Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2021/2022

COURSE NAME	:	CIVIL ENGINEERING STATISTIC
COURSE CODE	:	BFC 34303
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	JULY 2022
DURATION	:	3 HOURS
INSTRUCTION		1. ANSWER ALL QUESTIONS.
		2. THIS FINAL EXAMINATION IS AN **ONLINE** ASSESSMENT AND CONDUCTED VIA **CLOSE BOOK**.
		3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **SIXTEEN (16)** PAGES

Q1 (a) In a random sample of 200 buildings in Malaysia, it is found that 140 buildings being built today are three-bedroom homes. Determine a 95% confidence interval for the population proportion.

(5 marks)

(b) The average time taken to complete a project in a real estate company is 24 months with a standard deviation of 6 months. Assuming that the project completion time approximately follows a normal distribution. Calculate the probability that the mean completion time of 4 such projects will be less than 18 months?

(5 marks)

(c) A group of high-risk motorists (with three traffic violations in one year) is randomly assigned to attend traffic class or to do supervised volunteering. During the subsequent 3-year periods, these same motorists were cited for the following (refer to **Table Q1(c)**). Choose the appropriate nonparametric hypothesis test using a 0.01 significance level. Is there evidence to conclude that there is no difference between volunteer work and traffic class? Test and explain your answer.

(15 marks)

Q2 Drilling has many uses for a wide range of industries due to its effectiveness in cutting concrete. Concrete is one of the hardest materials used in construction. Drilling is the best option when making holes in concrete. An experiment was conducted to investigate whether the time to drill holes in concrete differs using "dry" or "wet" drilling. In wet drilling, water is used while in dry drilling, compressed air is used to finish the cuttings. Each method is used on 13 concretes. The drilling times (in $\frac{1}{100}$ minutes) for the two methods are shown in **Table Q2**. At the 0.10 level of significance, the average times for the **TWO (2)** methods are different. Assume the distribution to be normally distributed. Examine and test this claim.

(25 marks)

Q3 **Table Q3** shows the relationship between age and blood pressure. Using a statistical model, develop a mathematical relationship between these **TWO (2)** variables. Comment on the reliability of the relationship in estimating blood pressure. Give the reason why you are doing this analysis. Explain the rules before run this analysis.

(25 marks)

Q4 (a) A study on a public transport acceptance, particularly in terms of factor of safety before and during Covid-19 pandemic periods has been done. At total of 348 undergraduate UTHM student participated in the survey study via questionnaire instrument (5-point Likert Scale) and the results of the mean value for each question show in **Table Q4(a).** By using 0.10 significance level, determine the differences in the variation in the level of safety and security for both periods.

(18 marks)

(b) **Table Q4(b)** shows the incomplete analysis data in which the goal of the analysis is to determine the difference in the mean value of lane changing duration time (in seconds) from U-turn facility to the mainstream for each different types of vehicles. The data was taken during evening peak hour period. Complete the analysis data to achieve the above-mentioned goal. Use the 0.05 significance level.

(7 marks)

– END OF QUESTIONS –

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Table Q1(c): High risk motorist randomly assigned to attend traffic class or to do supervised volunteering during the subsequent 3-year period.

Volunteer work	Traffic class
14	4
7	7
3	15
4	6
9	20
11	2
6	

Table Q2: The drilling times (in 1/100 minutes) for the two methods.

Concrete	Wet drilling	Dry drilling
1	699	904
2	798	804
3	549	884
4	607	939
5	762	989
6	772	750
7	665	902
8	704	814
9	613	918
10	780	727
11	603	987
12	599	965
13	588	811
		777

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Table Q3: Age and blood pressure

Age (Years)	Blood pressure (mm/Hg)
35	120
43	127
47	132
53	136
59	142
62	143
66	148
69	153

Table Q4(a): Mean value for level of safety and security in using public transport questions

Mean value	
Before Covid-19	**During Covid-19**
3.7902	3.8678
3.4397	3.5718
3.6293	3.6753
3.8017	3.8764

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Table Q4(b): Analysis data of lane changing duration time (in seconds) from U-turn facility to the target lane for each types of vehicles during evening peak hour

	Lane changing duration time (in seconds)						TOTAL
	Motorcycle		Passenger Car		Lorry		
	X	X^2	X	X^2	X	X^2	
	2.97	8.82	2.98	8.88	4.32	18.66	
	3.36	11.29	4.51	20.34	4.28	18.32	
	2.11	4.45	3.02	9.12	3.32	11.02	
	2.14	4.58	2.64	6.97	3.11	9.67	
	2.10	4.41	3.36	11.29	3.38	11.42	
	2.03	4.12	3.59	12.89	4.17	17.39	
	2.11	4.45	2.31	5.34			
	2.04	4.16	4.34	18.84			
			10.1	102.01			
T_c	18.86		36.85		22.58		78.29
n_c	8		9		6		23
T_c^2/n_c	44.46		150.88		84.98		280.32
X^2		46.29		195.67		86.49	328.45

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APPENDIX A: STATISTICAL FORMULAS

The following information may be useful. The symbols have their usual meaning.

Mean and Variance of Ungrouped Data

$$\bar{x} = \frac{\sum x}{n} \qquad s^2 = \frac{\sum (x - \bar{x})^2}{n - 1}$$

Mean and Variance of Grouped Data

$$\bar{x} = \frac{\sum fx}{\sum f} \qquad s^2 = \frac{\sum fx^2 - \frac{(\sum fx)^2}{\sum f}}{(\sum f) - 1}$$

Standard Normal Distribution z-value

$$z = \frac{X - \mu}{\sigma}$$

Central Limit Theorem

$$\mu_{\bar{x}} = \mu \qquad \sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}} \qquad z = \frac{\bar{X} - \mu}{\left(\frac{\sigma}{\sqrt{n}}\right)}$$

$$\mu = E(X) = \sum x.P(X) \qquad \sigma = Std(X) = \sqrt{E(X^2) - [E(X)]^2} \qquad E(X^2) = \sum x^2.P(X)$$

Difference Between Two Means

$$Z = \bar{X} - \bar{Y} \qquad \mu_{\bar{X}-\bar{Y}} = \mu_{\bar{X}} - \mu_{\bar{Y}} \qquad \sigma_{\bar{X}-\bar{Y}} = \sqrt{\frac{{\sigma_X}^2}{n} + \frac{{\sigma_Y}^2}{m}}$$

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Confidence Interval

$$\bar{X} \pm z\frac{s}{\sqrt{n}} \qquad \bar{X} \pm t\frac{s}{\sqrt{n}} \qquad t = \frac{\bar{X} - \mu}{s/\sqrt{n}}$$

$$p \pm z\sqrt{\frac{p(1-p)}{n}} \qquad FPC = \sqrt{\frac{N-n}{N-1}} \qquad \bar{X} \pm z\frac{s}{\sqrt{n}}\sqrt{\frac{N-n}{N-1}}$$

$$(\mu_{\bar{X}} - \mu_{\bar{Y}}) \pm t_{\frac{\alpha}{2},df}\left(\sqrt{\frac{{s_{\bar{X}}}^2}{n} + \frac{{s_{\bar{Y}}}^2}{m}}\right) \qquad df = \frac{\left(\frac{{s_{\bar{X}}}^2}{n} + \frac{{s_{\bar{Y}}}^2}{m}\right)^2}{\frac{\left(\frac{{s_{\bar{X}}}^2}{n}\right)^2}{n-1} + \frac{\left(\frac{{s_{\bar{Y}}}^2}{m}\right)^2}{m-1}}$$

One-Sample Hypothesis Testing (z-Test and t-Test)

$$z = \frac{\bar{X} - \mu_o}{\sigma/\sqrt{n}} \qquad z = \frac{\bar{X} - \mu_o}{s/\sqrt{n}} \qquad t = \frac{\bar{X} - \mu_o}{s/\sqrt{n}}$$

Two-Sample Hypothesis Testing (z-Test and t-Test)

$$z = \frac{\bar{X}_X - \bar{X}_Y}{\sqrt{\frac{{s_X}^2}{n} + \frac{{s_Y}^2}{m}}} \qquad t = \frac{\bar{X}_X - \bar{X}_Y}{\sqrt{\frac{{s_P}^2}{n} + \frac{{s_P}^2}{m}}} \qquad {s_P}^2 = \frac{(n-1){s_X}^2 + (m-1){s_Y}^2}{n+m-2}$$

Simple Linear Regression

$$Y = a + bX \qquad a = \frac{\sum Y}{n} - b\frac{\sum X}{n} \qquad e = Y - \hat{Y}$$

$$b = \frac{n(\sum XY) - (\sum X)(\sum Y)}{n(\sum X^2) - (\sum X)^2} \qquad r = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{[n(\sum X^2) - (\sum X)^2][n(\sum Y^2) - (\sum Y)^2]}}$$

$$s_{y.x} = \sqrt{\frac{\sum Y^2 - a(\sum Y) - b(\sum XY)}{n-2}}$$

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F-Test

$$F = \frac{{s_1}^2}{{s_2}^2} \qquad v_1 = n_1 - 1 \qquad v_2 = n_2 - 1$$

One Way ANOVA Test

$$SS = \sum X^2 - \frac{(\sum X)^2}{n} \qquad SST = \sum \left(\frac{{T_c}^2}{n_c}\right) - \frac{(\sum X)^2}{n} \qquad SSE = SS - SST$$

$$MST = \frac{SST}{k-1} \qquad MSE = \frac{SSE}{n-k} \qquad F = \frac{MST}{MSE}$$

$$v_1 = k - 1 \qquad v_2 = n - k$$

Chi-Square Test

$$\chi^2 = \frac{(n-1)s^2}{\sigma^2} \qquad df = n - 1$$

Chi-Square Goodness of Fit Test

$$\chi^2 = \sum \left[\frac{(f_o - f_e)^2}{f_e}\right] \qquad df = k - 1$$

Chi-Square Contingency Table Analysis

$$\chi^2 = \sum \left[\frac{(f_o - f_e)^2}{f_e}\right] \qquad df = (r-1)(c-1)$$

Mann-Whitney Test

$$z = \frac{W - \frac{n_1(n_1 + n_2 + 1)}{2}}{\sqrt{\frac{n_1 n_2 (n_1 + n_2 + 1)}{12}}}$$

Mann-Whitney U Test

$$U_1 = n_1 n_2 + \frac{n_1(n_1+1)}{2} - R_1 \qquad U_2 = n_1 n_2 + \frac{n_2(n_2+1)}{2} - R_2$$

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APPENDIX B: STATISTICAL TABLES

I. Standard Normal Distribution (Right-Tail) showing P (Z > z)

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.4960	0.4920	0.4880	0.4840	0.4801	0.4761	0.4721	0.4681	0.4641
0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
0.2	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
0.4	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
0.5	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
0.7	0.2420	0.2389	0.2358	0.2327	0.2296	0.2266	0.2236	0.2206	0.2177	0.2148
0.8	0.2119	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
1.0	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
1.2	0.1151	0.1131	0.1112	0.1093	0.1075	0.1056	0.1038	0.1020	0.1003	0.0985
1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
1.5	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
1.7	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
1.8	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
1.9	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
2.0	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
2.1	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
2.3	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
2.4	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
2.5	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
2.6	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
2.7	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
2.8	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
2.9	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
3.0	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010
3.1	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007
3.2	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005
3.3	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
3.4	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002

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II. Standard Normal Distribution showing P (0 < Z < z)

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0753
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.2190	0.2224
0.6	0.2257	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2517	0.2549
0.7	0.2580	0.2611	0.2642	0.2673	0.2704	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.2910	0.2939	0.2967	0.2995	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.3340	0.3365	0.3389
1.0	0.3413	0.3438	0.3461	0.3485	0.3508	0.3531	0.3554	0.3577	0.3599	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.3790	0.3810	0.3830
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.3980	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4761	0.4767
2.0	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.4850	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.4890
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.4920	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4938	0.4940	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.4960	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.4970	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.4980	0.4981
2.9	0.4981	0.4982	0.4982	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3.0	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.4990	0.4990
3.1	0.4990	0.4991	0.4991	0.4991	0.4992	0.4992	0.4992	0.4992	0.4993	0.4993
3.2	0.4993	0.4993	0.4994	0.4994	0.4994	0.4994	0.4994	0.4995	0.4995	0.4995
3.3	0.4995	0.4995	0.4995	0.4996	0.4996	0.4996	0.4996	0.4996	0.4996	0.4997
3.4	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4998

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III. Critical Values of the Student's *t* distribution

df	Level of significance for One-Tailed Test, α						
	0.1	0.05	0.025	0.01	0.005	0.001	0.0005
	Level of significance for Two-Tailed Test, α						
	0.2	0.1	0.05	0.02	0.01	0.002	0.001
1	3.078	6.314	12.076	31.821	63.657	318.31	636.62
2	1.886	2.920	4.303	6.965	9.925	22.326	31.598
3	1.638	2.353	3.182	4.541	5.841	10.213	12.924
4	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	1.319	1.714	2.069	2.500	2.807	3.485	3.767
24	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	1.314	1.703	2.052	2.473	2.771	3.421	3.690
28	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	1.311	1.699	2.045	2.462	2.756	3.396	3.659
30	1.310	1.697	2.042	2.457	2.750	3.385	3.646

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IV. Critical Values of the F distribution

v_2	$\alpha = 0.05$									
	v_1									
	1	2	3	4	5	6	7	8	9	10
1	161.45	199.50	215.71	224.58	230.16	233.99	236.77	238.88	240.54	241.88
2	18.51	19.00	19.16	19.25	19.30	19.33	19.35	19.37	19.38	19.40
3	10.13	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96
5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14
10	4.96	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.85
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60
15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54	2.49
17	4.45	3.59	3.20	2.96	2.81	2.70	2.61	2.55	2.49	2.45
18	4.41	3.55	3.16	2.93	2.77	2.66	2.58	2.51	2.46	2.41
19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42	2.38
20	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35
21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37	2.32
22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34	2.30
23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.37	2.32	2.27
24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30	2.25
25	4.24	3.39	2.99	2.76	2.60	2.49	2.40	2.34	2.28	2.24

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V. Critical Values of the Chi-square, χ^2 distribution

df	α					
	0.1	0.05	0.025	0.01	0.005	0.001
1	2.706	3.841	5.024	6.635	7.879	10.828
2	4.605	5.991	7.378	9.210	10.597	13.816
3	6.251	7.815	9.348	11.345	12.838	16.266
4	7.779	9.488	11.143	13.277	14.860	18.467
5	9.236	11.070	12.833	15.086	16.750	20.515
6	10.645	12.592	14.449	16.812	18.548	22.458
7	12.017	14.067	16.013	18.475	20.278	24.322
8	13.362	15.507	17.535	20.090	21.955	26.124
9	14.684	16.919	19.023	21.666	23.589	27.877
10	15.987	18.307	20.483	23.209	25.188	29.588
11	17.275	19.675	21.920	24.725	26.757	31.264
12	18.549	21.026	23.337	26.217	28.300	32.909
13	19.812	22.362	24.736	27.688	29.819	34.528
14	21.064	23.685	26.119	29.141	31.319	36.123
15	22.307	24.996	27.488	30.578	32.801	37.697
16	23.542	26.296	28.845	32.000	34.267	39.252
17	24.769	27.587	30.191	33.409	35.718	40.790
18	25.989	28.869	31.526	34.805	37.156	42.312
19	27.204	30.144	32.852	36.191	38.582	43.820
20	28.412	31.410	34.170	37.566	39.997	45.315
21	29.615	32.671	35.479	38.932	41.401	46.797
22	30.813	33.924	36.781	40.289	42.796	48.268
23	32.007	35.172	38.076	41.638	44.181	49.728
24	33.196	36.415	39.364	42.980	45.559	51.179
25	34.382	37.652	40.646	44.314	46.928	52.620
26	35.563	38.885	41.923	45.642	48.290	54.052
27	36.741	40.113	43.195	46.963	49.645	55.476
28	37.916	41.337	44.461	48.278	50.993	56.892
29	39.087	42.557	45.722	49.588	52.336	58.301
30	40.256	43.773	46.979	50.892	53.672	59.703

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VI. Critical Values of the Mann-Whitney U (Two-tailed)

		n_1												
n_2	α	3	4	5	6	7	8	9	10	11	12	13	14	15
3	0.05	0	0	0	1	1	2	2	3	3	4	4	5	5
	0.01	0	0	0	0	0	0	0	0	0	1	1	1	2
4	0.05	0	0	1	2	3	4	4	5	6	7	8	9	10
	0.01	0	0	0	0	0	1	1	2	2	3	3	4	5
5	0.05	0	1	2	3	5	6	7	8	9	11	12	13	14
	0.01	0	0	0	1	1	2	3	4	5	6	7	7	8
6	0.05	1	2	3	5	6	8	10	11	13	14	16	17	19
	0.01	0	0	1	2	3	4	5	6	7	9	10	11	12
7	0.05	1	3	5	6	8	10	12	14	16	18	20	22	24
	0.01	0	0	1	3	4	6	7	9	10	12	13	15	16
8	0.05	2	4	6	8	10	13	15	17	19	22	24	26	29
	0.01	0	1	2	4	6	7	9	11	13	15	17	18	20
9	0.05	2	4	7	10	12	15	17	20	23	26	28	31	34
	0.01	0	1	3	5	7	9	11	13	16	18	20	22	24
10	0.05	3	5	8	11	14	17	20	23	26	29	33	36	39
	0.01	0	2	4	6	9	11	13	16	18	21	24	26	29
11	0.05	3	6	9	13	16	19	23	26	30	33	37	40	44
	0.01	0	2	5	7	10	13	16	18	21	24	27	30	33
12	0.05	4	7	11	14	18	22	26	29	33	37	41	45	49
	0.01	1	3	6	9	12	15	18	21	24	27	31	24	37
13	0.05	4	8	12	16	20	24	28	33	37	41	45	50	54
	0.01	1	3	7	10	13	17	20	24	27	31	34	38	42
14	0.05	5	9	13	17	22	26	31	36	40	45	50	55	59
	0.01	1	4	7	11	15	18	22	26	30	34	38	42	46
15	0.05	5	10	14	19	24	29	34	39	44	49	54	59	64
	0.01	2	5	8	12	16	20	24	29	33	37	42	46	51

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VII. Critical Values of the Mann-Whitney U (One-tailed)

		n_1												
n_2	α	3	4	5	6	7	8	9	10	11	12	13	14	15
3	0.05	0	0	1	2	2	3	4	4	5	5	6	7	7
	0.01	0	0	0	0	0	0	1	1	1	2	2	2	3
4	0.05	0	1	2	3	4	5	6	7	8	9	10	11	12
	0.01	0	0	0	1	1	2	3	3	4	5	5	6	7
5	0.05	1	2	4	5	6	8	9	11	12	13	15	16	18
	0.01	0	0	1	2	3	4	5	6	7	8	9	10	11
6	0.05	2	3	5	7	8	10	12	14	16	17	18	21	23
	0.01	0	1	2	3	4	6	7	8	9	11	12	13	15
7	0.05	2	4	6	8	11	13	15	17	19	21	24	26	28
	0.01	0	1	3	4	6	7	9	11	12	14	16	17	19
8	0.05	3	5	8	10	13	15	18	20	23	26	28	31	33
	0.01	0	2	4	6	7	9	11	13	15	17	20	22	24
9	0.05	4	6	9	12	15	18	21	24	27	30	33	36	39
	0.01	1	3	5	7	9	11	14	16	18	21	23	26	28
10	0.05	4	7	11	14	17	20	24	27	31	34	37	41	44
	0.01	1	3	6	8	11	13	16	19	22	24	27	30	33
11	0.05	5	8	12	16	19	23	27	31	34	38	42	46	50
	0.01	1	4	7	9	12	15	18	22	25	28	31	34	37
12	0.05	5	9	13	17	21	26	30	34	38	42	47	51	55
	0.01	2	5	8	11	14	17	21	24	28	31	35	38	42
13	0.05	6	10	15	19	24	28	33	37	42	47	51	56	61
	0.01	2	5	9	12	16	20	23	27	31	35	39	43	47
14	0.05	7	11	16	21	26	31	36	41	46	51	56	61	66
	0.01	2	6	10	13	17	22	26	30	34	38	43	47	51
15	0.05	7	12	18	23	28	33	39	44	50	55	61	66	72
	0.01	3	7	11	15	19	24	28	33	37	42	47	51	56