight: 30

Part A

Short Answer Questions

*(Answer any **eight** questions. Each question carries Weight **1**)*

1. What you mean by a Categorical data analysis?
2. Define relative risk.
3. Define Odds Ratio.
4. What you mean by sensitivity and specificity?
5. What is the relation between Odds and P(Y=1) in a logistic regression model.
6. Give the formula for the computation of the 95% confidence interval for the population odds ratios.
7. What are the Advantages of GLMs over traditional (OLS) regression?
8. What is the problem of over dispersion in Poisson Regression model?
9. Define hazard rate.
10. What you mean by simulation?

(8x1=8 Weights)

Part B

Short Essay Questions/Problems

*(Answer any **six** questions. Each question carries Weight **2**)*

11. What are the four data types based on the measurement?

12. Explain three components of a generalized linear model.
13. Imagine that the incidence of gun violence is compared in two cities, one with relaxed gun laws (A), the other with strict gun laws (B). In the city with relaxed gun laws, there were 50 shootings in a population of 100,000 and in the other city, 10 shootings in a population of 100,000. (1) What is the relative risk of gun violence in the city with relaxed gun laws (A)? (2) Compute the 90% confidence interval for RR.
14. What you mean by deviance measure?
15. Define log odds and derive the standard error of log odds
16. Explain the Hosmer-Lemeshow test statistics.
17. Explain how the significance of coefficients of Poisson regression model can be tested
18. State and prove Baye's theorem .

(6x2=12 Weights)

Part C
Long Essay Questions
*(Answer any **two** questions. Each question carries Weight **5**)*

19. Explain logistic regression model with assumptions if any. Derive the likelihood function of the logistic regression model. Explain how you will proceed to estimate the parameters from the likelihood equation.
20. Explain proportional Hazard regression model. Derive the likelihood function
21. Explain different methods of checking model adequacy in generalized linear models?
22. Explain Gibbs sampler.

(2x5=10 Weights)

FOURTH SEMESTER

Sl. No.	Course Code	Course Name
1	PG4STAC15	ECONOMETRIC METHODS
2	PG4STAC16	STATISTICAL COMPUTING USING SAS
3	PG4STAE03	TIME SERIES ANALYSIS
4	PG4STAE04	POPULATION DYNAMICS
5	PG4STAE05	SURVIVAL ANALYSIS

COURSE CODE : **PG4STAC15**

COURSE TITLE : **ECONOMETRIC METHODS**

CREDITS : **4**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	Course Outcome (Expected)	Cognitive Level	PSO No.
1	Understand and remember the different micro-economic concepts and apply them in the mathematical models	R, U, Ap	1,2
2	Understand different types of regression models. Analyze and apply them in modelling and prediction	U, Ap, An	2,3
3	Understand and apply different diagnostic testing. Analyze and evaluate the accuracy of the fitted models. Create remedial measures for assumption violations	U, Ap, An, E, C	2,3,4,
4	Understand the concept of structural models and their applications in econometric modelling	U, Ap	1,3,4

PSO – Programme Specific Outcome, CO-Course Outcome;

Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create.

Course Content:

Module	Course Description	Hours	CO No.
I	1.1. Theory of Demand, Supply, Elasticity, Market equilibrium and Types of markets	20	1
	1.2. Utility function, Indifference curves		1
	1.3. Cob-web model, Slutsky theorem		1
	1.4. Theory of Production and Cost Function		1
	1.5. Marginal analysis of firms		1
	1.6. Production Functions, Elasticity of production		1
	1.7. Homogeneous production functions, Cobb-Douglas Production function, Returns to scale		1
	1.8. Constraint maximizations		1
	1.9. Investment, Savings, Liquidity and Money		1
	1.10. Keynes' theory on demand for money, IS-LM model		1
	1.11. Input- Output analysis (Open and closed system)		

II	2.1. Simple linear regression models, Multiple linear regression models	20	2
	2.2. Estimation of the model parameters and tests concerning the value of the parameters		2
	2.3. Confidence and prediction intervals		2
	2.4. Use of Dummy variables in regression		2
	2.5. Polynomial regression models		2
	2.6. Step-wise regression		2
III	3.1. Multicollinearity- Consequences and Detection, Farrar-Glauber test, remedial measures	25	3
	3.2. Heteroscedasticity- Consequences, Detection tests, remedial measures		3
	3.3. Aitken's generalized least square method		3
	3.4. Auto-correlation-tests for auto correlation, consequences, and Estimation procedures		3
	3.5. Errors in variables-consequences, detection, remedial measures, instrumental variables		3
	3.6. Stochastic regressors, Distributed lagg models		3
	3.7 Regression Diagnostics, Outlier, Influential observations, Leverage		
IV	4.1. Simultaneous equation models	25	4
	4.2. Identification problems- rank and order conditions		4
	4.3. Methods of estimation from simultaneous equation models		4
	4.4. Indirect least squares, recursive models		4
	4.5. Two-stage and three-stage least squares		4
	4.6. Least variance ratio, LIML and FIML- methods		4

Reference books

1) Allen R.G.D. (2008) Mathematical Analysis For Economists, Aldine Transaction
2) Apte P.G. (1990) Text book of Econometrics, Tata Me Graw Hill.
3) Gujarati D. (1979) Basic Econometrics, McGraw Hill.
4) Johnston J. (1984) Econometric Methods (Third edition), McGraw Hill, New York.
5) Koutsoyiannis A. (1979) Theory of Econometrics, Macmillian Press Ltd.
6) Koutsoyiannis A. (2008) Modern Microeconomics, Second Edition, Macmillan Press Ltd
7) Kutner M. H, Nachtsheim C.J, Neter J and Li W. (2005), Applied Linear Statistical Model, Fifth edition. McGraw Hill
8) Montgomery D.C., Peck E.A. and Vining G.G. (2007) Introduction to Linear Regression Analysis, John Wiley, India.

9) Seber, G.A.F and Lee A.J. Linear Regression Analysis (2003). Wiley Series in Probability and Statistics.

10) Theil H. (1982) Introduction to the Theory and Practice of Econometrics, John Wiley.

Question Paper Blue Print

Module	**Part A** (Weight 1) 8/10	**Part B** (Weight 2) 6/8	**Part C** (Weight 5) 2/4
I	2	2	1
II	3	2	1
III	3	2	1
IV	2	2	1
Total	**10**	**8**	**4**

MODEL QUESTION PAPER

Fourth Semester

Programme – M.Sc. Statistics

PG4STAC15 - ECONOMETRIC METHODS

(2022 Admission – Regular)

Time: Three Hours Maximum Weight: 30

Part A

Short Answer Questions

*(Answer any **eight** questions. Each question carries Weight **1**)*

1. Define price elasticity of demand
2. Define cobb-Douglas production function and its importance
3. Explain the problem of hetroscdasticity and explain its consequences
4. What are instrumental variables and how they are used in econometrics?
5. Explain the problem of identifiability with an example
6. What is the use of dummy variables in regression analysis?
7. What you mean by stochastic regressors?
8. What is the importance of coefficient of determination in regression analysis?
9. How will test the global significance of a k variable linear model?
10. What you mean by an AR(1) model?

(8x1=8 Weights)

Part B

Short Essay Questions/Problems

*(Answer any **six** questions. Each question carries Weight **2**)*

11. Find the profit maximizing output when the total revenue R = $5x^2+45x$ and the average cost is $x^2 -8x+57+2/x$.
12. Explain CES production function
13. What you mean by multicollinearity? How it can be detected? What are the consequences.?
14. Obtain the least square estimates from the model Y= Xβ+U, where, U satisfies all the assumptions of CLRM. Also derive the dispersion matrix
15. Explain Cochran-Orcutt procedure of estimation in the presence of auto correlation
16. Explain the ILS method of estimation
17. Explain the consequence of the presence of errors in the linear regression model.
18. What you mean by the problem of auto correlation and how it can be detected.

(6x2=12 Weights)

Part C

Long Essay Questions

*(Answer any **two** questions. Each question carries Weight **5**)*

19. Explain the Leontifs open system of input output model with few applications.
20. Explain Aitken's genaralized least square (GLS) method of estimation
21. State and establish the rank and order conditions for identifiability
22. Describe the LIML method of estimation from simultaneous equation model.

(2x5=10 Weights)

COURSE CODE : **PG4STAC16**

COURSE TITLE : **STATISTICAL COMPUTING USING SAS**

CREDITS : **4**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	Course Outcome (Expected)	Cognitive Level	PSO No.
1	Understand basics of SAS and perform various analysis on data in SAS.	U, An	1,4
2	Apply suitable regression modelling techniques to different data sets, interpret the model coefficients and assess the model reliability. Computations required to supports different economic relations using real data and test the significance of the theories based on the data.	Ap	2,3,4
3	Solve the problems related to time series like estimation of trend and seasonality, forecasting using smoothing techniques, and model identification, fitting, diagnostic checking and forecasting of ARIMA models.	Ap	2,3,4
4	Calculation of problems related to different mortality rates, reproduction rates. Construction of Life tables, Abridged life tables. Population projection using various methods	Ap	2,3,4
5	Solve the problems related to survival analysis like estimation of the survival function for censored data, comparison of two or more survival curves, fitting and diagnostic checking of Cox proportional hazard model, and fitting of various parametric regression models.		2,3,4
6	Equips the student with the intellectual apparatus and cognitive skills with which theoretical learning is applied to analyse and solve both social behavioural patterns and statistical problems.	Ap	2,3,4

PSO – Programme Specific Outcome, CO-Course Outcome;
Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create.

Course Content:

Module	Course Description	Hours	CO No.
I	1.1. Production Functions, Elasticity of production	30	1,2,6
	1.2. Input- Output analysis		1,2,6
	1.3. Simple linear regression models		1,2,6
	1.4. Multiple linear regression model		1,2,6
	1.5. Dummy variable regression models		1,2,6
	1.6. Polynomial regression models, Step-wise regression		1,2,6

	1.7. Multicollinearity, Heteroscedasticity and Autocorrelation		1,2,6
	1.8. Stochastic regressors		1,2,6
	1.9. Regression Diagnostics		1,2,6
	1.10. Simultaneous equation models -Rank and Order condition		1,2,6
	1.11. ILS, 2SLS, LIML		1,2,6
II	2.1. Estimation of trend	30	1,3,6
	2.2. Estimation of seasonal indices		1,3,6
	2.3. Forecasting using moving averages and exponential smoothing		1,3,6
	2.4. Forecasting using Holt's exponential smoothing		1,3,6
	2.5. Forecasting using Holt-Winter's exponential smoothing		1,3,6
	2.6. Computation of ACF and PACF		1,3,6
	2.7. Model identification of ARIMA models		1,3,6
	2.8. Fitting of ARIMA models		1,3,6
	2.9. Diagnostic checking of ARIMA models		1,3,6
	2.10. Forecasting using ARIMA models		1,3,6
III_A	3.1. Calculation of various Mortality rates	30	1,4,6
	3.2. Gross & Net Reproduction rates		1,4,6
	3.2. Construction of Life Tables		1,4,6
	3.3. Construction of Abridged Life Tables		1,4,6
	3.5. Population projection techniques		1,4,6
III_B	4.1. Estimation of the survival function for censored data	30	1,5,6
	4.2. Computation of Kaplan-Meier estimator		1,5,6
	4.3 Computation of Nelson–Aalen cumulative hazard estimator		1,5,6
	4.4. Comparison of two or more survival curves		1,5,6
	4.5. Fitting of Cox proportional hazard model		1,5,6
	4.6. Checking the assumptions of Cox proportional hazard model		1,5,6
	4.7. Fitting of parametric regression models		1,5,6

Question Paper Blue Print

Total No. of Questions	**Module I** (Econometric Methods)	**Module II** (Time Series Analysis)	**Module III_A** (Population Dynamics)	**Module III_B** (Survival Analysis)
9 (11)	**3**	**3**	**3**	**3**

Nine *numeric questions, each having* ***six*** *weights, are to be asked.* ***Three*** *questions from* ***module I, II, III_A and III_B*** *must be asked. The student is expected to answer* ***five*** *questions* ***selecting at least one question from each of the modules I, & II and at least one question from either of module III_A OR III_B****. The use of Python, R, SPSS, and SAS packages is permitted for answering questions. An examination of 3 hours duration must be* *conducted in the computer lab under the supervision of an external examiner appointed by the Controller of Examinations.*

MODEL QUESTION PAPER

Fourth Semester

Programme – M.Sc. Statistics

PG4STAC16 - STATISTICAL COMPUTING USING SAS

Time: Three Hours Maximum Weight: 30

*(Answer any **five** questions without omitting any section.*
*Each question carries Weight **6**)*

Section I

1. The matrix of technological coefficients relating to 3 industries in an economy is as follows $\begin{bmatrix} 0.2 & 0.3 & 0.2 \\ 0.4 & 0.1 & 0.2 \\ 0.1 & 0.3 & 0.2 \end{bmatrix}$ Further, if b_j is the rupees amount of the primary input using in producing a rupee worth of the output of the jth industry (j=1,2,3). The following information is also provided. b_1 =0.3, $b_2 = 0.3$ and b_3 =0.4

   (a) Obtain the output of these industries in order to meet the final demand vector $(10, 5, 6)$

   (b)The amount available for primary unit is Rs-20, examine if the solution is feasible?

   (c) If the final demand for the 1st industry is raised to 11 what would be the additional requirement of the primary unit in the economy?

2. Fit a linear model for the following data by the method weighted least squares

Y	X	SD
3396	1	743.7
3787	2	851.4
4013	3	727.8
4104	4	805.06
4146	5	929.9
4241	6	1080.6
4387	7	1243.2
4538	8	1307.7
4843	9	1112.5

3. The following tables gives the data on 5 variables Y, X_1, X_2, X_3, X_4 in arbitrary units

Y	6	6	6.5	7.1	7.2	7.6	8	9	9	9.3
X1	40.1	40.3	47.5	49.2	52.3	58	61.3	62.5	64.7	66.8
X2	5.5	4.7	5.2	6.8	7.3	8.7	10.2	14.1	17.1	21.3
X3	108	94	108.0	100	99	99	101	97	93	102

X4	63	72	86.0	100	197	111	114	116	119	121

Test for multicollinearity. How does it affect the parameter estimates?

Section II

4. Consider the seasonal time series data shown in the following table.

	Q1	Q2	Q3	Q4
2016	318	380	358	423
2017	379	394	412	439
2018	413	458	492	493
2019	461	468	529	575
2020	441	548	561	620

a. Calculate the seasonal indices by the "Ratio to Moving Average" method.

b. Use Holt-Winters' method to develop a forecasting method for this data ($\alpha = 0.1$, $\beta = 0.2$, $\gamma = 0.1$).

5. Consider the time series data shown in the following table.

Period	y_t	Period	y_t	Period	y_t
1	29	11	29	21	31
2	20	12	28	22	30
3	25	13	28	23	37
4	29	14	26	24	30
5	31	15	27	25	33
6	33	16	26	26	31
7	34	17	30	27	27
8	27	18	28	28	33
9	26	19	26	29	37
10	30	20	30	30	29

(a) Calculate and plot the sample autocorrelation and partial autocorrelation functions (maximum 12 lags).

(b) What process would you tentatively suggest could represent the most appropriate model for this series?

(c) Fit the model identified in part (b).

6. Consider the following autocorrelation and partial autocorrelation coefficients using 500 observations for a weakly stationary series

Lag	ACF	PACF
1	0.307	0.307
2	-0.013	0.264
3	0.086	0.147
4	0.031	0.086
5	-0.079	0.049

(a) Determine which, if any, of the ACF and PACF coefficients are significant at the 5% level.

(b) Use both the Box-Pierce and Ljung-Box statistics to test the joint null hypothesis that the autocorrelation coefficients are jointly zero.

(c) What process would you tentatively suggest could represent the most appropriate model for this series?

(d) How could you estimate the model you suggest in part (c)?

Section III_A

7. The following table gives the age specific fertility rate per year and the female life table population for the certain country. Compute the gross and net production rate:

Age in years	Age specific fertility rate	Female life table population
15-19	0.0149	4528
20-24	0.1128	4419
25-29	0.1521	4712
30-34	0.1109	4328
35-39	0.0726	4574
40-44	0.0293	4525
45-49	0.0027	4456

8. The following table is an extract form All-India male Life table in standard notation

x	l_x	d_x	q_x	L_x	T_x	e_x^0
30	67629	534	0.00790	67362	1963400	29.03
31	67095	582	0.00867	66804	1896038	28.26
32			0.00949			
33			0.01040			
34			0.01135			

Compute all the missing values and also the value e_{35}^0.

9. The population of a country in the years 1990, 2000 and 2010 are respectively 354000, 478000 and 684000.

a. Project the population to 2020 using exponential curve.

b. Fit a logistic curve and give the projected population in 2020.

Section III_B

10. The following data are a sample from the 1967-1980 Evans County study. Survival times (in years) are given for two study groups, each with 25 participants. Group 1 has no history of chronic disease (CHR = 0), and group 2 has a positive history of chronic disease (CHR = 1):

Group 1 (CHR = 0): 12.3+, 5.4, 8.2, 12.2+, 11.7, 10.0, 5.7, 9.8, 2.6, 11.0, 9.2, 12.1+, 6.6, 2.2, 1.8, 10.2, 10.7, 11.1, 5.3, 3.5, 9.2, 2.5, 8.7, 3.8, 3.0

Group 2 (CHR = 1): 5.8, 2.9, 8.4, 8.3, 9.1, 4.2, 4.1, 1.8, 3.1, 11.4, 2.4, 1.4, 5.9, 1.6, 2.8, 4.9, 3.5, 6.5, 9.9, 3.6, 5.2, 8.8, 7.8, 4.7, 3.9

a) Plot the KM curves for groups 1 and 2 on the same graph. Comment on how these curves compare with each other.

b) Carry out the log–rank test for these data. What is your null hypothesis and how is the test statistic distributed under this null hypothesis? What are your conclusions from the test?

11. A study was performed to determine the efficacy of boron neutron capture therapy (BNCT) in treating the therapeutically refractory F98 glioma, using boronophenylalanine (BPA) as the capture agent. F98 glioma cells were implanted into the brains of rats. Three groups of rats were studied. One group went untreated, another was treated only with radiation, and the third group received radiation plus an appropriate concentration of BPA. The data for the three groups lists the death times (in days) and is given below:

Untreated	*Radiated*	Radiated + BPA
20	26	31
21	28	32
23	29	34
24	29	35
24	30	36
26	30	38
26	31	38
27	31	39
28	32	42^+
30	35^+	42^+

Create two dummy variables, Z_1 = 1 if animal is in the "radiation only" group, 0 otherwise; Z_2 = 1 if animal is in the "radiation plus BPA" group, 0 otherwise. Use the Breslow method of handling ties in the problems below.

a) Estimate β_1 and β_2 and their respective standard errors. Find a 95% confidence interval for the relative risk of death of an animal radiated only compared to an untreated animal.

b) Test the global hypothesis of no effect of either radiation or radiation plus BPA on survival.

c) Test the hypothesis that the effect a radiated only animal has on survival is the same as the effect of radiation plus BPA.

d) Find an estimate and a 95% confidence interval for the relative risk of death for a radiation plus BPA animal as compared to a radiated only animal.

12. Remission times in week of 21 chemotherapy patients were 6,6,6,6*,7,9*,10,10*,11*,13,16,17*,19*,20*,22,23,25*,32*,32*,34*,35* (*denotes censored observations). Find the Kaplan Meier estimate of survival function.

(5x6=30 Weights)

COURSE CODE : **PG4STAE03**

COURSE TITLE : **TIME SERIES ANALYSIS**

CREDITS : **3**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	Course Outcome (Expected)	Cognitive Level	PSO No.
1	Understand the concepts of time series with its components and able to apply various exponential smoothing methods.	U, Ap	1,3,4
2	Analyse auto regressive, moving average, ARMA, ARIMA models and able to compute autocovariance and autocorrelation of stationary time series models.	An, Ap	1,2,4
3	Apply Box-Jenkins approach to forecast time series data empirically and check and validate models with its residual analysis and diagnostic checking.	Ap, E	1,2,4
4	Understand the concepts of spectral analysis of time series, Seasonal ARIMA, ARCH and GARCH models.	U	1,3

PSO – Programme Specific Outcome, CO-Course Outcome;
Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create.

Course Content:

Module	Course Description	Hours	CO No.
I	1.1. Time series	25	1
	1.2. Components of time series		1
	1.3. Additive and multiplicative models		1
	1.4. Estimation and elimination of trend and seasonality		1
	1.5. Moving average		1
	1.6. Simple Exponential Smoothing		1
	1.7. Holt's exponential smoothing		1
	1.8. Holt-Winter's exponential smoothing		1
	1.9. Forecasting based on smoothing		1
II	2.1. Time series as a discrete parameter stochastic process	25	2
	2.2. Autocovariance function and its properties		2
	2.3. Autocorrelation function and its properties		2
	2.4. Stationary processes		2
	2.5. Wold representation of linear stationary processes		2
	2.6. Autoregressive processes		2
	2.7. Moving Average processes		2
	2.8. Autoregressive Moving Average processes		2
	2.9. Autoregressive Integrated Moving Average processes		2
III	3.1. Estimation of ARMA models	20	3
	3.2. Yule-Walker estimation for AR Processes		3

	3.3. Maximum likelihood estimation for ARMA Processes		3
	3.4. Least squares estimation for ARMA Processes		3
	3.5. Nature of characteristic roots of s special types of matrices		3
	3.6. Choice of AR and MA periods		3
	3.7. Forecasting using ARIMA models		3
	3.8. Residual analysis and diagnostic checking		3
IV	4.1. Spectral density of a stationary time series	25	4
	4.2. Periodogram		4
	4.3. Spectral density of ARMA processes		4
	4.4. Herglotz theorem		4
	4.5. Seasonal ARIMA models (Basic concepts)		4
	4.6. ARCH and GARCH models (Basic concepts)		4
	4.7. Cointegration (Basic concepts)		4

Reference Books

1) Abraham B. and Ledolter J.C. (2005) Statistical Methods for Forecasting, Second edition Wiley.
2) Box G.E.P, Jenkins G.M. and Reinsel G.C. (2008) Time Series Analysis: Forecasting and Control, Fourth Edition, Wiley.
3) Brockwell P.J and Davis R.A. (2002) Introduction to Time Series and Forecasting Second edition, Springer-Verlag.
4) Cryer, J. D. and Chan, K. (2008). Time Series Analysis with Applications in R, Second Edition, Springer-Verlag.
5) Shumway, R. H. and Stoffer, D. S. (2011) Time Series Analysis and Its Applications with R Examples, Third Edition, Springer-Verlag.

Question Paper Blue Print

Module	**Part A** (Weight 1) 8/10	**Part B** (Weight 2) 6/8	**Part C** (Weight 5) 2/4
I	2	2	1
II	3	2	1
III	2	2	1
IV	3	2	1
Total	**10**	**8**	**4**

MODEL QUESTION PAPER

Fourth Semester

Programme – M.Sc. Statistics

PG4STAE03 - TIME SERIES ANALYSIS

(2022 Admission – Regular)

Time: Three Hours | Maximum Weight: 30

Part A

Short Answer Questions

*(Answer any **eight** questions. Each question carries Weight **1**)*

1. Distinguish between additive and multiplicative models of time series.
2. Explain moving average method of measuring trend.
3. Explain the relationship between a time series and a stochastic process.
4. Define auto covariance function and auto correlation function.
5. Define ARIMA(p, d, q) model.
6. Define a stationary process and a white noise process.
7. Describe a method of estimation of parameters of an AR(1) model.
8. Explain residual analysis of a time series data.
9. Find the spectral density function of a white noise process.
10. Explain an ARCH model, clearly stating the assumptions.

(8x1=8 Weights)

Part B

Short Essay Questions/Problems

*(Answer any **six** questions. Each question carries Weight **2**)*

11. Describe a method for the estimation and elimination of trend and seasonal components in a time series.
12. Explain Holt's double exponential smoothing procedure.
13. Write down the ACF of order k for an $AR(1)$ model $X_t = 0.7X_{t-1} + \varepsilon_t$, where $\{\varepsilon_t\}$ is a white noise process. Show that this $AR(1)$ model can be expressed as a MA process of infinite order. Hence or otherwise discuss the stationarity of the $AR(1)$ process.
14. Derive the invertibility condition for an $MA(2)$ process in terms of its parameters.
15. Describe the maximum likelihood method of estimation of the parameters of an $AR(1)$ model.
16. Describe least squares estimation of parameters of the $AR(2)$ model $X_t = \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \varepsilon_t$, where $\{\varepsilon_t\}$ is a white noise process with mean 0 and variance σ^2.

17. Find the spectral density function of the $MA(2)$ model $X_t = 0.5\varepsilon_{t-2} + 0.8\varepsilon_{t-1} + \varepsilon_t$, where $\{\varepsilon_t\}$ is a white noise process with mean 0 and variance σ^2.

18. Explain seasonal ARIMA models.

(6x2=12 Weights)

Part C
Long Essay Questions
(Answer any ***two*** *questions. Each question carries Weight* ***5****)*

19. (i) Explain the important components of a time series.

    (ii) Describe Holt-Winters smoothing procedure.

20. (i) Derive the ACF and PACF of an MA(2) process.

    (ii) Show that the ARMA(1,1) process $X_t = 0.5X_{t-1} + \varepsilon_t - 0.3\varepsilon_{t-1}$ is stationary and invertible.

21. (i) Derive the Yule-Walker equations satisfied by the a.c.f. of an AR(p) process.

    (ii) How will you determine the order of an autoregressive process? Explain.

22. i) Define spectral density function and state its properties.

    ii) Find the spectral density function of an *ARMA* (*p*, *q*) process.

(2x5=10 Weights)

COURSE CODE : **PG4STAE04**

COURSE TITLE : **POPULATION DYNAMICS**

CREDITS : **3**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	Course outcome (expected)	Cognitive Level	PSO No.
1	Understand the fundamental ideas, objectives and applications of population dynamics. Recognise Population estimation methods and health indicators.	U	1,3
2	Provide a solid introduction to life tables – construction of life tables – and sampling distribution of life table functions – and estimation of survival probability by method of MLE.	U	1,3,4
3	Understand the fertility models and fertility indices and relation between CBR, GFR, TFR, NRR, and different types of models in fertility and human reproductive process.	U, Ap	1,2,4
4	The students are exposed to population growth indices, population growth models-Fitting of logistical models. They become an expert in population projection techniques by using a mathematical model such as logistic Gompertz or any other suitable determinate model which describe the natural growth of population by component method, projection by techniques suitable of stable or quasi stable population.	An, Ap	2,3,4
5	Understand the fundamental ideas about Leslie matrix techniques, properties of time independent Leslie matrix – and they become an expert in the population projection process using Leslie matrix method.	Ap	1,2,3

PSO Programme Specific Outcome, CO-Course Outcome;

Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create

Course Content

Module	Course Description	Hours	CO no.
I	1.1. Sources of mortality data	20	1
	1.2. Mortality measures-ratios and proportions		1

	1.3. Crude mortality rates		1
	1.4. Specific rates		1
	1.5. Standardisation of mortality rates-direct and indirect methods		1
	1.6. Gradation of mortality data		1
	1.7. Fitting of Gompertz		1
	1.8. Makeham curves		1
II	2.1. Life tables.	25	2
	2.2.Relation between life table functions		2
	2.3 Abridged life table.		2
	2.4.Construction of life tables		2
	2.5. Grivell's formula		2
	2.6. Reed and Merrell's formula		2
	2.7. Sampling distribution of life table functions		2
	2.8. Multivariate pgf		2
	2.9. Estimation of survival probability by method of MLE		2
III	3.1. Fertility models	20	3
	3.2. Fertility indices		3
	3.3. Relation between CBR,GFR		3
	3.4. Relation between TFR and NRR		3
	3.5. Stochastic models on fertility and human reproductive process		3
	3.6. Dandekar's modified Binomial and Poisson models		3
	3.7. Brass, Singh models		3
	3.8. Models for waiting time distributions		3
	3.9. Sheps and Perrin model		3
IV	4.1. Population growth indices	25	4
	4.2. Logistic Model		4
	4.3. Fitting of Logistic Model		4
	4.4. Other Growth models		4
	4.5. Lotka's stable population and Quasi stable population.		4
	4.6. Effect of declining mortality and fertility on age structure		
	4.7. Population projection		4
	4.7. Component method-Leslie matrix technique		4,5
	4.8. Properties of time independent Leslie matrix		4,5
	4.9. Models under random environment		4,5

Reference books

1) Amitava Mitra- Fundamentals of Quality Control and improvement-Pearson Education Asia 2001- Chapter 12 (relevant Parts)
2) Chin-KneiCho (1987) Quality Programming, John Wiley.
3) Duncan, A.J. (1986) Quality Control and Industrial Statistics
4) Grant E.L. and Leaven Worth, R.S. (1980) Statistical Quality Control, McGraw Hill.
5) Mittag, H.J.&Rinne,H.(1993) Statistical methods for quality assurance, Chapman& Hall, Chapters 1,3 and 4

6) Montgomery R.C.(1985).Introduction to Statistical Quality Control, Fourth edition , Wiley
7) Schilling, E.G.(1982) Acceptance Sampling in Quality Control, Marcel Dekker
8) The ISO 9000 book, Second edition , Rabbit, J T and Bergle, PA Quality resources, Chapter 1

Question Paper Blue Print

Module	**Part A** (Weight 1) 8/10	**Part B** (Weight 2) 6/8	**Part C** (Weight 5) 2/4
I	2	2	1
II	2	2	1
III	3	2	1
IV	3	2	1
Total	10	8	4

MODEL QUESTION PAPER

Fourth Semester

Programme – M.Sc. Statistics

PG4STAE04 - POPULATION DYNAMICS

(2022 Admission – Regular)

Time: Three Hours Maximum Weight: 30

Part A

Short Answer Questions

*(Answer any **eight** questions. Each question carries Weight **1**)*

1. Define infant mortality rate, neo-natal mortality rate and peri-natal mortality rate.
2. What is the need for the gradation of mortality rates?
3. If the expectation of life at birth of a life table population is 79 years, what is its CDR?
4. Establish the relationship between the force of mortality and the central mortality rate.
5. What are life tables? What are its uses?
6. Distinguish between a complete life table and an abridged life table.
7. Name the important indices of Fertility measures.
8. Distinguish between GRR and NRR. What does it imply, if NRR = 1?
9. Stationary population is a special case of the stable population. Discuss.
10. Explain the Gompers model of mortality.

(8x1=8 Weights)

Part B

Short Essay Questions/Problems

*(Answer any **six** questions. Each question carries Weight **2**)*

11. What are the important population growth models?
12. Define Pearl's Vital Index.
13. What is the purpose of standardization of a mortality data? Explain the direct and indirect methods of standardization.
14. What do you mean by Specific Death Rates? Mention the important among them and their advantages over the Crude Death Rate.
15. Explain the Makeham's model for mortality gradation.
16. What are the general assumptions involved in the construction of Life Tables?
17. Establish the Greville's abridged life table formula.
18. Describe the William Brass model for human fertility.

(6x2=12 Weights)

Part C

Long Essay Questions

*(Answer any **two** questions. Each question carries Weight **5**)*

19. Establish the Reed and Merrell's formula for the construction of life tables.
20. Derive the sampling distribution of the life table functions.
21. Explain the Shep and Perrin model of human reproductive process. What is the average waiting time between two successive live births?
22. Derive Alfred Lotka's fundamental equation of stable population. Show that age structure and birth rate of stable population are independent of time.

(2x5=10 Weights)

COURSE CODE : **PG4STAE05**

COURSE TITLE : **SURVIVAL ANALYSIS**

CREDITS : **3**

Course Outcome:

Upon the successful completion of the course students will be able to:

CO No.	Course Outcome (Expected)	Cognitive Level	PSO No.
1	Explain the key features of survival data and the roles played by censoring, and survival and hazard functions.	U	1,3
2	Use non-parametric methods such as the Kaplan-Meier estimator, the Nelson-Aalen estimator and the log rank test to analyse survival data.	U, An	1,3,4
3	Apply the Cox proportional hazards model to examine the effects of covariates on survival and assess whether the proportional hazards assumption is justified.	Ap, An	1,3,4
4	Fit parametric regression models such as Exponential, Weibull and Log Logistic to survival data and interpret the results.	U, An	1,3,4
5	Understand the major theory and methods of survival analysis and their applications in practical settings.	U, Ap	1,2,3

PSO – Programme Specific Outcome, CO-Course Outcome;
Cognitive Levels: R-Remember; U-Understanding; Ap-Apply; An-Analyze; E-Evaluate; C-Create.

Course Content:

Module	Course Description	Hours	CO No.
I	1.1. Introduction to survival analysis	20	1
	1.2. Survival function and Hazard function		1
	1.3. Mean residual life function and Median life		1
	1.4. Common parametric models for survival data		1
	1.5. Censoring: Right, Left and Interval censoring		1
	1.6. Truncation		1
	1.7. Likelihood construction for censored and truncated data		1, 5
II	2.1. Nonparametric estimators of the survival and cumulative hazard functions for right-censored data	25	2
	2.2. Kaplan–Meier or Product-limit estimator		2
	2.3. Nelson–Aalen cumulative hazard estimator		2
	2.4. Pointwise confidence intervals for the survival function*		2
	2.5. Estimation of the survival function for left-censored and interval-censored data		2
	2.6. Comparing two or more survival curves		2
	2.7. Log rank test, Gehan test		2

III	3.1. Semiparametric Proportional hazards regression with fixed covariates	25	3, 5
	3.2. Coding covariates		3
	3.3. Partial likelihoods for distinct-event time data		3, 5
	3.4. Partial likelihoods when ties are present		3, 5
	3.5. Model building using the Proportional hazards model		3
	3.6. Estimation for the survival function		3
	3.7. Regression diagnostics		3
	3.8. Cox-Snell residuals for assessing the fit of a Cox model		3
	3.9. Graphical checks of the Proportional hazards assumption		3
	3.10. Deviance Residuals		3
IV	4.1. Inference for Parametric Regression Models	20	4
	4.2. Exponential, Weibull, and Log Logistics		4
	4.3. Competing risk models		5
	4.4. Basic characteristics and model specification		5
	4.5. Likelihood function formulation		5
	4.6. Nonparametric Methods		5

Text Books

1) Klein, J.P. and Moeschberger, M.L. (2003) Survival Analysis - Techniques for censored and truncated data, Second Edition, Springer-Verlag, New York
2) Lawless, J.F. (2003) Statistical Models and Methods for Lifetime Data, Second Editon, John Wiley & Sons.

Reference Books

1) Kalbfleisch, J.D. and Prentice, R.L. (2002) The Statistical Analysis of Failure Time Data, Second Edition, John Wiley & Sons.
2) Kleinbaum D.G. and Klein, M. (2012) Survival Analysis- A Self-Learning Text, Third Edition, Springer-Verlag, New York.
3) Hosmer, D.W., Lemeshow, S. and May S. (2008). Applied Survival Analysis: Regression modeling of Time to Event Data, Second Edition, John Wiley & Sons.

Question Paper Blue Print

Module	**Part A** (Weight 1) 8/10	**Part B** (Weight 2) 6/8	**Part C** (Weight 5) 2/4
I	3	2	1
II	2	2	1
III	3	2	1
IV	2	2	1
Total	**10**	**8**	**4**

MODEL QUESTION PAPER

Fourth Semester

Programme – M.Sc. Statistics

PG4STAE05 - SURVIVAL ANALYSIS

(2022 Admission – Regular)

Time: Three Hours Maximum Weight: 30

Part A

Short Answer Questions

*(Answer any **eight** questions. Each question carries Weight **1**)*

1. Define mean residual life function.
2. Find the median survival time for an exponential distribution with mean λ.
3. Distinguish between censoring and truncation.
4. What you mean by non-parametric estimation?
5. Explain why Cox regression model is called proportional hazard model.
6. What do you mean by baseline hazard function?
7. Explain Gehan test.
8. What is partial likelihood?
9. Briefly explain hazard plots.
10. Define accelerated failure-time model.

(8x1=8 Weights)

Part B

Short Essay Questions/Problems

*(Answer any **six** questions. Each question carries Weight **2**)*

11. What are the different types of censoring? How will you construct the likelihood if the data is right censored?
12. A random variable $T(\geq 0)$ has hazard rate $h(t) = \alpha\lambda t^{\alpha-1}, t \geq 0$. Derive the distribution function $F(t)$ and survival function $S(t)$. Calculate $S(t)$ at $t = 5,$ if $\alpha = 2, \lambda = 1.$
13. Write a short note on Nelson-Aalen estimator for the cumulative hazard function.
14. Discuss the log-rank test in a two-sample problem.
15. Explain Cox-Snell residuals for assessing the fit of a Cox model.
16. Write short note on deviance residuals.
17. Describe the log logistic regression model.
18. Explain the concept of competing risk models.

(6x2=12 Weights)

Part C

Long Essay Questions

(Answer any ***two*** *questions. Each question carries Weight* ***5****)*

19. Define survival function, hazard function and establish their interrelationship with distribution function? For Weibull and log-normal distributions, find expressions for all of these three functions and comment.
20. Derive Kaplan-Meier product limit estimator and discuss its properties.
21. Obtain the partial maximum likelihood estimator for the proportional hazards model on distinct event time data.
22. Define cause specific hazard function and cumulative incidence function. Clearly stating all assumptions, derive the likelihood function for competing risk. Also, obtain the expression of the overall survival function $S(t)$.

(2x5=10 Weights)

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