GCE

Mathematics (MEI)

Unit **4767**: Statistics 2

Advanced GCE

Mark Scheme for June 2016

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

1. **Annotations and abbreviations**

Annotation in scoris	**Meaning**
✓and ✗	
BOD	Benefit of doubt
FT	Follow through
ISW	Ignore subsequent working
M0, M1	Method mark awarded 0, 1
A0, A1	Accuracy mark awarded 0, 1
B0, B1	Independent mark awarded 0, 1
SC	Special case
^	Omission sign
MR	Misread
Highlighting	
Other abbreviations in mark scheme	**Meaning**
E1	Mark for explaining
U1	Mark for correct units
G1	Mark for a correct feature on a graph
M1 dep*	Method mark dependent on a previous mark, indicated by *
cao	Correct answer only
oe	Or equivalent
rot	Rounded or truncated
soi	Seen or implied
www	Without wrong working
ito	In terms of

2. Subject-specific Marking Instructions for GCE Mathematics (MEI) Statistics strand

a Annotations should be used whenever appropriate during your marking.

The A, M and B annotations must be used on your standardisation scripts for responses that are not awarded either 0 or full marks. It is vital that you annotate standardisation scripts fully to show how the marks have been awarded.

For subsequent marking you must make it clear how you have arrived at the mark you have awarded.

b An element of professional judgement is required in the marking of any written paper. Remember that the mark scheme is designed to assist in marking incorrect solutions. Correct *solutions* leading to correct answers are awarded full marks but work must not be judged on the answer alone, and answers that are given in the question, especially, must be validly obtained; key steps in the working must always be looked at and anything unfamiliar must be investigated thoroughly.

Correct but unfamiliar or unexpected methods are often signalled by a correct result following an *apparently* incorrect method. Such work must be carefully assessed. When a candidate adopts a method which does not correspond to the mark scheme, award marks according to the spirit of the basic scheme; if you are in any doubt whatsoever (especially if several marks or candidates are involved) you should contact your Team Leader.

c The following types of marks are available.

M
A suitable method has been selected and *applied* in a manner which shows that the method is essentially understood. Method marks are not usually lost for numerical errors, algebraic slips or errors in units. However, it is not usually sufficient for a candidate just to indicate an intention of using some method or just to quote a formula; the formula or idea must be applied to the specific problem in hand, eg by substituting the relevant quantities into the formula. In some cases the nature of the errors allowed for the award of an M mark may be specified.

A
Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated Method mark is earned (or implied). Therefore M0 A1 cannot ever be awarded.

B
Mark for a correct result or statement independent of Method marks.

E

A given result is to be established or a result has to be explained. This usually requires more working or explanation than the establishment of an unknown result.

Unless otherwise indicated, marks once gained cannot subsequently be lost, eg wrong working following a correct form of answer is ignored. Sometimes this is reinforced in the mark scheme by the abbreviation isw. However, this would not apply to a case where a candidate passes through the correct answer as part of a wrong argument.

d When a part of a question has two or more 'method' steps, the M marks are in principle independent unless the scheme specifically says otherwise; and similarly where there are several B marks allocated. (The notation 'dep *' is used to indicate that a particular mark is dependent on an earlier, asterisked, mark in the scheme.) Of course, in practice it may happen that when a candidate has once gone wrong in a part of a question, the work from there on is worthless so that no more marks can sensibly be given. On the other hand, when two or more steps are successfully run together by the candidate, the earlier marks are implied and full credit must be given.

e The abbreviation ft implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A and B marks are given for correct work only — differences in notation are of course permitted. A (accuracy) marks are not given for answers obtained from incorrect working. When A or B marks are awarded for work at an intermediate stage of a solution, there may be various alternatives that are equally acceptable. In such cases, exactly what is acceptable will be detailed in the mark scheme rationale. If this is not the case please consult your Team Leader.

Sometimes the answer to one part of a question is used in a later part of the same question. In this case, A marks will often be 'follow through'. In such cases you must ensure that you refer back to the answer of the previous part question even if this is not shown within the image zone. You may find it easier to mark follow through questions candidate-by-candidate rather than question-by-question.

f Wrong or missing units in an answer should not lead to the loss of a mark unless the scheme specifically indicates otherwise.

Candidates are expected to give numerical answers to an appropriate degree of accuracy. 3 significant figures may often be the norm for this, but this always needs to be considered in the context of the problem in hand. For example, in quoting probabilities from Normal tables, we generally expect *some* evidence of interpolation and so quotation to 4 decimal places will often be appropriate. But even this does not always apply – quotations of the standard critical points for significance tests such as 1.96, 1.645, 2.576 (maybe even 2.58 – but not 2.57) will commonly suffice, especially if the calculated value of a test statistic is nowhere near any of these values. Sensible discretion *must* be exercised in such cases.

Discretion must also be exercised in the case of small variations in the degree of accuracy to which an answer is given. For example, if 3 significant figures are expected (either because of an explicit instruction or because the general context of a

problem demands it) but only 2 are given, loss of an accuracy ("A") mark is likely to be appropriate; but if 4 significant figures are given, this should not normally be penalised. Likewise, answers which are slightly deviant from what is expected in a very minor manner (for example a Normal probability given, after an attempt at interpolation, as 0.6418 whereas 0.6417 was expected) should not be penalised. However, answers which are *grossly* over- or under-specified should normally result in the loss of a mark. This includes cases such as, for example, insistence that the value of a test statistic is (say) 2.128888446667 merely because that is the value that happened to come off the candidate's calculator. Note that this applies to answers that are given as final stages of calculations; intermediate working should usually be carried out, and quoted, to a greater degree of accuracy to avoid the danger of premature approximation.

The situation regarding any particular cases where the accuracy of the answer may be a marking issue should be detailed in the mark scheme rationale. If in doubt, contact your Team Leader.

g Rules for replaced work

If a candidate attempts a question more than once, and indicates which attempt he/she wishes to be marked, then examiners should do as the candidate requests.

If there are two or more attempts at a question which have not been crossed out, examiners should mark what appears to be the last (complete) attempt and ignore the others.

NB Follow these maths-specific instructions rather than those in the assessor handbook.

h Genuine misreading (of numbers or symbols, occasionally even of text) occurs. If this results in the object and/or difficulty of the question being considerably changed, it is likely that all the marks for that question, or section of the question, will be lost. However, misreads are often such that the object and/or difficulty remain substantially unaltered; these cases are considered below.

The simple rule is that *all* method ("M") marks [and of course all independent ("B") marks] remain accessible but at least some accuracy ("A") marks do not. It is difficult to legislate in an overall sense beyond this global statement because misreads, even when the object and/or difficulty remains unchanged, can vary greatly in their effects. For example, a misread of 1.02 as 10.2 (perhaps as a quoted value of a sample mean) may well be catastrophic; whereas a misread of 1.6748 as 1.6746 may have so slight an effect as to be almost unnoticeable in the candidate's work.

A misread should normally attract *some* penalty, though this would often be only 1 mark and should rarely if ever be more than 2. Commonly in sections of questions where there is a numerical answer either at the end of the section or to be obtained and commented on (eg the value of a test statistic), this answer will have an "A" mark that may actually be designated as "cao" [correct answer only]. This should be interpreted *strictly* – if the misread has led to failure to obtain this value, then this "A" mark

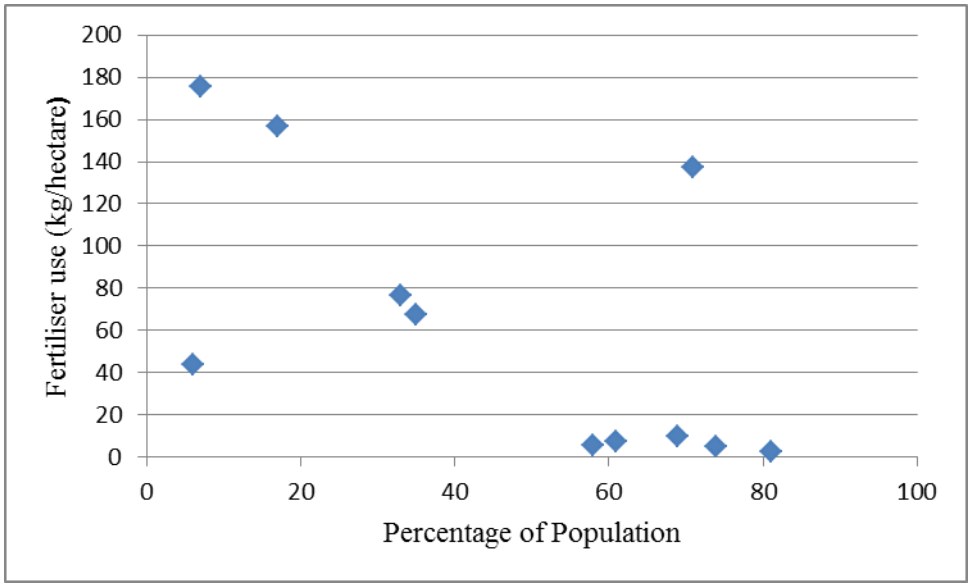
must be withheld even if all method marks have been earned. It will also often be the case that such a mark is implicitly "cao" even if not explicitly designated as such.

On the other hand, we commonly allow "fresh starts" within a question or part of question. For example, a follow-through of the candidate's value of a test statistic is generally allowed (and often explicitly stated as such within the marking scheme), so that the candidate may exhibit knowledge of how to compare it with a critical value and draw conclusions. Such "fresh starts" are not affected by any earlier misreads.

A misread may be of a symbol rather than a number – for example, an algebraic symbol in a mathematical expression. Such misreads are more likely to bring about a considerable change in the object and/or difficulty of the question; but, if they do not, they should be treated as far as possible in the same way as numerical misreads, *mutatis mutandis*. This also applied to misreads of text, which are fairly rare but can cause major problems in fair marking.

The situation regarding any particular cases that arise while you are marking for which you feel you need detailed guidance should be discussed with your Team Leader.

Note that a miscopy of the candidate's own working is not a misread but an accuracy error.

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th><th></th></tr>
<tr><td>1</td><td>(i)</td><td></td><td> 
</td><td>G1

G2,1,0

[3]</td><td>For suitably labelled axes. Condone absence of scale here.

G2 for 11 points correctly plotted relative to a suitable linear scale.

G1 if 9 or 10 correctly plotted.
G0 if 3 or more incorrectly plotted/omitted

Allow axes interchanged</td><td></td></tr>
<tr><td>1</td><td>(ii)</td><td></td><td>(The points in the scatter diagram) do not appear to be roughly elliptical.
The population may not have a bivariate Normal distribution.</td><td>E1
E1

[2]</td><td>For “not elliptical”.
For not underlying bivariate Normal. Do not allow “the data” in place of population/underlying. Allow “data is not from a bivariate Normal distribution”.
Do not allow Normal bivariate ….</td><td></td></tr>
<tr><td>1</td><td>(iii)</td><td></td><td><table>
<tr><td>Percentage</td><td>33</td><td>6</td><td>58</td><td>35</td><td>81</td><td>69</td><td>61</td><td>7</td><td>74</td><td>71</td><td>17</td></tr>
<tr><td>Fertiliser use</td><td>76</td><td>44</td><td>6</td><td>68</td><td>3</td><td>10</td><td>7</td><td>176</td><td>5</td><td>137</td><td>157</td></tr>
<tr><td>Rank percentage</td><td>4</td><td>1</td><td>6</td><td>5</td><td>11</td><td>8</td><td>7</td><td>2</td><td>10</td><td>9</td><td>3</td></tr>
<tr><td>Rank Fertiliser</td><td>8</td><td>6</td><td>3</td><td>7</td><td>1</td><td>5</td><td>4</td><td>11</td><td>2</td><td>9</td><td>10</td></tr>
<tr><td>d</td><td>4</td><td>5</td><td>-3</td><td>2</td><td>-10</td><td>-3</td><td>-3</td><td>9</td><td>-8</td><td>0</td><td>7</td></tr>
<tr><td>d^2</td><td>16</td><td>25</td><td>9</td><td>4</td><td>100</td><td>9</td><td>9</td><td>81</td><td>64</td><td>0</td><td>49</td></tr>
</table></td><td>M1

M1</td><td>For ranking (allow ranks reversed)

NB No ranking scores 0/5

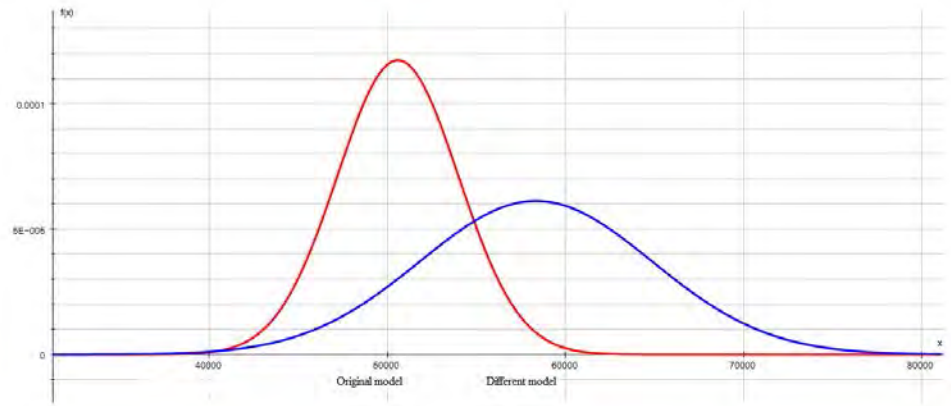
For d^2</td><td></td></tr>
</table>

Question			Answer	Marks	Guidance	
			$\Sigma d^2 = 366$	A1	For Σd^2 (May be embedded in the calculation)	
			$r_s = 1 - \frac{6\sum d^2}{n(n^2-1)} = 1 - \frac{6\times366}{11\times120} = 1 - \frac{2196}{1320} = 1 - 1.6636$	M1	For method for r_s	
			= - 0.664 (to 3 s.f.) [*allow* -0.66 to 2 s.f. or -73/110]	A1 **[5]**	FT their Σd^2 provided $-1 < r_s < 0$, and ranking used. **NB No ranking scores 0/5**	
1	**(iv)**		H_0: no association between percentage of population living in rural areas and fertiliser use (in the population of countries)	B1	For null hypothesis in context **NB** H_0 H_1 <u>not</u> ito ρ.	
			H_1: **negative** association between percentage of population living in rural areas and fertiliser use (in the population of countries)	B1 B1	For alternative hypothesis in context. Context needed in at least one of the hypotheses. For **population of countries** or **underlying population**.	
			One tail test critical value at 1% level is -0.7091	B1	For ±0.7091 **No further marks from here if incorrect**.	
			Since - 0.664 > -0.7091 [or 0.664 < 0.7901] there is …	M1	For sensible comparison of their "- 0.664" with ±0.7091 **seen**, leading to conclusion, only if $-1 <$ their $r_s < 0$.	
			…insufficient evidence to reject H_0. There is insufficient evidence to suggest that there is **negative** association between percentage of population living in rural areas and fertiliser use (in the population of countries)	A1 **[6]**	for not significant, oe, and correct conclusion in context. FT their r_s with correct cv.	

Question			Answer	Marks	Guidance	
1	(v)		It means that the probability of rejecting H_0 given that it is correct is 1% o.e.	E1 **[1]**	Allow "the probability of a false positive is 1%", "the probability of a Type I Error is 1%". Do not allow "It means that the probability rejecting H_0 when it should have been accepted is 1%"	
1	(vi)		None	E1 **[1]**		
2	(i)		'Randomly' means that **mutations** occur with no (predictable) pattern. 'Independently' means that the occurrence of one **mutation** does not affect the **probability** of another mutation occurring.	E1 E1 **[2]**	In context. Allow "not predictable" Must include 'probability' and context. Allow "chance". If not indicated, assume first comment relates to randomness.	
2	(ii)		P(Exactly one) = $\binom{30}{29} \times 0.85^{29} \times 0.15^{1}$ $^{20}C_1 \times 0.012^1 \times 0.988^{19}$ = 0.1908	M1 A1 **[2]**	For correct structure i.e. $20p(1-p)^{19}$ Allow 0.191. Allow 0.19 www.	
2	(iii)		Because the number of mutating genes/X is binomially distributed n is large and p is small.	E1 E1 **[2]**	Allow B(500, 0.012) or B(n, p). Allow the sample is large & $np \approx np(1-p)$ or np not too large. Condone suitable numerical ranges – e.g. $n > 30$, $p < 0.1$ Do not allow "the number is large and probability is small". Allow "probability of success/a gene mutating is small" for p is small	
2	(iv)	(*A*)	$\lambda = 500 \times 0.012 = 6$ P(2 mutations) = $e^{-0.85}\frac{0.85^1}{1!}$ [0.0620 – 0.0174 from tables] = 0.0446	B1 M1 A1 **[3]**	For mean Correct structure for P(= 2) using Poisson pdf or tables. CAO Allow 0.04462 or 0.045www	

Question			Answer	Marks	Guidance	
2	(iv)	(*B*)	From tables P(At least two) = 1 – P(≤1) = 1 – 0.0174 = 0.9826	 M1 A1 **[2]**	 For using 1 – P(≤ 1) using their mean. CAO Allow 0.983. Allow 0.98 www.	
2	(v)		Mean 50000 × 0.012 = 600 , Var = 50000 × 0.012 × 0.988 = 592.8 Using Normal approx. to the binomial, $X \sim$ N(600, 592.8) $P(X \geq 650) = P\left(Z \leq \frac{30.5-25.5}{\sqrt{25.5}}\right)$ = P(Z > 2.033) = 1 – Φ(2.033) = 1 – 0.9789 = 0.0211	 B1 B1 B1 M1 A1 **[5]**	 For Normal approximation (SOI). For correct parameters (SOI). For 649.5 For standardisation and probability calculation using correct tail. CAO (Allow answer from calculator 0.0210)	
2	(v)		**Alternative solution using Normal approx. to Poisson** Mean 100 × 6 = 600 Using Normal approx. to the Poisson, $X \sim$ N(600, 600) $P(X \geq 650) = P\left(Z \leq \frac{30.5-25.5}{\sqrt{25.5}}\right)$ = P(Z > 2.021) = 1 – Φ(2.021) = 1 – 0.9783 = 0.0217	 B1 B1 B1 M1 A1 **[5]**	 For Normal approximation (SOI). For correct parameters (SOI). For 649.5 For standardisation and probability calculation using correct tail. CAO (Allow answer from calculator 0.0216)	
3	(i)		P(50000 < X < 55000) = $P\left(Z \geq \frac{750-751.4}{2.5}\right)\left(\frac{50000-50600}{3400} < Z < \frac{55000-50600}{3400}\right)$ = P(-0.176 < Z < 1.294) = Φ(1.294) – (1 – Φ(0.176)) = 0.9022 – 1 + 0.5699 = 0.4721	M1 M1 A1 **[3]**	For standardising both. SOI. Penalise erroneous continuity corrections and wrong sd. Condone numerator(s) reversed. For correct structure Φ(positive z) - Φ(negative z) CAO including use of difference tables (Answer from calculator 0.4722 and from tables interpolated 0.4723)	

Question			Answer	Marks	Guidance	
3	(ii)		$P(X > 45000) = P\left(Z \geq \frac{750-751.4}{2.5}\right)\left(Z > \frac{45000-50600}{3400}\right) = P(Z > -1.647)$	B1*	For -1.647 or $-\Phi^{-1}(0.95) = -1.645$ or 1.647 seen with $P(X < 56200)$ or numerator reversed	
			$= \Phi(1.647) = 0.9502$	B1*	For 0.9502 or 45007 or 0.0498, or B1 for -1.645 if B1 for -1.647 already awarded.	
			0.9502 > 95% so agree with claim	depE1* **[3]**	**For comparison seen** e.g. -1.647 < -1.645 or 0.0498 < 0.05 or 1.647 > 1.645 or 95% last longer than 45007 hours, **and correct conclusion**. Dependent on B1, B1 awarded	
3	(iii)		From tables $\Phi^{-1}(0.999) = 3.09$	B1	±3.09 seen	
			$\frac{h-50600}{3400} = -3.09$	M1	For equation as seen with their negative z-value	
			$k = 50600 - (3.09 \times 3400) = 40100$ www	A1 **[3]**	CAO Allow 40094, 40090	

Question			Answer	Marks	Guidance	
3	(iv)		$P(Y < 60000) = 0.6 \Rightarrow P\left(Z < \frac{60000-\mu}{\sigma}\right) = 0.6$	B1	For ±0.2533 or ±1.282 seen	
			$\Rightarrow \frac{60000-\mu}{\sigma} = \Phi^{-1}(0.6) = 0.2533$	M1	For an equation ito μ, σ, z and y formed. NB using $z = \pm 0.2533$ with $y = 60\,000$ or ±1.282 with $y = 50\,000$	
			$\Rightarrow 60000 = \mu + 0.2533\sigma$			
			$P(Y > 50000) = 0.9 \Rightarrow P\left(Z > \frac{50000-\mu}{\sigma}\right) = 0.9$			
			$\Rightarrow \frac{50000-\mu}{\sigma} = \Phi^{-1}(0.1) = -1.282$	A1	For two correct equations seen.	
			$\Rightarrow 50000 = \mu - 1.282\sigma$			
			$1.5353\sigma = 10000$			
			$\sigma = 6513$	A1	CAO Allow 6510, 6515	
			$\Rightarrow \mu = 50000 + (1.282 \times 6513) = 58350$	A1 **[5]**	CAO Allow 58400	
3	(v)			G1 G1 G1 G1 **[4]**	For two Normal shapes including attempt at asymptotic behaviour with horizontal axis at each of the four ends. Penalise clear asymmetry. For means, shown explicitly or by scale **on a single diagram.** If shown explicitly, the positions must be consistent with horizontal scale if present. FT part (iv). For greater width (variance) for Different model. FT part (iv). For lower max height for Different model. FT part (iv) If not labelled assume the larger mean represents Different model. FT part(iv).	

Question			Answer	Marks	Guidance	
4	(a)	(i)	Expected frequency = $42/80 \times 29 = 15.225$ Contribution = $(12 - 15.225)^2 / 15.225$ $(= 0.6831$ AG$)$	B1 M1 A1 **[3]**	for 15.225 For valid attempt at $(O-E)^2/E$ leading to correct answer. ***NB Answer given***	
4		(ii)	H_0: no association between sex and attitude to Mathematics. H_1: some association between sex and attitude to Mathematics.	B1	For correct hypotheses in context (with context seen in at least one hypothesis). NB if H_0 H_1 reversed do not award first B1or final A1. Allow hypotheses expressed in terms of independence, and in context.	
			Test statistic $X^2 = 5.3236$	B1	Allow 5.324 or 5.32	
			Refer to χ^2_2	B1	Allow "2 degrees of freedom" or $\nu = 2$ seen.	
			Critical value at 5% level = 5.991	B1	No further marks from here if wrong or omitted.	
			(5.3236 < 5.991 so result is) not significant	M1	For not significant oe. FT their test statistic. Allow 'Accept H_0' or 'Reject H_1'	
			There is insufficient evidence **to suggest** that there is association <u>between sex and attitude to Mathematics</u>	A1 **[6]**	For **non-assertive** conclusion <u>in context</u> FT their test statistic. Do not allow "relationship" or "correlation" for "association".	

Question			Answer	Marks	Guidance	
4	(b)		$\bar{x} = 373/60 \quad = 6.217$	B1	Allow 6.22	
			$s = \sqrt{\dfrac{2498 - (373)^2/60}{59}} = \sqrt{\dfrac{179.183}{59}}$	M1	For correctly structured calculation (divisor = 59) for the sample standard deviation or variance.	
			$= \sqrt{3.0370} = 1.743$	A1	Allow answers which round to 1.74	
			H_0: $\mu = 5.64$; H_1 : $\mu > 5.64$	B1	For both hypotheses correct.	
			Where μ denotes the **mean** radioactivity level in (the population of) limpets	B1	For definition of μ in context. Do not allow other symbols unless clearly defined as population mean.	
			Test statistic $= \dfrac{6.217 - 5.64}{1.743/\sqrt{60}} = \dfrac{0.5767}{0.2250}$ $\frac{4.995-5.0}{0.0072/\sqrt{8}} = -\frac{0.005}{0.002546} = -1.964$	M1*	Structure of test statistic using their sd and mean. Must include correct use of √60. Do not condone numerator reversed.	
			= 2.563	A1	Allow answers between 2.56 and 2.57 inclusive.	
			Upper 5% level 1 tailed critical value of z = 1.645	B1	For 1.645 No further marks from here if wrong.	
			2.563 > 1.645 The result is…	depM1*	For sensible comparison leading to a conclusion (even if incorrect). FT their test statistic.	
			…significant. There is sufficient evidence to reject H_0	A1	Correct conclusion. FT their test statistic.	
			There is sufficient evidence **to suggest** that the **mean** level of radioactivity has increased.	A1 **[11]**	For correct **non-assertive** conclusion in words in context. FT their test statistic.	

Additional Notes on Sensible Comparisons

e.g. In Q4 (b) Neither 2.563 > 0.05 nor 0.0052 < 2.326 are considered sensible as each compares a z-value with a probability.
- 2.563 < 1.645 is not considered to be sensible.
For 2.563 < 1.645 leading to a conclusion, award M0 A0.

Additional Notes on Conclusions to Hypothesis Tests

The following are examples of conclusions which are considered too assertive.

There is sufficient evidence to reject H_0 and **conclude** that…
"there is a positive association between…" or
"there seems to be evidence that there is a positive association between…" or
"the mean level of radioactivity is greater …."
"there doesn't appear to be association between…"

Also note that final conclusions **must refer to H_1 in context** for the final mark to be given.
e.g. In Q4 (a) part (ii), a conclusion just stating that "there is insufficient evidence to suggest that there is an association" gets A0 as this does not refer to the context.

Additional Notes on Alternative Methods in Q4 (b)

Critical value method	cv = $5.64 + 1.645 \times 1.743 \div \sqrt{60}$ = 6.01 6.217 > 6.01	gets M1* (structure) FT their sd. B1 for 1.645 used (otherwise B0M0A0A0) gets A1 (replacing the A1 for 2.563) gets depM1* if a conclusion is made, FT their mean only if 1.645 used. Then A1, A1 available as before.
Probability Method	P(Z > 2.563) = 0.0052	gets B1 for value rounding to 0.005 which replaces the B1 for 1.645 (otherwise B0depM0*A0A0).
	0.005 < 0.05	gets depM1* if a conclusion is made only if B1for 0.005 has been awarded. Then A1, A1 available as before. NOTE Condone B1 for 0.995 obtained from P(Z < 2.563) only if compared with 0.95 at which point the final depM1*A1A1are available. B0depM0*A0A0 if 0.995 obtained from P(z > -2.563).

OCR (Oxford Cambridge and RSA Examinations)
1 Hills Road
Cambridge
CB1 2EU

OCR Customer Contact Centre

Education and Learning
Telephone: 01223 553998
Facsimile: 01223 552627
Email: general.qualifications@ocr.org.uk

www.ocr.org.uk