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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(ONLINE)
SEMESTER II
SESSION 2019/2020

COURSE NAME	:	CIVIL ENGINEERING STATISTICS
COURSE CODE	:	BFC 34303
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	JULY 2020
DURATION	:	6 HOURS
INSTRUCTIONS	:	ANSWER **ALL** QUESTIONS

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

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Q1 (a) A researcher studied the tensile yield strength of steel. She performed tests on 20 steel samples and obtained a mean ($\bar{X}$) of 305 MPa with a standard deviation (s) of 16 MPa. Based on her research, she claimed that the tensile yield strength of steel generally exceeds 300 MPa.

(i) Construct a 95% confidence interval for the population mean, assuming that the population is normally distributed.

(5 marks)

(ii) Validate the researcher's claim that the tensile yield strength of steel generally exceeds 300 MPa.

(3 marks)

(b) The permeability rate (in cm/hour) for samples of three different soil mixtures P, Q and R are provided in **Table Q1(b)**. At 0.05 significance level (α), determine if there is a significant difference in the mean permeability rate for the three soil mixtures.

(17 marks)

Q2 (a) Use the definition of p-value to explain why the null hypothesis, H_o would be rejected if p-value = 0.0003.

(3 marks)

(b) A sample of 40 speedometer readings is calibrated for accuracy at 52 km/h, resulting in a sample mean and sample standard deviation of 53.87 and 1.36, respectively. The data is tested at a 0.05 significance level (α) to see if the true average reading when speed is 52 km/h is in fact something other than 52.

(i) State the null hypothesis (H_o) and alternative hypothesis (H_a).

(2 marks)

(ii) Calculate the value of the z-statistic.

(4 marks)

(iii) Determine the p-value.

(4 marks)

(iv) State the conclusion of this hypothesis test.

(1 mark)

(c) To obtain information on the corrosion resistance properties of a certain type of steel, 29 specimens are buried in soil for an extended period. The maximum penetration (in mm) is then measured for each specimen, yielding a sample mean penetration of 1.34 and a sample standard deviation of 0.12. The steels were manufactured with the specification that true average penetration be at most 1.27 mm. The data is tested at a 0.01 significance level (α) to see if the specifications have or have not been met.

(i) State the null hypothesis (H_o) and alternative hypothesis (H_a).
(2 marks)

(ii) Calculate the value of the t-statistic.
(4 marks)

(iii) Determine the p-value.
(4 marks)

(iv) State the conclusion of this hypothesis test.
(1 mark)

Q3 Five randomly selected students took a math aptitude test before they began their Statistics course. The Statistics Department obtained the data from the students (see **Table Q3**) to find a relationship between statistics grades and math aptitude score.

(a) State the dependent variable (Y) and independent variable (X).
(1 mark)

(b) Using simple linear regression, calculate the slope (b) and intercept (a).
(12 marks)

(c) Write down the equation that relates variables Y and X.
(2 marks)

(d) Determine the coefficient of correlation (r) and comment on the value.
(4 marks)

(e) Determine the coefficient of determination (R^2) and comment on the value.
(4 marks)

(f) If a student obtained an 80 on the aptitude test, determine the grade we would expect her to get in statistics.
(2 marks)

Q4 A traffic safety researcher obtained speed data of light and heavy vehicles travelling on a highway segment (refer **Table Q4**). He hypothesised that light vehicles travel at higher speeds than heavy vehicles. You are required to test his hypothesis using the Mann-Whitney U Test at a 0.05 significance level (α).

(a) State the null hypothesis (H_o) and alternative hypothesis (H_a).
(4 marks)

(b) Suggest whether to use a one-tailed test or a two-tailed test.
(2 marks)

(c) Determine the critical U value ($U_{critical}$) and specify the criteria for rejection of the null hypothesis.

(6 marks)

(d) Calculate the U test statistic ($U_{calculated}$) and decide whether to reject or accept the null hypothesis. Provide a conclusion based on the result of this test.

(13 marks)

– END OF QUESTIONS –

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Table Q1(b): Permeability rate (in cm/hour) for samples of three different soil mixtures

P	Q	R
4.6	1.8	5.9
5.9	3.5	8.6
6.2	2.1	4.4
3.9	4.6	9.5
5.5	3.3	6.1
6.9	5.6	4.6
6.5	1.5	5.8
4.3	2.7	10.2

Table Q3: Statistics grade and math aptitude score on five differences students

Statistics Grade	Math Aptitude Score
85	95
95	85
70	80
65	70
70	60

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Table Q4: Speed (in km/hour) for light and heavy vehicles on a highway segment

Light Vehicles	Heavy Vehicles
86	80
75	85
92	62
112	76
95	87
79	74
65	60
108	108
98	82
71	94
65	
127	

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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