National Exams May 2014

04-Env-B7: Environmental Sampling and Analysis

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is an open book exam. Use either an approved Sharp or Casio calculator. Write the name and model designation of the calculator, on the first inside left hand sheet, of the exam work book.

3. Answer all 3 questions in Part A and any 2 questions in Part B.

4. All questions are of equal value. Part marks are as shown.

5. Use the statistical tables provided.

Tables Provided:

Standard normal table
t-distribution table
F-distribution table

Part A: Answer all three questions

1.   a)   List the two properties which make Simple Random Sampling (SRS) the standard by which other sampling methods are judged. Explain why SRS is not always used in practice. Give an example where another sampling scheme may be better. [5 marks]

     b)   List of 5 other methods used in environmental sampling besides SRS.   [5 marks]

     b)   List 5 typical characteristics of environmental data [5 marks].

     c)   Indicate whether each of the statements below is true or false: [1 mark each]

         (i) For statistical significance, the α-value must be greater than the p-value.

         (ii) The Pearson r is a measure of linear correlation only.

         (iii) We can increase the power of a statistical test by decreasing α or increasing the sample size n.

         (iv) As the sample size of a set of data increases, the data tend to be normally distributed.

         (v) The mean square error is a measure of precision of a statistical estimate.

2.   Air pollution concentrations at a location were measured. Eleven measurements were taken using two different methods and the following values in parts per million of CO_2 were obtained:

Method A: 66.3   63.5   64.9   61.8   64.3   64.7   65.1   64.5   68.4   63.2   67.4
Method B: 71.3   60.4   64.6   63.9   68.8   70.1   64.8   68.9   65.8   66.2   69.2

It is desired to show that the pollution values obtained using Method A are not significantly different from that using Method B at the 5% significance level. The following three tests were carried out in using a computer.

Test 1: Paired T for Method A - Method B (Paired test)

	N	Mean	StDev	SE Mean
Method A	11	64.918	1.885	0.568
Method B	11	66.727	3.238	0.976
Difference	11	-1.809	3.016	0.909

T-Test of mean difference = 0 (vs < 0): P-Value = 0.037

Test 2: Two-sample T for Method A vs Method B (One-tailed test)

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            N      Mean     StDev   SE Mean
Method A    11     64.92    1.88     0.57
Method B    11     66.73    3.24     0.98

Difference = mu Method A - mu Method B
Estimate for difference:  -1.81
T-Test of difference = 0 (vs <):   P-Value = 0.064   DF = 16
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Test 3: Two-sample T for Method A vs Method B (Two-tailed test)

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            N      Mean     StDev   SE Mean
Method A    11     64.92    1.88     0.57
Method B    11     66.73    3.24     0.98

Difference = mu Method A - mu Method B
Estimate for difference:  -1.81
T-Test of difference = 0 (vs not =): P-Value = 0.129   DF = 16
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a) Which of the above results is the appropriate one? Explain why this is so. What is the conclusion from the test?   [10 marks]

b) What is the main assumption of the t-test used? Use a simple graphical method to verify the assumption of the t-test used?   [5 marks]

c) Calculate the value of the test statistic for each of the above tests.   [5 marks]

3. Provide a brief explanation/definition of the following terms commonly used in environmental sampling and analysis:

   a) Background concentration   [2 marks]
   b) Detection limit   [2 marks]
   c) Grab sample versus a composite sample [3 marks]
   d) Colorimetric analysis versus instrumental analysis [3 marks]
   e) Bioassay   [2 marks]
   f) Maximum Contaminant Level (MCL) versus Quantification Limit (QL) [3 marks]
   g) Assessment monitoring versus compliance monitoring [3 marks]
   h) Data QA/QC   [2 marks]

Part B: Answer any 2 questions

4. Samples of soil, water, or air collected in the field are often sent to a certified laboratory for analysis. Discuss the protocol that should be followed so that the field data collected would be an accurate representation of the actual contaminants found in the samples. Points you should address include: types of sample collection methods, sample preparation and preservation techniques, quality assurance and control, data management, and sources of errors. [20 marks]

5. Ten samples of nitrate concentrations were taken from a well site. The data are as follows:

    2 5 8 120 9 13 45 24 57 16

    The summary statistics from obtained from a computer package are given below.

N	Mean	Median	StDev	Minimum	Maximum	Q1	Q3
10	29.9	14.5	36.4	2.0	120.0	7.3	48.0

    a) Draw accurately a dotplot and a standard boxplot for the data. Indicate clearly where the fences are for the boxplot. Indicate whether any outliers exist. [10 marks]

    b) From the numerical summary and the boxplot, what can you conclude about the characteristics of the data? Compute also the quartile skew and coefficient of skewness. [10 marks]

6. Consider an environmental monitoring program that you have been involved with. What were the short and long term objectives of the monitoring program? What were sampled? How were the samples collected? What sampling design(s) were used? How often was sampling done? How many samples were collected and over what period? What statistical hypotheses were being tested? What statistical analyses were carried out? What kinds of laboratory analyses were done? What relevant standards were used and compared to? Discuss any other relevant issues related to this monitoring program. Marks will be awarded based on the thoroughness of your answer. [20 marks]

$$\Phi(z) = P(Z \le z) = \int_{-x}^{\cdot} \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}u^2}\, du$$
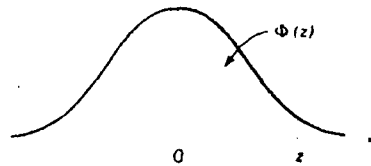

Table II   Cumulative Standard Normal Distribution

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.500000	0.503989	0.507978	0.511967	0.515953	0.519939	0.532922	0.527903	0.531881	0.535856
0.1	0.539828	0.543795	0.547758	0.551717	0.555760	0.559618	0.563559	0.567495	0.571424	0.575345
0.2	0.579260	0.583166	0.587064	0.590954	0.594835	0.598706	0.602568	0.606420	0.610261	0.614092
0.3	0.617911	0.621719	0.625516	0.629300	0.633072	0.636831	0.640576	0.644309	0.648027	0.651732
0.4	0.655422	0.659097	0.662757	0.666402	0.670031	0.673645	0.677242	0.680822	0.684386	0.687933
0.5	0.691462	0.694974	0.698468	0.701944	0.705401	0.708840	0.712260	0.715661	0.719043	0.722405
0.6	0.725747	0.729069	0.732371	0.735653	0.738914	0.742154	0.745373	0.748571	0.751748	0.754903
0.7	0.758036	0.761148	0.764238	0.767305	0.770350	0.773373	0.776373	0.779350	0.782305	0.785236
0.8	0.788145	0.791030	0.793892	0.796731	0.799546	0.802338	0.805106	0.807850	0.810570	0.813267
0.9	0.815940	0.818589	0.821214	0.823815	0.826391	0.828944	0.831472	0.833977	0.836457	0.838913
1.0	0.841345	0.843752	0.846136	0.848495	0.850830	0.853141	0.855428	0.857690	0.859929	0.862143
1.1	0.864334	0.866500	0.868643	0.870762	0.872857	0.874928	0.876976	0.878999	0.881000	0.882977
1.2	0.884930	0.886860	0.888767	0.890651	0.892512	0.894350	0.896165	0.897958	0.899727	0.901475
1.3	0.903199	0.904902	0.906582	0.908241	0.909877	0.911492	0.913085	0.914657	0.916207	0.917736
1.4	0.919243	0.920730	0.922196	0.923641	0.925066	0.926471	0.927855	0.929219	0.930563	0.931888
1.5	0.933193	0.934478	0.935744	0.936992	0.938220	0.939429	0.940620	0.941792	0.942947	0.944083
1.6	0.945201	0.946301	0.947384	0.948449	0.949497	0.950529	0.951543	0.952540	0.953521	0.954486
1.7	0.955435	0.956367	0.957284	0.958185	0.959071	0.959941	0.960796	0.961636	0.962462	0.963273
1.8	0.964070	0.964852	0.965621	0.966375	0.967116	0.967843	0.968557	0.969258	0.969946	0.970621
1.9	0.971283	0.971933	0.972571	0.973197	0.973810	0.974412	0.975002	0.975581	0.976148	0.976705
2.0	0.977250	0.977784	0.978308	0.978822	0.979325	0.979818	0.980301	0.980774	0.981237	0.981691
2.1	0.982136	0.982571	0.982997	0.983414	0.983823	0.984222	0.984614	0.984997	0.985371	0.985738
2.2	0.986097	0.986447	0.986791	0.987126	0.987455	0.987776	0.988089	0.988396	0.988696	0.988989
2.3	0.989276	0.989556	0.989830	0.990097	0.990358	0.990613	0.990863	0.991106	0.991344	0.991576
2.4	0.991802	0.992024	0.992240	0.992451	0.992656	0.992857	0.993053	0.993244	0.993431	0.993613
2.5	0.993790	0.993963	0.994132	0.994297	0.994457	0.994614	0.994766	0.994915	0.995060	0.995201
2.6	0.995339	0.995473	0.995604	0.995731	0.995855	0.995975	0.996093	0.996207	0.996319	0.996427
2.7	0.996533	0.996636	0.996736	0.996833	0.996928	0.997020	0.997110	0.997197	0.997282	0.997365
2.8	0.997445	0.997523	0.997599	0.997673	0.997744	0.997814	0.997882	0.997948	0.998012	0.998074
2.9	0.998134	0.998193	0.998250	0.998305	0.998359	0.998411	0.998462	0.998511	0.998559	0.998605
3.0	0.998650	0.998694	0.998736	0.998777	0.998817	0.998856	0.998893	0.998930	0.998965	0.998999
3.1	0.999032	0.999065	0.999096	0.999126	0.999155	0.999184	0.999211	0.999238	0.999264	0.999289
3.2	0.999313	0.999336	0.999359	0.999381	0.999402	0.999423	0.999443	0.999462	0.999481	0.999499
3.3	0.999517	0.999533	0.999550	0.999566	0.999581	0.999596	0.999610	0.999624	0.999638	0.999650
3.4	0.999663	0.999675	0.999687	0.999698	0.999709	0.999720	0.999730	0.999740	0.999749	0.999758
3.5	0.999767	0.999776	0.999784	0.999792	0.999800	0.999807	0.999815	0.999821	0.999828	0.999835
3.6	0.999841	0.999847	0.999853	0.999858	0.999864	0.999869	0.999874	0.999879	0.999883	0.999888
3.7	0.999892	0.999896	0.999900	0.999904	0.999908	0.999912	0.999915	0.999918	0.999922	0.999925
3.8	0.999928	0.999931	0.999933	0.999936	0.999938	0.999941	0.999943	0.999946	0.999948	0.999950
3.9	0.999952	0.999954	0.999956	0.999958	0.999959	0.999961	0.999963	0.999964	0.999966	0.999967

t-distribution table

Critical Values of the t-Distribution

v	α						
	0.40	0.30	0.20	0.15	0.10	0.05	0.025
1	0.325	0.727	1.376	1.963	3.078	6.314	12.706
2	0.289	0.617	1.061	1.386	1.886	2.920	4.303
3	0.277	0.584	0.978	1.250	1.638	2.353	3.182
4	0.271	0.569	0.941	1.190	1.533	2.132	2.776
5	0.267	0.559	0.920	1.156	1.476	2.015	2.571
6	0.265	0.553	0.906	1.134	1.440	1.943	2.447
7	0.263	0.549	0.896	1.119	1.415	1.895	2.365
8	0.262	0.546	0.889	1.108	1.397	1.860	2.306
9	0.261	0.543	0.883	1.100	1.383	1.833	2.262
10	0.260	0.542	0.879	1.093	1.372	1.812	2.228
11	0.260	0.540	0.876	1.088	1.363	1.796	2.201
12	0.259	0.539	0.873	1.083	1.356	1.782	2.179
13	0.259	0.537	0.870	1.079	1.350	1.771	2.160
14	0.258	0.537	0.868	1.076	1.345	1.761	2.145
15	0.258	0.536	0.866	1.074	1.341	1.753	2.131
16	0.258	0.535	0.865	1.071	1.337	1.746	2.120
17	0.257	0.534	0.863	1.069	1.333	1.740	2.110
18	0.257	0.534	0.862	1.067	1.330	1.734	2.101
19	0.257	0.533	0.861	1.066	1.328	1.729	2.093
20	0.257	0.533	0.860	1.064	1.325	1.725	2.086
21	0.257	0.532	0.859	1.063	1.323	1.721	2.080
22	0.256	0.532	0.858	1.061	1.321	1.717	2.074
23	0.256	0.532	0.858	1.060	1.319	1.714	2.069
24	0.256	0.531	0.857	1.059	1.318	1.711	2.064
25	0.256	0.531	0.856	1.058	1.316	1.708	2.060
26	0.256	0.531	0.856	1.058	1.315	1.706	2.056
27	0.256	0.531	0.855	1.057	1.314	1.703	2.052
28	0.256	0.530	0.855	1.056	1.313	1.701	2.048
29	0.256	0.530	0.854	1.055	1.311	1.699	2.045
30	0.256	0.530	0.854	1.055	1.310	1.697	2.042
40	0.255	0.529	0.851	1.050	1.303	1.684	2.021
60	0.254	0.527	0.848	1.045	1.296	1.671	2.000
120	0.254	0.526	0.845	1.041	1.289	1.658	1.980
∞	0.253	0.524	0.842	1.036	1.282	1.645	1.960

F-Table for 5%

Percentage points of the F-distribution:
upper 5% points
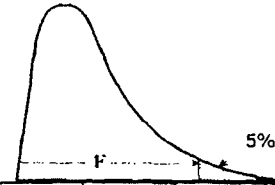
df_{num} / df_{den}	1	2	3	4	5	6	7	8	9	10	15	20
1	161.45	199.50	215.71	224.58	230.16	233.99	236.77	238.88	240.54	241.88	245.95	248.01
2	18.513	19.000	19.164	19.247	19.296	19.330	19.353	19.371	19.385	19.396	19.429	19.446
3	10.128	9.552	9.277	9.117	9.013	8.941	8.887	8.845	8.812	8.786	8.703	8.660
4	7.709	6.944	6.591	6.388	6.256	6.163	6.094	6.041	5.999	5.964	5.858	5.803
5	6.608	5.786	5.409	5.192	5.050	4.950	4.876	4.818	4.772	4.735	4.619	4.558
6	5.987	5.143	4.757	4.534	4.387	4.284	4.207	4.147	4.099	4.060	3.938	3.874
7	5.591	4.737	4.347	4.120	3.972	3.866	3.787	3.726	3.677	3.637	3.511	3.445
8	5.318	4.459	4.066	3.838	3.687	3.581	3.500	3.438	3.388	3.347	3.218	3.150
9	5.117	4.256	3.863	3.633	3.482	3.374	3.293	3.230	3.179	3.137	3.006	2.936
10	4.965	4.103	3.708	3.478	3.326	3.217	3.135	3.072	3.020	2.978	2.845	2.774
11	4.844	3.982	3.587	3.357	3.204	3.095	3.012	2.948	2.896	2.854	2.719	2.646
12	4.747	3.885	3.490	3.259	3.106	2.996	2.913	2.849	2.796	2.753	2.617	2.544
13	4.667	3.806	3.411	3.179	3.025	2.915	2.832	2.767	2.714	2.671	2.533	2.459
14	4.600	3.739	3.344	3.112	2.958	2.848	2.764	2.699	2.646	2.602	2.463	2.388
15	4.543	3.682	3.287	3.056	2.901	2.790	2.707	2.641	2.588	2.544	2.403	2.328
16	4.494	3.634	3.239	3.007	2.852	2.741	2.657	2.591	2.538	2.494	2.352	2.276
17	4.451	3.592	3.197	2.965	2.810	2.699	2.614	2.548	2.494	2.450	2.308	2.230
18	4.414	3.555	3.160	2.928	2.773	2.661	2.577	2.510	2.456	2.412	2.269	2.191
19	4.381	3.522	3.127	2.895	2.740	2.628	2.544	2.477	2.423	2.378	2.234	2.155
20	4.351	3.493	3.098	2.866	2.711	2.599	2.514	2.447	2.393	2.348	2.203	2.124
21	4.325	3.467	3.072	2.840	2.685	2.573	2.488	2.420	2.366	2.321	2.176	2.096
22	4.301	3.443	3.049	2.817	2.661	2.549	2.464	2.397	2.342	2.297	2.151	2.071
23	4.279	3.422	3.028	2.796	2.640	2.528	2.442	2.375	2.320	2.275	2.128	2.048
24	4.260	3.403	3.009	2.776	2.621	2.508	2.423	2.355	2.300	2.255	2.108	2.027
25	4.242	3.385	2.991	2.759	2.603	2.490	2.405	2.337	2.282	2.236	2.089	2.007
26	4.225	3.369	2.975	2.743	2.587	2.474	2.388	2.321	2.265	2.220	2.072	1.990
27	4.210	3.354	2.960	2.728	2.572	2.459	2.373	2.305	2.250	2.204	2.056	1.974
28	4.196	3.340	2.947	2.714	2.558	2.445	2.359	2.291	2.236	2.190	2.041	1.959
29	4.183	3.328	2.934	2.701	2.545	2.432	2.346	2.278	2.223	2.177	2.027	1.945
30	4.171	3.316	2.922	2.690	2.534	2.421	2.334	2.266	2.211	2.165	2.015	1.932
40	4.085	3.232	2.839	2.606	2.449	2.336	2.249	2.180	2.124	2.077	1.924	1.839
60	4.001	3.150	2.758	2.525	2.368	2.254	2.167	2.097	2.040	1.993	1.836	1.748
120	3.920	3.072	2.680	2.447	2.290	2.175	2.087	2.016	1.959	1.910	1.750	1.659
100K	3.842	2.996	2.605	2.372	2.214	2.099	2.010	1.939	1.880	1.831	1.666	1.571

K (Multiply this value by 1000)