Version 1.0

General Certificate of Education (A-level)
June 2013

Statistics SS06

(Specification 6380)

Statistics 6

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of students' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

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Key to mark scheme abbreviations

M	mark is for method
m or dM	mark is dependent on one or more M marks and is for method
A	mark is dependent on M or m marks and is for accuracy
B	mark is independent of M or m marks and is for method and accuracy
E	mark is for explanation
√or ft or F	follow through from previous incorrect result
CAO	correct answer only
CSO	correct solution only
AWFW	anything which falls within
AWRT	anything which rounds to
ACF	any correct form
AG	answer given
SC	special case
OE	or equivalent
A2,1	2 or 1 (or 0) accuracy marks
–*x* EE	deduct *x* marks for each error
NMS	no method shown
PI	possibly implied
SCA	substantially correct approach
c	candidate
sf	significant figure(s)
dp	decimal place(s)

No Method Shown

Where the question specifically requires a particular method to be used, we must usually see evidence of use of this method for any marks to be awarded.

Where the answer can be reasonably obtained without showing working and it is very unlikely that the correct answer can be obtained by using an incorrect method, we must award **full marks**. However, the obvious penalty to candidates showing no working is that incorrect answers, however close, earn **no marks**.

Where a question asks the candidate to state or write down a result, no method need be shown for full marks.

Where the permitted calculator has functions which reasonably allow the solution of the question directly, the correct answer without working earns **full marks**, unless it is given to less than the degree of accuracy accepted in the mark scheme, when it gains **no marks**.

Otherwise we require evidence of a correct method for any marks to be awarded.

<table>
<tr><th>Q</th><th>Solution</th><th>Marks</th><th>Total</th><th>Comments</th></tr>
<tr><td>1(a)(i)</td><td>H_0 pop mean diff $\mu_d = 0$
H_1 pop mean diff $\mu_d \neq 0$
2 tail 5%</td><td>B1</td><td></td><td>Must refer to pop mean differences or μ_d</td></tr>
<tr><td></td><td>d = K – EMC<table><tr><td></td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr><tr><td>d</td><td>–0.4</td><td>0.8</td><td>-0.4</td><td>–0.5</td><td>0.1</td></tr><tr><td></td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr><tr><td></td><td>–0.8</td><td>-0.5</td><td>0</td><td>–0.6</td><td>0.1</td></tr></table></td><td>M1</td><td></td><td>Differences – can be reversed</td></tr>
<tr><td></td><td>$\bar{d} = -0.22 \quad s = 0.471 \quad n = 10$</td><td>m1</td><td></td><td>attempt to find $\bar{d}$, s can be implied</td></tr>
<tr><td></td><td>$t = \dfrac{-0.22 - 0}{0.47/\sqrt{10}} = \mathbf{-1.48}$</td><td>m1
m1
A1</td><td></td><td>Use of $\dfrac{s}{\sqrt{10}}$ ft
Method for t
(±) 1.48 (1.46 – 1.48)</td></tr>
<tr><td></td><td>df = 9 cv = –2.262
$-2.262 < -1.48$</td><td>B1</td><td></td><td>for correct cv (or p =0.17 $>$ 0.05 B1)</td></tr>
<tr><td></td><td>Accept H_0</td><td></td><td></td><td>*sc4 ‘0’ ignored scores B1 M1m1m1 $\dfrac{s}{\sqrt{9}}$</td></tr>
<tr><td></td><td>No significant evidence to suggest that there is a difference in mean measurements for the two devices.</td><td>E1</td><td>8</td><td>correct conclusion in context</td></tr>
<tr><td>(ii)</td><td>Assumed that differences in first ray foot measurements are normally distributed</td><td>E1
E1</td><td>2</td><td>Normal distribution mentioned in a sentence E1
Differences in foot measurements are normal gains other E1</td></tr>
<tr><td>(b)(i)</td><td>Attempt at double ss
1^{st} 0 1 1
2^{nd} 0 1 for acceptance</td><td>M1</td><td></td><td></td></tr>
<tr><td></td><td>P(Acc) = P(0) + P(1)×P(0) + P(1)×P(1)
= P(0) + P(1)×P(1 or fewer)
= 0.5438 + 0.3364×0.8802
= 0.840 (0.839)</td><td>M1

m1
A1</td><td>4</td><td>

Use of B (20, 0.03) .5438, .3364, .8802
Correct probs used in correct formula cao</td></tr>
<tr><td>(ii)</td><td>Expected number tested
= 20 + (extra 20)×P(1)
= 20 + 20×0.3364</td><td>M1</td><td></td><td>20 + (20×prob from B(20, 0.03)) as above</td></tr>
<tr><td></td><td>= 26.7</td><td>A1</td><td>2</td><td>26.5–26.8 disallow integer answer</td></tr>
<tr><td></td><td>Total</td><td></td><td>16</td><td></td></tr>
</table>

<table>
<tr><th>Q</th><th>Solution</th><th>Marks</th><th>Total</th><th>Comments</th></tr>
<tr><td>2(a)(i)</td><td>The furnace run</td><td>B1</td><td></td><td></td></tr>
<tr><td>(ii)</td><td>The dose of implant material</td><td>B1</td><td></td><td></td></tr>
<tr><td>(iii)</td><td>To eliminate bias – ensures that all wafers were produced in the same way so any difference detected should be due to implant dose or furnace run</td><td>E1E1</td><td>4</td><td>E1 eliminate bias
E1 any difference detected</td></tr>
<tr><td>(b)(i)</td><td>Harriet's design/Rand Block design takes into account any differences that result from the different furnace runs involved; Eric's does not take this into account</td><td>E1
E1</td><td>2</td><td>Harriet accounts for furnace effect
Eric ignores furnace effect</td></tr>
<tr><td>(ii)</td><td><table><tr><th>F1</th><th>F2</th><th>F3</th></tr><tr><td>D1</td><td>D1</td><td>D1</td></tr><tr><td>D2</td><td>D2</td><td>D2</td></tr><tr><td>D3</td><td>D3</td><td>D3</td></tr><tr><td>D4</td><td>D4</td><td>D4</td></tr></table></td><td>B1
B1</td><td>2</td><td>Use of D1 – D4
Correctly placed – any order within each run</td></tr>
<tr><td>(c)</td><td>Two factor analysis of variance</td><td>E1E1</td><td>2</td><td>ANOVA E1
Two factor E1</td></tr>
<tr><td></td><td>Total</td><td></td><td>10</td><td></td></tr>
</table>

Q	Solution	Marks	Total	Comments
3(a)(i)	*Low level* *Medium level* *High level* $T_{\text{low}} = 85.8$ $T_{\text{med}} = 108.6$ $T_{\text{high}} = 85.6$ $n_{\text{low}} = 5$ $n_{\text{med}} = 6$ $n_{\text{high}} = 5$ $T = 280$ $\sum\sum x_{ij}^2 = 4910.2$ $N = 16$ $\sum \frac{T_i^2}{n_i} = \frac{85.8^2}{5} + \frac{108.6^2}{6} + \frac{85.6^2}{5}$ $= 4903.46$			
	$\text{SS}_{\text{treats}} = 4903.46 - \frac{280^2}{16}$ $= \mathbf{3.46}$	M1		SS for treatments
	$\text{SS}_{\text{Total}} = 4910.2 - \frac{280^2}{16}$ $= \mathbf{10.2}$	M1		SS for total
	$\begin{array}{\|l\|l\|l\|l\|} \hline & \text{SS} & \text{df} & \text{ms} \\ \hline \text{Treats} & 3.46 & 2 & \mathbf{1.73} \\ \hline \text{Error} & \mathbf{6.74} & 13 & \mathbf{0.52} \\ \hline \text{Total} & 10.2 & 15 & \\ \hline \end{array}$	M1dep M1dep		Error SS ft (not –ve) Either ms correct method (SS/df)
	$\text{F} = \frac{1.73}{0.52} = \mathbf{3.33}$	M1dep A1		Method for F (ft) ‘their ms treats/ms error’ 3.1–3.5
	$\text{F}^{\,2}_{\,13} = \mathbf{3.806}$	B1 B1		df correct 2,13 cv correct (or $p = 0.068 > 0.05$ B2)
	H_O $\mu_{low} = \mu_{med} = \mu_{high}$ H_1 at least 2 of the means differ oe One mean sig different from others	B1		Hypotheses
	3.806 > 3.33 **Accept $\mathbf{H_0}$.** There is no significant evidence of a difference in mean breaking strength for the 3 thread treatment levels.	A1	10	Conclusion correct
(a)(ii)	Since there is **no significant difference** detected between mean **breaking strength** for the **three** thread **treatments/levels**, **the company should not be advised** to use any one particular treatment level.	E1 E1	2	No difference in strengths for treatments Could not advise company to use a specific level of treatment or choose cheapest/easiest to obtain
(b)	The **Kruskal–Wallis** test as this is distribution free so **does not depend on assumption that breaking strengths are normally distributed.**	B1 E1dep	2	Kruskal–Wallis Does not require underlying normal distribution/distribution free.
	Total		**14**	

Q	Solution	Marks	Total	Comments
4(a)(i)	Warning			
	$1 \pm 1.96 \times {}^{0.015}\!/_{\sqrt{4}}$ **(0.985, 1.015)**	B1		For 1.96 **and** 3.09
		M1		For ${}^{0.015}\!/_{\sqrt{4}}$
	Action			
	$1 \pm 3.09 \times {}^{0.015}\!/_{\sqrt{4}}$ **(0.977, 1.023)**	A1		Warning correct to 3 dp
		A1		Action correct to 3 dp
(ii)	Standard deviations $0.015 \times 0.09 = 0.0013(5)$ **0.001**			
	$0.015 \times 0.27 = 0.0040(5)$ **0.004**	M1		E values correct × 0.015
	$0.015 \times 1.76 = 0.0264$ **0.026**	A1	6	Correct to 3 dp
	$0.015 \times 2.33 = 0.0350$ **0.035**			
(b)(i)	Sample 5 Sample 6 Sample 7 Sample 8			
	$\bar{x}$ (1.010) **0.980** 1.000 **0.995**	M1		One mean OK
		M1		One sd OK
	s **0.041** (0.022) 0.032 **0.029**	A1	3	All means and sd values correct
(ii)	Since sd **beyond upper action limit**	M1		A1 dep on M1
	production **should have been stopped**.	A1	2	scB1 Production stopped
(iii)	Process fine up to sample 5	E1		
	Mean **sample 6** is **0.980** (between warning and action limits)	E1		Sample 6 a warning for mean
	Sd **sample 5** a **problem** Samples **7 and 8 sd lie between warning and action limits.**	E1	3	General comments on sd problems - beyond action for sample 5 or problems for samples 7 and 8.
(c)	P(0.9853 < $\bar{X}$ < 1.0147)	M1		Identification of need for evaluation of probability of mean between values 0.985 – 1.015
	$z = \dfrac{0.9853 - 1.004}{{}^{0.02}\!/_{\sqrt{4}}} = -1.87$			
	$z = \dfrac{1.0147 - 1.004}{{}^{0.02}\!/_{\sqrt{4}}} = 1.07$	M1		z-values
	P(0.9853 < $\bar{X}$ < 1.0147) = **0.827**	A1	3	0.82 – 0.84
	Total		**17**	

Q	Solution	Marks	Total	Comments
5(a)	Latin Square	M1	1	
(b)(i)	$T_A = 121$ $T_B = 136.6$ $T_C = 114.2$ $T_D = 124.4$ $n_A = 4$ $n_B = 4$ $n_C = 4$ $n_D = 4$ $\sum \frac{T_i^2}{n_i} = \frac{121^2}{4} + \frac{136.6^2}{4} + \frac{114.2^2}{4} + \frac{124.4^2}{4}$ $= 15454.39$			
	SS $_{\text{Blends}}$ $= 15454.39 - \frac{496.2^2}{16}$ **= 65.99**	M1		SS for Blends
	SS $_{\text{Total}}$ $= 15606.3 - \frac{496.2^2}{16}$ = **217.89**	M1		SS for total

	SS	df	ms	*F*
Driver	14.47	3	4.82	(0.49)
Car model	77.8	**3**	**25.96**	**2.62**
Blends petrol	**65.99**	**3**	**22.00**	**2.22**
Error	**59.56**	**6**	**9.93**	
Total	**217.89**	**15**		

Q	Solution	Marks	Total	Comments
		m1 B1		Error SS ft (not –ve) 59.56 df error = 6 correct
		m1		Method for MS (dep error ss/df) prev m1B1
	$F = \frac{25.96}{9.93} = 2.62$ for blends	m1		Method for F (ft)
	$F = \frac{22.00}{9.93} = 2.22$ for models	A1	7	Either 2.58 – 2.64 or 2.10 – 2.32 correct
(ii)	$F^{3}_{6} = \mathbf{4.757}$	B1 B1		df correct 3,6 cv correct cao (or p =0.146, p =0.187 > 0.05) B1 M1)
	2.61, 2.22 < 4.757	M1		Comparison *F*’s and cv (4.757) ft - can be implied
	$H_0 : \mu_A = \mu_B = \mu_C = \mu_D$ H_1 : at least 2 of the means differ one mean different from other two $H_0 : \mu_I = \mu_{II} = \mu_{III} = \mu_{IV}$ H_1 : as above	B1		Hypotheses
	Accept H_0 for both blends and for models	A1	5	Both **Accept H_0**

Q	Solution	Marks	Total	Comments
5(b)(iii)	There is no significant evidence of a difference in mean miles per gallon/fuel efficiency between the four blends of petrol and also none between the four models of car.	E1 E1	2	No difference in mean mpg/miles for either blends or models. Fully explained in context using 'mean mpg'or 'fuel eff' ,'blends of petrol' and models of car'
(c)	Fuel efficiency measurements, mpg, are normally distributed.	E1		Normal dist in context sentence
	There is a common underlying variability for mpg measurements.	E1		Common variability in context
	There is no interaction between petrol blend, car model and driver.	E1	3	Must be in context
	Total		**18**	
	TOTAL		**75**	