Paired Wilcoxon Signed Rank Test

1. Ten athletes ran a fixed 200m distance on successive days, firstly on a synthetic athletic track and then on a conventional cinder track. The decision whether each athlete ran on cinder first or synthetic first was made at random. The results in seconds were as follows:

Athlete	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Synthetic	26.5	25.8	27.2	28.1	25.6	25.5	28.8	27.1	24.1	26.6
Cinder	26.6	26.1	27.4	28.0	25.8	26.6	29.1	27.0	24.8	26.8

Carry out a Wilcoxon signed-rank test, at the 5% significance level, to determine whether the nature of the surface influences athletes' performance in the 200m.

2. Ten psychology students carried out an experiment. They wished to test whether the ability to perform a simple control task is influenced by the presence of an audience.
Each student carried out the task on their own first and measured the time taken. Then, each student performed the same task again in front of an audience. The time results (seconds) were:

Student	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Alone	45.4	48.2	47.5	49.1	54.3	45.5	58.2	47.1	54.3	46.8
Audience	46.7	51.2	47.8	48.0	55.8	46.6	59.1	47.0	54.8	49.6

Carry out a Wilcoxon signed-rank test at the 5% significance level to investigate whether the median time taken by students to perform the task is greater when an audience is present.

3. Pairs of twins, where each twin suffers from moderate eczema, are recruited for the trial of a new skin preparation. The trial is a double blind trial in which the twin selected at random to be in the control group is given a placebo. The percentage improvement after 4 weeks of treatment was assessed with the following results:

Twin	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Placebo	16	10	16	22	22	24	24	11
New Prep	21	16	20	25	20	28	26	15

Carry out a Wilcoxon signed-rank test, at the 1% significance level, to investigate whether the new preparation results in a twin having a higher mean percentage improvement of their eczema

4. Identical programs were run on two different makes of personal computers and the load times (seconds) on each machine, for each program were noted

Program	1	2	3	4	5	6	7	8	9	10	11	12
PC A	37	77	49	26	23	16	12	12	45	25	10	55
PC B	30	66	47	22	20	14	17	13	43	31	7	41

Use the Wilcoxon signed-rank test, at the 5% level of significance, to determine whether there is any evidence of a difference in mean load times between the two personal computers

5. The blood clotting times for eight people were measured before and after they had consumed a fixed amount of alcohol. The times (seconds) are given below:

Person	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Before	124	167	129	117	146	16	119	149
After	126	117	134	127	126	128	114	99

(a) Comment on the use of a paired design for this experiment
(b) Test, at the 5% level of significance, the hypothesis that the consumption of alcohol has no effect on the median clotting times of blood. Use a Wilcoxon signed-rank test.

6. The Ministry of Defence is considering which of two shoe leathers it should adopt for its new Army boot. They are particularly interested in how boots made from these leathers wear and so 15 soldiers are selected at random and each soldier wears one boot of each type. After six months the wear, in millimetres, for each boot is recorded as follows:

Soldier	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Leather A	5.4	2.6	4.3	1.1	3.3	6.6	4.4	3.5	1.2	1.3	4.8	1.2	2.8	2.0	6.1
Leather B	4.7	3.2	3.8	2.3	3.6	7.2	4.4	3.9	1.9	1.2	5.8	2.0	3.7	1.8	6.1

Use the Wilcoxon signed-rank test, to investigate the hypothesis that the wear in the two leathers is the same. Use the 5% significance level.

7. Trace metal in drinking water affect the flavour of water and high concentrations can pose a health hazard. The following table shows the zinc concentrations, in milligrams, per 1000 litres, of water on the surface and on the river bed at each of the 12 locations on a river.

Location	1	2	3	4	5	6	7	8	9	10	11	12
Surface	387	515	721	341	689	599	743	541	717	523	524	445
Bed	435	532	817	366	827	735	812	669	808	622	476	387

Using a Wilcoxon signed-rank test, examine the claim that Zinc concentration of water in this river is higher on the river bed than on the surface. Use a 1% significance level.

8. A random sample of 11 adults, who had eaten breakfast at 8am, had their pulse rates measured at 11am, and then again at 7pm, immediately after they had eaten their evening meal. The results were

Person	A	B	C	D	E	F	G	H	J	K	L
11am	62	75	87	80	89	81	84	82	75	59	68
7pm	60	69	83	79	87	76	75	84	75	58	69

Test whether there is any significant difference, at the 5% significance level, between pulse rates mid-morning and pulse rates immediately after an evening meal.

(a) Carry this test out:
   a. Using a sign test
   b. Using a Wilcoxon signed-rank test

(b) Compare the results from these two distribution-free tests. Why might a Wilcoxon signed-rank test be preferred to the sign test?

9. Jim, a market trader, decided to find out whether changing his vegetable supplier would increase his takings. He told a friend, Yasmin, who is a statistician: 'It worked. Yesterday using my old supplier my takings were £180, today with the new supplier my takings were £260.' Yasmine persuaded him to carry out a further trial over a two-week period with the following results.

	1st Week						2nd Week					
Day	Mon	Tues	Wed	Thurs	Fri	Sat	Mon	Tues	Wed	Thurs	Fri	Sat
Supplier	old	old	new	old	new	new	new	new	old	new	old	Old
Takings (£)	165	199	215	170	387	408	183	204	221	168	345	389

(a) Using the data from the further trial, apply Wilcoxon signed-rank test, at the 5% significance level, to investigate whether takings increased when the new supplied was used

(b) Explain why the conclusion drawn from Jim's original 1-day trial may be invalid and the advantages of the trial designed by Yasmin.