UNIVERSITI SAINS MALAYSIA

Final Examination
2015/2016 Academic Session

May/June 2016

JIM 420 – Design and Analysis of Experiments
[Rekabentuk dan Analisis Ujikaji]

Duration : 3 hours
[*Masa: 3 jam*]

Please ensure that this examination paper contains **FOURTEEN** printed pages before you begin the examination.

Answer **ALL** questions. You may answer either in Bahasa Malaysia or in English.

Read the instructions carefully before answering.

Each question is worth 100 marks.

In the event of any discrepancies, the English version shall be used.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **EMPAT BELAS** muka surat yang bercetak sebelum anda memulakan peperiksaan ini.*

*Jawab **SEMUA** soalan. Anda dibenarkan menjawab sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.*

Baca arahan dengan teliti sebelum anda menjawab soalan.

Setiap soalan diperuntukkan 100 markah.

Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

1. A completely randomized experiment is conducted to investigate the effect of tube conductivity of four different types of coating. The following conductivity data are obtained:

Coating Type	Conductivity			
1	143	141	150	146
2	152	149	137	143
3	134	136	132	127
4	129	127	132	129

SS_{Total} =1080.94

(a) Is there a difference in conductivity due to coating type? Use the *p*-value method and let $\alpha = 0.05$.

(35 marks)

(b) Estimate the overall mean and the treatment effects of coating type 1.

(15 marks)

(c) Compute a 99% interval estimate of the mean difference between coating types 1 and 4.

(15 marks)

(d) Test all pairs of means using the Fisher LSD method with $\alpha = 0.05$.

(25 marks)

(e) What are your recommendations to the manufacturer if we wish to minimize conductivity?

(10 marks)

2. Five randomly selected batteries from each of the 3 brands, A, B and C, are tested with the following results:

Weeks of Life		
Brand A	Brand B	Brand C
100	76	108
96	80	100
92	75	96
96	84	98
92	82	100

SS_{Total} =1383.33

(a) Write down the effects model for this experiment and their assumptions.
(5 marks)

(b) What are the relevant hypothesis of interest based on (a)?
(5 marks)

(c) Test the hypothesis in (b). Use $\alpha = 0.05$.
(35 marks)

(d) If the manufacturer will replace without charge any battery of Brand C that fails in less than 85 weeks, what percentage would the company expect to replace? Assume MS_E is an estimate of σ^2 .
(25 marks)

(e) If we wish to detect a maximum difference in mean battery life of 10 hours with a probability of at least 0.90, what sample size should be used? Assume MS_E is an estimate of σ^2 .
(30 marks)

3. A test is run to determine the effects of four factors, A, B, C and D, on cracks. Two replicated of a 2^4 design are run, and the length of crack (in μm) is measured. The data are shown below:

A	B	C	D	Treatment Combination	Replicate I	Replicate II
-	-	-	-	(1)	7.037	6.376
+	-	-	-	a	14.707	15.219
-	+	-	-	b	11.635	12.089
+	+	-	-	ab	17.273	17.815
-	-	+	-	c	10.403	10.151
+	-	+	-	ac	4.368	4.098
-	+	+	-	bc	9.360	9.253
+	+	+	-	abc	13.440	12.923
-	-	-	+	d	8.561	8.951
+	-	-	+	ad	16.867	17.052
-	+	-	+	bd	13.876	13.658
+	+	-	+	abd	19.824	19.639
-	-	+	+	cd	11.846	12.337
+	-	+	+	acd	6.125	5.904
-	+	+	+	bcd	11.190	10.935
+	+	+	+	abcd	15.653	15.053

(a) Estimate the factor effect of A.

(20 marks)

(b) With your answer to part (a) and the table given below, use the half normal plot of effects to determine factors that should be included in your model.

Term	Effect	SS	% Contribution
A	(a)	72.9089	12.7408
B	3.97588	126.461	22.099
C	–3.59625	103.464	8.0804
D	1.95775	30.6623	5.35823
AB	1.93412	29.9267	5.22969
AC	–4.00775	128.496	22.4548
AD	0.0765	0.046818	0.00818145
BC	0.096	0.073728	0.012884
BD	0.04725	0.0178605	0.00312112
CD	–0.076875	0.0472781	0.00826185
ABC	3.1375	78.7512	13.7618
ABD	0.098	0.076832	0.0134264
ACD	0.019125	0.00292613	0.00051134
BCD	0.035625	0.0101531	0.00177426
ABCD	0.014125	0.00159613	0.000278923

(30 marks)

(c) Conduct an analysis of variance to confirm your findings in (b). Use α=0.05.

(30 marks)

(d) Write down a regression model that can be used to predict crack length as a function of the significant main effects and interactions you have identified in part (c).

(20 marks)

4. (a) An experiment was performed to investigate the capability of a measuring system. Four parts were randomly selected and each part was measured three times. Data for the experiment is given below.

Part No.	Measurements		
1	2.76	5.67	4.49
2	1.43	1.70	2.19
3	2.34	1.97	1.47
4	0.94	1.36	1.65

(i) Estimate the variability due to parts.

(30 marks)

(ii) Estimate the random error component.

(6 marks)

(iii) Estimate the total variability in the measurements.

(8 marks)

(iv) How much of the total variability in the measurements is due to the difference in the parts used?

(8 marks)

(v) To what level could the variability in the measurements be reduced, if the variability in the parts could be eliminated? Is this a significant reduction?

(8 marks)

(b) A replicated fractional factorial is used to investigate the effects of five factors, A, B, C, D and E, on the response variable Y. The data are shown below.

A	*B*	*C*	*D*	*E*	Response (Y)		
-	-	-	-	-	7.78	7.78	7.81
+	-	-	+	-	8.15	8.18	7.88
-	+	-	+	-	7.50	7.56	7.50
+	+	-	-	-	7.59	7.56	7.75
-	-	+	+	-	7.54	8.00	7.88
+	-	+	-	-	7.69	8.09	8.06
-	+	+	-	-	7.56	7.52	7.44
+	+	+	+	-	7.56	7.81	7.69
-	-	-	-	+	7.50	7.25	7.12
+	-	-	+	+	7.88	7.88	7.44
-	+	-	+	+	7.50	7.56	7.50
+	+	-	-	+	7.63	7.75	7.56
-	-	+	+	+	7.32	7.44	7.44
+	-	+	-	+	7.56	7.69	7.62
-	+	+	-	+	7.18	7.23	7.25
+	+	+	+	+	7.81	7.50	7.59

Write out the alias structure for this design. What is the resolution of this design?

(40 marks)

1. Satu eksperimen rawak lengkap dijalankan untuk mengkaji kesan konduktiviti terhadap empat jenis salutan. Data konduktiviti berikut diperolehi:

Jenis Salutan	Konduktiviti			
1	143	141	150	146
2	152	149	137	143
3	134	136	132	127
4	129	127	132	129

SS_{Total} =1080.94

(a) Adakah terdapat perbezaan dalam konduktiviti yang disebabkan oleh jenis salutan? Gunakan kaedah nilai-*p* dan andai $\alpha = 0.05$.

(35 markah)

(b) Anggarkan min keseluruhan dan kesan rawatan salutan jenis 1.

(15 markah)

(c) Kira anggaran selang 99% bagi perbezaan min di antara jenis salutan 1 dan 4.

(15 markah)

(d) Uji semua pasangan min dengan menggunakan kaedah Fisher LSD dengan $\alpha = 0.05$.

(25 markah)

(e) Apakah cadangan anda kepada pengilang jika kita ingin mengurangkan konduktiviti?

(10 markah)

2. Lima bateri yang dipilih secara rawak daripada setiap satu 3 jenama, A, B dan C, diuji dengan keputusan berikut:

Hayat dalam minggu		
Jenama A	Jenama B	Jenama C
100	76	108
96	80	100
92	75	96
96	84	98
92	82	100

SS_{Total} =1383.33

(a) Tuliskan model kesan untuk eksperimen ini dan andaian model.
(5 markah)

(b) Apakah hipotesis yang relevan berdasarkan (a).
(5 markah)

(c) Uji hipotesis dalam (b). Guna $\alpha = 0.05$.
(35 markah)

(d) Jika pengilang akan menggantikan tanpa bayaran mana-mana bateri Jenama C yang gagal dalam masa kurang daripada 85 minggu, berapa peratuskah syarikat itu dijangka akan menggantikan bateri yang gagal tersebut? Andaikan MS_E satu anggaran bagi σ^2.
(25 markah)

(e) Jika kita ingin mengesan perbezaan maksimum 10 jam dalam min hayat bateri dengan kebarangkalian sekurang-kurangnya 0.90, apakah saiz sampel yang perlu digunakan? Andaikan MS_E adalah satu anggaran bagi σ^2.
(30 markah)

3. Satu ujian dijalankan untuk menentukan kesan daripada empat faktor, A, B, C dan D, pada retak. Dua replikasi rekabentuk 2^4 dijalankan, dan panjang retak (dalam μm) diukur. Data ditunjukkan di bawah:

A	B	C	D	Kombinasi Rawatan	Replikasi I	Replikasi II
-	-	-	-	(1)	7.037	6.376
+	-	-	-	a	14.707	15.219
-	+	-	-	b	11.635	12.089
+	+	-	-	ab	17.273	17.815
-	-	+	-	c	10.403	10.151
+	-	+	-	ac	4.368	4.098
-	+	+	-	bc	9.360	9.253
+	+	+	-	abc	13.440	12.923
-	-	-	+	d	8.561	8.951
+	-	-	+	ad	16.867	17.052
-	+	-	+	bd	13.876	13.658
+	+	-	+	abd	19.824	19.639
-	-	+	+	cd	11.846	12.337
+	-	+	+	acd	6.125	5.904
-	+	+	+	bcd	11.190	10.935
+	+	+	+	abcd	15.653	15.053

(a) Anggar kesan faktor A.

(20 markah)

(b) Dengan jawapan anda dalam (a) dan jadual yang diberi di bawah, gunakan plot normal separuh bagi kesan untuk menentukan faktor-faktor yang perlu dimasukkan dalam model anda.

Sebutan	Kesan	SS	% Sumbangan
A	(a)	72.9089	12.7408
B	3.97588	126.461	22.099
C	–3.59625	103.464	8.0804
D	1.95775	30.6623	5.35823
AB	1.93412	29.9267	5.22969
AC	–4.00775	128.496	22.4548
AD	0.0765	0.046818	0.00818145
BC	0.096	0.073728	0.012884
BD	0.04725	0.0178605	0.00312112
CD	–0.076875	0.0472781	0.00826185
ABC	3.1375	78.7512	13.7618
ABD	0.098	0.076832	0.0134264
ACD	0.019125	0.00292613	0.00051134
BCD	0.035625	0.0101531	0.00177426
ABCD	0.014125	0.00159613	0.000278923

(30 markah)

(c) Jalankan analisis varians untuk mengesahkan penemuan anda dalam (b). Guna α=0.05.

(30 markah)

(d) Tulis satu model regresi yang boleh digunakan untuk meramalkan panjang retak sebagai fungsi kesan utama dan interaksi yang signifikan yang anda telah kenal pasti dalam bahagian (c).

(20 markah)

4. (a) Satu eksperimen telah dijalankan untuk menyiasat keupayaan suatu sistem ukuran. Empat bahagian telah dipilih secara rawak dan setiap bahagian diukur tiga kali. Data untuk eksperimen diberikan di bawah.

No. Alat	Ukuran		
1	2.76	5.67	4.49
2	1.43	1.70	2.19
3	2.34	1.97	1.47
4	0.94	1.36	1.65

(i) Anggarkan variasi yang berpunca daripada alat-alat.
(30 markah)

(ii) Anggarkan komponen rawak ralat.
(6 markah)

(iii) Anggarkan jumlah variasi dalam ukuran.
(8 markah)

(iv) Berapa banyak daripada jumlah variasi ukuran yang disebabkan oleh perbezaan dalam alat-alat yang digunakan?
(8 markah)

(v) Pada tahap mana variasi dalam ukuran boleh dikurangkan, jika variasi dalam alat-alat boleh dihapuskan? Adakah ini satu pengurangan yang signifikan?
(8 markah)

(b) Satu replikasi faktorial pecahan digunakan untuk menyiasat kesan lima faktor, A, B, C, D dan E, pada pembolehubah respon Y. Data ditunjukkan di bawah.

A	*B*	*C*	*D*	*E*	Respon (Y)		
-	-	-	-	-	7.78	7.78	7.81
+	-	-	+	-	8.15	8.18	7.88
-	+	-	+	-	7.50	7.56	7.50
+	+	-	-	-	7.59	7.56	7.75
-	-	+	+	-	7.54	8.00	7.88
+	-	+	-	-	7.69	8.09	8.06
-	+	+	-	-	7.56	7.52	7.44
+	+	+	+	-	7.56	7.81	7.69
-	-	-	-	+	7.50	7.25	7.12
+	-	-	+	+	7.88	7.88	7.44
-	+	-	+	+	7.50	7.56	7.50
+	+	-	-	+	7.63	7.75	7.56
-	-	+	+	+	7.32	7.44	7.44
+	-	+	-	+	7.56	7.69	7.62
-	+	+	-	+	7.18	7.23	7.25
+	+	+	+	+	7.81	7.50	7.59

Tulis struktur alias untuk rekabentuk ini. Apakah resolusi rekabentuk ini?
(40 markah)

LAMPIRAN

Formula

$$SS_T = \sum_{i=1}^{a}\sum_{j=1}^{n} y_{ij}^2 - \frac{y_{..}^2}{N}$$

$$SS_{\text{Treatments}} = \frac{1}{n}\sum_{i=1}^{a} y_{i.}^2 - \frac{y_{..}^2}{N}$$

$$LSD = t_{\alpha/2,N-a}\sqrt{MS_E\left(\frac{1}{n_i}+\frac{1}{n_j}\right)}$$

$$LSD = t_{\alpha/2,N-a}\sqrt{\frac{2MS_E}{n}}$$

$$\Phi^2 = \frac{nD^2}{2a\sigma^2}$$

$$\text{Contrast}_{AB\cdots k} = (a \pm 1)(b \pm 1)\cdots(k \pm 1)$$

$$AB\cdots K = \frac{2}{n2^k}\left(\text{Contrast}_{AB\cdots K}\right)$$

$$SS_{AB\cdots K} = \frac{1}{n2^k}\left(\text{Contrast}_{AB\cdots K}\right)^2$$

IV Percentage Points of the F Distribution (*Continued*)

$F_{0.05,\nu_1,\nu_2}$

ν_2 \ ν_1 (Degrees of Freedom for the Numerator (ν_1))	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	∞
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	248.0	249.1	250.1	251.1	252.2	253.3	254.3
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	19.45	19.45	19.46	19.47	19.48	19.49	19.50
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	8.66	8.64	8.62	8.59	8.57	8.55	8.53
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	5.80	5.77	5.75	5.72	5.69	5.66	5.63
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	4.56	4.53	4.50	4.46	4.43	4.40	4.36
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	3.87	3.84	3.81	3.77	3.74	3.70	3.67
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	3.44	3.41	3.38	3.34	3.30	3.27	3.23
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	3.15	3.12	3.08	3.04	3.01	2.97	2.93
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	2.94	2.90	2.86	2.83	2.79	2.75	2.71
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	2.77	2.74	2.70	2.66	2.62	2.58	2.54
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	2.65	2.61	2.57	2.53	2.49	2.45	2.40
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	2.54	2.51	2.47	2.43	2.38	2.34	2.30
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	2.46	2.42	2.38	2.34	2.30	2.25	2.21
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	2.39	2.35	2.31	2.27	2.22	2.18	2.13
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	2.33	2.29	2.25	2.20	2.16	2.11	2.07
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	2.28	2.24	2.19	2.15	2.11	2.06	2.01
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	2.23	2.19	2.15	2.10	2.06	2.01	1.96
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	2.19	2.15	2.11	2.06	2.02	1.97	1.92
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	2.16	2.11	2.07	2.03	1.98	1.93	1.88
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	2.12	2.08	2.04	1.99	1.95	1.90	1.84
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	2.10	2.05	2.01	1.96	1.92	1.87	1.81
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	2.07	2.03	1.98	1.94	1.89	1.84	1.78
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	2.05	2.01	1.96	1.91	1.86	1.81	1.76
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	2.03	1.98	1.94	1.89	1.84	1.79	1.73
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	2.01	1.96	1.92	1.87	1.82	1.77	1.71
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	1.99	1.95	1.90	1.85	1.80	1.75	1.69
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	1.97	1.93	1.88	1.84	1.79	1.73	1.67
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	1.96	1.91	1.87	1.82	1.77	1.71	1.65
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	1.94	1.90	1.85	1.81	1.75	1.70	1.64
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	1.93	1.89	1.84	1.79	1.74	1.68	1.62
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	1.84	1.79	1.74	1.69	1.64	1.58	1.51
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	1.75	1.70	1.65	1.59	1.53	1.47	1.39
120	3.92	3.07	2.68	2.45	2.29	2.17	2.09	2.02	1.96	1.91	1.83	1.75	1.66	1.61	1.55	1.55	1.43	1.35	1.25
∞	3.84	3.00	2.60	2.37	2.21	2.10	2.01	1.94	1.88	1.83	1.75	1.67	1.57	1.52	1.46	1.39	1.32	1.22	1.00

Degrees of Freedom for the Denominator (ν_2)

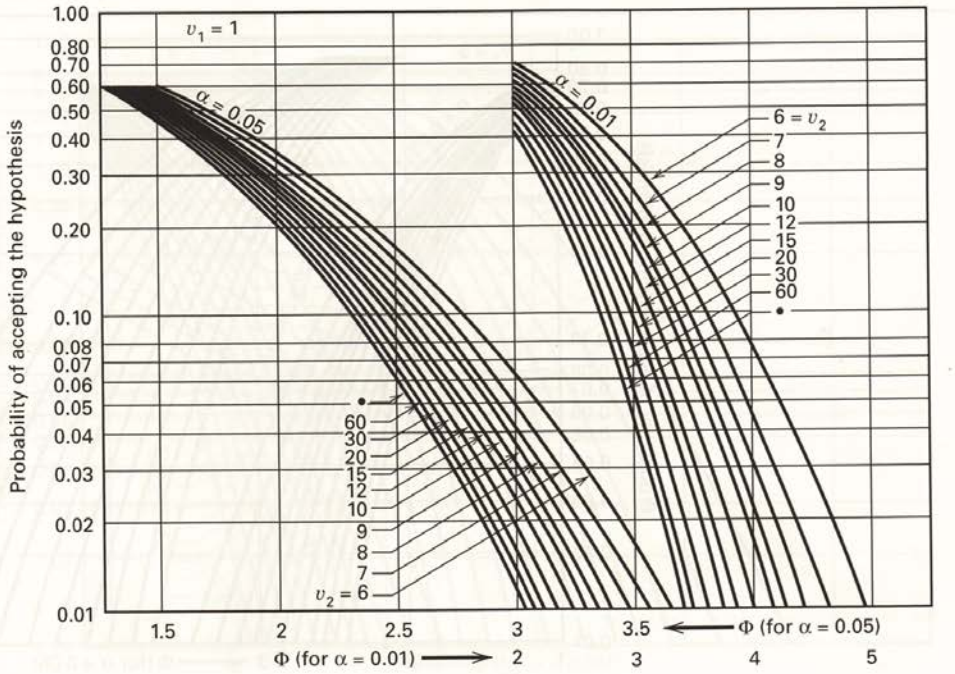
II Percentage Points of the t Distribution[a]

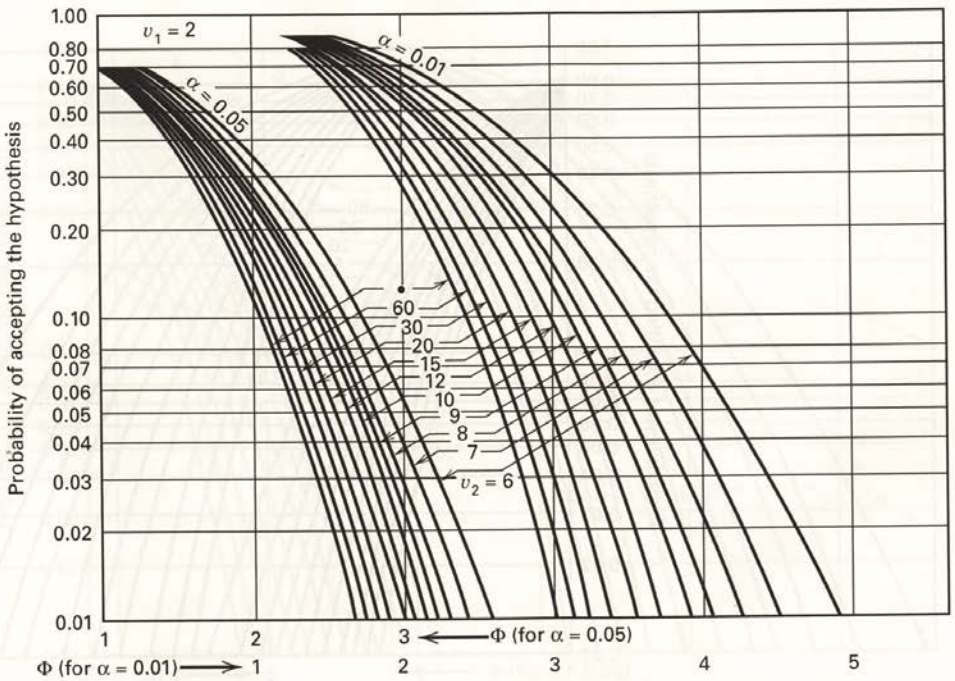
ν \ α	0.40	0.25	0.10	0.05	0.025	0.01	0.005	0.0025	0.001	0.0005
1	0.325	1.000	3.078	6.314	12.706	31.821	63.657	127.32	318.31	636.62
2	0.289	0.816	1.886	2.920	4.303	6.965	9.925	14.089	23.326	31.598
3	0.277	0.765	1.638	2.353	3.182	4.541	5.841	7.453	10.213	12.924
4	0.271	0.741	1.533	2.132	2.776	3.747	4.604	5.598	7.173	8.610
5	0.267	0.727	1.476	2.015	2.571	3.365	4.032	4.773	5.893	6.869
6	0.265	0.727	1.440	1.943	2.447	3.143	3.707	4.317	5.208	5.959
7	0.263	0.711	1.415	1.895	2.365	2.998	3.499	4.019	4.785	5.408
8	0.262	0.706	1.397	1.860	2.306	2.896	3.355	3.833	4.501	5.041
9	0.261	0.703	1.383	1.833	2.262	2.821	3.250	3.690	4.297	4.781
10	0.260	0.700	1.372	1.812	2.228	2.764	3.169	3.581	4.144	4.587
11	0.260	0.697	1.363	1.796	2.201	2.718	3.106	3.497	4.025	4.437
12	0.259	0.695	1.356	1.782	2.179	2.681	3.055	3.428	3.930	4.318
13	0.259	0.694	1.350	1.771	2.160	2.650	3.012	3.372	3.852	4.221
14	0.258	0.692	1.345	1.761	2.145	2.624	2.977	3.326	3.787	4.140
15	0.258	0.691	1.341	1.753	2.131	2.602	2.947	3.286	3.733	4.073
16	0.258	0.690	1.337	1.746	2.120	2.583	2.921	3.252	3.686	4.015
17	0.257	0.689	1.333	1.740	2.110	2.567	2.898	3.222	3.646	3.965
18	0.257	0.688	1.330	1.734	2.101	2.552	2.878	3.197	3.610	3.922
19	0.257	0.688	1.328	1.729	2.093	2.539	2.861	3.174	3.579	3.883
20	0.257	0.687	1.325	1.725	2.086	2.528	2.845	3.153	3.552	3.850
21	0.257	0.686	1.323	1.721	2.080	2.518	2.831	3.135	3.527	3.819
22	0.256	0.686	1.321	1.717	2.074	2.508	2.819	3.119	3.505	3.792
23	0.256	0.685	1.319	1.714	2.069	2.500	2.807	3.104	3.485	3.767
24	0.256	0.685	1.318	1.711	2.064	2.492	2.797	3.091	3.467	3.745
25	0.256	0.684	1.316	1.708	2.060	2.485	2.787	3.078	3.450	3.725
26	0.256	0.684	1.315	1.706	2.056	2.479	2.779	3.067	3.435	3.707
27	0.256	0.684	1.314	1.703	2.052	2.473	2.771	3.057	3.421	3.690
28	0.256	0.683	1.313	1.701	2.048	2.467	2.763	3.047	3.408	3.674
29	0.256	0.683	1.311	1.699	2.045	2.462	2.756	3.038	3.396	3.659
30	0.256	0.683	1.310	1.697	2.042	2.457	2.750	3.030	3.385	3.646
40	0.255	0.681	1.303	1.684	2.021	2.423	2.704	2.971	3.307	3.551
60	0.254	0.679	1.296	1.671	2.000	2.390	2.660	2.915	3.232	3.460
120	0.254	0.677	1.289	1.658	1.980	2.358	2.617	2.860	3.160	3.373
∞	0.253	0.674	1.282	1.645	1.960	2.326	2.576	2.807	3.090	3.291

ν = Degrees of freedom.

[a]Adapted with permission from *Biometrika Tables for Statisticians*, Vol. 1, 3rd edition, by E. S. Pearson and H. O. Hartley, Cambridge University Press, Cambridge, 1966.

V Operating Characteristic Curves for the Fixed Effects Model Analysis of Variance[a]





v_1 = Numerator degrees of freedom, v_2 = Denominator degrees of freedom

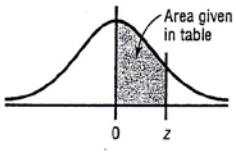
[a]Adapted with permission from *Biometrika Tables for Statisticians*, Vol. 2, by E. S. Pearson and H. O. Hartley, Cambridge University Press, Cambridge, 1972.

Table E The Standard Normal Distribution

z	*.00*	*.01*	*.02*	*.03*	*.04*	*.05*	*.06*	*.07*	*.08*	*.09*
0.0	.0000	.0040	.0080	.0120	.0160	.0199	.0239	.0279	.0319	.0359
0.1	.0398	.0438	.0478	.0517	.0557	.0596	.0636	.0675	.0714	.0753
0.2	.0793	.0832	.0871	.0910	.0948	.0987	.1026	.1064	.1103	.1141
0.3	.1179	.1217	.1255	.1293	.1331	.1368	.1406	.1443	.1480	.1517
0.4	.1554	.1591	.1628	.1664	.1700	.1736	.1772	.1808	.1844	.1879
0.5	.1915	.1950	.1985	.2019	.2054	.2088	.2123	.2157	.2190	.2224
0.6	.2257	.2291	.2324	.2357	.2389	.2422	.2454	.2486	.2517	.2549
0.7	.2580	.2611	.2642	.2673	.2704	.2734	.2764	.2794	.2823	.2852
0.8	.2881	.2910	.2939	.2967	.2995	.3023	.3051	.3078	.3106	.3133
0.9	.3159	.3186	.3212	.3238	.3264	.3289	.3315	.3340	.3365	.3389
1.0	.3413	.3438	.3461	.3485	.3508	.3531	.3554	.3577	.3599	.3621
1.1	.3643	.3665	.3686	.3708	.3729	.3749	.3770	.3790	.3810	.3830
1.2	.3849	.3869	.3888	.3907	.3925	.3944	.3962	.3980	.3997	.4015
1.3	.4032	.4049	.4066	.4082	.4099	.4115	.4131	.4147	.4162	.4177
1.4	.4192	.4207	.4222	.4236	.4251	.4265	.4279	.4292	.4306	.4319
1.5	.4332	.4345	.4357	.4370	.4382	.4394	.4406	.4418	.4429	.4441
1.6	.4452	.4463	.4474	.4484	.4495	.4505	.4515	.4525	.4535	.4545
1.7	.4554	.4564	.4573	.4582	.4591	.4599	.4608	.4616	.4625	.4633
1.8	.4641	.4649	.4656	.4664	.4671	.4678	.4686	.4693	.4699	.4706
1.9	.4713	.4719	.4726	.4732	.4738	.4744	.4750	.4756	.4761	.4767
2.0	.4772	.4778	.4783	.4788	.4793	.4798	.4803	.4808	.4812	.4817
2.1	.4821	.4826	.4830	.4834	.4838	.4842	.4846	.4850	.4854	.4857
2.2	.4861	.4864	.4868	.4871	.4875	.4878	.4881	.4884	.4887	.4890
2.3	.4893	.4896	.4898	.4901	.4904	.4906	.4909	.4911	.4913	.4916
2.4	.4918	.4920	.4922	.4925	.4927	.4929	.4931	.4932	.4934	.4936
2.5	.4938	.4940	.4941	.4943	.4945	.4946	.4948	.4949	.4951	.4952
2.6	.4953	.4955	.4956	.4957	.4959	.4960	.4961	.4962	.4963	.4964
2.7	.4965	.4966	.4967	.4968	.4969	.4970	.4971	.4972	.4973	.4974
2.8	.4974	.4975	.4976	.4977	.4977	.4978	.4979	.4979	.4980	.4981
2.9	.4981	.4982	.4982	.4983	.4984	.4984	.4985	.4985	.4986	.4986
3.0	.4987	.4987	.4987	.4988	.4988	.4989	.4989	.4989	.4990	.4990

Note: Use 0.4999 for *z* values above 3.09.

Source: Frederick Mosteller and Robert E. K. Rourke, *Sturdy Statistics*, Table A–1 (Reading, Mass.: Addison-Wesley, 1973). Reprinted with permission of the copyright owners.



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