

ZIMBABWE EZEKIEL GUTI UNIVERSITY



FACULTY OF LAW, BUSINESS INTELLIGENCE & ECONOMICS
DEPARTMENT OF ECONOMICS, MARKETING AND ENTREPRENEURSHIP
MASTERS IN STRATEGIC MANAGEMENT EXAMINATION

Examination Details

Course Name : Quantitative Management

Course Code : MSTM511

Date : December 2023

13 FEB 2024

Duration : 3 Hours 15 minutes

Instructions to candidate

Answer Question **One (1)** and any other **Three (3)** questions.

Question 1 carries 40 marks and each other question carries 20 marks.

Start each question on a new page.

The formula sheet is provided

You may use a non-programmable calculator

Additional Material

Formula booklet

Graph paper

Question one

a) ZG Manufacturers plc claims that 8% of its industrial products are defective. When 250 items were drawn from a large production run, 10.5% were found to be defective.

- i) What is the population of interest? [2 marks]
- ii) State the statistic relating to the population of interest. [1 mark]
- iii) Explain briefly how the statistic can be used to make references about the parameter to test the claim. [2 marks]

b) After the screening the 2023 CEO round-the-table conference in Victoria Falls ZTV, a random sample of 250 people were selected and asked whether they watched the programme; 200 people indicated that they had watched the programme.

- i) Calculate the point estimate of the population proportion of people who watched this ZTV programme. [2 marks]
- ii) Calculate the 99.8% confidence interval for the population proportion of people who did not watch the ZTV programme. [4 marks]
- iii) Explain the concept of estimate precision and how it can be enhanced. [2 marks]

c) Describe what stratified random is sampling and give business application where such sampling can be used. [4 marks]

d) The speed of cars recorded at a speed trap in Banket by a detector between 7:00am and 11:00am on an Easter Monday morning was summarized in the table below:

Speed in Km/h	35 - < 45	45 - < 55	55 - < 65	65 - < 75
Frequency	33	40	30	20

- i) Present the data on a Histogram and use the presentation to estimate the modal speed. [5 marks]
- ii) Compute and interpret the mean, mode, median and coefficient of variation [6 marks]
- iii) Write a brief report commenting on the statistics computed in (ii) above. Be sure to include the skewness of the speed, the variability of the speeds as well as the reliability of the measures of central location. [6 marks]
- iv) What strategic recommendations can you give the Police Superintendent for Banket? [4 marks]

e) The mean internal diameter of a sample of 300 washers produced by a machine is 10.0 mm and a standard deviation of 0.1 mm. The purpose for which the washers are intended allows

for diameters of between 9.9 mm and 10.1 mm, otherwise the washers are considered defective. Assuming that the dimensions are normally distributed:

Calculate the approximate number of washers which are defective. [5 marks]

[Total - 40 marks]

Question two

a) The Human Resources Manager of a manufacturing company in Bindura industrial area, recorded the number of days 8 employees came late before and after the warning. His findings are summarized in the table below:

Employee	1	2	3	4	5	6	7	8
Before (X)	16	12	18	7	14	19	6	17
After (Y)	14	13	12	6	9	15	8	15

- i) What is the significance of correlation analysis and regression analysis to the two random variables above? [2 marks]
- ii) Present the findings on the scatter plot and comment. [3 marks]
- iii) Establish the equation of regression Y on X and comment on the significance of the coefficients. [6 marks]
- iv) Calculate and comment on the Pearson correlation coefficient. [4 marks]

b) A manager wants to determine at 2% level of significance if the hourly wages for semi-skilled workers are the same in two Zimbabwe's main industrial cities, Harare and Bindura. In order to do this a random sample of 40 semi-skilled workers was taken from Harare and the hourly average wage was \$6.00 with a variance of \$4.00. In Bindura a sample of 54 semi-skilled workers was chosen and the average wage was \$5.40 with a standard deviation of \$1.80.

Required

Test whether there is any significant difference in the average hourly wages of semi-skilled workers in the two cities? [5 marks]

[Total - 20 marks]

Question three

a) Monya Real Estate Agent owns 600 buildings in the greater Harare metropolitan city. One fifth of the properties are shops and the remainder are either offices or hotels. There are an equal number of offices and hotels. Thirty percent of the properties are in the Northern suburbs of the city, 25% are in the Eastern, 10% in the Western and the rest in the Southern. All the properties in the Western suburbs are hotels. One third of the properties in the Northern suburbs are shops and none is a hotel. Meanwhile, there is an equal number of each type of property in the Eastern suburbs.

i) Construct a suitably labelled contingency table to display all the information in the case above. [5 marks]

ii) What is the probability that a property selected at random will be a shop given that it is in the Northern suburbs? State the probability type and comment on your result. [4 marks]

iii) What is the probability that a property selected at random will be an office or found in the Southern suburbs? State the probability type and comment on your answer. [4 marks]

b) A machine operator has noticed that one of the machines stops randomly due to overloading. If there are four stoppages on average per hour;

i) What is the mean and standard deviation of this distribution? [2 marks]

ii) Calculate the probability that there are at least two stoppages in any in any 45 minute period. Assume that the stoppages are independent of each other. [5 marks]

[Total – 20 marks]

Question four

a) In response to the possible third wave attack of the COVID 19 pandemic, government through the COVID 19 Response Committee is considering the economic benefits of a program of preventative COVID 19 vaccinations. If vaccinations are not introduced then the estimated cost to the government if the virus strikes again in the next six months is \$3.5m with probability 0.1, \$5m with probability 0.3 and \$7.5m with probability 0.6. It is estimated that such a program will cost \$3.5m and that the probability of the virus striking in the next six months is 0.75.

One alternative open to the COVID 19 Response Committee is to institute an "early-warning" monitoring scheme (costing \$1.5m) which will enable it to detect an outbreak of the virus early and hence institute a rush vaccination program (costing \$5m because of the need to vaccinate quickly before the outbreak spreads).

Required

What recommendations should the COVID 19 Response Committee make to the government if their objective is to maximise expected monetary value (EMV) (Show appropriate computations and diagrams)? [15 marks]

b) The following are losses and profits for a selected number of firms in the manufacturing sector after the first phase of the COVID 19 pandemic.

Loss/Profit (\$'000)	-20 -<-10	-10 -< 0	0 -< 10	10-< 20
Number of firms (>cumulative frequency)	40	27	17	8

Required

Construct a histogram and estimate the modal profit/loss.

[5 marks]

[Total – 20 marks]

Question five

a) Explain the usefulness and potential challenges of index numbers. [5 marks]

b) HEMAS is a higher education medical aid fund in Zimbabwe with over 500 000 members. Data on the number of claims and the average value of these claims by different medical categories (General Practitioners –GPs, Specialists and Dentists) is given for 2009 to 2023 in the following Table 5.1 and 5.2 below:

Table 5.1: Average value of claims

Claim type	Average value of claims (\$)				
	2009	2020	2021	2022	2023
GPs	18050	19235	21050	21950	22400
Specialists	25650	26200	27350	28645	31280
Dentists	39575	42580	43575	43950	46750

Table 5.2: Number of claims received

Claim type	Claims received				
	2009	2020	2021	2022	2023
GPs	205	185	168	215	225
Specialists	462	386	402	519	538
Dentists	88	70	111	146	132

2009 = 100

- i) Compute and comment on the unweighted aggregate quantity indices for each of the last three years. [3 marks]
 - ii) Determine the change in the value of claims in 2023. Use the Fisher index. Interpret the results for the management of HEMAS medical aid fund. [6 marks]
- c) If a new drug for novel pandemic affecting the elderly has been found to be effective 40% of the time, assess the probability that in a random sample of 6 patients, it will be effective in not fewer than three of the patients. [6 marks]

[Total – 20 marks]

END OF QUESTION PAPER

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EXAMINATION OFFICE

**FACULTY OF LAW, BUSINESS
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**DEPARTMENT OF ECONOMICS,
MARKETING AND ENTREPRENEURSHIP**

QUANTITATIVE MANAGEMENT- MSTM511

**(LEAVE THIS FORMULA SHEET IN THE EXAMINATION ROOM –
PLEASE DO NOT WRITE ON THE FORMULA SHEETS)**

1. Measures of Central Location

Arithmetic mean (ungrouped data)

$$\bar{X} = \frac{\sum X_i}{n}$$

Grouped data

$$\bar{X} = \frac{\sum f_i X_i}{n}$$

Mode (grouped data)

$$\text{Mode} = O_{mo} + \frac{l(f_m - f_{m-1})}{2f_m - f_{m-1} - f_{m+1}}$$

Median (grouped data)

$$\text{Median} = O_{me} + \frac{\left[\frac{n}{2} - f(<)\right]}{f_{mc}}$$

Geometric mean (ungrouped data)

$$\text{G.M} = \sqrt[n]{x_1 \times x_2 \times x_3 \times \dots \times x_n}$$

Grouped data

$$\text{G.M} = \text{Antilog} \left[\frac{\sum f_i \log(x_i)}{\sum f_i} \right]$$

$$\text{Harmonic mean} = \frac{n}{\frac{1}{x_1} + \frac{1}{x_2} + \frac{1}{x_3} + \dots + \frac{1}{x_n}}$$

weighted arithmetic mean

$$\text{Weighted } \bar{X} = \frac{\sum f_i X_i}{n}$$

2. Measures of Dispersion/ Variation

Range (ungrouped data) = Maximum value - Minimum value

$$= X_{max} - X_{min}$$

Range (grouped data) = Upper limit(highest class) - Lower limit(lowest class)

Interquartile Range = $Q_3 - Q_1$.

Quartile deviation = $\frac{Q_3 - Q_1}{2}$

Variance (ungrouped data)

$$S_x^2 = \frac{\sum(X_i - \bar{X})^2}{n-1} \quad \text{or} \quad S_x^2 = \frac{\sum X_i^2 - n\bar{X}^2}{n-1}$$

Variance (grouped data)

$$S_x^2 = \frac{\sum f_i(X_i - \bar{X})^2}{n-1} \quad \text{or} \quad S_x^2 = \frac{\sum f_i X_i^2 - n\bar{X}^2}{n-1}$$

Standard of Deviation $S_x = \sqrt{S_x^2}$

Coefficient of variation $CV = \frac{S_x}{\bar{X}} \times 100\%$

3. Measures of Position

Lower Quartile (grouped data) $Q_1 = O_{q1} + \frac{i[\frac{n}{4} - f(<)]}{f_{q1}}$

Upper Quartile (grouped data) $Q_3 = O_{q3} + \frac{i[\frac{3n}{4} - f(<)]}{f_{q4}}$

Percentiles divide by 100, Deciles by 10, Octiles by 8 etc.

4. Measures of Skewness

Pearson's coefficient of skewness $Sk_p = \frac{3(\text{mean} - \text{median})}{\text{standard deviation}}$

Bowley's coefficient of skewness $Sk_p = \frac{(Q_3 - Q_2) - (Q_2 - Q_1)}{(Q_3 - Q_1)}$

5. Probability Concepts

Conditional Probability $P(A/B) = \frac{P(A \cap B)}{P(B)}$

Non-mutually exclusive events $P(A \cup B) = P(A) + P(B) - P(A \cap B)$

Mutually exclusive events $P(A \cup B) = P(A) + P(B)$

Independent events $P(A \cap B) = P(A) \times P(B)$

Permutations ${}_n P_r = \frac{n!}{(n-r)!}$ Combinations ${}_n C_r = \frac{n!}{r!(n-r)!}$

6. Probability Distributions

Binomial Distribution $P(r) = {}_n C_r \cdot p^r \cdot q^{(n-r)}$ for $r = 0, 1, 2, 3, \dots, n$

Binomial descriptive measures

Mean $\mu = np$. Standard deviation $\delta = \sqrt{npq}$ where $q = 1 - p$

Poisson Distribution $P(x) = \frac{e^{-a} \cdot a^x}{x!}$ for $x = 0, 1, 2, 3, 4, \dots$

Poisson descriptive measures $\mu = a$ and $\delta = \sqrt{a}$

Standard normal probability $z = \frac{x - \mu_x}{\sigma_x}$

7. Confidence Intervals

Single mean, large sample ($n \geq 30$) Single mean, small sample ($n < 30$)

$$\bar{X} - Z_{\alpha/2} \cdot \frac{\sigma_x}{\sqrt{n}} \leq \mu \leq \bar{X} + Z_{\alpha/2} \cdot \frac{\sigma_x}{\sqrt{n}}$$

$$\bar{X} - t_{df} \cdot \frac{\sigma_x}{\sqrt{n}} \leq \mu \leq \bar{X} + t_{df} \cdot \frac{\sigma_x}{\sqrt{n}}$$

Single proportion large sample

Single proportion small sample

$$p - Z \cdot \sqrt{\frac{pq}{n}} \leq \pi \leq p + Z \cdot \sqrt{\frac{pq}{n}}$$

$$p - t \cdot \sqrt{\frac{pq}{n}} \leq \pi \leq p + t \cdot \sqrt{\frac{pq}{n}}$$

Difference between two means n_1 and n_2 large sample.

$$(\bar{X}_1 - \bar{X}_2) - Z \left(\sqrt{\frac{\delta_1^2}{n_1} + \frac{\delta_2^2}{n_2}} \right) \leq (\mu_1 - \mu_2) \leq (\bar{X}_1 - \bar{X}_2) + Z \left(\sqrt{\frac{\delta_1^2}{n_1} + \frac{\delta_2^2}{n_2}} \right)$$

Difference between two means n_1 and n_2 small sample.

$$(\bar{X}_1 - \bar{X}_2) - t \left(\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}} \right) \leq (\mu_1 - \mu_2) \leq (\bar{X}_1 - \bar{X}_2) + t \left(\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}} \right)$$

Difference between two proportion n_1 and n_2 large sample

$$(p_1 - p_2) - Z \sqrt{\frac{p_1 q_1}{n_1} + \frac{p_2 q_2}{n_2}} \leq (\pi_1 - \pi_2) \leq (p_1 - p_2) + Z \sqrt{\frac{p_1 q_1}{n_1} + \frac{p_2 q_2}{n_2}}$$

Difference between two proportions n_1 and n_2 small sample.

$$(p_1 - p_2) - t \sqrt{\frac{p_1 q_1}{n_1} + \frac{p_2 q_2}{n_2}} \leq (\pi_1 - \pi_2) \leq (p_1 - p_2) + t \sqrt{\frac{p_1 q_1}{n_1} + \frac{p_2 q_2}{n_2}}$$

8. Hypotheses Tests

Single mean- Large sample: $Z_{cal} = \frac{\bar{X} - \mu_x}{\frac{\sigma_x}{\sqrt{n}}}$

Single mean- Small sample: $t_{cal} = \frac{\bar{X} - \mu_x}{\frac{s_x}{\sqrt{n}}}$

Single proportion $Z_{cal} = \frac{p - \pi}{\sqrt{\frac{\pi(1-\pi)}{n}}}$

Difference between two means - Large sample

$$Z_{cal} = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

Difference between two means - small sample

$$t_{cal} = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \text{ where } s^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}$$

Difference between two proportions

$$Z_{cal} = \frac{(p_1 - p_2) - (\pi_1 - \pi_2)}{\sqrt{\frac{\pi_1(1-\pi_1)}{n_1} + \frac{\pi_2(1-\pi_2)}{n_2}}}$$

Chi-square

$$\chi_{cal}^2 = \sum \frac{(f_o - f_e)^2}{f_e} \text{ where } f_e = \frac{\text{row total} \times \text{column total}}{\text{grand total}}$$

9. Index Numbers

$$\text{Price Relative} = \frac{P_1}{P_0} \times 100\%$$

$$\text{Quantity relative} = \frac{Q_1}{Q_0} \times 100\%$$

$$\text{Laspeyres price index} = \frac{\sum(P_1 \times Q_0)}{\sum(P_0 \times Q_0)} \times 100\%$$

$$\text{Paasche Price index} = \frac{\sum(P_1 \times Q_1)}{\sum(P_0 \times Q_1)} \times 100\%$$

$$\text{Unweighted price index} = \frac{\sum P_1}{\sum P_0} \times 100\%$$

$$\text{Laspeyres quantity index} = \frac{\sum(P_0 \times Q_1)}{\sum(P_0 \times Q_0)} \times 100\%$$

$$\text{Paasche quantity index} = \frac{\sum(P_1 \times Q_1)}{\sum(P_1 \times Q_0)} \times 100\%$$

$$\text{Unweighted quantity index} = \frac{\sum Q_1}{\sum Q_0} \times 100\%$$

10. Regression and Correlation

$$\text{Formula: } \hat{y} = a + bx$$

$$\text{Coefficients: } b = \frac{n\sum xy - \sum x \sum y}{n\sum x^2 - (\sum x)^2} \quad a = \frac{\sum y - b\sum x}{n}$$

$$\text{Pearson's correlation coefficient: } r = \frac{n\sum xy - \sum x \sum y}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

$$\text{Spearman's rank correlation coefficient: } R_s = 1 - \frac{6 \times \sum d^2}{n(n^2 - 1)}$$

11. Time series analysis

$$\text{Regression trend coefficients: } b = \frac{\sum xy}{\sum x^2}$$

$$a = \frac{\sum y}{n} \text{ when } \sum x = 0.$$

$z \leq \text{limit}$

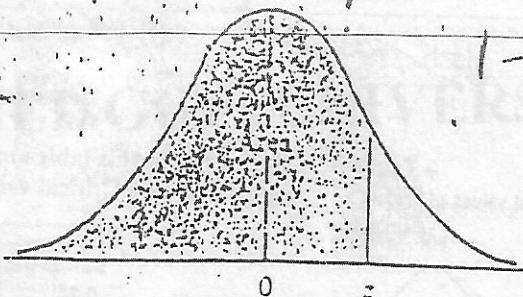


Table I
Areas Under the Normal Curve

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
-3.4	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002
-3.3	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
-3.2	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005
-3.1	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0008	0.0007
-3.0	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010
-2.9	0.0019	0.0018	0.0017	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
-2.8	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0022	0.0021	0.0020	0.0019
-2.7	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
-2.6	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
-2.5	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
-2.4	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
-2.3	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
-2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
-2.1	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
-2.0	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
-1.9	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
-1.8	0.0359	0.0352	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
-1.7	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
-1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
-1.5	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
-1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0722	0.0708	0.0694	0.0681
-1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
-1.2	0.1151	0.1131	0.1112	0.1093	0.1075	0.1056	0.1038	0.1020	0.1003	0.0985
-1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
-1.0	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
-0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
-0.8	0.2119	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
-0.7	0.2420	0.2389	0.2358	0.2327	0.2296	0.2266	0.2236	0.2206	0.2177	0.2148
-0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
-0.5	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
-0.4	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
-0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
-0.2	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
-0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
-0.0	0.5000	0.4960	0.4920	0.4880	0.4840	0.4801	0.4761	0.4721	0.4681	0.4641
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9278	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9691	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9992	0.9992

$a = 1 - \Phi(z_a)$

a z_a

0.10 1.2815

0.05 1.6449

0.025 1.9600

0.010 2.3263

0.005 2.5758

0.001 3.0902

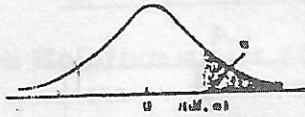
0.0005 3.2905

0.0001 3.7190

0.00005 3.8906

0.00001 4.2649

Table 2
Critical values of Student's t
distribution



The entries in this table are the critical values for Student's t for an area of α in the right-hand tail. Critical values for the left-hand tail are found by symmetry

df	Amount of α in One-tail					
	0.25	0.10	0.05	0.025	0.01	0.005
1	1.000	3.08	6.31	12.7	31.8	63.7
2	0.816	1.89	2.92	4.30	6.97	9.92
3	0.765	1.64	2.35	3.13	4.54	5.84
4	0.741	1.53	2.13	2.78	3.75	4.60
5	0.727	1.48	2.02	2.57	3.37	4.03
6	0.718	1.44	1.94	2.45	3.14	3.71
7	0.711	1.42	1.89	2.36	3.00	3.50
8	0.706	1.40	1.86	2.31	2.90	3.36
9	0.703	1.38	1.83	2.26	2.82	3.25
10	0.700	1.37	1.81	2.23	2.76	3.17
11	0.697	1.36	1.80	2.20	2.72	3.11
12	0.695	1.36	1.78	2.18	2.68	3.05
13	0.694	1.35	1.77	2.16	2.65	3.01
14	0.692	1.35	1.76	2.14	2.62	2.98
15	0.691	1.34	1.75	2.13	2.60	2.95
16	0.690	1.34	1.75	2.12	2.58	2.92
17	0.689	1.33	1.74	2.11	2.57	2.90
18	0.688	1.33	1.73	2.10	2.55	2.88
19	0.688	1.33	1.73	2.09	2.54	2.86
20	0.687	1.33	1.72	2.09	2.53	2.85
21	0.686	1.32	1.72	2.08	2.52	2.83
22	0.686	1.32	1.72	2.07	2.51	2.82
23	0.685	1.32	1.71	2.07	2.50	2.81
24	0.685	1.32	1.71	2.06	2.49	2.80
25	0.684	1.32	1.71	2.06	2.49	2.79
26	0.684	1.32	1.71	2.06	2.48	2.78
27	0.684	1.31	1.70	2.05	2.47	2.77
28	0.683	1.31	1.70	2.05	2.47	2.76
29	0.683	1.31	1.70	2.05	2.46	2.76
z	0.674	1.28	1.65	1.96	2.33	2.58

NOTE: For $df \geq 30$, the critical value $t(df, \alpha)$ is approximated by $z(\alpha)$, given in the bottom row of table.