Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
June 2008
Advanced Level Examination

ENVIRONMENTAL SCIENCE **ESC7**
Unit 7 Alternative to Practical Investigation

Tuesday 24 June 2008 9.00 am to 11.00 am

You will need no other materials.
You may use a calculator.

Time allowed: 2 hours

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Answers written in margins or on blank pages will not be marked.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The maximum mark for this paper is 75.
- The marks for questions are shown in brackets.
- You are reminded of the need for good English, clear presentation and appropriate use of specialist vocabulary. Question 4 should be answered in continuous prose. Quality of Written Communication will be assessed in this answer.
- This unit assesses your understanding of the relationship between the different aspects of Environmental Science.

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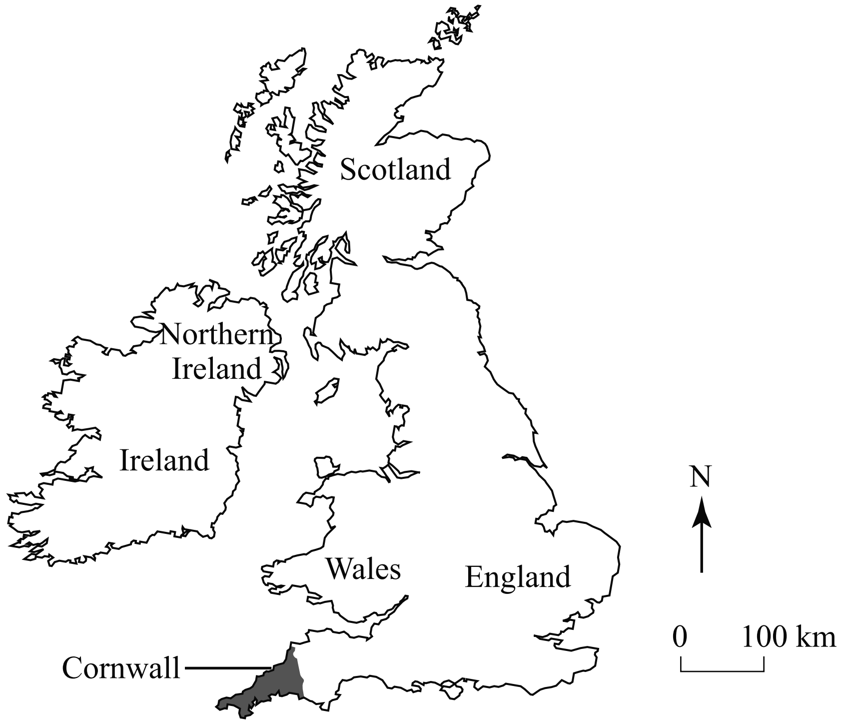
Question	Mark	Question	Mark
1		3	
2		4	
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

Investigation into some of the environmental impacts of china clay and metal mining in Cornwall

Introduction

South west England is rich in minerals. Cornwall has had a long history of tin and china clay mining although most active metal mining ceased in the 1990s. The wastes from Cornish tin and china clay mines cause many environmental problems, ranging from large, unsightly and unstable spoil heaps to heavy metal contamination of soils and acid mine drainage affecting river systems and groundwater sources.

Figure 1



Other environmental issues associated with mining include the loss of habitat, the impact on access and the particulate pollution of the air caused by dust. Large areas of land used for mining have required extensive remediation and restoration so that they can be returned to productive agricultural land or land with improved amenity value.

Case Study 1: China clay extraction

The china clay industry began in the area around St Austell in Cornwall in the late eighteenth century. China clay (kaolin) is extracted by high-pressure water jets from the sides and base of deep pits. The pits are worked continuously to increasing depths so the wastes cannot be disposed of in disused pits. For every tonne of china clay extracted, eight tonnes of waste are produced. The waste consists of six parts sand, one part mica and one part undecomposed granite. The sand is separated by washing and is tipped onto the land in large spoil heaps, whilst the finer particles are deposited in shallow lagoons, many of which appear blue and lifeless because of clay particles suspended in the water. It is estimated that, since china clay extraction began, the industry has created 10 000 hectares of spoil heaps, abandoned clay pits and lagoons.

Photograph 1

Partly vegetated spoil heap from a china clay mine

Photograph: Richard Genn

Natural revegetation is a very slow process taking up to 10 years to establish a pioneer community. It takes at least 75 years to establish a climax community which is either heather moorland or acid oak woodland. However, with careful management and remediation, a functioning and partly productive ecosystem can be established within a much shorter time span. Gullying and landslides are also problems.

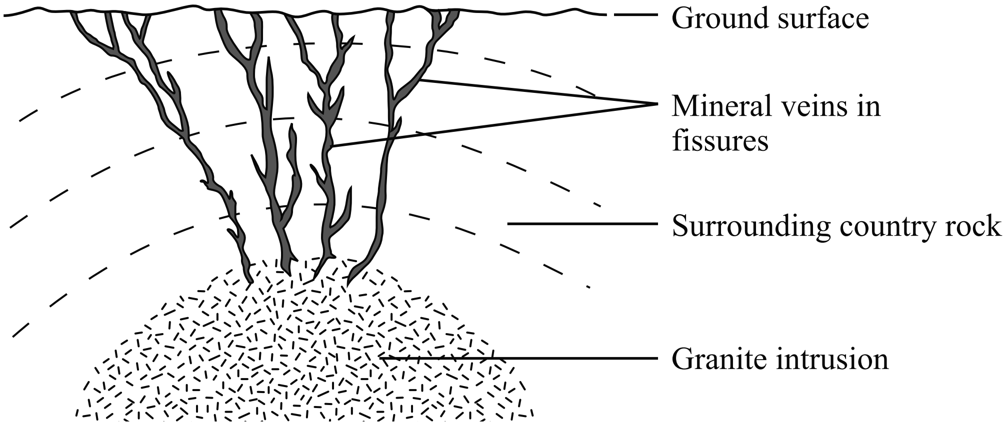
Case Study 2: Metal mining in Cornwall

Cornwall has a long history of mining for metals because of its geology. During the late stages of the cooling of the mass of granite that makes up a lot of Cornwall, fissures opened up where mineral veins of tin, copper, zinc, lead, iron and silver eventually formed. A great many shafts were needed because each vein had to be followed individually.

Metal mining reached its peak in the nineteenth century and then foreign competition depressed the price of tin so that Cornish ore was unprofitable and much of the mining ceased.

Figure 2

Formation of mineral veins associated with a granite intrusion



When mineral deposits that contain sulphides are mined, they have the potential to produce acid mine drainage and this is one of the main chemical threats to groundwater and river quality in the area. Elements such as lead, zinc, tin, copper and iron are bound in minerals when underground. However, mining activity exposes these minerals to the air and sulphides are oxidised to form sulphuric acid. Production of acid mine drainage can occur long after the mines are abandoned if waste rock is in contact with air and water. The mineral iron pyrites (FeS_2) is commonly found in spoil from mines. In a wet, oxidising environment, this will oxidise to produce sulphuric acid and iron III hydroxide ($Fe(OH)_3$). An overall summary reaction is shown below:

$$4FeS_2 + 15O_2 + 14H_2O \rightarrow 4Fe(OH)_3 + 8H_2SO_4$$

iron pyrites + oxygen + water → iron III hydroxide + sulphuric acid

The sulphuric acid created can oxidise other metal sulphides and leach metals from the surrounding rocks. Leaching is significant if the pH drops below 5.5. As the acidic waters rise through the mine workings, they pick up these dissolved metals and transport them to the nearby watercourses. The acid wastes reduce water to a pH well below the tolerance level of the majority of organisms and may also result in toxic levels of metal ions. When these metals are in a dissolved form, they are more readily absorbed and accumulated by both plants and animals and therefore can be passed along food chains.

Additional problems are caused by the presence of iron III hydroxide which forms a yellow-orange precipitate in acidic conditions. This turns the acidic runoff to an orange or red colour that covers the stream bed with a slimy coating and kills aquatic life.

Aims of the investigation

- to compare china clay wastes with moorland and agricultural soils in the same area in order to assess the problems of revegetation
- to assess the effectiveness of revegetating spoil heaps from old mine workings
- to investigate the effect of acid mine drainage on freshwater invertebrate populations
- to analyse pollutants entering a Cornish river

The following questions test the skills of planning, implementing, analysing and drawing conclusions from investigative work. They also test the ability to discuss the findings and evaluate methods, as well as suggesting modifications to the methods used and relevant further work.

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

1 Comparison of the composition of china clay wastes with the composition of moorland and agricultural soils

Table 1 shows the composition of typical wastes from the china clay industry compared with the composition of a relatively poor soil from a nearby area of moorland and that of a local, improved agricultural soil.

Table 1

	China clay waste		**Moorland soil**	**Agricultural soil**
Properties	**Silica sand**	**Mica**		
Soil particle size	*Composition / % mass*			
Very coarse sand	56	0	0	0
Coarse sand	30	5	25	1
Fine sand	11	44	15	34
Silt	2	47	20	40
Clay	1	4	40	25
Plant nutrients	*Available to plants / ppm*			
Potassium	10	13	110	176
Magnesium	16	20	71	130
Calcium	85	115	880	990
Phosphorus	2	3	42	46
Nitrogen	9	18	1275	1560
pH	4.5	4.0	5.5	6.5

Source: adapted from AD Bradshaw and MJ Chadwick, *The restoration of land; the ecology and reclamation of derelict and degraded land*, Blackwell Scientific Publications (1980)

Question 1 continues on the next page

Turn over ➤

1 (a) Describe, giving full practical details, a method for:

1 (a) (i) choosing and obtaining representative samples of moorland soil

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(5 marks)

1 (a) (ii) measuring the percentage of the various sized particles in the soil sample.

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(3 marks)

1 (b) The pH of soil can be measured using a digital probe or universal indicator.
Describe the limitations of using universal indicator.

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(2 marks)

1 (c) Suggest **two** further tests that could be carried out on the soil samples that would be relevant to the ability of the soil to support plant growth.

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(2 marks)

1 (d) With reference to the information in **Table 1**, discuss the problems of re-establishing vegetation on china clay wastes.

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(6 marks)

18

Turn over for the next question

Turn over ➤

2 Effectiveness of revegetating spoil heaps from old mine workings

The vegetation on a large spoil heap from an old china clay pit was investigated using a transect placed down a south facing slope. The percentage cover of the vegetation was determined using a point quadrat.

2 (a) (i) Explain why a transect was an appropriate method for this study in preference to an alternative technique.

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(3 marks)

2 (a) (ii) Describe how a point quadrat is used to collect data on the percentage cover of the vegetation.

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(3 marks)

2 (b) The slope angle and soil moisture content were also measured at intervals along the belt transect with quadrats placed every five metres down the slope. The results are shown in **Table 2**.

Table 2

Quadrat	Angle of slope / °	Vegetation cover / %	Moisture content of soil / %
1	45	60	14.3
2	39	68	17.2
3	30	70	14.9
4	28	68	20.3
5	24	73	22.7
6	15	98	23.5
7	12	93	21.2
8	9	88	20.3
9	7	95	22.0
10	1	100	22.9

Plot a graph to show how the slope angle and vegetation cover change down the slope.

(4 marks)

2 (c) Describe the trends shown by the data in **Table 2** and your graph.

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(3 marks)

Question 2 continues on the next page

Turn over ➤

2 (d) The student wanted to test whether there was a relationship between the vegetation cover and the moisture content of the soil.

2 (d) (i) State a hypothesis (H_1) suggested by the results shown in the table.

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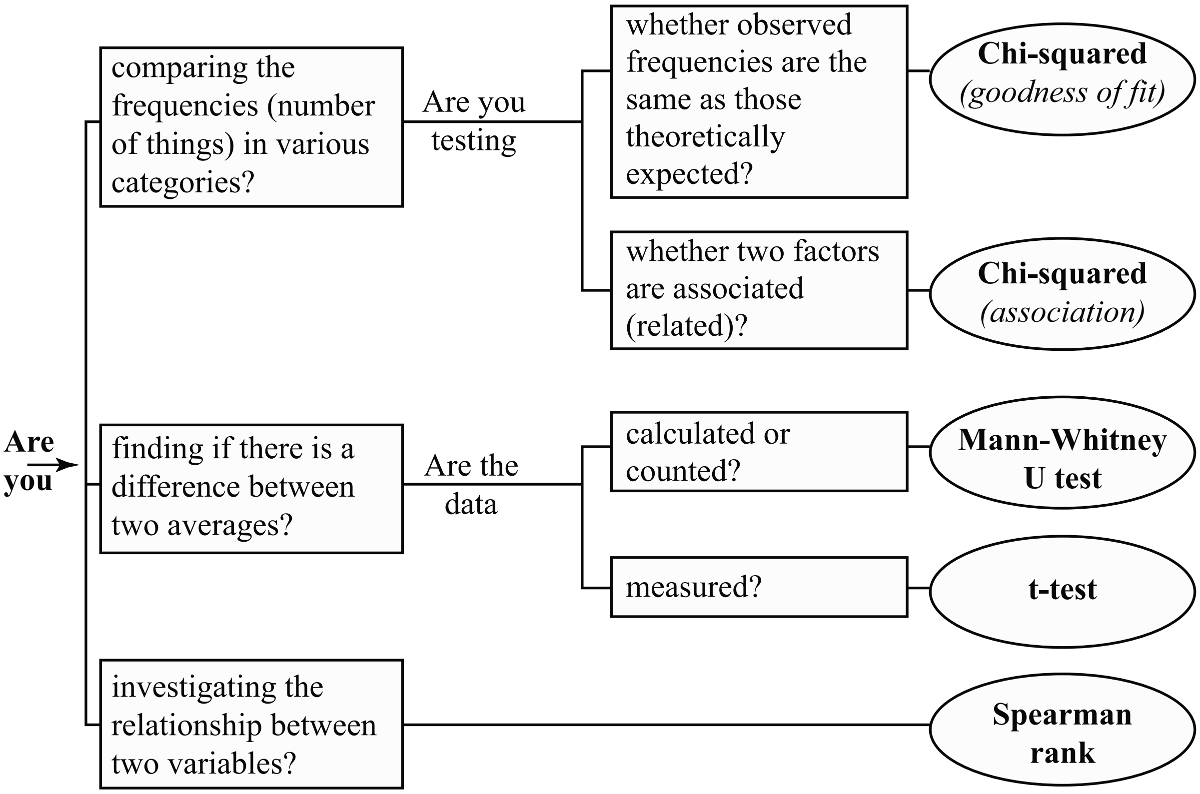
(1 mark)

2 (d) (ii) Use the flow diagram to choose an appropriate statistical test to test your hypothesis. Give **two** reasons to justify your choice of test.

Figure 3



Choice of statistical test

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Reasons for choice

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2 ....

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(3 marks)

2 (d) (iii) Carry out your chosen test using the data in **Table 2** and information in the Appendix. Show your working.

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(6 marks)

2 (d) (iv) State your conclusions.

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(2 marks)

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25

3 The effect of acid mine drainage on freshwater invertebrate populations

A student wanted to investigate whether, despite a long period of time since mine closure, the drainage from old mine workings was still affecting invertebrate populations in streams in Cornwall. The student chose to compare two streams in similar geographical locations using the technique of kick-sampling to obtain samples of invertebrates. Identification of the species was difficult, so the organisms collected were put into broad groups as shown in the table. The pH was assessed at the same time using a pH meter. Data for concentrations of zinc and copper in the water were obtained from secondary sources.

The data obtained are shown in **Table 3**. Common names have been used for simplicity.

Table 3

	Number of invertebrates found:									
	Upstream of mine discharge					**Downstream of mine discharge**				
	Sample number					**Sample number**				
Invertebrate groups	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Freshwater shrimps	42	28	30	25	43	1		1		
Beetle larvae	5	7	3	4	2	1	2			1
Adult beetles	2	3	1		2		1			
Cased caddis fly larvae	5	6	8	3	2			1		
Caseless caddis fly larvae	3		1	2					1	
Water snails		1		1						
Simuliidae fly larvae	10	9	14	5	7					
Dragonfly larvae		1								
Stonefly larvae						3	5	2	3	1
Mayfly nymphs						10	12	22	32	10
Worms				1						1
Midge larvae	2		4	3	1		1		3	
Water mites						3		2		1
Bivalve molluscs	1			1						
Freshwater leeches		1								
pH	5.7	5.7	5.9	6.0	6.0	5.2	5.3	5.5	5.6	5.4
Secondary data	*Concentration / mg* l^{-1}					*Concentration / mg* l^{-1}				
Zinc	0.07					1.56				
Copper	0.03					0.27				

3 (a) (i) Describe how the technique of kick-sampling would be carried out in this survey.

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(5 marks)

3 (a) (ii) Discuss the limitations of kick-sampling as a method of sampling invertebrates in streams.

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(3 marks)

Question 3 continues on the next page

Turn over ➤

3 (a) (iii) Suggest modifications and improvements that could be made to the investigation in order to collect more reliable data.

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(3 marks)

3 (b) Suggest ways in which the data in **Table 3** could be displayed and analysed.

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(4 marks)

3 (c) Suggest **one** reason for the difference in the size of the freshwater shrimp populations upstream and downstream of the mine discharge.

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(2 marks)

3 (d) (i) Excluding other invertebrates, suggest **one** other group of organisms that could be monitored as indicators of water quality.

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(1 mark)

3 (d) (ii) Briefly describe an appropriate technique that could be used to monitor your chosen group of organisms.

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(2 marks)

20

Turn over for the next question

4 In January 1992, there was a major pollution event in the River Carnon in west Cornwall. This was caused by the discharge of several million litres of highly polluted water from the abandoned Wheal Jane mine from which tin, silver, copper and zinc ore had been extracted. The Centre for Ecology and Hydrology monitored the river water each day over an 18-month period in order to assess the level and behaviour of pollutants. They recorded the pH and levels of major and trace elements just downstream from the main mine discharge.

The mean results for some elements during the 18-month period are summarised in **Table 4**.

Table 4

pH range	**3.0–3.9**	**4.0–4.9**	**5.0–5.9**	**6.0–6.9**	**>7**
Major elements (concentration / mgl^{-1})					
Sodium (Na)	28.60	28.20	34.50	31.60	24.90
Potassium (K)	4.32	4.40	5.20	5.08	4.23
Calcium (Ca)	85	89	142	135	90
Sulphur (S) as sulphate	263	262	355	330	207
Silicon (Si)	5.19	4.78	4.33	3.87	3.06
Trace elements (concentration / μgl^{-1})					
Cadmium (Cd)	9	9	6	4	2
Copper (Cu)	759	696	539	366	78
Iron (Fe)	15 930	11 360	1 977	916	128
Manganese (Mn)	886	825	773	602	317
Zinc (Zn)	10 125	8 497	3 157	2 217	810

Source: reprinted from *Science of the Total Environment Vol 338*, C Neal, PG Whitehead, H Jeffery and M Neal, *Water Quality of River Carnon* (2005), with permission from Elsevier

4 (a) Suggest:

4 (a) (i) the advantage of measuring the pollution levels daily rather than at longer intervals

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(1 mark)

4 (a) (ii) **one** important physical characteristic of the river water that could have been recorded in order to assess the behaviour of pollutants.

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(1 mark)

4 (b) Describe the trends indicated by the data in **Table 4** and suggest how these data would help the future remediation of the River Carnon.

Quality of Written Communication will be assessed in this answer.

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(10 marks)

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END OF QUESTIONS

APPENDIX

Statistical formulae and tables

1 Mean $\bar{x} = \frac{\sum x}{n}$

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

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

3 Chi-squared (χ^2) test $\chi^2 = \sum \frac{(O - E)^2}{E}$

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

Critical values for the Chi-squared (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

$$U = n_1n_2 + \frac{n_1(n_1+1)}{2} - R_1$$

$$U' = n_1n_2 + \frac{n_2(n_2+1)}{2} - R_2$$

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_2																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Values of n_1	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

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

where:

s = standard deviation (candidates should note that on some calculators the symbol σ 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)

$$r_s = 1 - \frac{6\sum d^2}{n(n^2 - 1)}$$

where:

$\sum$ = the sum of

d = the difference between each pair of ranks

n = sample size

Critical values for the Spearman Rank Correlation (at the $p = 0.05$ level).

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

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Case Study 1 Photograph: R Genn

Question 1 Source: AD Bradshaw and MJ Chadwick, *The restoration of land; the ecology and reclamation of derelict and degraded land*, Blackwell Scientific Publications (1980)

Question 4 Source: reprinted from *Science of the Total Environment Vol 338*, C Neal, PG Whitehead, H Jeffery and M Neal, *Water Quality of River Carnon* (2005), with permission from Elsevier