

- (iv) Is χ^2 test a non-parametric test ?
 - (v) What are Yate's corrections ?
 - (vi) Explain how χ^2 test is used in the test of homogeneity.
 - (vii) How degrees of freedom are determined in testing of independence ?
 - (viii) What is additive property of χ^2 test ?
 - (ix) What precautions should be kept in mind while using the χ^2 test ?
- Answer the following questions, each question carries four marks:
- 1. (i) Define χ^2 distribution. State the uses of χ^2 test. (M. Com., M.K. Univ., Nov 2003)
 - (ii) Explain the characteristics of χ^2 test. (M. Com., M.K. Univ., April 2003)
 - (iii) What is χ^2 distribution ? Describe the uses of χ^2 test ? (M. Com., M.K. Univ., April 2003)
 - (iv) Explain χ^2 test of goodness of fit. (MBA, Madras Univ., Nov 2003)
 - (v) Explain the significance of χ^2 distribution. (MBA, Sukhadia Univ., 1995)
 - 2. (a) What is χ^2 test ? What are its uses ?
 - (b) What is χ^2 test ? Under what conditions is it applicable ? Point out its role in business decision-making.
 - 3. What is chi-square test of independence ? What cautions are necessary while applying this test ?
 - 4. Explain Yates's method of correction for small frequencies in contingency table.
 - 5. What is χ^2 test of goodness of fit ? What cautions are necessary while applying this test ?
 - 6. (a) What is χ^2 test ? Explain its important uses with the help of an example.
 - (b) What is χ^2 test ? Point out its applications. Under what conditions this test is applicable ?
 - 7. Write short notes on :
 - (i) Yates's corrections for continuity, (ii) Degrees of freedom, (iii) Test of Goodness of fit.
 - 8. Discuss the chi-square test of goodness of fit of theoretical distribution to an observed frequency distribution. State the conditions for the validity of chi-square test.
 - 9. (a) Discuss the importance of χ^2 test. How is it used to test the association ?
 - (b) Describe the χ^2 test of significance and state the various uses to which it can be put.
 - (c) Show that the sum of two independent chi-square variables is also a chi-square variable. (MBA, Anna Univ., 2001)
 - 10. 1000 families were selected at random in a city to test the belief that high income families usually send their children to public school and the low income families often send their children to government schools. The following results were obtained :

Income	School		Total
	Public	Govt.	
Low	370	430	800
High	130	200	330
Total	400	500	1000

Test, whether income and type of school are independent.
 $[\chi^2 = 22.5, \text{No.}]$

- 11. A study is conducted of the volume of calls recieved on the switchboard of an insurance firm. A count is made of the number of incoming calls per minute for a sample of 120 minutes. The results of the study are shown below :

No. of calls per annum	0	1	2	3	4	5
No. of minutes	50	40	16	10	5	1

 The statistician making the study believes that the incoming calls are distributed according to the Poisson distribution. Do you think his assumption is true ?
- 12. A survey was carried out in a state among the Doctors, belonging to the Kural Health Service cadre (500 doctors) and among the medical Education directorate cadre (300 teaching doctors). They were asked a question "would it be acceptable to you, if the govt. proposes to hire all the doctors on fixed period contractual basis?" The doctors were to answer either as "Acceptable" or "Not acceptable". There was no third answer category "undecided". The following was the data compiled in a cross tabulated format :

Doctors	Acceptable	Not acceptable	Total
Teaching Cadre	140	160	300
Total	335	465	800

(MBA, HCA, DU, 2002)

- 13. Apply χ^2 test and test the null hypothesis.
- Two factories using material from the same supplier and closely controlled to an agreed specification, produce output for a given period classified into three quality grades as follows :

Factory	Quality grades (Output in tonnes)			Total
	A	B	C	
X	42	13	33	88
Y	20	8	25	53
Total	62	21	58	141

Do this output figures show a significant difference at the 5% level ?

14. The theory predicts the production of beans in the four groups *A, B, C* and *D* should be 9 : 3 : 3 : 1. In an experiment among 1,600 beans, the numbers in the four groups were 882, 313, 287, and 118. Does the experimental result support the theory? [$\chi^2 = 4.72$]

15. The following data relate to the sales in a time of trade depression, a certain article in great demand. Do the data suggest that the sales are significantly affected by depression?

District where sales are :	Districts	
	Not hit by depression	Hit by depression
Satisfactory	140	60
Not satisfactory	40	60

16. Based on information on 1,000 randomly selected fields about the tenancy status of the cultivators of these fields and use of fertilisers collected in an agro-economic enquiry, the following classification was noted :

	Districts	
	Owned	Rented
Using fertilizer	416	184
Not using fertilizer	64	336

Would you conclude that owner-cultivators are more inclined towards the use of fertilizers?

17. Two researchers adopted different sampling techniques while investigating the same group of students, to find the number of students falling in different intelligence levels. The results are as follows :

Researcher	No. of students in each level			
	Below average	Average	Above average	Genius
X	86	60	44	10
Y	40	33	25	2

Would you say that the sampling techniques adopted by the two researchers are significantly different? (MBA, DU, 2001) [$\chi^2 = 1.1971$]

18. A random sample of size 20 from a normal population gives a sample mean of 12 and sample standard deviation of 6. Test the hypothesis that the population standard deviation is 9. Clearly state the alternative hypothesis you allow for and the level of significance adopted. [$\chi^2 = 8.89$]

19. A manufacturer of TV sets was trying to find out what variables influenced the purchase of a TV set. Level of income was suggested as possible variable influencing the purchase of TV set. A sample of 500 households was selected and the information obtained is classified as shown below :

	Ownership	
	Have TV Set	Do not have TV Set
Low income group	0	250
Middle income group	50	100
High income group	80	20

Is there evidence from the above data of a relation between ownership of TV sets and level of income?

20. A book has 700 pages. The number of pages with various numbers of misprints is recorded below. At the 5% significance level, are the misprints distributed according to Poisson law?

No. of misprints	0	1	2	3	4	5	Total
No. of pages with misprints	616	70	10	2	1	1	700

21. The following contingency table shows the classifications of 2,000 workers in a factory, according to the disciplinary action taken by the management and their promotional experience :

Disciplinary action	Promotional Experience	
	Promoted	Not promoted
Not-offenders	146	462
Offenders	54	1338

Test, whether the disciplinary action taken and promotional experience are independent. [$\chi^2 = 1.227$]

22. Four machines A, B, C and D are used to manufacture certain machine parts which are classified as first grade, second grade and third grade. The quality control engineer wants to test whether the quality of the product from the four machines is same. Data collected is as follows :

Grade	Machines				Total
	A	B	C	D	
First	620	750	400	530	2,300
Second	130	200	140	130	600
Third	50	50	60	40	200
Total	800	1,000	600	700	3,100

- [$\chi^2 = 31.89$]
 23. A certain drug is claimed to be effective in curing colds. In an experiment on 328 people with cold, half of them were given the drug and half of them were given sugar pills. The patients' reactions to the treatment are recorded in the following table :

	Helped	Harmed	No effect
Drug	104	20	40
Sugar pills	88	24	52

- Test the hypothesis that the drug is no better than sugar pills for curing colds.
 24. From the following data, find out whether there is any relationship between sex and preference of colour :

Colour	Male	Female	Total
Green	40	60	100
White	35	25	60
Yellow	25	15	40
Total	100	100	200

25. In a survey of 200 boys, of whom 75 were intelligent, 40 had skilled fathers; while 85 of the unintelligent boys had unskilled fathers. Do these figures support the hypothesis that skilled fathers have intelligent boys?
 [$\chi^2 = 8.89$] (MBA, DU, 1999)

26. The figures given below are (i) the theoretical frequencies of a distribution and (ii) the frequencies of the normal distribution having the same mean, standard deviation and the total frequencies as in (i)

(i)	1	5	20	28	42	15	5	2
(ii)	1	6	18	25	40	25	18	6

- Apply χ^2 test of goodness of fit.
 27. Four different drugs have been developed for a certain disease. These drugs are used under three different environment (it is assumed that the environment might affect efficacy of drugs). The number of cases of recovery from the disease per 100 people who have taken the drugs is tabulated as follows :

Environment	Drugs			
	A ₁	A ₂	A ₃	A ₄
I	19	8	23	8
II	10	9	12	6
III	11	10	13	16

- Test, whether the drugs differ in their efficacy to treat the disease, also whether there is any effect of environment on the efficacy of disease.
 (MBA, Kurukshetra Univ., 1993)

28. 2,000 digits were selected at random from a set of tables. The frequencies of the digits were given as below :

Digit	:	0	1	2	3	4	5	6	7	8	9
Frequency	:	180	200	190	230	210	160	250	220	210	150

- Use the chi-square test to assess the correctness of the hypothesis that the digits were distributed in equal numbers in the tables from which these were chosen.

29. The result of a certain survey shows that out of 50 ordinary shops of small size, 35 are managed by men of which 17 are in cities, 12 shops in villages are run by women. Can it be inferred that shops run by women are relatively more in villages than in cities? Use chi-square test.

[$\chi^2 = 3.572$]

30. For 2×2 contingency table :

	<i>A</i>	not <i>A</i>
<i>B</i>	<i>a</i>	<i>b</i>
not <i>B</i>	<i>c</i>	<i>d</i>

Prove that the chi-square test for independence of the two attributes *A* and *B* gives :

$$\chi^2 = \frac{(a+b+c+d)(ad-bc)^2}{(a+b)(c+d)(a+c)(b+d)}$$

31. In a group of 100 persons, 56 were tall and 44 short. Of those who were tall 30 acted as leaders, 16 as followers and the rest were unclassifiable. Among those who were short, 14 acted as leaders, 22 as followers and the rest were unclassifiable. Tabulate the data and find out whether or not there is significant association between height and leadership.

32. In a study of market penetration, the marketing division of a company selected random samples of 200, 150 and 300 consumers from three cities and obtained the data given below. Do the data indicate that the extent of market penetration in the three cities is independent of the consumers knowledge of the product ?

City	Never heard of product	Group heard but did not buy	Bought it at least once	Total
1	36	55	109	200
2	45	56	49	150
3	54	78	168	300
Total		189	326	650

33. The number of machine malfunctions per shift at a factory is recorded for 180 shifts and the following data are obtained:

No. of malfunctions :	0	1	2	3	4	5	6	Total
No. of shifts :	82	42	31	12	8	3	2	180

What is a reasonable probability model for this type of data ?

Test, if this model describe the data adequately.

34. Study the effectiveness of three teaching methods (*A*), (*B*) and (*C*) from the following table :

Aptitude	Age			Total
	Young	Middle	Old	
Low	82(<i>A</i>)	87(<i>B</i>)	80(<i>C</i>)	249
Middle	92(<i>B</i>)	82(<i>C</i>)	81(<i>A</i>)	255
High	90(<i>C</i>)	83(<i>A</i>)	88(<i>B</i>)	261
Total	264	252	249	765

Do the teaching methods significantly differ in effectiveness on aptitude ?

35. An automobile company gives you the following information about age groups and the liking for particular model of car which it plans to introduce :

Persons who	Age Group			Total
	Below 25	25-50	Above 50	
liked the car	45	30	25	100
Disliked the car	55	20	25	100
Total	100	50	50	200

On the basis of above data, can it be concluded that the model appeal is independent of the age group ?

$[\chi^2 = 3]$

(MBA, DU, 1990)

16. Boys and girls were sampled from a school and tested for their mathematical skills. Their classification into well skilled and poorly skilled categories was as below :

	Mathematical Skills		Total
	Good	Poor	
Boys	50	10	60
Girls	20	20	40
Total	70	30	100

Apply χ^2 test to find whether boys are better in mathematical skills to girls.

17. L. Chandra, salesman for D. Paper Company, has 5 accounts to visit per day. It is suggested that the variable sales by Mr. Chandra may be described by the binomial distribution, with the probability of selling each account being 0.3. Given the following observed distribution of Chandra's number of sales per day, can we conclude that the distribution does in fact follow the suggested distribution? Use the .05 significance level.

No. of sales per day	:	0	1	2	3	4	5
Frequency of no. of sales	:	20	65	42	14	6	3

(MFC, Delhi Univ., 1997)

18. You are given the distribution of the number of defective units produced in a single shift in a factory over 100 shifts. Would you say that the defective units follow a Poisson distribution?

No. of defective units	:	0	1	2	3	4	5	6
No. of shifts	:	4	14	23	23	18	9	9

(MBA, DU, 1995)

19. Price of a basket of goods and services showed the following trend in up-country and mid-town markets :

	Increasing	Not increasing
Mid-town	56	31
Up-country	18	6

Show the trends in up-country prices and in mid-town prices has any significant association.

20. "A sample of 300 students of Under-Graduate and 300 students of Post-Graduate class of a University were asked to give their opinion towards the autonomous colleges. 190 of the Under-Graduate and 210 of the Post-Graduate students favoured the autonomous status."

Present the above fact in the form of a frequency table and test at 5% level, that opinions of Under-Graduate and Post-Graduate students on autonomous status of colleges are independent.

21. Calculate the expected frequencies for the following data presuming the two attributes, viz., condition of home and condition of child as independent :

Condition of Child	Condition of Home	
	Clean	Dirty
Clean	70	50
Fairly clean	80	20
Dirty	35	45

Use chi-square test at 5% level to state whether the two attributes are independent.

22. 1000 students at college level were graded according to their IQ and economic conditions of their home. Use χ^2 test to find out, whether there is any association between economic condition at home and I.Q.

Economic Condition	I.Q.		Total
	High	Low	
Rich	460	140	600
Poor	240	160	400
Total	700	300	1000

(MBA, Osmania, 1996; MBA, Kurnool Univ., 1999)

23. The following table gives the number of car accidents that occurred during the various days of the week. Find, whether the accidents are uniformly distributed over the week.

Day	Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.
No. of accidents	: 14	16	8	12	11	9	14

(M.Com., M.D. Univ., 1999; MBA, DU, 2001)

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44. What are the assumptions in carrying out test of independence of attributes through chi-square? Set up an appropriate hypothesis for the data given below and draw your conclusions through some suitable test of significance method.

Family Status	Level of Intelligence		
	Dull	Average	Brilliant
Lower Middle	20	35	25
Middle	40	70	30
Upper Middle	40	30	30

(M. Com., AMU, 2001)

45. (a) A marketing agency gives following information about the age groups and their liking for a particular model which the company plans to introduce :

	Age group			Total
	Below 20	20-39	40-59	
Liked	125	420	60	605
Disliked	75	220	100	395
Total	200	640	160	1000

On the basis of the above data, can it be concluded that the model appeal is independent of the age group.

(MBA, Kumaun Univ., 2002)

- (b) A die was thrown 9,000 times and of these 3,220 yielded a 3 or 4. Is this consistent with the hypothesis that the die was unbiased?

(MBA, Bharathidasan Univ., 2001)

46. A random sample of 400 persons was selected from each of three age groups and each person was asked to specify which of three types of TV programmes be preferred. The results are shown in the following table :

Age Group	Table Programme		
	A	B	C
Under 30	120	30	50
30-44	10	75	15
45 and above	10	30	60
Total	140	135	125

Test the hypothesis that the populations are homogeneous with respect to the types of television programme they prefer.

(MBA, Guru Jambheshwar Univ., 2000)

47. The following information is obtained concerning an investigation of 50 ordinary shops of small size :

	No. of Shops		Total
	in towns	in villages	
Run by Men	17	18	35
Run by Women	3	12	15
Total	20	30	50

Can it be inferred that shops run by women are relatively more in villages than in towns? Use chi-square test.

(MBA, Madurai Kamaraj, April 2001)

48. The number of analysis sum by three operators during different shifts is given below. Test the hypothesis that the performance of the operators is independent of shifts

	Operator		
	1	2	3
I	97	58	32
II	78	46	39

49. Fit a Poisson distribution to the following data and test for goodness of fit.

X :	0	1	2	3	4	5	6
f :	275	72	30	7	5	2	1

(MBA, Anna Univ., 2003)

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ANOVA TABLE

Source of Variation	SS	d.f.	MS	F
Between samples	40	2	20	$\frac{20}{5} = 4$
Within samples	60	12	5	
Total	100	14		

For $v_1 = 2$ and $v_2 = 12$, the table value of F at 5% level of significance is 3.38. The calculated value of F is more than the table value. The hypothesis is rejected. Hence, the population means are not equal.

Caution while Applying Analysis of Variance Technique

The analysis of variance has been developed under a set of rigid assumptions as pointed out in the beginning of the chapter. Whenever, any of these assumptions is not met, the F -test cannot be employed to yield valid inferences. It is indeed fortunate that many economic and business experiments do conform to these assumptions. However, where departure from the premises exist, the analysis of variance may still be applied by way of *transformation*. Transformation refers to a process of transforming the original data into some other form, such as square roots, inverse sines of logarithms, before the analysis is made.

PROBLEMS

1-A: Answer the following questions, each question carries one mark:

- What is Analysis of Variance?
- The technique of analysis of variance was developed by.....
- Define F -test
- Give two applications of analysis of variance.
- On what assumptions, analysis of variance is based?
- What do you understand by one-way analysis of variance?
- Give the format of ANOVA table in one-way classification.
- What is two-way classification in analysis of variance?
- Give the components of source of variation in one-way classification.
- What is coding method in analysis of variance?

(M. Com., M.K. Univ., Nov. 2002)

(MBA, Madurai-Kamaraj, April 2002)

(M. Com., M.K. Univ., 2001)

1-B: Answer the following questions, each question carries four marks:

- Explain one-way classification technique in analysis of variance.
- Tabulate the ANOVA table in one-way classification.
- Explain the F -test. What are the assumptions of F -test?
- Differentiate between one-way and two-way classification by giving suitable example.
- Explain the procedure involved in ANOVA for testing of a hypothesis.
- What is ANOVA?

(M. Com., M.K. Univ., Nov. 2002)

(M. Com., M.K. Univ., 2001)

(M. Com., M.K. Univ., Nov. 2001)

(MBA, Madras Univ., 2002)

2. What is 'analysis of variance' and where it is used? Give two suitable examples.

3. How is analysis of variance technique helpful in solving business problems? Illustrate your answer with suitable examples.

(MBA, Kumaun Univ., 2000)

4. Briefly describe the procedure followed in analysis of variance.

5. What are the basic and common assumptions made for analysis of variance?

6. Distinguish between one-way and two-way classification models and explain the procedure followed for carrying out analysis of variance.

7. (a) Explain the meaning and significance of Analysis of Variance.

(b) State some applications of the analysis of variance.

(c) Explain the use of Analysis of variance (ANOVA) to check how good is the regression.

(IGNOU, MBA, 2000)

8. How is the F -distribution related to the Student's t -distribution and the chi-square distribution? What important hypothesis can be tested by the F -distribution?

In order to determine, whether there are significant differences in the durability of three makes of computer, samples of size $n=5$ are selected from each make and the frequency of repair during the first year of purchase is observed. The results are as follows :

	Make		
	A	B	C
	5	8	7
	6	10	3
	8	11	5
	9	12	4
	7	4	1

In view of the above data, what conclusion can you draw ?

[$F = 5.34, F_{2,12}$ at 5% level = 3.89]

11. A plastic manufacturer tests the tensile strength of different types of polythene material. A sample of three measurements is taken for each material type and data in pounds per square inch are as follows :

	Type I	Type II	Type III
	200	260	245
	215	255	248
	218	277	272

Determine, if the mean tensile strength of the three different types of materials differ significantly.

[$F = 16.30, F_{2,6}$ at 5% level = 5.14, yes]

12. The number of automobiles arriving at four toll stations were recorded for 2 hours time period (10 A.M. to 12 P.M.) for each of six different days. The data are as follows :

Day	Gate 1	Gate 2	Gate 3	Gate 4
Monday	200	228	215	301
Tuesday	208	230	228	305
Wednesday	225	240	224	288
Thursday	223	242	235	212
Friday	228	210	245	215
Saturday	220	208		200

(a) Determine, whether the rate of arrival is essentially the same at each toll station.

(b) Determine, whether the rate of arrival differs significantly during the six different days of the week or not.

[(a) $F = 1.78$, No ; (b) $F = 0.56$, No]

13. Following table gives the number of refrigerators sold by 4 salesmen in three months:

Month	Salesmen			
	A	B	C	D
May	50	40	48	39
June	46	48	50	45
July	39	44	40	39

(a) Determine, whether there is any significant difference in the average sales made by four salesmen.

(b) Determine, whether the sales differ with respect to different months.

[(a) $F = 1.01$, No ; (b) $F = 3.29$, No]

14. Miss Neena, a supervisor has 3 typists working under her supervision. She is concerned with the time they spend on the tea in addition to the normal lunch tea break. Her observations recorded in minutes for each typist are as follows :

	Average time (minutes)								
	A	B	C	A	B	C	A	B	C
1	25	18	30	32	35	37	19	26	32
2	24	22	26	28	30	32	28	23	27
3	28	20	27	19	29	35	30		

Can the differences in average time that the three typists spend on tea break be explained by chance variation ?

14. Five different brands of tyres used by a car rental agency in the process of deciding the brand of tyre to purchase as standard equipment for their fleet, find that each of five tyres of each brand last the following number of kilometres (in '000s):

		Tyre Brand				
		A	B	C	D	E
	1	36	46	35	45	41
	2	37	39	42	36	39
	3	42	35	37	39	37
	4	48	37	43	35	35
	5	47	48	38	32	38

Test the hypothesis that the five different brands of tyres have identical average life.

15. It is suspected that four machines, each in a canning operation fills cans to different levels on the average. Random samples of cans produced from each machine were taken and the fill in ounces was measured. The results are tabulated below:

		Machine			
		A	B	C	D
	1	10.20	10.22	10.17	10.15
	2	10.18	10.27	10.22	10.37
	3	10.36	10.26	10.34	10.28
	4	10.21	10.25	10.27	10.40
	5	10.25			10.30

Do the machines appear to be filling the cans at different average levels?

16. During the last week, there were 14 sales calls. A made 5 calls, B made 4 calls and C made 5 calls. Following are the weekly sales (in 000's Rs.) record of the three salesmen:

		Salesmen		
		A	B	C
Calls	1	3	6	7
	2	4	3	3
	3	3	3	4
	4	5	4	6
	5	0	-	-

With the help of analysis of variance, test the selling ability of the three salesmen.

(MBE, Delhi Univ., 1989)

17. Suppose that we are interested in establishing the yield producing ability of four types of soyabeans, A, B, C and D. We have three blocks of land X, Y and Z which may be different in fertility. Each block of land is divided into four plots, and the different types of soyabeans are assigned to the plots in each block by a random procedure. The following results are obtained:

		Type			
		A	B	C	D
Block	X	5	9	11	10
	Y	4	7	8	10
	Z	3	5	8	9

Test whether A, B, C and D are significantly different.

18. The chairman of a large chain of supermarkets was prepared to order a large number of frozen food display cases for use in the markets. Before placing the order, he decided to test the products by storing half-litre containers of milk in the case made by different manufacturers and observing the spoilage time of each types of case. The display case came from three different manufacturers designated, A, B and C. Nine half-litre containers of milk were randomly selected and assigned, three to each case. The response variable observed was the spoilage time in day. The data for this test is provided below:

		Treatment		
		A	B	C
	1	7	8	7
	2	5	4	8
	3	9	7	10

Test for a significant difference in the effect of the display cases at 5% level of significance.

19. The following table gives the monthly sales (in thousand rupees) of a certain firm in three different States by your different salesmen:

		Salesmen			
		W	X	Y	Z
States	A	10	8	8	14
	B	14	16	10	8
	C	18	12	12	14

State, whether the difference between sales affected by the four salesmen and difference between sales affected in three States are significant.

20. Four brands of tyres were tested for durability and wear on specially designed machines which simulate road conditions. Four tyres of each brand were subjected to the same test and the number of kilometres until wear out was noted for each tyre. The data in thousands of kilometres is provided below :

	Tyre Brand			
	A	B	C	D
	24	26	28	12
	18	16	17	18
	23	19	26	30
	13	30	19	20

Test for a significant difference tyre mileage at the 5% level of significance.

21. Four different drugs have been developed for the cure of a certain disease. These drugs are tried on patients in three different hospitals. The results given below show the number of cases of recovery from the disease per 100 people who have taken the drugs. The randomized blocks design has been employed to eliminate the effects of the hospital.

	A	B	C	D
H ₁	32	18	20	21
H ₂	15	23	26	13
H ₃	26	10	17	17

Carry out an analysis of variance and interpret your results.

22. A manufacturer of footballs wants to introduce two additional styles of footballs to accompany the plastic version he already produces. The new footballs will be made of leather and rubber. All three styles were test marketed in five different stores. The manufacturer wants to concentrate on producing the type that promises the most sales. Is there a difference in sales of three types of footballs in the five different stores ?

Store	Rubber	Plastic	Leather
1	550	600	450
2	720	700	520
3	680	750	380
4	600	800	250
5	650	550	250

What should the manufacturer do about marketing his footballs?

23. A manufacturer has just introduced a new product that will be sold in sizes : small, medium and large. Five salesmen are randomly selected from the sales force and given each of the three products to sell. The sales figure for one month are used to find out whether there is a difference in sales volume for the different sizes. The amounts sold by the five salesmen are as follows :

Salesman	Small	Medium	Large
1	850	900	880
2	720	880	760
3	880	970	670
4	900	890	880
5	750	960	880

Using a 0.05 level of significance, determine whether there is a significantly difference in the amount sold by size. What is your marketing decision ?

24. An economist wishes to assess the effects of Factor A (education) with five levels and Factor B (occupation) with four levels upon a person's annual earnings. The following data have been obtained for 20 randomly chosen person :

SSW = 8,00,000; SSB = 9,00,000 and Total SS = 20,00,000.

(a) Construct a one factor ANOVA table, using education as the only treatment. At 5 per cent significance level, can you conclude that the treatment means differ? (b) Construct a two factor ANOVA table, using education for education levels and occupation? can you conclude about the respective null hypothesis for identical mean incomes for education levels and occupation?

25. Mr. Ram wants to build a service station on one of three locations. He measures the traffic passing each location for six days. The following are the average amounts of traffic per hour passing each location for each of the six days :

Day	Location A	Location B	Location C
1	75	85	90
2	78	94	118
3	65	90	125
4	76	68	70
5	88	74	81
6	98	87	80

Is there any significant difference in the amount of traffic passing the three locations? Where would you advise Mr. Ram to build his service station?

26. A company selling coffee appoints four salesmen A, B, C and D. Observe their sales in 3 seasons; summer, winter and monsoon.

The figures (in lakhs of rupees) are given below :

Season	Salesman			
	A	B	C	D
Summer	30	25	33	20
Winter	28	26	31	35
Monsoon	32	30	32	32

Carry out an analysis of variance and comment on your results.

27. The numbers of automobiles arriving at four gasoline stations were recorded for four-hour period from 8 A.M. to 12 Noon, from Monday through Saturday. Determine, whether the rate of arrival is essentially same at all stations.

Day	Stations			
	1	2	3	4
Monday	49	53	48	53
Tuesday	45	51	46	51
Wednesday	51	47	53	49
Thursday	48	53	42	51
Friday	50	50	50	53
Saturday	48	51	47	54

28. Three machines in a workshop are equally efficient. To measure the efficiency of four operators, the data on the number of units produced per shift by each operator on different machines on randomly selected shifts has been collected as follows:

Operator	Machine		
	A	B	C
I	22	20	19
II	24	19	17
III	27	23	21
IV	23	24	18

Test at 5% level of significance, whether machine operators are equally efficient.

29. A large retailer must make a choice between three sales locations within a shopping complex. The following data are traffic counts for a 7-day period :

Location X :	643	542	569	552	607	514	576
Location Y :	249	404	378	337	426	298	345
Location Z :	458	513	485	482	539	491	368

Is there is significant difference in the average traffic count at the three locations ?

30. The following table gives monthly sales (in thousand rupees) of a certain firm in three States by its four salesmen :

States	Salesmen			
	I	II	III	IV
A	6	5	5	8
B	8	9	6	5
C	10	7	8	7

Test, whether there is any significant difference (i) between sales by the firm salesmen, and (ii) between sales by the four salesmen, and (iii) between sales in the three States.

31. The following are the defective pieces produced by four operators working, in turn, on four different machines :

Machine	Operator			
	B ₁	B ₂	B ₃	B ₄
A ₁	34	28	33	29
A ₂	31	24	35	23
A ₃	27	20	43	72
A ₄	28	28	29	76

Perform analysis of variance at 0.05 level of significance to ascertain whether variability in production is due to variability in operators' performance or variability in machines' performance.

32. To study the performance of three detergents and three different water temperatures, the following 'Whiteness' readings were obtained with specially designed equipment :

Water Temperature	Detergent		
	A	B	C
Cold water	57	55	67
Warm water	49	52	68
Hot water	54	46	58

Perform a two-way analysis of variance, using 5% level of significance.

33. Agricultural engineers conducted an experiment to assess the effects of three different fertilisers on the yields of mango trees. They planted 15 plots of equal size and treated them alike except for the type of fertiliser applied. Fertiliser A was applied to 4 plots, fertiliser B to 5 plots and fertiliser C to 6 plots. The following table shows the yields, in quintals, per plot. Do these data provide sufficient evidence to indicate a difference in the treatment effect? Use 5% level of significance.

Fertiliser	Yields (quintals)					
	1	2	3	4	5	6
A	7	5	6	4		
B	8	5	5	5	2	
C	5	6	4	1	2	3

34. The performances of a class of 300 students in the subjects of Statistics and Finance were graded into four classes A, B, C and D. The table below gives the cross tabulation of the number of students by grades in each of the two subjects:

Finance	Statistics			
	A	B	C	D
A	12	12	10	6
B	16	25	12	7
C	18	21	14	17
D	4	12	9	5

Test at significance of 5% and 1%, whether the performance can be inferred as independent.

35. The following table gives the number of units of production per day turned out by four different employees, using four different types of machines:

Employee	Type of machines			
	M_1	M_2	M_3	M_4
E_1	40	36	45	41
E_2	38	42	50	35
E_3	36	30	48	44
E_4	46	47	52	44

Using analysis of variance (i) test the hypothesis that the mean production is the same for the four machines and (ii) test the hypothesis that the four employees do not differ with respect to mean productivity.

36. In order to evaluate four comparable typewriters of different brands, five typists are randomly assigned to each machine and asked to type the same copy matter for 10 minutes. At the end of the period, the words per minute (wpm) are recorded. The data are presented in the table below.

Typewriter	Output from typewriter (wpm)				
	A	B	C	D	E
A Brand	69	62	70	57	62
B Brand	67	72	76	69	71
C Brand	76	70	71	66	77
D Brand	60	64	67	58	66

Carry out an analysis of variance to assess whether the mean wpm on the different brands of typewriters may be assumed to be the same, or are different.

37. Experiments were performed to determine whether the yield from a chemical process is influenced by the concentration of the catalyst and the temperature of the reaction. Five different concentration levels C_1 to C_5 were combined with three levels of temperature T_1 to T_3 .

Temperature Levels	Concentration levels of Catalyst				
	C_1	C_2	C_3	C_4	C_5
T_1	66	72	59	74	68
T_2	64	70	62	73	72
T_3	68	74	64	70	70

Test at 5 per cent significance level, whether the mean yields are influenced by concentration of catalyst or by temperature of reaction.

38. In a certain factory, production can be accomplished by four different types of machines. A sample study, in context of a two-way design without repeated values, is being made with two-fold objectives of examining whether the four workers differ with respect to mean productivity and whether the mean productivity is the same for the five different machines. The researcher involved in this study reports while analysing the gathered data as under:

- (i) Sum of squares for variance between machines = 35.2
- (ii) Sum of squares for variance between workmen = 53.4
- (iii) Sum of squares for total variance = 174.2

Set up ANOVA table for the given information and draw the inference about variance at 5 per cent level of significance.

39. Three training methods were compared to see if they led to greater productivity after training. Below are productivity measures for individuals trained by each method :

Method 1 :	10	6	8	12	6					
Method 2 :	6	6	7	9	4	6	10	5	6	8
Method 3 :	11	8	13	10	10	12				

At 0.05% level of significance, do the three training methods lead to different levels of productivity ?

40. Perform a two-way ANOVA on the data given below :

Plots of Land	Treatment			
	A	B	C	D
I	38	40	41	39
II	45	42	49	36
III	40	38	42	42

41. The following data pertain to the number of units of a product manufactured per day by five workmen from four different brands of machines.

Workmen	Machine Brands			
	A	B	C	D
1	46	40	49	38
2	48	42	54	45
3	36	38	46	34
4	35	40	48	35
5	40	44	51	41

- (i) Test, whether the mean productivity is the same for the four brands of machine type.
- (ii) Test, whether five different workmen differ with respect to productivity. (M.Com., DU, 1999)

42. The following data represent the number of units produced by 4 operators during 3 different shifts :

Shifts	Operator			
	A	B	C	D
I	10	8	12	13
II	10	12	11	15
III	12	10	11	14

Perform a two-way analysis of variance and interpret the result.

(MBA, Madras Univ., 1999)

43. What is 'Analysis of variance' and where it is used ? Given below are the lives (in hours) of three randomly selected batches of electric lamps.

Batch 1	1610	1615	1625	1630	
" 2	1590	1605	1620		
" 3	1580	1585	1600	1610	1625

Analyse the data and draw your conclusions.

For $\alpha = 0.5$, $F_{2,9} = 4.26$, $F_{2,10} = 4.10$, $F_{2,11} = 3.98$
 $F_{3,8} = 4.07$, $F_{3,9} = 3.87$, $F_{4,7} = 4.12$

(M. Com., A.M.U., 2001)

44. As part of the investigation of the collapse of the roof of a building, a testing laboratory is given all the available bolts that connected the steel structure at three different positions on the roof. The forces required to shear each of these bolts (coded values) are as follows :

Position 1	90	82	79	98	83	91	
Position 2	105	89	93	104	89	95	86
Position 3	83	89	80	94			

Perform an analysis of variance to test at the 0.05 level of significance, whether the differences among the sample means at the three positions are significant.

(B.E./B.Tech, Madras Univ., 2003)

45. The R & D manager of an automobile company wishes to study the effect of "Tyre Brand" on the tread loss (in millimetre) of tires. Four tyres from each of four different brands (A, B, C and D) are fitted to four different cars using the completely randomized design. The data as per this design are presented below :

	Tyre Brand			
	A	B	C	D
	6	3	8	4
	7	6	6	2
	10	2	7	1
	9	3	2	4

- (i) Write the corresponding model.
- (ii) Check whether the tyre brand has effect on the tread loss of tyres at a significant level of 5%.

46. There are three main brands of a certain powder. A set of 120 sales is examined and found to be allocated among four groups (A, B, C and D) and brands (I, II and III) as shown below :

(MBA, Bharathidasan Univ., 2002)

		Replications			
		Groups			
Brands		A	B	C	D
Factor	I	0	4	8	15
	II	5	8	13	13
	III	18	19	11	13

Check whether the factor "Brand" has significant effect on the sales at $\alpha = 0.05$ using one way ANOVA.

(MBA, Bharathidasan Univ., April 2001)

47. The following are the number of mistakes made in 5 successive days by 4 technicians working for a photographic laboratory. Test at a level of significance $\alpha = 0.01$, whether the differences among the four sample means can be attributed to chance.

Mistakes	Technician I	Technician II	Technician III	Technician IV
Day 1	6	14	10	9
Day 2	14	9	12	12
Day 3	10	12	7	8
Day 4	8	10	15	10
Day 5	11	14	11	11

(MBA, Anna Univ., 2003)

PROBLEMS

1-A: Answer the following questions, each question carries one mark:

- (i) What is SQC ?
- (ii) Give two important uses of SQC.
- (iii) What is Control Chart ?
- (iv) What is process control ?
- (v) Why R-Chart is prepared ?
- (vi) What are the control limits for p-chart ?
- (vii) Is 100% inspection totally reliable ?
- (viii) How do control charts reveal that the process is out of control ?
- (ix) Distinguish between defects and defectives.
- (x) What is OC curve ?
- (xi) Define the terms 'AQL' and 'RQL'.

1-B: Answer the following questions, each question carries four marks:

- (i) Differentiate between control chart of variables and attributes.
 - (ii) Explain the terms 'chance variation' and 'assignable variation' with suitable example.
 - (iii) What is \bar{X} -chart ? How are the control limits determined while drawing this chart ?
 - (iv) What is C-chart ? Point out its uses.
 - (v) What is acceptance sampling ? Point out its role in business decision-making.
 - (vi) Distinguish between single sampling and double sampling plans.
2. What is a statistical quality control ? Point out its importance in the industrial world. Also explain the use of control charts. (M.Com., M.D. Univ., 1999)
3. (a) Distinguish between the process control and product control.
(b) Distinguish between the control limits and tolerance limits.
4. What is a control chart ? Describe how a control chart is constructed and interpreted.
5. Discuss the basic principles underlying control charts. Explain in brief the construction and use of p-chart and C-chart.
6. What is control chart ? Explain in brief, the construction and use of mean chart, p-chart and range chart.
7. (a) What is acceptance sampling ? Point out the role of operating characteristic curve.
(b) Critically examine the different types of acceptance sampling plans.
8. (a) What do you mean by SQC ? Discuss briefly its need and utility in industry. Discuss the causes of variation in quality. (MBA, Vikram Univ., 1998)
(b) What are the various types of control charts known to you ? Explain them with examples.
9. "Quality control is attained most efficiently of course, not by the inspection operation itself but by getting at the causes." Comment on the statement. Describe the various devices employed for the maintenance of quality in a uniform flow of manufactured products.
10. Describe control charts for \bar{X} and σ and derive expression for their control limits. What are the advantages of σ -chart over the R-chart ?
11. Explain the term "Statistical quality control". How is the process control achieved with the help of control chart ? What are the fundamentals underlying the construction of quality control chart ?
12. (a) Describe how a control chart for fraction defective is set ? What modification is needed if varying numbers are inspected on different occasions ?
(b) Discuss the role of C-chart in statistical quality control.
13. Explain the following terms occurring in sampling inspection plans :
(a) A.O.Q.L., (b) lot tolerance per cent defectives, (c) producer's risk, and (d) consumer's risk.

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14. (a) Explain what are chance causes and assignable causes of variation in the quality of manufactured product.
 (b) Assuming the characteristic variable follows a normal distribution (mean and standard deviation unknown), specify the control limits and the central line for the mean and range charts.
15. (a) Distinguish between process control and product control.
 (b) State the different types of acceptance sampling plans.
16. (a) "The control charts make it possible to distinguish between those variations which are due to chance causes and those due to assignable causes".

Explain the terms 'chance causes' and 'assignable causes' and elucidate the statement.

- (b) Distinguish between:
- Chance causes and assignable causes of variation.
 - Defect and defectives.
 - Control charts for variables and control charts for attributes.
17. What is the mathematical justification on which the control limits in \bar{X} -charts are set up? What is the purpose of an \bar{X} control chart?
18. Explain how a control chart helps to control the quality of a manufactured product. Describe the basis of control chart. Distinguish clearly between the charts for variables and charts for attributes.
19. (a) Why \bar{X} and R -charts should be used simultaneously? Justify with the help of an example.
 (b) Explain OC curve. Also explain how various points on the curve are calculated, i.e., show calculations for any point (not for $p = 0$).
 (c) Discuss the uses of statistical quality control and control charts.
20. (a) What is an 'OC' curve? Which OC curve would be called ideal?
 (b) Draw OC curve for the following single sampling plan.
 $N = 50, n = 10, C = 1$.
 (c) Write a short note on C-chart.
21. (a) Explain the construction and function of
- \bar{X} -chart
 - R chart.
- (b) State the advantages of quality control.
- (c) Explain the construction of double sampling plan.
- (d) Differentiate between p -chart and C -chart in context of statistical quality control.
22. (a) Distinguish between random variations and assignable variations. How is the distinction relevant in statistical quality control? (M.Com., DU, 1999)
 (b) 25 sub-groups of 5 items each were taken in the measurement of an important dimension of a manufactured part. The mean of the 25 sub-groups was 0.6000 inches and the sum of the ranges of the sub-groups was 0.5 inches. Find the upper and lower control limits for the control chart for \bar{X} and R .
23. The following data are the results of life tests on 15 samples of 6 fluorescent lamps each. The values are in hours.

Sample No.	\bar{X}	R	Sample No.	\bar{X}	R
1	4209	450	9	4420	320
2	4380	390	10	4385	510
3	4560	480	11	4182	490
4	3490	330	12	4260	385
5	3360	460	13	4550	220
6	3450	380	14	3890	490
7	3280	400	15	4280	160
8	3380	440			

- (a) Is the process in a state of statistical quality control?
 (b) Assuming assignable causes could be discovered and eliminated, what is your best estimate of the capability of this process?

Jewel's Care Collected

24. A plant produces paper for newspaper, and rolls of paper are inspected for defects. The results of the inspection of 25 rolls of paper are given below:

Roll No.	No. of defects	Roll No.	No. of defects
1	10	14	5
2	20	15	4
3	8	16	2
4	12	17	3
5	13	18	6
6	15	19	8
7	25	20	9
8	7	21	15
9	13	22	18
10	18	23	20
11	16	24	10
12	14	25	5
13	6		

Draw control chart for defects and determine whether inspection results indicate stability.

25. Samples of 50 calculators are drawn randomly from the output of a process that produces several thousand units daily. Sampled items are inspected for quality, and faulty calculators are rejected. The result to a series of samples are given below:

Sample results of 15 lots of 50 calculators

Lot No.	No. inspected	No. defectives	Lot No.	No. inspected	No. defectives
1	50	4	9	50	5
2	50	5	10	50	6
3	50	8	11	50	8
4	50	10	12	50	5
5	50	6	13	50	12
6	50	7	14	50	4
7	50	3	15	50	2
8	50	2			

Draw a control chart and interpret it.

26. The number of defects found in inspecting television set assemblies are as follows for 20 inspection units of five sets each:

Unit	1	2	3	4	5	6	7	8	9	10
No. of defects	2	40	38	63	92	45	18	120	45	38
Unit	11	12	13	14	15	16	17	18	19	20
No. of defects	40	73	68	90	63	85	56	72	40	50

Set up a control chart to be used for future production.

27. A manufacturer purchases small bolts in cartons that usually contain several thousand bolts. Each shipment consists of a number of cartons. As part of the acceptance procedure for these bolts, 400 bolts are selected at random from each carton and are subjected to visual inspection for certain defects. In a shipment of 10 cartons, the respective percentages of defectives in the sample from each carton are 0.0, 0.5, 0.75, 0.20, 2.250, 0.25 and 1.25. Plot the appropriate control chart and draw your conclusions.

28. A machine is designed to produce ball bearings having a mean diameter of 0.574 cms and a standard deviation of 0.001 cms. To determine whether the machine is in proper working order, a sample of 6 ball bearings is taken every two hours on all the working days (namely Monday to Friday) of the week and the mean diameter is computed from this sample. Design a rule whereby one can be fairly certain that the quality of the products are conforming to required standards. Give a sketch of the control chart.

29. A sample of 200 bolts is drawn at regular intervals from the production line, and each bolt is checked. The number of defective bolts in 20 successive samples are given below :

Sample No.	Defective bolts	Sample No.	Defective bolts
1	3	11	2
2	3	12	3
3	1	13	2
4	3	14	1
5	2	15	1
6	3	16	3
7	2	17	3
8	2	18	3
9	3	19	2
10	3	20	3

Draw a suitable control chart and test whether the process is under control.

30. The following figures give the number of defectives in 20 samples ; each sample containing 2,000 items :

425, 430, 216, 341, 225, 322, 280, 306, 337, 305, 356, 402, 216, 264, 126, 409, 193, 326, 210, 389.

Calculate the values for central line and the control limits for p -chart (Fraction Defective chart). Draw the p -chart and comment if the process can be regarded in control or not.

31. With a view to examine the quality of an engineering product, 10 samples of 200 items each were taken from a day's production and the number of defective items in each sample was recorded as follows:

Sample No.	1	2	3	4	5	6	7	8	10
No. of defectives	14	20	36	42	22	18	26	12	8

(i) Draw a fraction defective quality control chart, showing clearly the upper and lower control limits.

(ii) What inference do you draw from this quality control chart?

32. A large sample of a product gave an "average fraction defective" of 0.068. Calculate for a p -chart the values of control limits (upper, lower and central line), if the size of each sample sub-group is 200.

33. In a glass factory, the task of quality control was done with the help of mean (\bar{X}) and standard deviation (σ) charts. 18 samples of 10 items each were chosen and their values ΣX and $\Sigma \sigma$ were found to be 595.1 and 8.28 respectively. Determine 3σ limits for mean and standard deviation charts. You may use the following control factors for your calculations:

n	A_1	B_2	B_3
10	1.03	0.28	1.72

34. In a factory that produces steel tubes, the thickness of walls is to be controlled. Every hour a sample of 6 tubes is taken and after measurements average thickness in centimetres and the range for each sample is noted.

Sample No.	1	2	3	4	5	6	7	8	9	10
Average thickness :	0.25	0.32	0.42	0.22	0.28	0.10	0.25	0.40	0.06	0.29
Range :	0.25	0.48	0.12	0.12	0.19	0.10	0.06	0.46	0.10	0.32

Draw average and range charts and give your comments whether the process is under control or not.

35. (a) Draw an OC curve for the following sampling plan, which is used to inspect lots of size 500 items each. Sample size = 10; Acceptance No. = 1; Rejection No. = 2

(b) Describe briefly a multiple acceptance sampling plan.

36. Control on measurements of pitch diameter of thread in aircraft fittings is checked with 5 successive items measured at regular intervals, 5 such samples are given below :

Sample	Measurement on each item of 5 items per hour				
1	45	45	44	43	42
2	41	41	44	42	40
3	40	40	42	40	42
4	42	43	42	42	45
5	43	44	47	47	45

(Values are expressed in units of 0.001 inch.)

(i) Construct the \bar{X} and R-charts.

(ii) What inference do you draw from these quality control charts ?

($n = 5, A_1 = 0.546, A_2 = 0.577, D_2 = 4.981, D_3 = 0, D_4 = 2.115$)

37. It has been ascertained that when a manufacturing process is under control, the average of the defectives per sample batch of 10 is 12. What limits would you set in a quality control chart based on the examination of defectives in sample batches of 10 ?
38. Process for producing solid state devices such as transistors frequently have a rather high fraction defective. One particular line for making transistors has a long run fraction defective of 0.28 when functioning properly. Every two hours a sample of 50 transistors is examined and the number of defectives in the sample determined. What are the control limits for the p -chart used to control this process ?
39. The Quality Electric Bulbs Ltd. manufactures electric bulbs under an improved process. The Production Engineer takes a random sample of 100 bulbs off the run from each day's output for inspection. The number of defective pieces is determined by applying a high voltage test. Suppose that the process of manufacture when under control admits of a long run fraction defectives of 0.05 ? Determine the control limits on the p -chart.

40. When will you use a control chart for defects ? Plot control chart for the following data pertaining to number of defects in the calculators manufactured by a company :

Calculator No. :	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
No. of Defects :	5	1	0	7	3	6	0	10	2	11	5	8	6	4	1

41. Given below is a record of the number of defects seen in circuit panels used in a computer. Prepare an appropriate control chart to control the quality of the product. Does the process is in control as per data observed.

If assignable causes have been found to explain outliers, how does this affect the control chart. Show the necessary changes in control limits.

Panel :	1	2	3	4	5	6	7	8	9	10	11	12	13	14
No. of defects :	4	0	1	4	5	3	6	2	2	0	5	10	3	4

42. The following data refers to visual defect found during the inspection of the first 10 samples of size 50 each from a lot of Two-wheelers manufactured by an Automobile Company :

Sample No. :	1	2	3	4	5	6	7	8	9	10
No. of Defectives :	4	3	2	3	4	4	4	1	3	2

Draw the ' p ' chart to show that the fraction defectives are under control.

[$UCL = 0.1608; LCL = 0$]

43. The following data show the values of sample mean and the range for ten samples of size 5 each. Construct the \bar{X} and Range charts :

Sample No. :	1	2	3	4	5	6	7	8	9	10
Mean (\bar{X}) :	11.2	11.8	10.8	11.6	11.0	9.6	10.4	9.6	10.6	10.0
Range (R) :	7	4	8	5	7	4	8	4	7	9

44. The average number of defectives, in 22 sampled lots of 2000 rubber belts each, was found to be 16%. Determine the 3-sigma control limits for the p -chart. (Diploma in Mgt., AIMA, May 2002)

45. The following data shows the mean and the range for ten samples of size each. Calculate the values for the central line and control limits for mean-chart and range-chart, and determine whether the process is in control.

Sample No. :	1	2	3	4	5	6	7	8	9	10
Mean :	11.4	12.0	11.0	11.8	11.2	9.8	10.6	9.8	10.8	10.2
Range :	7	4	8	5	7	4	8	4	7	9

(M.Com., DU, 2000)

Jewel's Care Collected

$$= \sqrt{\frac{0.36 + 0.4225 - 0.546}{0.51}} = \sqrt{0.464} = 0.681.$$

PROBLEMS

1-A: Answer the following questions, each question carries one mark:

- What is the difference between $r_{12.3}$ and $r_{21.3}$?
- Write the formula for partial correlation $r_{23.1}$.
- Define partial and multiple correlation.
- What purpose does partial correlation coefficient serves?
- Write the formula for coefficient of multiple correlation $R_{1.23}$.
- What is coefficient of determination?
- Write the formula for standard error of estimate $S_{1.23}$.
- What is the difference between simple linear and multiple linear regression?
- How multiple correlation differs from partial correlation?
- What do you understand by reliability of estimates?

(MBA, Madurai-Kamaraj, Nov)

1-B: Answer the following questions, each question carries four marks:

- In a three variate multiple correlation analysis, the following results were obtained:
 $r_{12} = 0.7$, $r_{13} = 0.6$, and $r_{23} = 0.4$
Find the multiple correlation coefficient $R_{1.23}$.
(M. Com., M.K. Univ., Nov 20)
 - Describe the three steps in the process of multiple regression and correlation analysis.
(MBA, Madurai Univ., Nov 20)
 - What are zero-order, first-order and second-order coefficients?
 - What are the uses and limitations of partial correlation analysis?
 - What are the advantages and limitations of multiple correlation analysis?
 - What are 'normal equations' and how are they used in multiple regression analysis?
- Define partial and multiple correlation. With the help of an example distinguish clearly between partial and multiple correlation.
 - What is partial correlation? Under what circumstances is it to be preferred to the total correlation?
 - (a) What is multiple linear regression? Explain clearly the difference between simple linear and multiple linear regression.
(b) With the help of an example illustrate how does multiple linear regression help in the analysis of business problem.
 - Explain the concept of multiple regression and try to find out an example in practical field where multiple regression analysis is likely to be helpful.
 - Distinguish between partial and multiple correlation and point out their usefulness in statistical analysis.
 - Explain the terms: (i) Coefficient of determination, (ii) Regression coefficient, and (iii) Partial and multiple correlation.
 - How do we determine the reliability of estimates obtained from the multiple regression of X_1 on X_2 and X_3 ?
 - (a) In the multiple regression equation of Y_1 on X_2 and X_3 , what are the two regression coefficients and how do you interpret them?
(b) Explain the concepts of simple, partial and multiple correlation.
(c) When is multiple regression needed? Explain with the help of an example.
(M. Com. DU, 1988)
 - Within what limits the coefficient of multiple correlation $R_{1.23}$ lies? What inference would you draw if $R_{1.23} = 1$, $R_{1.23} = 0.92$?
 - How do we distinguish between zero-order, first-order and second-order correlation coefficients? Illustrate your answer with the help of some examples.
 - What precautions do you think must be observed while making use of partial and multiple correlation techniques?
 - If $r_{12} = 0.6$, $r_{13} = 0.8$ and $r_{23} = -0.4$, find the values of $r_{12.3}$, $r_{13.2}$ and $r_{23.1}$. Also calculate $R_{1.23}$ and $R_{3.12}$.
 - Calculate $R_{1.23}$, $R_{2.13}$ and $R_{3.12}$ for the following:
 $r_{12} = 0.6$, $r_{13} = 0.7$, $r_{23} = 0.65$
and comment on these values.
 - In a certain investigation, the following values were obtained:
 $r_{12} = 0.8$, $r_{13} = 0.2$, $r_{23} = -0.5$.
Do you think that the computations are free from error?

The following information about a trivariate population is given to you :

$$\sigma_1 = 3.2, \sigma_2 = 4.5, \sigma_3 = 2.8, r_{12} = 0.3, r_{23} = 0.6 \text{ and } r_{13} = 0.8.$$

Do you think that the given data are consistent? If so, calculate $r_{23.1}$ and $r_{1.23}$.

Given the following data, find the regression equation of X_1 on X_2 and X_3 .

X_1 :	12	22	32	28
X_2 :	6	12	16	22
X_3 :	4	6	12	18

Also predict the value of X_1 when $X_2 = 5$ and $X_3 = 7$.

B. Given the following data :

Performance evaluation (X_1):	28	33	21	40	38	46
Aptitude Test Score (X_2):	74	87	69	69	81	97
Prior Experience (X_3):	5	11	4	9	7	10

(i) Develop the estimating equation, best describing these data.

(ii) If an employee scored 83 on the aptitude test and had a prior experience of 7 years, what performance evaluation would be expected?

(M.Com., DU, 2001)

Jewel's Care Collected

.....

$$E = 6xy + x(1-y) - 3(1-x)y + 2(1-x)(1-y)$$

For maximizing the expectation, the first partial derivative must be equal to zero.

$$\frac{\partial E}{\partial x} = 6y + (1-y) - 3y - 2(1-y) = 0$$

$$\text{or, } y = \frac{1}{10}; \text{ and } (1-y) = \frac{9}{10}$$

$$\frac{\partial E}{\partial y} = 6x - x - 3(1-x) - 2(1-x) = 0$$

$$\text{or, } x = \frac{1}{2}; \text{ and } (1-x) = \frac{1}{2}$$

to obtain the value of the game, substitute the values of x and y in the expression E .

$$E = 6 \times \frac{1}{2} \times \frac{1}{10} + \frac{1}{2} \times \frac{9}{10} - 3 \times \frac{1}{2} \times \frac{1}{10} + 2 \times \frac{1}{2} \times \frac{9}{10} = 1.5$$

Hence the optimal strategies for both the manufacturers are that manufacturer ABC should adopt strategy 'decrease price' 50% times and strategy 'maintain present strategy, 50% times. Similarly, manufacturer XYZ should adopt strategy 'give coupons' 10% times and strategy 'decrease price' 90% times. The value of the game would be in favour of manufacturer ABC and the increase in market share would be 1.5.

PROBLEMS

I-A: Answer the following questions, each question carries one mark:

- (i) What is Statistical decision theory?
- (ii) What is payoff table?
- (iii) What is opportunity loss table?
- (iv) What is EVPI?
- (v) What is the difference between course of action and state of nature?
- (vi) What is decision-making under risk?
- (vii) What is decision-making under uncertainty?
- (viii) What is the difference between pure strategy and mixed strategy?
- (ix) What do you understand by dominance principle?
- (x) What is graphical method of a two-person zero-sum game?

I-B: Answer the following questions, each question carries four marks:

- (i) Explain briefly, the ingredients of a decision problem with suitable examples.
 - (ii) Describe any two methods of decision-making under uncertainty, pointing out their relative merits and demerits.
 - (iii) What is a two-person zero-sum game? What are its major limitations?
 - (iv) Differentiate between maximin and minimax principle.
 - (v) List the different steps in decision-making. (MBA, Madras Univ, Nov. 2003)
 - (vi) Explain the difference between decision-making under certainty, risk and uncertainty by giving suitable example.
 - (vii) Describe at least two methods of solving a two-person zero-sum game problem.
1. Explain how statistics is useful in the decision-making process of business and management.
 2. How is Expected Value calculated? What are the advantages and disadvantages of using Expected Value as a decision criterion?
 3. (a) Decision criteria under situation of uncertainty is governed by the attitude of the decision-maker. Explain.
(b) Describe some methods which are useful for decision-making under uncertainty. Illustrate each by an example.
 4. Explain clearly the following:

(i) Course of action	(ii) State of nature
(iii) Payoff table	(iv) Opportunity loss.

(MBA, HPU, 2002)
 5. Explain the following, giving a suitable example:

(i) The minimax principle	(ii) The maximin principle,	(iii) The Bâyes principle	(iv) Expected value of perfect information.
(v) Highest Expected payoffs with information,	(vi) Highest expected payoffs under uncertainty.		

(MBA, Sukhadia Univ, 1998)
 6. Explain the difference between expected opportunity loss and expected value of perfect information.
 7. Explain the maximin and minimax regret criteria of decision-making under uncertainty giving suitable examples.
 8. What is meant by "Statistical Decision Theory". How is it different from other methods used in decision-making? Describe some methods which are useful for decision-making under uncertainty.

Jewel's Care Collected

10. Explain the following terms :
 (i) Two-person zero-sum games, (ii) Principle of dominance, and
 (iii) Pure strategy in game theory.
11. What is game theory? Include in your answer various approaches in solving for strategies and game values. *(MBA, M.D. Univ., 1996)*
12. What is two-person zero-sum game? What are its major limitations? *(MBA, Sukhadia Univ., 1997)*
13. Explain the terms : minimax strategies, saddle point, mixed strategies and principle of dominance. *(MBA, Delhi Univ., 1998)*
14. "The primary contribution of the game theory has been its concept rather than its formal application to solving real-life problems." Do you agree? Discuss.
15. (a) "Game theory deals with making decisions under conflict caused by opposing interests." Elucidate this statements by giving appropriate examples.
 (b) Explain the criterion of maximin and minimax regret in the context of decision theory. *(M. Com., DU, 1999)*
16. A baker makes a certain kind of pastry at night and sells it the next day. It is perishable and must be thrown if not sold during the day. The unit cost and price of the pastry are Re.1 and Rs.3 respectively. According to the past experience, the daily demand (in hundred) and the respective probabilities are :
- | | | | | | |
|-------------|-----|-----|-----|-----|-----|
| Demand | 20 | 21 | 22 | 23 | 24 |
| Probability | 0.1 | 0.2 | 0.3 | 0.3 | 0.1 |
- (i) Construct the payoff table.
 (ii) Construct the loss table.
 (iii) Determine the maximin and maximax action.
 (iv) Compute the highest expected payoff with perfect information.
17. A certain product is manufactured at Rs. 50 and sold at Rs. 75 per unit. The product is such that if it is produced but not sold during a week's time, it becomes worthless. The weekly sales records in the past are as follows :
- | | | | | |
|--|-----|-----|-----|-----|
| Demand per week | 20 | 21 | 22 | 23 |
| No. of weeks each sales level was recorded | 200 | 350 | 800 | 150 |
- (i) Calculate the expected sales of the month.
 (ii) Prepare a table of payoff for different possible acts.
 (iii) Prepare a table of expected payoffs and select the optimal act.
18. A stall agent at a certain railway station sells for Rs. 1.50 a copy of daily newspaper for which it repays Rs. 1.22. Unsold papers are returned for a refund of 50 paise a copy. The daily sales and corresponding probabilities are as follows :
- | | | | |
|-------------|-----|-----|-----|
| Daily sales | 500 | 600 | 700 |
| Probability | 0.5 | 0.3 | 0.2 |
- (i) How many copies should he order each day?
 (ii) If unsold copies cannot be returned and are useless, what should be optimal order each day?
19. N. Sombhai & Co., a wholesale dealer in electrical appliances, was offered an agency for selling Godrej refrigerators. The company estimated that his fixed costs in taking up the agency would be Rs. 1,20,000 per year. Contribution per refrigerator sold would be Rs. 2,000. From a potential target audience of 2,000 buyers in the region, the company assessed that its market for the refrigerator sales would be 2%, 4% or 6% of the target audience with probability 0.1, 0.6 and 0.3 respectively. For a fixed cost of Rs. 10,000, the company could get a sample survey of potential buyers conducted. Whether the company should go in for additional information? Support your decision with appropriate reason in terms of EMV.
20. A company is currently involved in negotiations with its union on the upcoming wage contract. With the aid of an outside mediator, the table below was constructed by the management group. The plus points are to be interpreted as proposed wage increases while a minus figure indicates that a wage reduction is proposed. The mediator informs the management group that he has been in touch with the union and they have constructed a table that is comparable to the table developed by management. Both the company and the union must decide on an overall strategy, before negotiation. The management group understands the relationships of company strategies to union strategies in the following table but lacks specific knowledge of game theory to select the best strategy (or strategies) for the company. You have been called in to assist management on this problem. What game value and strategies are available to the opposing groups?

CONDITIONAL COST (Rs.) TO COMPANY

		Union Strategies			
		U_1	U_2	U_3	U_4
Company Strategies	C_1	+0.25	+0.25	+0.35	-0.02
	C_2	+0.20	+0.16	+0.08	+0.08
	C_3	+0.14	+0.12	+0.15	+0.13
	C_4	+0.30	+0.14	+0.19	0

21. A and B play a game in which each has three coins, a 5p., a 10p. and a 20p. Each selects a coin without the knowledge of other's choice. If the sum of the coins is an odd amount, A wins B's coin; if the sum is even, B wins A's coin. Find the best strategy for each player and the value of the game. (MBA, Delhi Univ. 1997)
22. A businessman has three alternative; open to him and each of which can be allowed by any of the four possible events. The conditional payoffs for each action event combination are given below :

Action	Event			
	A	B	C	D
S_1	8	0	-10	6
S_2	-4	12	18	-2
S_3	14	6	0	8

- (a) If he adopts maximin criterion, what act he should choose?
- (b) If the criterion of choice is minimax regret; what action should be chosen?
- (c) If he uses EMV (Expected Monetary Value) as his decision criterion, what action should he choose (assume that events have equal probability of occurrence)?
23. A person has the choice of running a hot snack stall or an ice-cream and cold drink shop at a certain holiday resort during the coming summer season. If the weather during the season is cool and rainy he can expect to make a profit of Rs. 15,000 and if it is warm he can expect to make a profit of only 3,000 by running a hot snack stall. On the other hand, if his choice is to run an ice-cream and cold drink shop he can expect to make a profit of Rs. 18,000, if the weather is warm and only Rs. 3,000 if the weather is cool and rainy. The meteorological authorities predict that there is 40% chance of the weather being warm during the coming season. You are to advise him as to the choice between the two types of stalls. Base clearly your argument on the expectation of the results of the two courses of action and show the result in a tabular form.
24. Vishal who possesses an amount of Rs. 1 lakh is planning to invest it among three companies : equity shares in company A, B and C. The payoff terms of (i) growth in capital and (ii) return on capital are known for each of the investments under each of the three economic conditions which may prevail, that is recession, growth and stability. Assuming that Vishal must make his choice among the three portfolios for a period of one year in advance, his expectations of the net earning (in Rs '000) of his Rs. 1 lakh portfolio after one year is represented by the following matrix :

	Recession	Stability	Growth
Company A	-15	6	10
Company B	4	7.5	8
Company C	6.5	6	5

- Determine the optimal strategies for investment and the expected per cent return for the investor under such a policy.
25. A physician purchases a particular vaccine on Monday each week. The vaccine must be used within the following quantities, otherwise it becomes worthless. The vaccine costs Rs. 5 per dose and the physician charges Rs. 10 per dose. In the past 50 weeks, the physician has administered the vaccine in the following quantities :
- | | | | | |
|-----------------|----|----|----|----|
| Dose per week | 20 | 25 | 50 | 60 |
| Number of weeks | 5 | 15 | 25 | 5 |
- Determine how many doses the physician should buy every week. (AI Com., Delhi Univ. 1995)

26. Given is the following payoff matrix :

State of nature	Probability	(Decision Rs.)		
		Do not expand	Expand	Expand
		100 units	200 units	400 units
High demand	0.4	2500	3500	5000
Medium demand	0.4	2500	3500	1000
Low demand	0.2	2500	1500	1000

- What should be the decision, if we use (i) EMV criterion (ii) the maximin criterion, (iii) the maximax criterion and (iv) minimax regret criterion?

27. A toy camera manufacturer produces two models (standard and deluxe). In preparation for the heavy Christmas selling season, he must decide how many of each model to produce. Variable cost of standard camera is Rs. 10 and selling price is Rs. 20; variable cost of the deluxe model is Rs. 35. He estimates demand as follows :

Standard model		Deluxe model	
Demand	Probability	Demand	Probability
6,000	0.30	2,000	0.20
8,000	0.70	4,000	0.80

Any camera not sold during the season is sold at salvage price of Rs. 5 for the standard camera and Rs. 10 for the deluxe camera. The manufacturer feels that different segments of the market purchase the two different models, thus the probabilities of sales given above are independent. Assuming unlimited production capacity, the two decisions can be made independently. What are the optimal quantities of each model to produce? What are the two optimal EMV's? (MBA, M.D. Univ., 1997)

28. Crown Auto is trying to decide about the size of the plant to be built in Noida. Three alternatives of annual capacity, viz., (i) 10,000 units (ii) 20,000 units and (iii) 30,000 units are under consideration. Demand for the product is not known with certainty but the management has estimated the probabilities for 5 different levels of demand. The profit for each size of plant at different levels of demand is as follows :

Level of demand	Probability	Decision (Rs. in lakhs)		
		10,000 units	20,000 units	30,000 units
Very high	0.15	-0	-6	-8
High	0.30	1	0	-2
Moderate	0.25	1	7	5
Low	0.20	1	7	5
Very low	0.10	1	2	11

What plant capacity would you suggest to the management? Also find EVPI

29. Two leading firms Nirmala Textiles Ltd., and Swati Rayons Ltd. have been selling, shirting which is but a small part of both firms total sales. The Marketing Director of Nirmala Textiles raised the question: "What should his firm's strategies be in terms of advertising for the product?" The system group of Nirmala Textiles developed the following data for varying degrees of advertising:

- (i) No advertising, medium advertising and heavy advertising for both firms will result in equal market share.
- (ii) Nirmala Textiles with no advertising : 40 per cent of the market with medium advertising by Swati Rayons and 28 per cent of the market with heavy advertising by Swati Rayons.
- (iii) Nirmala Textiles using medium advertising : 70 per cent of the market with no advertising by Swati Rayons and 45 per cent of the market with heavy advertising by Swati Rayons.
- (iv) Nirmala Textiles using heavy advertising ; 75 per cent of the market with no advertising by Swati Rayons and 52.5 per cent of market with medium advertising by Swati Rayons.

Based upon the above information, answer the marketing director's question. (MBA, Delhi Univ., 1996)

30. A newspaper boy buys papers for Rs. 1.75 each and sells them for Rs. 1.95 each. He cannot return unsold newspapers. Daily demand has the following distribution :

No. of customers	: 220	221	222	223	224	225	226	227	228
Probability	: 0.22	0.03	0.05	0.05	0.25	0.05	0.20	0.10	0.05

If each day's demand is independent of the previous day's demand, how many newspapers should be ordered each day?

31. Solve the following two-person zero-sum game :

		Player B				
		1	2	3	4	5
Player A	1	2	-4	-6	-3	5
	2	-3	4	-4	1	0

32. Two firms are competing for business. Whatever firm A gains, firm B loses. The table below shows advertising strategies of both firms and the utilities to firm A for various market shares in percentages.

		Firm B		
		Press	Radio	TV
Firm A	Press	60	45	40
	Radio	75	75	60
	TV	80	60	70

Find optimal strategies for both firms and expected percentage of market shares of firm A.

33. A small industry finds from the past data that the cost of making an item is Rs. 25, the selling price of an item is Rs. 30, if it is sold within a week, and it could be disposed of at Rs. 20 per item at the end of the week.

Weekly Sales :	≤ 3	4	5	6	7	≥ 8
No. of Weeks :	0	10	20	40	30	0

Find the optimum number of items per week the industry should produce.

34. A management is faced with the problem of choosing one of three products for manufacturing. The potential demand for each product may turn out to be good, moderate or poor. The probabilities for each of states of nature were estimated as follows :

Product	Nature of Demand		
	Good	Moderate	Poor
X	0.70	0.20	0.10
Y	0.50	0.30	0.20
Z	0.40	0.50	0.10

The estimated profit or loss under the various types of nature of demand may be taken as :

	Rs.	Rs.	Rs.
X	30,000	20,000	10,000
Y	60,000	30,000	20,000
Z	40,000	10,000	-15,000

Prepare the expected monetary value table and advise the management about the choice of product.

35. Solve the following game by using the principle of dominance :

		Player B					
		I	II	III	IV	V	VI
Player A	1	4	2	0	2	1	1
	2	4	3	1	3	2	2
	3	4	3	7	-5	1	2
	4	4	3	4	-1	2	2
	5	5	3	3	-2	2	2

36. Solve the following two-person zero-sum game :

		Player B		
		B ₁	B ₂	B ₃
Player A	A ₁	4	5	8
	A ₂	-2	-3	4
	A ₃	-6	-4	0
	A ₄	6	-5	2

37. A firm makes pastries, which it sells for Rs. 8 per piece in special boxes containing one dozen each. The direct cost of pastries for the firm is Rs. 4.50 per piece. At the end of the week, the stale pastries are sold off for a lesser price of Rs. 2.50 per piece. The overhead expense attributable to the pastry production is Rs. 1.25 per piece. Fresh pastries are sold in special boxes which cost 50 paise each and the stale pastries are sold wrapped in ordinary paper. The probability distribution of demand per week is as under :

Demand (in dozen) :	0	1	2	3	4	5
Probability :	0.01	0.14	0.29	0.50	0.10	0.05

Find the optimal production level of pastries per week.

38. Firm X is fighting for its life against the determination of firm Y to drive it out of the industry. Firm X has the choice of increasing its price, leaving it unchanged or lowering it. Firm Y has the same three options. Firm X's gross sales in the event of each of the possible pairs of choice are shown below :

		Firm Y's Pricing Strategy		
		Increase price	Do not change	Reduce price
Firm X's Pricing Strategy	Increase Price	90	0	110
	Do not change	110	100	90
	Reduce price	120	70	80

Find the optimal strategies for both the firms and also the value of the game.

39. Assume that two firms are competing for market share for a particular product. Each firm is considering what promotional strategy to employ for the coming period. Assume that the following payoff matrix describes the increase in market share for firm A and the decrease in market share for firm B :

		Firm B		
		No Promotion	Moderate Promotion	Heavy Promotion
Firm A	No. Promotion	3	0	-3
	Moderate Promotion	2	7	1
	Heavy Promotion	-4	2	-1

Determine the optimal strategies for each firm and the value of the game.

(MBA, Delhi Univ., 1995)

40. For the following payoff matrix, find the value of the game and the strategies of players A and B by using graphical method :

		Player B		
		B ₁	B ₂	B ₃
Player A	A ₁	3	-1	4
	A ₂	6	7	-2

41. The management of a corporation is in the process of deciding whether to agree to negotiate with the striking union, now or to delay. The decision is difficult because the management does not know the union leadership's position. The union leaders may be adamant and insist on their original demands, they may be ready to compromise or they may be ready to yield and accept the original management offer. The matrix of payoffs to management, as management sees it, is (in Rs. 1 million units) given below :

		UNION POSITION		
		B ₁ Adamant	B ₂ Compromise	B ₃ Yield
A ₁ Negotiate		-2	-1	2
A ₂ Delay		5	-2	-3

- Solve management's problem.
- What should be the union's strategy.
- Discuss the implications of a conclusion to adopt a random strategy.

42. A producer of boats has estimated the following distribution of demand for a particular kind of boats :

No. demanded :	0	1	2	3	4	5	6
Probability :	0.14	0.27	0.27	0.18	0.09	0.04	0.01

Each boat cost him Rs. 70,000 and he sells for Rs. 1,00,000 each. Any left unsold at the end of the season must be disposed for Rs. 60,000 each. How many should he stock so as to maximise his expected payoff?

43. There are two companies A and B in a certain city. Both companies have similar reputation and the total number of customers is equally divided between the two companies. Both the companies want to attract more number of customers by using different media of advertisement. By seeing the market trend, the company A constructed the following payoff matrix, where the numbers in the matrix indicate a gain or a loss of customers.

		Company B		
		Newspaper	Radio	T.V.
Company A	Newspaper	40	50	-70
	Radio	10	25	-10
	T.V.	100	30	60

Find optimal strategies for both the companies and value of the game.

44. A group of students raise money each year by selling Souvenirs outside the stadium after a cricket match between Teams A and B. They can buy any of the three different types of Souvenirs from a supplier. Their sales are mostly dependent on which team wins the match. A conditional payoff table is as under :

		Type of Souvenir		
		I	II	III
Team A wins		Rs. 1,200	Rs. 800	Rs. 300
Team B wins		Rs. 250	Rs. 700	Rs. 1,100

(i) Construct the opportunity loss table.

(ii) Which type of Souvenir should the students buy if probability of Team A winning is 0.6?

45. The conditional payoffs in rupees for each action-event combination are as under :

		Action			
		1	2	3	4
Event					
A		4	-2		8
B		0	6		5
C		-5	9	2	-3
D		3	1	4	5
E		6	6	3	2

(i) Which is the best action in accordance with the maximin criterion?

(ii) Which is the best action in accordance with EMV criterion, presuming all events have equal probabilities of occurrence?

In a duopolistic market, two competitor compete for profit with promotional effort as their only controllable variables. Each competitor has the option of increasing or decreasing the promotional expenditure or staying at the normal level. The expected increase in profit of competitor 1 under various situations is shown here (in Rs. 10,000 units) :

		Competitor 2		
		Increase	Normal	Decrease
Competitor 1	Increase	-200	-20	30
	Decrease	-50	20	40
	Normal	80	10	50

Assuming a zero-sum game, find the optimal strategy of each competitor and the value of the game.

47. Two companies A and B are competing for the similar type of product. Their different strategies are given in the following payoff matrix.

		Company B		
		B ₁	B ₂	B ₃
Company A	A ₁	2	-2	3
	A ₂	-3	5	-1

Determine the best strategies for both the companies and also the value of the game

48. In a recreation beach, two persons, A and B, are interested in starting a refreshment stall. Initially, only three places are under consideration. The following payoff matrix for different strategies of the players is given :

		B's position		
		Entrance	Centre	Exit
A's Position	Entrance	50	30	40
	Centre	70	50	60
	Exit	60	70	50

(MBA, Delhi Univ., 1998)

- What is the best strategy for A and B to start the refreshment stall ?
49. A soft drink company calculated the market share of two products against its major competitor having three products and found out the impact of additional advertisement in any one of its product against the other.

		Competitor		
		1	2	3
Company	1	6	7	15
	2	20	12	10

What is the best strategy for the company as well as the competitor ? What is the payoff obtained by the company and the competitor in the long run? Use graphical method to obtain the solution.

50. Two candidates, X and Y, are competing for the councillors seat in a city municipal corporation, and X is attempting to increase his total votes at the expense of Y. The strategies available to each candidate involve personal contacts, newspapers insertions or television advertising. The increase in votes available to X given various combinations of strategies are given below. Assuming two-person zero-sum game, determine the optimal strategies that should be adopted by X during his election campaign. How many votes should X gain by the following optimal strategy ?

		Y		
		Personal Contacts	Newspaper	Television
X	Personal contacts	30,000	20,000	10,000
	Newspaper	60,000		25,000
	Television	20,000	40,000	30,000

51. A production manager has calculated that for every additional unit sold he makes an additional profit of Rs. 2, but for every unit left unsold, he loses Rs. 1.20. The probability distribution for the demand (in lakh units) of the product per week is given below :

Demand per week :	20	21	22	23	24	25	26	27
Probability :	0.24	0.08	0.09	0.17	0.15	0.13	0.09	0.05

Determine the optimal number of units the production manager should store for a week.

52. Assume that a manager sells an article having normally distributed sales with a mean of 50 units daily and a standard deviation in daily sales of 15 units. The manager purchases this article for Rs. 4 per unit and sells it for Rs. 9 per unit. If the article is not sold on the selling day, it is worth nothing. Determine the optimal size of the order of the article, the manager should make daily.

(MFC, Delhi Univ., 1996)

53. A big breeder can either produce 20 or 30 pigs. The total production of his competitors can be either 5,000 or 10,000 pigs. If they produce 5,000 pigs, his profit per pig is Rs. 60; if they produce 10,000 pigs, his profit per pig is only Rs. 45. Construct a payoff table and also state what would the big breeder decide.

54. Two firms A and B are competing for the same type of product. Their different strategies are given in the following payoff matrix :

		Firm B			
		B ₁	B ₂	B ₃	B ₄
Firm A	A ₁	35	65	25	5
	A ₂	30	20	15	0
	A ₃	40	50	0	10
	A ₄	55	60	10	50

Using the concept of dominance, reduce this game to 2 × 2 matrix. Also determine their optimal strategies and the value of the game.

55. For the following matrix, find the optimal strategies for A and B and the value of the game :

		Firm B		
		B ₁	B ₂	B ₃
Firm A	A ₁	12	10	8
	A ₂	14	14	10
	A ₃	16	12	15

56. Under an employment promotion scheme, it is proposed to allow sale of newspaper on the buses during off peak hours. A vendor can purchase the newspaper at a concessional rate of Rs. 1.70 per copy and sell it for Rs. 1.90. Copies unsold at the end of the day are, however, a dead loss. The demand probability distribution has been estimated as follows :

Demand :	160	170	180	190	200	210
Probability :	0.04	0.19	0.33	0.26	0.11	0.07

How many copies should the vendor order so as to maximise his expected profit ?

(M.Com., DU, 1999)

57. Consider the following payoff (profit) matrix :

		State of nature				
		N ₁	N ₂	N ₃	N ₄	N ₅
Strategy	S ₁	68	70	-10	0	40
	S ₂	30	45	20	35	-15
	S ₃	40	35	25	20	30
	S ₄	50	-20	35	25	20

No probabilities are known for the occurrence of the state of nature. Compare the solutions obtained by each of the following criteria: (a) Maximin, (b) Regret, (c) Laplace (d) Hurwicz

(MBA, Madras Univ., 1999)

58. Consider the following pay off (profit) matrix.

		State of Nature				
		N ₁	N ₂	N ₃	N ₄	N ₅
Strategy	S ₁	60	70	-10	0	40
	S ₂	30	45	20	35	-15
	S ₃	40	35	25	20	30
	S ₄	50	-20	35	25	20

Compare the solutions obtained by Minimax (Savage) and Laplace criterion.

(MBA, Madras Univ., Oct 2003)

A company needs to increase its production beyond its existing capacity. It has narrowed the alternatives to two approaches so : (a) expansion at a cost of Rs. 8 million, or (b) modernization at a cost of Rs. 5 million. Both approaches would require the same amount of time for implementation. Management believes that over the required payback period, demand will either be high or moderate. Since high demand is considered to be somewhat less likely than moderate demand, the probability of high demand has been set at 0.35. If the demand is high, expansion would gross an estimated additional Rs. 12 million but modernization only an additional Rs. 6 million, due to a lower maximum production capability. On the other hand, if the demand is moderate, the comparable figures would be Rs. 7 million for expansion and Rs. 5 million for modernization.

- Calculate the conditional profit in relation to variance action and outcome combinations and states of nature.
- If the company wishes to maximize its expected monetary value (EMV), should it modernize or expand ?
- Calculate the EVPI.
- Construct the conditional opportunity loss table and also calculate EOL. (MBA, Delhi Univ., 1998)

60. Suppose an analysis of demand for a product in the last one year (52 weeks) revealed the demand distribution given in the table given below :

Table : Demand Distribution

Quantity demanded	No. of weeks this quantity was sold	Probability
30	5	0.10
31	10	0.20
32	16	0.30
33	13	0.25
34	5	0.10
35	3	0.05
	52	1.00

Selling price of the product = Rs. 3.00.

Cost price of the product = Rs. 2.00.

Selling price of more than one week old product = Rs. 1.00 (i.e., loss of unsold unit)

- (i) Construct the conditional profit table.
 - (ii) Determine the optimum number of units of his commodity, to order weekly in order to maximize his profit.
 - (iii) Compute *EPPI* and *EVPI*.
 - (iv) Construct the conditional loss table.
 - (v) Compute *EOL*.
 - (vi) Compare (iii) and (v).
61. A Company has to decide on marketing one of the following two types of portable transistor radios—Deluxe and Popular. The market forecast for the coming festival season indicates 75% chance that the market will be good, 15% chance it will be fair and 10% chance it will be poor. The payoffs for each strategy corresponding to the different states of nature is given in the following matrix :

	States of Nature			
	Market Good	Market Fair	Market poor	
	Probability	0.75	0.15	0.10
Strategy		Pay offs (Rs.)		
Deluxe Model		35,000	15,000	5,000
Popular Model		50,000	20,000	(-) 3,000

Which strategy the company should choose ?

62. Mr. Ram buys a perishable commodity at Rs. 5 each. The profit per unit is Rs. 5. This perishable commodity he can keep in his shop for a week and at the end of each week the leftover are sold to a restaurant for Rs. 3 each (a loss of Rs. 2 each). Mr. Ram has the record for past 100 weeks for his weekly sales as given below :

Weekly demand	:	1	2	3	4	5	6	7
Number of weeks	:	5	10	25	30	20	5	5

- (i) Construct the conditional profit table.
- (ii) Determine the optimum number of units of his commodity to order weekly in order to maximize his profit.
- (iii) Compute *EPPI* and *EVPI*.
- (iv) Construct the conditional loss table.
- (v) Compute *EOL*.
- (vi) Compare (iii) and (v).

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