UNIVERSITI SAINS MALAYSIA

Second Semester Examination
Academic Session 2007/2008

April 2008

BOI 109/4 – Biostatistics
[Biostatistik]

Duration: 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains THIRTEEN printed pages and TEN Appendices before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi TIGA BELAS muka surat dan SEPULUH Lampiran yang bercetak sebelum anda memulakan peperiksaan ini.]

Instructions: Answer **FIVE** (5) out of **SIX** (6) questions, in English or Bahasa Malaysia. Each question carries 20 marks.

*[**Arahan:** Jawab **LIMA** (5) daripada **ENAM** (6) soalan yang diberikan dalam Bahasa Inggeris atau Bahasa Malaysia. Tiap-tiap soalan bernilai 20 markah.]*

1. A student from School of Biological Sciences carried out a project to determine the quality of marketable mango fruits in Perlis. He sampled 100 marketable mango fruits from an orchard and found the mean weight and standard deviation were 314.7 gm and 52.8 gm, respectively. Assuming that the weights of mango fruits follow a normal distribution, if we pick up a mango fruit randomly in a market in Perlis, what is the probability in having the weight of the fruit?

   [a] Between 310 to 320 g?

   (6 marks)

   [b] More than 370 g?

   (6 marks)

   [c] You have been told that the probability in having a mango fruit with more than 300 g is 51.1%. If you randomly pick 5 mango fruits, what is the probability in having 4 mango fruits with more than 300 g each?

   (8 marks)

2. [a] The earth's temperature affects seed germination, crop survival, and many other aspects of agricultural production. The temperature can be measured by using either ground-based or infra-red sensing devices mounted on a space satellite. Ground-based devices are tedious and require many replications to obtain accurate ground temperature readings. On the other hand, infra-red waves appear to produce higher temperature readings. To determine this, the earth's temperature readings were obtained from 9 different locations by using ground-based and satellite-based temperature sensors. The readings, in degree Celsius (ºC) are as follows:

Location	Ground-based	Satellite-based
1	46.9	47.3
2	45.4	48.1
3	36.3	37.9
4	31.0	32.7
5	24.7	26.2
6	23.9	26.8
7	30.6	33.6
8	26.7	29.3
9	22.7	25.4

Do the data present sufficient evidence to indicate that the satellite-based devices give higher temperature readings than those by ground-based devices ($\alpha = 0.05$).

(15 marks)

[b] Write a short note on normal distribution curve.

(5 marks)

3. [a] The following data are volumes (μ^3) of avian erythrocytes taken from normal (diploid) and intersex (triploid) individuals. Test the hypothesis that shows the volume of intersex cells is greater than that of normal cells ($\alpha = 0.05$).

Normal	Intersex
248	280
236	291
269	277
254	292
249	298
251	274
260	260
245	274
239	240
255	290

(10 marks)

[b] A species of marine arthropod lives in seawater that contains calcium in a concentration of 32 mmole/kg of water. Thirteen of the animals were collected and the calcium concentrations in their coelomic fluids were: 28, 27, 29, 29, 30, 30, 31, 30, 33, 27, 30, 32, and 31 mmole/kg ($\alpha = 0.05$). By using an appropriate statistical test, show that the members of this species maintain a coelomic calcium concentration less than that of their environment.

(10 marks)

4. Kidney beans (*Phaseolus vulgaris* L.) were planted by farmers at the slope of Cameron Highlands which was divided into 5 blocks. It was believed that inoculating the plants with *Agrobacterium tumefaciens* could affect the oil content of the beans. A study was carried out to investigate whether inoculation of the bacteria at different stages of the plant growth could affect the production of the oil content in the kidney beans. The bacteria were inoculated at four different stages, the seedling stage (S), early bloom (EB), full bloom (FB) and seed ripening stage (R) and the uninoculated plants (C) were used as controls. After 3 months, the oil contents in the kidney beans were determined and the results were as follows:-

Block	Treatment Stages				
	S	EB	FB	R	C
1	4.4	3.3	4.4	6.3	6.4
2	5.9	1.9	4.0	6.9	7.3
3	6.0	4.9	4.5	5.9	7.7
4	4.1	3.1	3.1	7.1	6.7
5	5.2	2.4	4.9	7.0	6.6

[a] Select the most suitable experimental design for this study.

(2 marks)

[b] With the aid of a table indicate how you are going to assign the treatments (using the given symbols) in the field plots.

(3 marks)

[c] The researcher has used 5 different instruments to determine the oil contents of the kidney beans. With the aid of a table indicate how you are going to assign the treated samples for each of the instruments and which experimental design will be more suitable.

(5 marks)

[d] Analyze the results obtained and determine whether the oil contents of the kidney beans are affected by the treatment of *A. tumefaciens* at different growth stages, the slope of the highlands and the different instruments used.

(10 marks)

5. An experiment was carried out to study the effect of different relative humidities on the weight loss of flour beetle (*Tribolium confusum*). Nine batches of 25 beetles per batch were weighed, kept at different relative humidities, and weighed again after six days of starvation. Weight loss in milligrams was computed for each batch and the data collected were tabulated as below:-

Percent relative humidity	**Weight loss (mg)**
0	8.98
12.0	8.14
29.5	6.67
43.0	6.08
53.0	5.90
62.5	5.83
75.5	4.68
85.0	4.20
93.0	3.72

[a] Draw a scattergram to examine the relationship between these two variables and interpret the results.

(4 marks)

[b] What is the strength of the correlation?

(4 marks)

[c] Determine the mathematical relationship of these two variables.

(5 marks)

[d] By using the regression formula and draw the regression line on the scattergram.

(4 marks)

[e] Estimate the weight loss of the beetles if they were placed in 80% relative humidity.

(3 marks)

6. [a] It is believed that attempted suicide is not affected by the days of the week. To test this theory, you obtained reports of attempted suicides from the police Department. Results for the past two years are as follows:-

Day	Sun.	Mon.	Tues.	Wed.	Thurs	Fri.	Sat.	Total
No. of attempts	32	10	13	13	4	40	35	147

Do these results support the theory?

(10 marks)

[b] A researcher carried out a study on the dry matter digestibility of corn in sheep. Two groups of sheep were used in the study. One group of seven sheep was obtained from Sarawak while the other group of six sheep was from Selangor. The data below shows the percent dry matter digestibility obtained. Determine whether the two groups of sheep have the same digestive abilities. Assume that the population do not distribute normally.

Dry matter digestibility of sheep (%)	
Sheep from Sarawak	**Sheep from Selangor**
57.8	64.2
56.2	58.7
61.9	63.1
54.4	62.5
53.6	59.8
56.4	59.2
53.2	

(10 marks)

1. Seorang pelajar Pusat Pengajian Sains Kajihayat menjalankan projek untuk menentukan mutu buah mangga yang dipasarkan di Perlis. Dia mensampel 100 buah mangga yang sudah boleh dipasarkan di dalam sebuah kebun dan mendapati min berat dan sisihan piawai ialah 314.7 gm and 52.8 gm. Dengan anggapan bahawa berat buah mangga mengikuti taburan normal, jika kita mengambil satu buah mangga di sebuah pasar di Perlis, apakah kebarangkalian untuk menperolehi berat buah tersebut?

   [a] Antara 310 hingga 320 g?

   (6 markah)

   [b] Melebihi 370 g?

   (6 markah)

   [c] Anda diberitahu bahawa kebarangkalian memperolehi buah mangga yang beratnya melebihi 300 g ialah 51.1%. Jika anda mengambil 5 buah mangga, berapakah kebarangkalian untuk memperolehi 4 buah mangga fruits yang setiap satunya melebihi 300 g?

   (8 markah)

2. [a] Suhu bumi mempengaruhi percambahan biji benih, kemandirian tanaman, dan banyak lagi aspek yang berkaitan dengan pengeluaran pertanian. Suhu tersebut boleh diukur sama ada menggunakan peranti di bumi atau peranti penderia infra-merah yang dipasang pada satelit. Penggunaan peranti bumi lebih rumit dan memerlukan banyak ulangan untuk memperolehi bacaan suhu yang lebih tepat. Sebaliknya, gelombang infra-merah pula tampaknya menghasilkan bacaan suhu yang lebih tinggi. Untuk membuktikan pendapat ini, bacaan suhu dilakukan di 9 lokasi yang berbeza, masing-masing dengan menggunakan peranti bumi dan peranti penderia infra-merah. Bacaannya dalam darjah Celsius (ºC) adalah seperti berikut:

Lokasi	Peranti bumi	Peranti penderia infra-merah
1	46.9	47.3
2	45.4	48.1
3	36.3	37.9
4	31.0	32.7
5	24.7	26.2
6	23.9	26.8
7	30.6	33.6
8	26.7	29.3
9	22.7	25.4

Apakah data tersebut benar-benar menunjukkan bahawa peranti yang dipasang pada satelit memberikan bacaan suhu yang lebih tinggi daripada bacaan menggunakan peranti di bumi ($\alpha = 0.05$)?

(15 markah)

[b] Tulis satu nota ringkas tentang lengkok taburan normal.

(5 markah)

3. [a] Data berikut ialah isipadu (μ3) eritrosit burung yang diambil daripada individu normal (diploid) and interseks (triploid). Lakukan ujian statistik untuk menunjukkan bahawa isipadu eritrosit daripada sel burung interseks adalah lebih besar jika dibandingkan dengan isipadu daripada sel burung normal ($\alpha = 0.05$).

Normal	**Interseks**
248	280
236	291
269	277
254	292
249	298
251	274
260	260
245	274
239	240
255	290

(10 markah)

[b] Satu spesies artropod marin hidup di dalam air laut yang mengandungi kalsium pada kepekatan 32 mmol/kg air. Sebanyak 13 haiwan tersebut dikutip dan kepekatan kalsium di dalam cairan selomnya ialah: 28, 27, 29, 29, 30, 30, 31, 30, 33, 27, 30, 32, and 31 mmol/kg ($\alpha = 0.05$). Dengan menggunakan satu ujian statistik yang sesuai, tunjukkan bahawa ahli daripada spesies haiwan ini berupaya mempertahankan kepekatan kalsium berada dalam kepekatan yang rendah di dalam cairan selomnya jika dibandingkan dengan persekitarannya.

(10 markah)

4. Kacang buncis (*Phaseolus vulgaris* L.) telah ditanam oleh petani di Cameron Highlands di bahagian cerun bukit yang dibahagi kepada 5 blok. Dipercayai bahawa tumbuhan yang diinokulat dengan *Agrobacterium tumefaciens* boleh mempengaruhi kandungan minyak dalam kacang. Satu kajian dijalankan untuk menentukan sama ada inokulasi bakteria tersebut pada peringkat pertumbuhan yang berlainan boleh mempengaruhi penghasilan minyak dalam kacang buncis. Bakteria diinokulat pada empat peringkat pertumbuhan yang berbeza, peringkat biji benih (S), awal pembungaan (EB), pembugaan penuh (FB) dan peringkat matang biji benih (R) dan tumbuhan yang tidak diinokulat dengan bakteria digunakan sebagai kawalan. Selepas 3 bulan, kandungan minyak dalam kacang buncis ditentukan dan keputusan adalah seperti berikut:-

Blok	**Peringkat Olahan**				
	S	EB	FB	R	C
1	4.4	3.3	4.4	6.3	6.4
2	5.9	1.9	4.0	6.9	7.3
3	6.0	4.9	4.5	5.9	7.7
4	4.1	3.1	3.1	7.1	6.7
5	5.2	2.4	4.9	7.0	6.6

[a] Pilih rekabentuk eksperimen yang paling sesuai untuk kajian ini.

(2 markah)

[b] Dengan bantuan satu jadual tunjukkan bagaimana anda akan mengagihkan olahan (gunakan simbol yang diberi) dalam plot-plot di ladang.

(3 markah)

[c] Penyelidik tersebut telah munggunakan 5 alat yang berbeza untuk menentukan kandungan minyak dalam kacang buncis, dengan bantuan satu jadual tunjukkan bagaimana anda akan agihkan sampel-sampel yang telah diolah kepada setiap alat yang diguna dan rekabentuk eksperimen yang mana satu lebih sesuai?

(5 markah)

[d] Jalankan analisis data yang perolehi dan tentukan sama ada kandungan minyak dalam kacang dipengaruhi olahan *A. tumefaciens* pada peringkat pertumbuhan yang berlainan, kecerunana bukit dan alat yang berbeza.

(10 markah)

5. Satu kajian dijalankan untuk menentukan kesan kelembapan relatif yang berbeza terhadap kehilangan berat dalam kumbang tepung (*Tribolium confusum*). Sembilan kumpulan yang terdiri daripada 25 ekor setiap kumpulan ditimbang dan diletakkan dalam kelembapan relatif yang berbeza dan ditimbangkan semula selepas enam hari kebuluran. Kehilangan berat dalam miligram ditentukan bagi setiap kumpulan dan data yang dikutip adalah seperti berikut:-

Peratus kelembapan relatif	**Kehilangan berat (mg)**
0	8.98
12.0	8.14
29.5	6.67
43.0	6.08
53.0	5.90
62.5	5.83
75.5	4.68
85.0	4.20
93.0	3.72

[a] Lukiskan satu rajah serakan untuk menunjukkan pertalian antara dua pembolehubah dan huraikan keputusan.

(4 markah)

[b] Apakah kekuatan korelasi ini ?

(4 markah)

[c] Tentukan pertalian matematik untuk dua pembolehubah tersebut.

(5 markah)

[d] Gunakan persamaan regresi dan lukiskan garis regresi dalam rajah serakan.

(4 markah)

[e] Anggarkan kehilangan berat kumpang jika diletakkan dalam kelembapan relatif 80%.

(3 markah)

6. [a] Adalah dipercayai bahawa kebarangkalian percubaan membunuh diri tidak dipengaruhi oleh hari. Untuk menguji teori ini, anda telah mendapatkan laporan mengenai percubaan membunuh diri daripada Jabatan Polis. Keputusan bagi dua tahun yang lepas adalah seperti berikut :-

Hari	Ahad	Isnin	Selasa	Rabu	Khamis	Jumaat	Sabtu	Jumlah
Bil. pembunuh diri	32	10	13	13	4	40	35	147

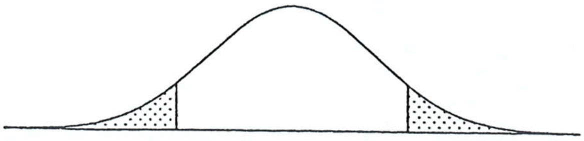
Adakah keputusan ini menyokong teori tersebut?

(10 markah)

[b] Seorang penyelidik menjalankan satu kajian terhadap penghadaman bahan kering jagung pada kambing. Dua kumpulan kambing digunakan dalam kajian ini. Satu kumpulan terdiri daripada tujuh ekor kambing yang diambil dari Sarawak manakala satu kumpulan lagi yang terdiri daripada enam ekor kambing dari Selangor. Data berikut menunjukkan peratusan penghadaman bahan kering yang diperolehi. Tentukan sama ada kedua-dua kumpulan kambing mempunyai keupayaan penghadaman yang sama. Anggap populasi tidak bertabur secara normal.

Penghadaman bahan kering (%)	
Kambing dari Sarawak	Kambing dari Selangor
57.8	64.2
56.2	58.7
61.9	63.1
54.4	62.5
53.6	59.8
56.4	59.2
53.2	

(10 markah)



1-tail 2-tail	0.25 0.50	0.10 0.20	0.05 0.10	0.025 0.05	0.01 0.02	0.005 0.010	0.0025 0.005	0.001 0.002	0.0005 0.001	1-tail 2-tail
df: 1	1.000	3.078	6.314	12.71	31.82	63.66	127.3	636.6	1273	df: 1
2	0.816	1.886	2.920	4.303	6.965	9.925	14.09	31.60	44.70	2
3	0.765	1.638	2.353	3.182	4.541	5.841	7.453	12.92	16.33	3
4	0.741	1.533	2.132	2.776	3.747	4.604	5.598	8.610	10.31	4
5	0.727	1.476	2.015	2.571	3.365	4.032	4.773	6.869	7.976	5
6	0.718	1.440	1.943	2.447	3.143	3.707	4.317	5.959	6.788	6
7	0.711	1.415	1.895	2.365	2.998	3.499	4.029	5.408	6.082	7
8	0.706	1.397	1.860	2.306	2.896	3.355	3.833	5.041	5.617	8
9	0.703	1.383	1.833	2.262	2.821	3.250	3.690	4.781	5.291	9
10	0.700	1.372	1.812	2.228	2.764	3.169	3.581	4.587	5.049	10
11	0.697	1.363	1.796	2.201	2.718	3.106	3.497	4.437	4.863	11
12	0.695	1.356	1.782	2.179	2.681	3.055	3.428	4.318	4.717	12
13	0.694	1.350	1.771	2.160	2.650	3.012	3.372	4.221	4.597	13
14	0.692	1.345	1.761	2.145	2.624	2.977	3.326	4.140	4.499	14
15	0.691	1.341	1.753	2.131	2.602	2.947	3.286	4.073	4.417	15
16	0.690	1.337	1.746	2.120	2.583	2.921	3.252	4.015	4.346	16
17	0.689	1.333	1.740	2.110	2.567	2.898	3.222	3.965	4.286	17
18	0.688	1.330	1.734	2.101	2.552	2.878	3.197	3.922	4.233	18
19	0.688	1.328	1.729	2.093	2.539	2.861	3.174	3.883	4.187	19
20	0.687	1.325	1.725	2.086	2.528	2.845	3.153	3.850	4.146	20
21	0.686	1.323	1.721	2.080	2.518	2.831	3.135	3.819	4.109	21
22	0.686	1.321	1.717	2.074	2.508	2.819	3.119	3.792	4.077	22
23	0.685	1.319	1.714	2.069	2.500	2.807	3.104	3.768	4.047	23
24	0.685	1.318	1.711	2.064	2.492	2.797	3.091	3.745	4.021	24
25	0.684	1.316	1.708	2.060	2.485	2.787	3.078	3.725	3.997	25
26	0.684	1.315	1.706	2.056	2.479	2.779	3.067	3.707	3.974	26
27	0.684	1.314	1.703	2.052	2.473	2.771	3.057	3.689	3.954	27
28	0.683	1.313	1.701	2.048	2.467	2.763	3.047	3.674	3.935	28
29	0.683	1.311	1.699	2.045	2.462	2.756	3.038	3.660	3.918	29
30	0.683	1.310	1.697	2.042	2.457	2.750	3.030	3.646	3.902	30
31	0.682	1.309	1.696	2.040	2.453	2.744	3.022	3.633	3.887	31
32	0.682	1.309	1.694	2.037	2.449	2.738	3.015	3.622	3.873	32
33	0.682	1.308	1.692	2.035	2.445	2.733	3.008	3.611	3.860	33
34	0.682	1.307	1.691	2.032	2.441	2.728	3.002	3.601	3.848	34
35	0.682	1.306	1.690	2.030	2.438	2.724	2.996	3.591	3.836	35
36	0.681	1.306	1.688	2.028	2.434	2.719	2.990	3.582	3.825	36
37	0.681	1.305	1.687	2.026	2.431	2.715	2.985	3.574	3.816	37
38	0.681	1.304	1.686	2.024	2.429	2.712	2.980	3.566	3.806	38
39	0.681	1.304	1.685	2.023	2.426	2.708	2.976	3.558	3.797	39
40	0.681	1.303	1.684	2.021	2.423	2.704	2.971	3.551	3.788	40
41	0.681	1.303	1.683	2.020	2.421	2.701	2.967	3.544	3.780	41
42	0.680	1.302	1.682	2.018	2.418	2.698	2.963	3.538	3.773	42
43	0.680	1.302	1.681	2.017	2.416	2.695	2.959	3.532	3.765	43
44	0.680	1.301	1.680	2.015	2.414	2.692	2.956	3.526	3.758	44
45	0.680	1.301	1.679	2.014	2.412	2.690	2.952	3.520	3.752	45

Tables of Distributions and Critical Values

$P(F_{\nu_1,\nu_2}) \le 0.95$

$\nu_2 \backslash \nu_1$	1	2	3	4	5	6	7	8	9	10	12	15
1	161.4	199.5	215.7	224.6	230.2	234.0	236.8	238.9	240.5	241.9	243.9	245.9
2	18.51	19.00	19.16	19.25	19.30	19.33	19.35	19.37	19.38	19.40	19.41	19.43
3	10.13	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.74	8.70
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.91	5.86
5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74	4.68	4.62
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	4.00	3.94
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64	3.57	3.51
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.28	3.22
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.07	3.01
10	4.96	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98	2.91	2.85
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.85	2.79	2.72
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75	2.69	2.62
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67	2.60	2.53
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60	2.53	2.46
15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54	2.48	2.40
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54	2.49	2.42	2.35
17	4.45	3.59	3.20	2.96	2.81	2.70	2.61	2.55	2.49	2.45	2.38	2.31
18	4.41	3.55	3.16	2.93	2.77	2.66	2.58	2.51	2.46	2.41	2.34	2.27
19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42	2.38	2.31	2.23
20	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35	2.28	2.20
21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37	2.32	2.25	2.18
22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34	2.30	2.23	2.15
23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.37	2.32	2.27	2.20	2.13
24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30	2.25	2.18	2.11
25	4.24	3.39	2.99	2.76	2.60	2.49	2.40	2.34	2.28	2.24	2.16	2.09
26	4.23	3.37	2.98	2.74	2.59	2.47	2.39	2.32	2.27	2.22	2.15	2.07
27	4.21	3.35	2.96	2.73	2.57	2.46	2.37	2.31	2.25	2.20	2.13	2.06
28	4.20	3.34	2.95	2.71	2.56	2.45	2.36	2.29	2.24	2.19	2.12	2.04
29	4.18	3.33	2.93	2.70	2.55	2.43	2.35	2.28	2.22	2.18	2.10	2.03
30	4.17	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.16	2.09	2.01
40	4.08	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.12	2.08	2.00	1.92
50	4.03	3.18	2.79	2.56	2.40	2.29	2.20	2.13	2.07	2.03	1.95	1.87
60	4.00	3.15	2.76	2.53	2.37	2.25	2.17	2.10	2.04	1.99	1.92	1.84
70	3.98	3.13	2.74	2.50	2.35	2.23	2.14	2.07	2.02	1.97	1.89	1.81
80	3.96	3.11	2.72	2.49	2.33	2.21	2.13	2.06	2.00	1.95	1.88	1.79
90	3.95	3.10	2.71	2.47	2.32	2.20	2.11	2.04	1.99	1.94	1.86	1.78
100	3.94	3.09	2.70	2.46	2.31	2.19	2.10	2.03	1.97	1.93	1.85	1.77
120	3.92	3.07	2.68	2.45	2.29	2.18	2.09	2.02	1.96	1.91	1.83	1.75
150	3.90	3.06	2.66	2.43	2.27	2.16	2.07	2.00	1.94	1.89	1.82	1.73
∞	3.84	3.00	2.60	2.37	2.21	2.10	2.01	1.94	1.88	1.83	1.75	1.67

$P(F_{\nu_1,\nu_2}) \leq 0.95$

$\nu_2 \backslash \nu_1$	18	20	24	25	30	40	50	60	90	120	∞
1	247.3	248.0	249.1	249.3	250.1	251.1	251.8	252.2	252.9	253.3	254.3
2	19.44	19.45	19.45	19.46	19.46	19.47	19.48	19.48	19.48	19.49	19.50
3	8.67	8.66	8.64	8.63	8.62	8.59	8.58	8.57	8.56	8.55	8.53
4	5.82	5.80	5.77	5.77	5.75	5.72	5.70	5.69	5.67	5.66	5.63
5	4.58	4.56	4.53	4.52	4.50	4.46	4.44	4.43	4.41	4.40	4.37
6	3.90	3.87	3.84	3.83	3.81	3.77	3.75	3.74	3.72	3.70	3.67
7	3.47	3.44	3.41	3.40	3.38	3.34	3.32	3.30	3.28	3.27	3.23
8	3.17	3.15	3.12	3.11	3.08	3.04	3.02	3.01	2.98	2.97	2.93
9	2.96	2.94	2.90	2.89	2.86	2.83	2.80	2.79	2.76	2.75	2.71
10	2.80	2.77	2.74	2.73	2.70	2.66	2.64	2.62	2.59	2.58	2.54
11	2.67	2.65	2.61	2.60	2.57	2.53	2.51	2.49	2.46	2.45	2.40
12	2.57	2.54	2.51	2.50	2.47	2.43	2.40	2.38	2.36	2.34	2.30
13	2.48	2.46	2.42	2.41	2.38	2.34	2.31	2.30	2.27	2.25	2.21
14	2.41	2.39	2.35	2.34	2.31	2.27	2.24	2.22	2.19	2.18	2.13
15	2.35	2.33	2.29	2.28	2.25	2.20	2.18	2.16	2.13	2.11	2.07
16	2.30	2.28	2.24	2.23	2.19	2.15	2.12	2.11	2.07	2.06	2.01
17	2.26	2.23	2.19	2.18	2.15	2.10	2.08	2.06	2.03	2.01	1.96
18	2.22	2.19	2.15	2.14	2.11	2.06	2.04	2.02	1.98	1.97	1.92
19	2.18	2.16	2.11	2.11	2.07	2.03	2.00	1.98	1.95	1.93	1.88
20	2.15	2.12	2.08	2.07	2.04	1.99	1.97	1.95	1.91	1.90	1.84
21	2.12	2.10	2.05	2.05	2.01	1.96	1.94	1.92	1.88	1.87	1.81
22	2.10	2.07	2.03	2.02	1.98	1.94	1.91	1.89	1.86	1.84	1.78
23	2.08	2.05	2.01	2.00	1.96	1.91	1.88	1.86	1.83	1.81	1.76
24	2.05	2.03	1.98	1.97	1.94	1.89	1.86	1.84	1.81	1.79	1.73
25	2.04	2.01	1.96	1.96	1.92	1.87	1.84	1.82	1.79	1.77	1.71
26	2.02	1.99	1.95	1.94	1.90	1.85	1.82	1.80	1.77	1.75	1.69
27	2.00	1.97	1.93	1.92	1.88	1.84	1.81	1.79	1.75	1.73	1.67
28	1.99	1.96	1.91	1.91	1.87	1.82	1.79	1.77	1.73	1.71	1.65
29	1.97	1.94	1.90	1.89	1.85	1.81	1.77	1.75	1.72	1.70	1.64
30	1.96	1.93	1.89	1.88	1.84	1.79	1.76	1.74	1.70	1.68	1.62
40	1.87	1.84	1.79	1.78	1.74	1.69	1.66	1.64	1.60	1.58	1.51
50	1.81	1.78	1.74	1.73	1.69	1.63	1.60	1.58	1.53	1.51	1.44
60	1.78	1.75	1.70	1.69	1.65	1.59	1.56	1.53	1.49	1.47	1.39
70	1.75	1.72	1.67	1.66	1.62	1.57	1.53	1.50	1.46	1.44	1.35
80	1.73	1.70	1.65	1.64	1.60	1.54	1.51	1.48	1.44	1.41	1.32
90	1.72	1.69	1.64	1.63	1.59	1.53	1.49	1.46	1.42	1.39	1.30
100	1.71	1.68	1.63	1.62	1.57	1.52	1.48	1.45	1.40	1.38	1.28
120	1.69	1.66	1.61	1.60	1.55	1.50	1.46	1.43	1.38	1.35	1.25
150	1.67	1.64	1.59	1.58	1.54	1.48	1.44	1.41	1.36	1.33	1.22
∞	1.60	1.57	1.52	1.51	1.46	1.39	1.35	1.32	1.26	1.22	1.00

Tables of Distributions and Critical Values

$P(F_{\nu_1,\nu_2}) \leq 0.99$

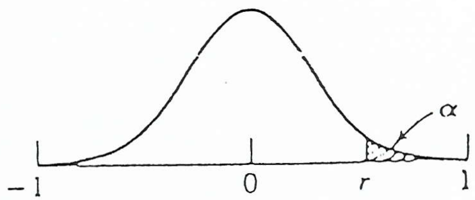
ν_2 \ ν_1	1	2	3	4	5	6	7	8	9	10	12	15
1	4052	4999	5404	5624	5764	5859	5928	5981	6022	6056	6107	6157
2	98.50	99.00	99.16	99.25	99.30	99.33	99.36	99.38	99.39	99.40	99.42	99.43
3	34.12	30.82	29.46	28.71	28.24	27.91	27.67	27.49	27.34	27.23	27.05	26.87
4	21.20	18.00	16.69	15.98	15.52	15.21	14.98	14.80	14.66	14.55	14.37	14.20
5	16.26	13.27	12.06	11.39	10.97	10.67	10.46	10.29	10.16	10.05	9.89	9.72
6	13.75	10.92	9.78	9.15	8.75	8.47	8.26	8.10	7.98	7.87	7.72	7.56
7	12.25	9.55	8.45	7.85	7.46	7.19	6.99	6.84	6.72	6.62	6.47	6.31
8	11.26	8.65	7.59	7.01	6.63	6.37	6.18	6.03	5.91	5.81	5.67	5.52
9	10.56	8.02	6.99	6.42	6.06	5.80	5.61	5.47	5.35	5.26	5.11	4.96
10	10.04	7.56	6.55	5.99	5.64	5.39	5.20	5.06	4.94	4.85	4.71	4.56
11	9.65	7.21	6.22	5.67	5.32	5.07	4.89	4.74	4.63	4.54	4.40	4.25
12	9.33	6.93	5.95	5.41	5.06	4.82	4.64	4.50	4.39	4.30	4.16	4.01
13	9.07	6.70	5.74	5.21	4.86	4.62	4.44	4.30	4.19	4.10	3.96	3.82
14	8.86	6.51	5.56	5.04	4.69	4.46	4.28	4.14	4.03	3.94	3.80	3.66
15	8.68	6.36	5.42	4.89	4.56	4.32	4.14	4.00	3.89	3.80	3.67	3.52
16	8.53	6.23	5.29	4.77	4.44	4.20	4.03	3.89	3.78	3.69	3.55	3.41
17	8.40	6.11	5.19	4.67	4.34	4.10	3.93	3.79	3.68	3.59	3.46	3.31
18	8.29	6.01	5.09	4.58	4.25	4.01	3.84	3.71	3.60	3.51	3.37	3.23
19	8.18	5.93	5.01	4.50	4.17	3.94	3.77	3.63	3.52	3.43	3.30	3.15
20	8.10	5.85	4.94	4.43	4.10	3.87	3.70	3.56	3.46	3.37	3.23	3.09
21	8.02	5.78	4.87	4.37	4.04	3.81	3.64	3.51	3.40	3.31	3.17	3.03
22	7.95	5.72	4.82	4.31	3.99	3.76	3.59	3.45	3.35	3.26	3.12	2.98
23	7.88	5.66	4.76	4.26	3.94	3.71	3.54	3.41	3.30	3.21	3.07	2.93
24	7.82	5.61	4.72	4.22	3.90	3.67	3.50	3.36	3.26	3.17	3.03	2.89
25	7.77	5.57	4.68	4.18	3.85	3.63	3.46	3.32	3.22	3.13	2.99	2.85
26	7.72	5.53	4.64	4.14	3.82	3.59	3.42	3.29	3.18	3.09	2.96	2.81
27	7.68	5.49	4.60	4.11	3.78	3.56	3.39	3.26	3.15	3.06	2.93	2.78
28	7.64	5.45	4.57	4.07	3.75	3.53	3.36	3.23	3.12	3.03	2.90	2.75
29	7.60	5.42	4.54	4.04	3.73	3.50	3.33	3.20	3.09	3.00	2.87	2.73
30	7.56	5.39	4.51	4.02	3.70	3.47	3.30	3.17	3.07	2.98	2.84	2.70
40	7.31	5.18	4.31	3.83	3.51	3.29	3.12	2.99	2.89	2.80	2.66	2.52
50	7.17	5.06	4.20	3.72	3.41	3.19	3.02	2.89	2.78	2.70	2.56	2.42
60	7.08	4.98	4.13	3.65	3.34	3.12	2.95	2.82	2.72	2.63	2.50	2.35
70	7.01	4.92	4.07	3.60	3.29	3.07	2.91	2.78	2.67	2.59	2.45	2.31
80	6.96	4.88	4.04	3.56	3.26	3.04	2.87	2.74	2.64	2.55	2.42	2.27
90	6.93	4.85	4.01	3.53	3.23	3.01	2.84	2.72	2.61	2.52	2.39	2.24
100	6.90	4.82	3.98	3.51	3.21	2.99	2.82	2.69	2.59	2.50	2.37	2.22
120	6.85	4.79	3.95	3.48	3.17	2.96	2.79	2.66	2.56	2.47	2.34	2.19
150	6.81	4.75	3.91	3.45	3.14	2.92	2.76	2.63	2.53	2.44	2.31	2.16
∞	6.64	4.61	3.78	3.32	3.02	2.80	2.64	2.51	2.41	2.32	2.18	2.04

$P(F_{\nu_1,\nu_2}) \leq 0.99$

ν_2 \ ν_1	18	20	24	25	30	40	50	60	90	120	∞
1	6191	6209	6234	6240	6260	6286	6302	6313	6331	6340	6366
2	99.44	99.45	99.46	99.46	99.47	99.48	99.48	99.48	99.49	99.49	99.50
3	26.75	26.69	26.60	26.58	26.50	26.41	26.35	26.32	26.25	26.22	26.13
4	14.08	14.02	13.93	13.91	13.84	13.75	13.69	13.65	13.59	13.56	13.46
5	9.61	9.55	9.47	9.45	9.38	9.29	9.24	9.20	9.14	9.11	9.02
6	7.45	7.40	7.31	7.30	7.23	7.14	7.09	7.06	7.00	6.97	6.88
7	6.21	6.16	6.07	6.06	5.99	5.91	5.86	5.82	5.77	5.74	5.65
8	5.41	5.36	5.28	5.26	5.20	5.12	5.07	5.03	4.97	4.95	4.86
9	4.86	4.81	4.73	4.71	4.65	4.57	4.52	4.48	4.43	4.40	4.31
10	4.46	4.41	4.33	4.31	4.25	4.17	4.12	4.08	4.03	4.00	3.91
11	4.15	4.10	4.02	4.01	3.94	3.86	3.81	3.78	3.72	3.69	3.60
12	3.91	3.86	3.78	3.76	3.70	3.62	3.57	3.54	3.48	3.45	3.36
13	3.72	3.66	3.59	3.57	3.51	3.43	3.38	3.34	3.28	3.25	3.17
14	3.56	3.51	3.43	3.41	3.35	3.27	3.22	3.18	3.12	3.09	3.00
15	3.42	3.37	3.29	3.28	3.21	3.13	3.08	3.05	2.99	2.96	2.87
16	3.31	3.26	3.18	3.16	3.10	3.02	2.97	2.93	2.87	2.84	2.75
17	3.21	3.16	3.08	3.07	3.00	2.92	2.87	2.83	2.78	2.75	2.65
18	3.13	3.08	3.00	2.98	2.92	2.84	2.78	2.75	2.69	2.66	2.57
19	3.05	3.00	2.92	2.91	2.84	2.76	2.71	2.67	2.61	2.58	2.49
20	2.99	2.94	2.86	2.84	2.78	2.69	2.64	2.61	2.55	2.52	2.42
21	2.93	2.88	2.80	2.79	2.72	2.64	2.58	2.55	2.49	2.46	2.36
22	2.88	2.83	2.75	2.73	2.67	2.58	2.53	2.50	2.43	2.40	2.31
23	2.83	2.78	2.70	2.69	2.62	2.54	2.48	2.45	2.39	2.35	2.26
24	2.79	2.74	2.66	2.64	2.58	2.49	2.44	2.40	2.34	2.31	2.21
25	2.75	2.70	2.62	2.60	2.54	2.45	2.40	2.36	2.30	2.27	2.17
26	2.72	2.66	2.58	2.57	2.50	2.42	2.36	2.33	2.26	2.23	2.13
27	2.68	2.63	2.55	2.54	2.47	2.38	2.33	2.29	2.23	2.20	2.10
28	2.65	2.60	2.52	2.51	2.44	2.35	2.30	2.26	2.20	2.17	2.06
29	2.63	2.57	2.49	2.48	2.41	2.33	2.27	2.23	2.17	2.14	2.03
30	2.60	2.55	2.47	2.45	2.39	2.30	2.25	2.21	2.14	2.11	2.01
40	2.42	2.37	2.29	2.27	2.20	2.11	2.06	2.02	1.95	1.92	1.80
50	2.32	2.27	2.18	2.17	2.10	2.01	1.95	1.91	1.84	1.80	1.68
60	2.25	2.20	2.12	2.10	2.03	1.94	1.88	1.84	1.76	1.73	1.60
70	2.20	2.15	2.07	2.05	1.98	1.89	1.83	1.78	1.71	1.67	1.54
80	2.17	2.12	2.03	2.01	1.94	1.85	1.79	1.75	1.67	1.63	1.49
90	2.14	2.09	2.00	1.99	1.92	1.82	1.76	1.72	1.64	1.60	1.46
100	2.12	2.07	1.98	1.97	1.89	1.80	1.74	1.69	1.61	1.57	1.43
120	2.09	2.03	1.95	1.93	1.86	1.76	1.70	1.66	1.58	1.53	1.38
150	2.06	2.00	1.92	1.90	1.83	1.73	1.66	1.62	1.54	1.49	1.33
∞	1.93	1.88	1.79	1.77	1.70	1.59	1.52	1.47	1.38	1.32	1.00

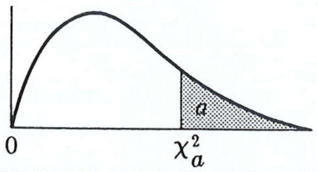
Critical values Table for Pearson correlation constant, r

For two-tail test at $\alpha = 0.05$, read at $\alpha = 0.025$



n \ α	0.05	0.025	0.010	0.005
5	0.805	0.878	0.934	0.959
6	0.729	0.811	0.882	0.917
7	0.669	0.754	0.833	0.875
8	0.621	0.707	0.789	0.834
9	0.582	0.666	0.750	0.798
10	0.549	0.632	0.716	0.765
11	0.521	0.602	0.685	0.735
12	0.497	0.576	0.658	0.708
13	0.476	0.553	0.634	0.684
14	0.457	0.532	0.612	0.661
15	0.441	0.514	0.592	0.641
16	0.426	0.497	0.574	0.623
17	0.412	0.482	0.558	0.606
18	0.400	0.468	0.542	0.590
19	0.389	0.456	0.528	0.575
20	0.378	0.444	0.516	0.561
25	0.337	0.396	0.462	0.505
30	0.306	0.361	0.423	0.463
40	0.264	0.312	0.366	0.402
50	0.235	0.279	0.328	0.361
60	0.214	0.254	0.300	0.330
80	0.185	0.220	0.260	0.286
100	0.165	0.196	0.232	0.256

Percentage Points of the Chi-Square Distribution



df	a = .995	a = .990	a = .975	a = .950	a = .900
1	0.0000393	0.0001571	0.0009821	0.0039321	0.0157908
2	0.0100251	0.0201007	0.0506356	0.102587	0.210720
3	0.0717212	0.114832	0.215795	0.351846	0.584375
4	0.206990	0.297110	0.484419	0.710721	1.063623
5	0.411740	0.554300	0.831211	1.145476	1.61031
6	0.675727	0.872085	1.237347	1.63539	2.20413
7	0.989265	1.239043	1.68987	2.16735	2.83311
8	1.344419	1.646482	2.17973	2.73264	3.48954
9	1.734926	2.087912	2.70039	3.32511	4.16816
10	2.15585	2.55821	3.24697	3.94030	4.86518
11	2.60321	3.05347	3.81575	4.57481	5.57779
12	3.07382	3.57056	4.40379	5.22603	6.30380
13	3.56503	4.10691	5.00874	5.89186	7.04150
14	4.07468	4.66043	5.62872	6.57063	7.78953
15	4.60094	5.22935	6.26214	7.26094	8.54675
16	5.14224	5.81221	6.90766	7.96164	9.31223
17	5.69724	6.40776	7.56418	8.67176	10.0852
18	6.26481	7.01491	8.23075	9.39046	10.8649
19	6.84398	7.63273	8.90655	10.1170	11.6509
20	7.43386	8.26040	9.59083	10.8508	12.4426
21	8.03366	8.89720	10.28293	11.5913	13.2396
22	8.64272	9.54249	10.9823	12.3380	14.0415
23	9.26042	10.19567	11.6885	13.0905	14.8479
24	9.88623	10.8564	12.4011	13.8484	15.6587
25	10.5197	11.5240	13.1197	14.6114	16.4734
26	11.1603	12.1981	13.8439	15.3791	17.2919
27	11.8076	12.8786	14.5733	16.1513	18.1138
28	12.4613	13.5648	15.3079	16.9279	18.9392
29	13.1211	14.2565	16.0471	17.7083	19.7677
30	13.7867	14.9535	16.7908	18.4926	20.5992
40	20.7065	22.1643	24.4331	26.5093	29.0505
50	27.9907	29.7067	32.3574	34.7642	37.6886
60	35.5346	37.4848	40.4817	43.1879	46.4589
70	43.2752	45.4418	48.7576	51.7393	55.3290
80	51.1720	53.5400	57.1532	60.3915	64.2778
90	59.1963	61.7541	65.6466	69.1260	73.2912
100	67.3276	70.0648	74.2219	77.9295	82.3581

Percentage Points of the Chi-Square Distribution

Table 3 (*continued*)

$a = .10$	$a = .05$	$a = .025$	$a = .010$	$a = .005$	*df*
2.70554	3.84146	5.02389	6.63490	7.87944	1
4.60517	5.99147	7.37776	9.21034	10.5966	2
6.25139	7.81473	9.34840	11.3449	12.8381	3
7.77944	9.48773	11.1433	13.2767	14.8602	4
9.23635	11.0705	12.8325	15.0863	16.7496	5
10.6446	12.5916	14.4494	16.8119	18.5476	6
12.0170	14.0671	16.0128	18.4753	20.2777	7
13.3616	15.5073	17.5346	20.0902	21.9550	8
14.6837	16.9190	19.0228	21.6660	23.5893	9
15.9871	18.3070	20.4831	23.2093	25.1882	10
17.2750	19.6751	21.9200	24.7250	26.7569	11
18.5494	21.0261	23.3367	26.2170	28.2995	12
19.8119	22.3621	24.7356	27.6883	29.8194	13
21.0642	23.6848	26.1190	29.1413	31.3193	14
22.3072	24.9958	27.4884	30.5779	32.8013	15
23.5418	26.2962	28.8454	31.9999	34.2672	16
24.7690	27.5871	30.1910	33.4087	35.7185	17
25.9894	28.8693	31.5264	34.8053	37.1564	18
27.2036	30.1435	32.8523	36.1908	38.5822	19
28.4120	31.4104	34.1696	37.5662	39.9968	20
29.6151	32.6705	35.4789	38.9321	41.4010	21
30.8133	33.9244	36.7807	40.2894	42.7956	22
32.0069	35.1725	38.0757	41.6384	44.1813	23
33.1963	36.4151	39.3641	42.9798	45.5585	24
34.3816	37.6525	40.6465	44.3141	46.9278	25
35.5631	38.8852	41.9232	45.6417	48.2899	26
36.7412	40.1133	43.1944	46.9630	49.6449	27
37.9159	41.3372	44.4607	48.2782	50.9933	28
39.0875	42.5569	45.7222	49.5879	52.3356	29
40.2560	43.7729	46.9792	50.8922	53.6720	30
51.8050	55.7585	59.3417	63.6907	66.7659	40
63.1671	67.5048	71.4202	76.1539	79.4900	50
74.3970	79.0819	83.2976	88.3794	91.9517	60
85.5271	90.5312	95.0231	100.425	104.215	70
96.5782	101.879	106.629	112.329	116.321	80
107.565	113.145	118.136	124.116	128.299	90
118.498	124.342	129.561	135.807	140.169	100

From " Tables of the Percentage Points of the χ^2–Distribution." *Biometrika*, Vol. 32 (1941). pp. 188–189, by Catherine M. Thompson. Reproduced by permission of the *Biometrika* Trustees.

Critical value T for Wilcoxon Mann-Whitney (2-tailed test)

n_2 = saiz sampel yang besar	p	n_1 = saiz sampel yang kecil													
		2	3	4	5	6	7	8	9	10	11	12	13	14	15
4	.05			10											
	.01			-											
5	.05		6	11	17										
	.01		-	-	15										
6	.05		7	12	18	26									
	.01		-	10	16	23									
7	.05		7	13	20	27	36								
	.01		-	10	17	24	32								
8	.05	3	8	14	21	29	38	49							
	.01	-	-	11	17	25	34	43							
9	.05	3	8	15	22	31	40	51	63						
	.01	-	6	11	18	26	35	45	56						
10	.05	4	9	15	23	32	42	53	65	78					
	.01	-	6	12	19	27	37	47	58	71					
11	.05	4	9	16	24	34	44	55	68	81	96				
	.01	-	6	12	20	28	38	49	61	74	87				
12	.05	4	10	17	26	35	46	58	71	85	99	115			
	.01	-	7	13	21	30	40	51	63	76	90	106			
13	.05	4	10	18	27	37	48	60	73	88	103	119	137		
	.01	-	7	14	22	31	41	53	65	79	93	109	125		
14	.05	4	11	19	28	38	50	63	76	91	106	123	141	160	
	.01	-	7	14	22	32	43	54	67	81	96	112	129	147	
15	.05	4	11	20	29	40	52	65	79	94	110	127	145	164	185
	.01	-	8	15	23	33	44	56	70	84	99	115	133	151	171
16	.05	4	12	21	31	42	54	67	82	97	114	131	150	169	
	.01	-	8	15	24	34	46	58	72	86	102	119	137	155	
17	.05	5	12	21	32	43	56	70	84	100	117	135	154		
	.01	-	8	16	25	36	47	60	74	89	105	122	140		
18	.05	5	13	22	33	45	58	72	87	103	121	139			
	.01	-	8	16	26	37	49	62	76	92	108	125			
19	.05	5	13	23	34	46	60	74	90	107	124				
	.01	3	9	17	27	38	50	64	78	94	111				
20	.05	5	14	24	35	48	62	77	93	110					
	.01	3	9	18	28	39	52	66	81	97					
21	.05	6	14	25	37	50	64	79	95						
	.01	3	9	18	29	40	53	68	83						
22	.05	6	15	26	38	51	66	82							
	.01	3	10	19	29	42	55	70							
23	.05	6	15	27	39	53	60								
	.01	3	10	19	30	43	57								
24	.05	6	16	28	40	55									
	.01	3	10	20	31	44									
25	.05	6	16	28	42										
	.01	3	11	20	32										
26	.05	7	17	29											
	.01	3	11	21											
27	.05	7	17												
	.01	4	11												
28	.05	7													
	.01	4													

Sumber: Colin White. The use of ranks in a test of significance for comparing two treatments. 1950. Biometrics.

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