Surname		Other Names	
Centre Number			Candidate Number				
Candidate Signature									

Leave blank

General Certificate of Education
June 2003
Advanced Level Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

ENVIRONMENTAL SCIENCE ESC7
Unit 7 Alternative to Practical Investigation

Wednesday 25 June 2003 1.30 pm to 3.30 pm

No additional materials are required.
You may use a calculator.

Time allowed: 2 hours

Instructions

- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions in the spaces provided.
- Do all rough work in this book. Cross through any work you do not want marked.

Information

- The maximum mark for this paper is 75.
- Mark allocations are shown in brackets.
- You are expected to use a calculator where appropriate.
- You will be assessed on your ability to use an appropriate form and style of writing, to organise relevant information clearly and coherently, and to use specialist vocabulary, where appropriate.
- The degree of legibility of your handwriting and the level of accuracy of your spelling, punctuation and grammar will also be taken into account.
- This unit assesses your understanding of the relationship between the different aspects of Environmental Science.

For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
5			
Total (Column 1)			
Total (Column 2)			
TOTAL			
Examiner's Initials			

THE INVESTIGATION

The effect of agricultural practices on species diversity, soils and crop growth.

AIM

This investigation focuses on the effect of the use of inorganic fertilisers compared with organic fertilisers and times of crop planting on:

- plant diversity;
- crop growth;
- soil pH and organic content;
- populations of farmland birds.

BACKGROUND INFORMATION

Monitoring of wild bird populations over the last 30 years has shown a great decline in the populations of species that depend on farmland habitats. Many birds such as the skylark *(Alauda arvensis)*, linnet *(Acanthis cannabina)* and corn bunting *(Emberiza calandra)* are no longer found in areas where they were once common. Similarly the populations of many insects and other invertebrates, mammals and plants are also declining, both in numbers and diversity. This is particularly true of invertebrate and plant species associated with arable crops. A study by the Game Conservancy Trust showed a decline of 4.2% in cereal invertebrates. Nearly 50 % of wild bee species are also under threat.

Plants which were once common in meadows, such as the corncockle (*Agrostemma githago)*, are no longer found and it is estimated that more plant species have gone extinct from arable farmland than from any other habitat in the UK. The plant composition of farmland has also changed with annual grasses becoming more common as they are more competitive in high nutrient status soils. This has led to the decline of types of broadleaved weeds which is especially important as many birds feed on broadleaved weed seeds and the insects associated with these plants.

Source: RSPB website, *www.rspb.org.uk*

A mixed (arable and pastoral) farm in Eastern England was surveyed by a student as part of an ongoing investigation carried out by a local birdwatching group.

A chalk stream runs through the farm and the unimproved meadows adjacent to this are used as grazing for both a dairy herd and for sheep. It is on relatively flat, fertile, agricultural land and the climate is suitable to enable the growth of a variety of arable crops such as barley, wheat and turnips. The farmer is considering converting to organic farming methods and has been conducting trials in some of his fields by using artificial inorganic fertilisers on some fields and organic farmyard manure on others for a period of five years. Fields to the west of the chalk stream (fields **A**, **B**, and **C**) have been treated with standard inorganic fertiliser at a rate of 1200 kilograms per hectare, whilst the fields to the east of the chalk stream (**D**, **E**, and **F**) received organic farmyard manure at a rate of 15 tonnes per hectare.

(The sketch map on page 4 shows the location of the crop fields, pasture and chalk stream together with hedgerows and headlands in the study area.)

The cereals sown include both winter and spring varieties of wheat and barley. For winter varieties, a period of exposure to cold temperatures is necessary before the plants can flower and produce the grain that is harvested. Winter cereals, therefore, are sown in the autumn prior to the cold temperatures of winter. For spring cereals there is no such requirement for cold temperatures. They are sown in spring and flower in response to the stimulus of increasing day length. Winter and spring cereals are both harvested at the same time.

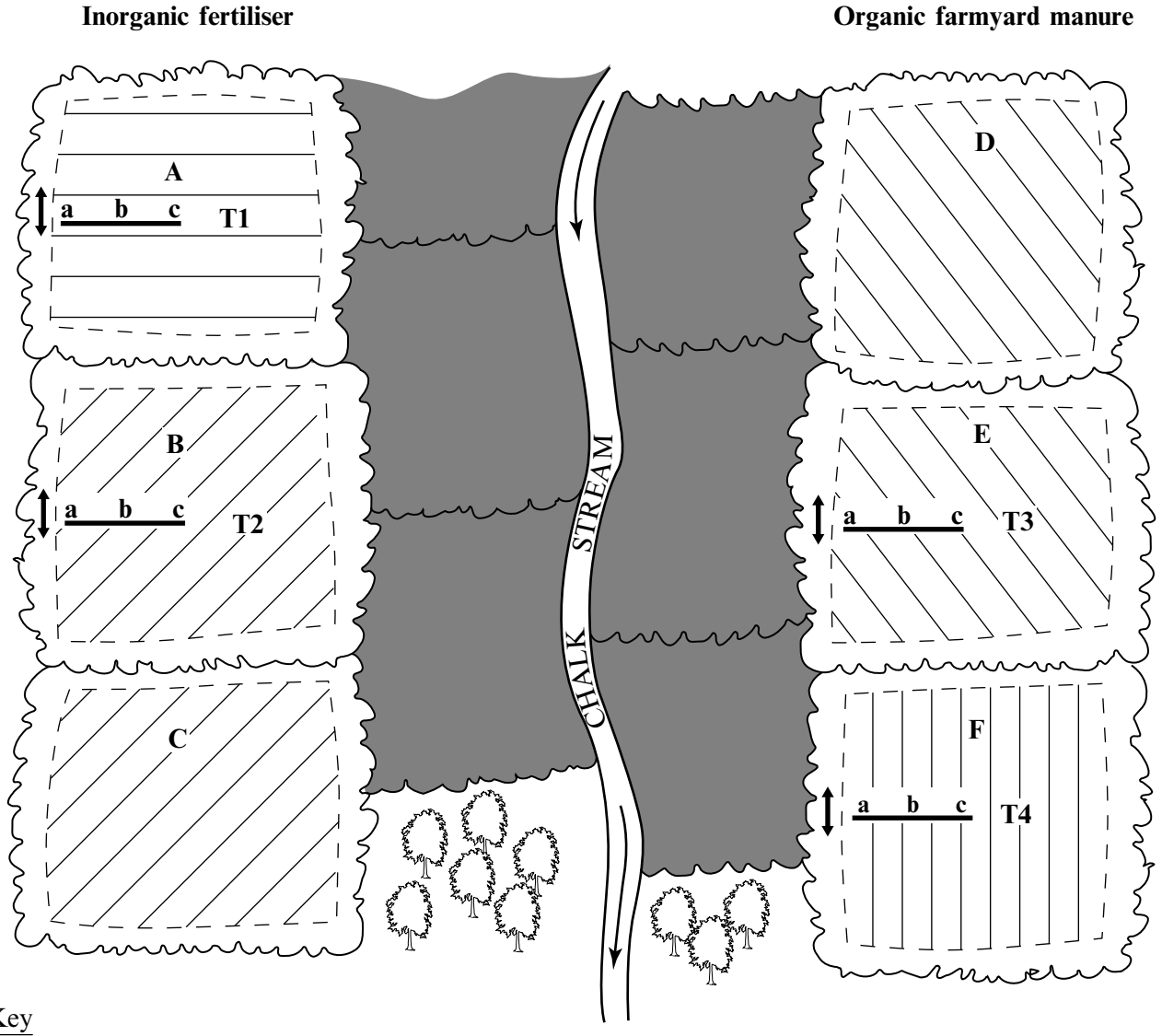
The crop fields feature headlands, 2 metre borders of wild (unsown) grasses and self-seeded wild flowers which act as a buffer against spray-drift of fertilisers and other agrochemicals, such as pesticides and herbicides, onto the hedgerows. The hedgerows and headlands also provide a hunting habitat for birds of prey such as the common kestrel *(Falco tinnunculus)* and the barn owl *(Tyto alba)*.

Repair of the original hedgerows, thought to be at least 400 years old, began 6 years ago under the Hedgerow Incentive Scheme (10 year plan). The repair is being carried out using native species including:

hazel *(Corylus avellana)*
holly *(Ilex aquifolium)*
rowan *(Sorbus aucuparia)*
blackthorn *(Prunus spinosa)*
hawthorn *(Crataegus monogyna)*
elder *(Sambucus nigra)*

After undertaking a risk analysis the student made a preliminary visit in the autumn to trial equipment and methods and to complete a land use survey. The student then returned the following June and July to sample the vegetation growing in the headlands, measure crop growth and take soil samples.

A sketch map of part of a mixed lowland farm in Eastern England. *(not to scale)*



Key

winter barley	**A – F** fields sampled
spring barley	**T1 – T4** transects
winter wheat	**a – c** sample sites
spring wheat	headland sampling area
hedgerow	deciduous woodland
pasture (unimproved meadow)	limit of headland

*This investigation is in **two** sections.*
***Section A** is in **four** parts and tests the skills of planning, implementing, analysing and drawing conclusions.*
***Section B** tests the ability to discuss the findings and evaluate the whole investigation.*

SECTION A

Answer **all** questions in the spaces provided.

1 Vegetation analysis of the headlands to assess the effect of inorganic fertilisers compared with organic fertilisers and times of crop planting.

(a) Plant species in the headlands were sampled along a 10 metre strip at the edge of each of fields **A**, **B**, **E** and **F** next to the position of the transects (**T1 – T4**) shown on the map on page 4.

The student identified and recorded all the different plant species present in sample areas bordering the four fields. **Table 1** shows the number of different species found.

Field	Number of species of broadleaved plants	Number of grass species
A	11	3
B	13	2
E	19	8
F	21	7

Table 1

(i) Describe and suggest an explanation for the trend shown by these data.

.....

.....

.....

.....

.....

.....

(3 marks)

Turn over ►

(ii) Give **two** limitations of this method of assessing plant diversity in the sample areas.

1. .....

.....

2. .....

.....

(2 marks)

(iii) Suggest a better method of assessing plant diversity.

.....

.....

(1 mark)

(b) The student also decided to record the *species frequency* and *species density* of some of the more common plant species in the headlands of the same four fields using random quadrats.

(i) Suggest why random quadrat sampling was an appropriate technique to use in this part of the study rather than alternative techniques.

.....

.....

.....

.....

.....

(2 marks)

(ii) Describe how, in order to ensure a fair test, the student would have carried out quadrat sampling to record:

species frequency; .....

.....

.....

.....

.....

.....

.....

.....

species density. .....

.....

.....

.....

.....

.....

.....

.....

(5 marks)

(c) A quadrat frame of area 0.25 m^2 was placed randomly ten times in the headland area of field **A** and all plants, excluding grasses, rooted in the quadrat were identified, counted and recorded. **Table 2** shows a sample of the results from this part of the investigation. Common names of the plant species were used.

Species	**Quadrat number**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Meadow buttercup	4	2	0	5	0	2	1	1	5	0
Common poppy	0	4	5	6	2	0	1	3	3	1
Birds-foot trefoil	3	2	0	1	5	6	2	0	1	2

Table 2

(i) Calculate the species frequency of the meadow buttercup. Show your working.

Answer .....

(1 mark)

Turn over ▶

(ii) Calculate the species density of the common poppy. Show your working.

Answer .....
(2 marks)

(iii) Describe how the method would be modified in order to record the percentage cover of birds-foot trefoil.

.....

.....

.....

.....

.....
(2 marks)

18

NO QUESTIONS APPEAR ON THIS PAGE

TURN OVER FOR THE NEXT QUESTION

2 Comparison of crop growth in fields treated with inorganic and organic fertilisers and planted with spring and winter crops.

Crop growth was estimated by measuring the mean height of 10 randomly selected plant stalks in each of three 0.25 m^2 quadrats (**a**, **b** and **c**) placed along the transect lines (**T1 – T4**) shown on the map.

(a) Suggest why it was appropriate to place the quadrats along a transect line, rather than randomly.

.....

.....

(1 mark)

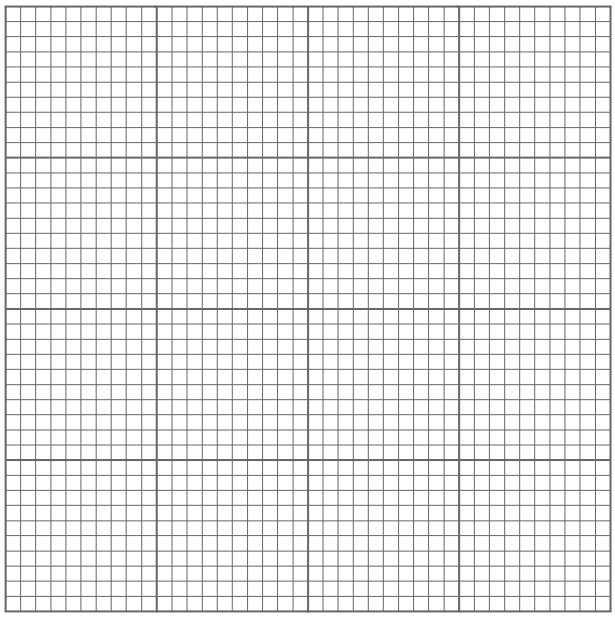
Table 3 shows the results of the crop measurements.

Field	Transect	Mean height of plant stalks per quadrat/cm			Mean height /cm
		Sample point a	Sample point b	Sample point c	
A	**T1**	31.9	32.4	32.5	
B	**T2**	18.2	18.6	18.7	
E	**T3**	23.1	27.3	29.1	
F	**T4**	12.3	14.1	15.2	

Table 3

(b) (i) Calculate the mean crop height for each field and insert your figures in the final column of the table. Show your working. *(2 marks)*

(ii) Display the results in a suitable graphical manner on the graph paper.



(4 marks)

(c) Suggest an hypothesis that could have been tested in this part of the investigation.

.....

.....

(1 mark)

(d) Discuss fully the trends indicated by the graph drawn from the results shown in **Table 3**.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(6 marks)

14

TURN OVER FOR THE NEXT QUESTION

3 Soil analysis to assess the use of inorganic fertilisers compared with organic fertilisers on fields planted with spring and winter crops.

Soil samples were taken at points **a**, **b** and **c** along each of the transects **T1 – T4**. The soil samples were tested for pH.

Table 4 shows the results of the tests for pH.

Field	Transect	pH		
		Sample point a	Sample point b	Sample point c
A	**T1**	6.8	6.7	6.7
B	**T2**	6.8	6.7	6.7
E	**T3**	6.5	6.5	6.4
F	**T4**	6.5	6.4	6.4

Table 4: Soil pH

(a) The student decided to investigate whether there was a significantly greater amount of organic matter in the fields treated with farmyard manure compared to that in the fields where inorganic fertilisers were used. Eight random soil samples were taken from each field and the percentage organic matter in each sample calculated.

The results are shown in **Table 5**.

	% organic matter							
	Sample number							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Fields treated with inorganic fertilisers	12.5	10.9	14.6	15.5	16.4	14.0	11.2	15.2
Field treated with farmyard manure	15.7	16.9	17.3	12.5	18.6	14.5	19.5	16.2

Table 5: Soil organic matter/% in samples from fields treated with different fertilisers.

(i) Suggest a statistical test that could be used to find out whether there is a significant difference in the organic matter (%) in fields treated with inorganic fertilizers and those treated with farmyard manure. Justify your choice of test.

.....

.....

.....

.....

.....

.....

(3 marks)

(ii) State the null hypothesis that would be tested by your chosen test.

.....

.....

(1 mark)

QUESTION 3 CONTINUES ON THE NEXT PAGE

(iii) Carry out your chosen test using the data from **Table 5** and the formulae and tables in the Appendix. State the degrees of freedom, the chosen significance level and your conclusions. Show your working.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(7 marks)

(b) (i) What conclusions can be drawn from the results of the soil tests?

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(4 marks)

(ii) Describe **one** further test that could be carried out on the soil samples indicating the relevance of your chosen test to this study.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(4 marks)

19

TURN OVER FOR THE NEXT QUESTION

4 Bird Surveys to compare the effect of the use of inorganic fertilisers compared with organic fertilisers on fields planted with spring and winter crops.

Volunteers from a local birdwatching group visited the farm for a day on three separate occasions. They recorded all the bird species seen at least once in or over the fields or hedgerows of fields **A**, **B**, **E** and **F**. **Table 6** shows the common names of the bird species recorded during the survey.

Species	Field A	Field B	Field E	Field F
Common kestrel	✔		✔	✔
Red-legged partridge		✔		
Grey partridge				✔
Northern lapwing			✔	✔
Common wood pigeon	✔	✔	✔	✔
Barn owl				✔
Skylark			✔	✔
Meadow pipit	✔		✔	✔
Hedge accentor	✔	✔	✔	✔
European robin				✔
Common blackbird		✔	✔	✔
Song thrush				✔
Common whitethroat				✔
Common starling	✔	✔	✔	
House sparrow	✔	✔	✔	✔
Chaffinch	✔	✔	✔	✔
European greenfinch			✔	✔
European goldfinch			✔	✔
Common linnet			✔	✔
Yellowhammer		✔	✔	✔
Corn bunting			✔	
TOTAL	**7**	**8**	**15**	**18**

Table 6

The student used these secondary data to support the investigation. Describe and explain the trends indicated.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(4 marks)

4

TURN OVER FOR THE NEXT QUESTION

SECTION B

Answer **all** parts of the question in the spaces provided.

In order to gain credit in this section your answer should be written in continuous prose and expressed logically and in clear scientific terms.

5 (a) Using information in the background section and with reference to the various investigations carried out, discuss the effects of the application of inorganic and organic fertilisers on winter and spring grown crops and biodiversity.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(6 marks)

(b) Discuss any factors relating to the methods used that might affect the reliability of the results. Refer to attempts to standardise conditions and control variables in the student's methodology.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(5 marks)

(c) Suggest how you would modify or extend the study of the effect of agricultural practices on species diversity.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(4 marks)

(d) Suggest how the farmer, conservation organisations and government agencies might use information from the study to manage arable farmland for wildlife.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(5 marks)

20

END OF QUESTIONS

APPENDIX

Statistical formulae and tables

1 Mean

$$\bar{x} = \frac{\bullet\ x}{n}$$

where:
$\bar{x}$ = mean
x = the individual measurements
n = total number of measurements
$\bullet$ = the sum of

2 Standard deviation(s)

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

3 Chi-squared (χ^2) test

$$\chi^2 = \bullet\ \frac{(O - E)^2}{E}$$

where:
$\bullet$ = the sum of
O = the observed value
E = the expected value

Critical Values for the Chi-Square (χ^2) Test

Degrees of Freedom (df)	**Level of significance (*P*)**				
	0.05	0.025	0.01	0.005	0.001
1	3.84	5.02	6.63	7.88	10.83
2	5.99	7.38	9.21	10.60	13.81
3	7.81	9.35	11.34	12.84	16.27
4	9.49	11.14	13.28	14.86	18.47
5	11.07	12.83	15.09	16.75	20.52
6	12.59	14.45	16.81	18.55	22.46
7	14.07	16.01	18.48	20.28	24.32
8	15.51	17.53	20.09	21.96	26.13
9	16.92	19.02	21.67	23.59	27.88
10	18.31	20.48	23.21	25.19	29.59
11	19.68	21.92	24.73	26.76	31.26
12	21.03	23.34	26.22	28.30	32.91
13	22.36	24.74	27.69	29.82	34.53
14	23.68	26.12	29.14	31.32	36.12

Turn over ▶

4 Mann-Whitney U Test

$$U = n_1 n_2 + \frac{n_1(n_1 + 1)}{2} - R_1$$

$$U' = n_1 n_2 + \frac{n_2(n_2 + 1)}{2} - R_2$$

where:
R_1 = sum of the ranks of sample 1
R_2 = sum of the ranks of sample 2
n_1 = size of the smaller sample
n_2 = size of the larger sample

Critical values for the Mann-Whitney U test (at the p = 0.05 level). If the smallest U value is less than or equal to the critical value then there is a significant difference between the two sets of data.

Values of n_1	Values of n_2																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1																				
2								0	0	0	0	1	1	1	1	1	2	2	2	2
3					0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8
4				0	1	2	3	4	4	5	6	7	8	9	10	11	11	12	13	13
5			0	1	2	3	5	6	7	8	9	11	12	13	14	15	17	18	19	20
6			1	2	3	5	6	8	10	11	13	14	16	17	19	21	22	24	25	27
7			1	3	5	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
8		0	2	4	6	8	10	13	15	17	19	22	24	26	29	31	34	36	38	41
9		0	2	4	7	10	12	15	17	20	23	26	28	31	34	37	39	42	45	48
10		0	3	5	8	11	14	17	20	23	26	29	33	36	39	42	45	48	52	55
11		0	3	6	9	13	16	19	23	26	30	33	37	40	44	47	51	55	58	62
12		1	4	7	11	14	18	22	26	29	33	37	41	45	49	53	57	61	65	69
13		1	4	8	12	16	20	24	28	33	37	41	45	50	54	59	63	67	72	76
14		1	5	9	13	17	22	26	31	36	40	45	50	55	59	64	67	74	78	83
15		1	5	10	14	19	24	29	34	39	44	49	54	59	64	70	75	80	85	90
16		1	6	11	15	21	26	31	37	42	47	53	59	64	70	75	81	86	92	98
17		2	6	11	17	22	28	34	39	45	51	57	63	67	75	81	87	93	99	105
18		2	7	12	18	24	30	36	42	48	55	61	67	74	80	86	93	99	106	112
19		2	7	13	19	25	32	38	45	52	58	65	72	78	85	92	99	106	113	119
20		2	8	13	20	27	34	41	48	55	62	69	76	83	90	98	105	112	119	127

5 t-test

$$t = \frac{\left[\bar{x}_1 - \bar{x}_2\right]}{\sqrt{\left[\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right]}} \qquad v = n_1 + n_2 - 2$$

where:
s = standard deviation (candidates should note that on some calculators the symbol □ may appear in place of the symbol s).
$\bar{x}$ = mean
n = sample size
v = degrees of freedom

Degrees of freedom (df)	***p* values**			
	0.10	0.05	0.01	0.001
1	6.31	12.71	63.66	636.60
2	2.92	4.30	9.92	31.60
3	2.35	3.18	5.84	12.92
4	2.13	2.78	4.60	8.61
5	2.02	2.57	4.03	6.37
6	1.94	2.45	3.71	5.96
7	1.89	2.36	3.50	5.41
8	1.86	2.31	3.36	5.04
9	1.83	2.26	3.25	4.78
10	1.81	2.23	3.17	4.59
12	1.78	2.18	3.05	4.32
14	1.76	2.15	2.98	4.14
16	1.75	2.12	2.92	4.02
18	1.73	2.10	2.88	3.92
20	1.72	2.09	2.85	3.85
22	1.72	2.08	2.82	3.79
24	1.71	2.06	2.80	3.74
26	1.71	2.06	2.78	3.71
28	1.70	2.05	2.76	3.67
30	1.70	2.04	2.75	3.65
40	1.68	2.02	2.70	3.55
60	1.67	2.00	2.66	3.46
120	1.66	1.98	2.62	3.37
□	1.64	1.96	2.58	3.29

Turn over ▶

6 Spearman Rank Correlation Coefficient (r_s)

$$r_s = 1 - \frac{6 \bullet D^2}{n(n^2 - 1)}$$

where:
• = the sum of
D = the difference between each pair of ranks
n = sample size

Critical values for the Spearman Rank Correlation (r_s)

Number of pairs of measurements	Critical value
5	1.00
6	0.89
7	0.79
8	0.74
9	0.68
10	0.65
12	0.59
14	0.54
16	0.51
18	0.48
20	0.45
22	0.43
24	0.41
26	0.39
28	0.38
30	0.36