GCE

Further Mathematics A

Y542/01: Statistics

A Level

Mark Scheme for June 2025

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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.

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MARKING INSTRUCTIONS

PREPARATION FOR MARKING
RM ASSESSOR

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM Assessor Online Training: OCR Essential Guide to Marking*.

2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are available in RM Assessor

3. Log-in to RM Assessor and mark the **required number** of practice responses ("scripts") and the **required number** of standardisation responses.

MARKING

1. Mark strictly to the mark scheme.

2. Marks awarded must relate directly to the marking criteria.

3. The schedule of dates is very important. It is essential that you meet the RM Assessor 50% and 100% (traditional 40% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.

4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone, email or via the RM Assessor messaging system.

5. **Crossed-Out Responses**
   Where a candidate has crossed out a response and provided a clear alternative then the crossed-out response is not marked. Where no alternative response has been provided, examiners may give candidates the benefit of the doubt and mark the crossed-out response where legible.

Rubric Error Responses – Optional Questions
Where candidates have a choice of question across a whole paper or a whole section and have provided more answers than required, then all responses are marked and the highest mark allowable within the rubric is given. Enter a mark for each question answered into RM Assessor, which will select the highest mark from those awarded. *(The underlying assumption is that the candidate has penalised themselves by attempting more questions than necessary in the time allowed.)*

Multiple-Choice Question Responses
When a multiple-choice question has only a single, correct response and a candidate provides two responses (even if one of these responses is correct), then no mark should be awarded (as it is not possible to determine which was the first response selected by the candidate).
When a question requires candidates to select more than one option/multiple options, then local marking arrangements need to ensure consistency of approach.

Contradictory Responses
When a candidate provides contradictory responses, then no mark should be awarded, even if one of the answers is correct.

Short Answer Questions (requiring only a list by way of a response, usually worth only one mark per response)
Where candidates are required to provide a set number of short answer responses then only the set number of responses should be marked. The response space should be marked from left to right on each line and then line by line until the required number of responses have been considered. The remaining responses should not then be marked. Examiners will have to apply judgement as to whether a 'second response' on a line is a development of the 'first response', rather than a separate, discrete response. *(The underlying assumption is that the candidate is attempting to hedge their bets and therefore getting undue benefit rather than engaging with the question and giving the most relevant/correct responses.)*

Short Answer Questions (requiring a more developed response, worth two or more marks)
If the candidates are required to provide a description of, say, three items or factors and four items or factors are provided, then mark on a similar basis – that is downwards (as it is unlikely in this situation that a candidate will provide more than one response in each section of the response space).

Longer Answer Questions (requiring a developed response)
Where candidates have provided two (or more) responses to a medium or high tariff question which only required a single (developed) response and not crossed out the first response, then only the first response should be marked. Examiners will need to apply professional judgement as to whether the second (or a subsequent) response is a 'new start' or simply a poorly expressed continuation of the first response.

6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there, then add the annotation 'SEEN' to confirm that the work has been seen and mark any responses using the annotations in section 11.

7. There is a NR (**No Response**) option. Award NR (No Response):

   - if there is nothing written at all in the answer space
   - OR if there is a comment which does not in any way relate to the question (e.g., 'can't do', 'don't know')
   - OR if there is a mark (e.g., a dash, a question mark) which is not an attempt at the question.

   Note: Award 0 marks – for an attempt that earns no credit (including copying out the question).

8. The RM Assessor **comments box** is used by your Team Leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**

9. Assistant Examiners will send a brief report on the performance of candidates to their Team Leader (Supervisor) via email by the end of the marking period. The report should contain notes on particular strengths displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

10. For answers marked by levels of response: Not applicable in F501
    To determine the level – start at the highest level and work down until you reach the level that matches the answer
    To determine the mark within the level, consider the following

Descriptor	Award mark
On the borderline of this level and the one below	At bottom of level
Just enough achievement on balance for this level	Above bottom and either below middle or at middle of level (depending on number of marks available)
Meets the criteria but with some slight inconsistency	Above middle and either below top of level or at middle of level (depending on number of marks available)
Consistently meets the criteria for this level	At top of level

11. **Annotations**

Annotation	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
BP	Blank Page
Seen	
Highlighting	

Other abbreviations in mark scheme	Meaning
dep*	Mark dependent on a previous mark, indicated by *. The * may be omitted if only one previous M mark
cao	Correct answer only
oe	Or equivalent
rot	Rounded or truncated
soi	Seen or implied
www	Without wrong working
AG	Answer given
awrt	Anything which rounds to
BC	By Calculator
DR	This question included the instruction: In this question you must show detailed reasoning.

Subject Specific Marking Instructions

a. Annotations must be used during your marking. For a response awarded zero (or full) marks a single appropriate annotation (cross, tick, M0 or ^) is sufficient, but not required.

For responses that are not awarded either 0 or full marks, you must make it clear how you have arrived at the mark you have awarded and all responses must have enough annotation for a reviewer to decide if the mark awarded is correct without having to mark it independently.

It is vital that you annotate standardisation scripts fully to show how the marks have been awarded.

Award NR (No Response)
- if there is nothing written at all in the answer space and no attempt elsewhere in the script
- OR if there is a comment which does not in any way relate to the question (e.g. 'can't do', 'don't know')
- OR if there is a mark (e.g. a dash, a question mark, a picture) which isn't an attempt at the question.

Note: Award 0 marks only for an attempt that earns no credit (including copying out the question).

If a candidate uses the answer space for one question to answer another, for example using the space for 8(b) to answer 8(a), then give benefit of doubt unless it is ambiguous for which part it is intended.

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 always 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, escalate the question to your Team Leader who will decide on a course of action with the Principal Examiner.

If you are in any doubt whatsoever 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, e.g. 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 method mark may usually be implied by a correct answer unless the question includes the DR statement, the command words “Determine” or “Show that”, or some other indication that the method must be given explicitly.

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.

Unless otherwise indicated, marks once gained cannot subsequently be lost, e.g. 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, what is acceptable will be detailed in the mark scheme. If this is not the case please, escalate the question to your Team Leader who will decide on a course of action with the Principal Examiner.

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. We are usually quite flexible about the accuracy to which the final answer is expressed; over-specification is usually only penalised where the scheme explicitly says so.
   - When a value is **given** in the paper only accept an answer correct to at least as many significant figures as the given value.
   - When a value is **not given** in the paper accept any answer that agrees with the correct value to **3 s.f.** unless a different level of accuracy has been asked for in the question, or the mark scheme specifies an acceptable range.
     NB for Specification B (MEI) the rubric is not specific about the level of accuracy required, so this statement reads "2 s.f".

   Follow through should be used so that only one mark in any question is lost for each distinct accuracy error.
   Candidates using a value of 9.80, 9.81 or 10 for g should usually be penalised for any final accuracy marks which do not agree to the value found with 9.8 which is given in the rubric.

g. Rules for replaced work and multiple attempts:
   - If one attempt is clearly indicated as the one to mark, or only one is left uncrossed out, then mark that attempt and ignore the others.
   - If more than one attempt is left not crossed out, then mark the last attempt unless it only repeats part of the first attempt or is substantially less complete.
   - if a candidate crosses out all of their attempts, the assessor should attempt to mark the crossed out answer(s) as above and award marks appropriately.

h. For a genuine misreading (of numbers or symbols) which is such that the object and the difficulty of the question remain unaltered, mark according to the scheme but following through from the candidate's data. A penalty is then applied; 1 mark is generally appropriate, though this may differ for some units. This is achieved by withholding one A or B mark in the question. Marks designated as cao may be awarded as long as there are no other errors. If a candidate corrects the misread in a later part, do not continue to follow through. Note that a miscopy of the candidate's own working is not a misread but an accuracy error.

i. If a calculator is used, some answers may be obtained with little or no working visible. Allow full marks for correct answers, provided that there is nothing in the wording of the question specifying that analytical methods are required such as the bold "In this question you must show detailed reasoning", or the command words "Show" or "Determine". Where an answer is wrong but there is some evidence of method, allow appropriate method marks. Wrong answers with no supporting method score zero. If in doubt, consult your Team Leader.

j. If in any case the scheme operates with considerable unfairness consult your Team Leader.

Question	Answer	Marks	AO	Guidance
1	$y = 5.75 + 1.91176x$ BC or $y = \frac{23}{4} + \frac{65}{34}x$	**B2**	**1.1** **1.1**	If B0, allow B1 for correct gradient seen anywhere. Allow a in range [5.748, 5.77]. If letters wrong, B1. Can be implied by correct estimate with no working.
	Substitute $x = 8.5$	**M1**	**1.1**	Can be implied
	$y = 22$	**A1** **[4]**	**1.1**	Awrt 22.0, cwo. Allow 4 for correct answer from no working or from means only. NB: can get 22 from wrong gradient: B0B0M1A1. Correct gradient and wrong intercept should lead to wrong answer: B0B1 M1A0. But 22 can be obtained directly BC: B0B1 M1A1 Correct gradient, wrong intercept: probably B0B1M1A0.

Question		Answer	Marks	AO	Guidance
2	(a)	Po(12) P(16 < X < 20) = 0.08(00) BC	M1 A2 [3]	3.4 1.1 1.1	Po(12) or Po(3×4) stated or implied, e.g. by any of answers listed below Awrt 0.0800, e.g. 0.08, 0.080, www 0.0897, 0.134, 0.144, or 0.080xx wrong in 3rd SF: M1A1A0
2	(b)	$e^{-36}\frac{36^z}{z!}$	M1 A1 [2]	1.1 1.1	Correct formula, any appropriate letter and number (e.g. 12) 36 and z correct
2	(c)	The sum of independent Poisson random variables has a Poisson distribution	B1 [1]	2.4	Need to mention "independent", or explanation, e.g. "number of trees in A does not affect number of trees in B (and vice versa)". *Not* focus on each separately being independent. Allow "Variables independent", but *not just* "they are independent". Ignore irrelevant statements but don't award if contradictory or wrong.
2	(d)	E.g. $Y - X$ can take negative values, *or* 12 ≠ 36 so mean ≠ variance, etc	B1 [1]	2.4	*Ignore* argument based on modelling assumptions; explanation must be capable of definite reason why not Poisson. Allow for 8 – 4 ≠ 8 + 4 but not other wrong values. Allow "Var($X + Y$) ≠ Var($Y - X$)". *Not* "probability can be negative". *Not* mean < 0. *Not* "12 not close to 36"

Question			Answer	Marks	AO	Guidance
3	(a)		H_0: $\mu = 13.2$, H_1: $\mu \neq 13.2$, where μ is the population mean length of lizards in the remote location	**B2**	**1.1** **2.5**	One error, e.g. "population" or context not mentioned: B1 Allow "H_0: Mean length of lizard is 13.2, H_1: Mean length of lizard is not 13.2" oe. $\bar{x}$ or x or z used: B0 unless "population" stated
			$z = (14.02 - 13.2)/(3.4/\sqrt{50})$ (var = $\frac{289}{1250}$) Likely p-values for M1A0: 0.0457, 0.0914, 0.00083, 0.00166, 0.0945 (from t)	**M1**	**3.3**	Can be implied by answer. If $\sqrt{(11.8/50)} = 3.43/\sqrt{50}$ used (spurious $n/(n-1)$), leading to $z = 1.688$ or $p = 0.0457$, can get M1A0 and rest of marks. $2p = 0.00083$ (from $\sigma = 3.4$): M1. Other values: need evidence of 50 or $\sqrt{50}$ for M1 (and final M1).
			$2p = 0.0881$ or $p = 0.04406$ or $z = 1.705...$ BC	**A1**	**3.4**	$2p \in [0.088, 0.0882]$ or $p \in [0.044, 0.0441]$ or $z \in [1.70, 1.71]$.
			$2p > 0.05$ or $p > 0.025$ or $z < 1.96$	**A1**	**1.1**	Explicit like-with-like comparison, allow 0.05 if their "2×0.04405" used. 0.04405 < 0.05 is A0 here (but can get final M1A1).
			Or $13.2 + z \times 3.4/\sqrt{50}$	**M1**		Must be centred on 13.2 (not 14.02 but can get final M1A1) with $\sqrt{50}$ or 50
			$z = 1.96$	**B1**		Can be given for $14.02 - 1.96 \times 3.4/\sqrt{50} = 13.077$
			$14.14 > 14.02$	**A1ft**		FT on their 1.96, e.g. $13.99 < 14.02$ from 1.645
			Do not reject H_0. Insufficient evidence that mean length of lizards in the remote location is not 13.2 cm.	**M1ft** **A1ft** **[7]**	**1.1** **2.2b**	FT on their TS if first M1 earned. Contextualised, not too assertive, not "significant evidence that mean length is 13.2". *Not* "may be …" Wrong first conclusion: M0A0. Inconsistent interpretation, or based on hypotheses wrong way round, etc: M1A0. NB 1.645/0.05 used: Reject H_0, significant evidence ...: M1A1 SC: P($\bar{X} > 13.2$ from N(14.02, 0.2313): m ax (B2) M0B1A0 M1A1
3	(b)	(i)	50 is large/larger than 25	**B1** **[1]**	**2.4**	Allow "n is large" (provided "population" not seen) or "sample is large". *Not* "population is large". If numerical comparison used, must be with 20 or 25 or 30. Allow ≥ 25, etc. No wrong extras (e.g. "sample is approx. normal" or "not told that population is normal").
3	(b)	(ii)	The (distribution of the) sample mean can be assumed to be (approximately) normal, *or* CLT used when using $\bar{L}$ ~ N(...)	**B1** **[1]**	**1.1**	Must mention sample mean or $\bar{L}$ or $\bar{X}$ or similar. No wrong extras, e.g. mention of parameters, though BOD for "$\bar{X} \sim N(13.2, 3.4^2/50)$". *Not* "<u>sample</u> is normally distributed" or "it is normally distributed".

3(a) exemplars: ***Hypotheses:***

	Their hypotheses	Comments	Mark
i	H_0: $\mu = 13.2$, H_1: $\mu \neq 13.2$, where μ is the population mean length of lizard	Correct	B1B1
ii	H_0: $\mu = 13.2$, H_1: $\mu \neq 13.2$	No definition	B1
ii′	H_0: $\mu = 13.2$, H_1: $\mu \neq 13.2$, where μ is the population mean	No context	B1
iii	H_0: $\mu = 13.2$, H_1: $\mu > 13.2$	Two errors: one-tailed, μ not defined	B0
iv	H_0: $\mu = 13.2$, H_i: $\mu \neq 13.2$, where μ is the mean length of lizard	BOD	B1B1
iv′	H_0: $m = 13.2$, H_i: $m \neq 13.2$, where m is the mean length of lizard	Not BOD: needs "population"	B1B0
v	H_0: $\mu = 13.2$, H_i: $\mu \neq 13.2$, where μ is the sample mean length of lizard	"sample" is wrong	B1
vi	H_0: The mean length of lizard is 13.2, H_1: The mean length of lizard is not 13.2	OK, BOD as *iv* above	B1B1
vii	H_0: The average length of lizard is 13.2. H_1: average length of lizard is not 13.2	Not "mean"	B1
viii	H_0: There is no change in the mean length of lizard, etc		B1
viii′	H_0: There is no change in the mean, H_1: the mean has changed	No context	B0
ix	H_0: There is no evidence that the mean length of lizard is not 13.2, etc	"Evidence" doesn't belong in hypotheses	B1
x	Hypotheses stated in terms of 14.02 or $\bar{x}$ or x or z	(unless $\bar{x}$ or x or z defined as population)	B0

Calculations (assuming no other evidence of using correct formula for z):

	Their calculation	Comments	Mark	Can get last M1A1?
i	$z = 1.705$ or $p = 0.0441$	Correct	Full marks	Yes
ii	$p = 0.0881 > 0.05$	Correct	Full marks if compared with 0.05	Yes
iii	$p = 0.0457 > 0.025$	Spurious 50/49 used	M1A0	Yes
iv	$p = 0.0914 > 0.05$	Spurious 50/49 used	M1A0	Yes
v	$z = 0.241$ or $p = 0.4047$ or 0.328	Divisor 50 omitted	M0A0A0	No
vi	Other values of z or p	0 unless they show evidence of using $\sigma/\sqrt{50}$ or $\sigma^2/\sqrt{50}$ or $\sigma^2/50$ or $\sigma/50$, in which case they can get M1A0		No unless evidence as in previous column, in which case yes
vii	CV $13.2 - 1.96\times3.4/\sqrt{50}$ (= 12.25) $12.25 < 14.02$	Wrong tail for CV	M0 B1 A0	No
viii	$13.2 + 1.645\times3.4/\sqrt{50}$ (= 13.99) $13.99 < 14.02$ (Reject H_0, etc)	1.645 wrong	M1B0A1 (ft on 1.645)	Yes (Conclusion reversed)
ix	$14.02 - 1.96\times3.4/\sqrt{50}$ (= 13.077) $13.077 < 13.2$	Confidence interval, not critical value	M0B1A0 Same marking for H_0: $\mu = 14.02$	Yes

Comparisons:

	Their comparison	Comments	Mark	Can get last M1A1?
i	$1.705 < 1.96$	Correct	M1A1A1	Yes
ii	$1.705 > 1.645$	Wrong z_{crit}	M1A1A0	Yes
iii	$0.0441 > 0.025$	Correct	M1A1A1	Yes
iv	$0.0881 > 0.05$	Correct	M1A1A1	Yes
v	$0.0881 > 0.025$	Wrong mix of p and p_{crit}	M1A1A0	Yes
vi	$0.0441 < 0.05$	Wrong mix of p and p_{crit}	M1A1A0	Yes
vii	$0.0881 < 0.95$	Wrong tail	M1A1A0	No
viii	$0.0441 < 1.96$	Not like-with-like	M1A1A0	No

Conclusions:

	Their conclusion	Comments	Mark
i	Accept H_0. There is insufficient evidence that mean length is not 13.2	Correct, allow "accept H_0" and no mention of "lizard".	M1A1
ii	There is insufficient evidence that μ is not 13.2	No context. Condone omission of "do not reject H_0"	M1A0
iii	Do not reject H_0. There is significant evidence that the mean length is 13.2	Wrong conclusion	M1A0
iv	Do not reject H_0. The mean length of lizard in this location is 13.2	Too assertive (need double negative)	M1A0
iv′	Do not reject H_0. The mean length of lizard in this location may be 13.2	Doesn't tell us anything	M1A0
v	Insufficient evidence to reject H_0. Mean length can be assumed to be 13.2	BOD	M1A1
vi	Accept H_0. There is insufficient evidence that length of lizard has changed	BOD	M1A1
vii	*(following use of 1.645 and/or one-tail:)* Reject H_0. There is significant evidence that the length of lizard is greater than 13.2	Consistent, ft	M1 A1

Question		Answer	Marks	AO	Guidance
4	(a)	N(546, ...	M1	3.1a	Normal, mean 546, stated or implied
		..., 157)	A1	1.1	Variance 1009 is from $5^2\times3^2 + 7^2\times4^2$: (M1)A0A0 Allow 12.53 (= σ) if answer implies that 12.53^2 is meant (e.g. 0.868) Allow even if 157 seems to be standard deviation. Otherwise, withhold if wrong variance used (e.g. 157/5) even if correct variance seen. SC: Wrong mean but variance correct: SC B1
		P(> 560) = 0.132 **BC**	A1 [3]	1.1	Awrt 0.132. 0.464 is from σ = 157: M1A1A0. 0.330 is from N(546, 1009): M1A0A0 SC: If no working seen, 0.132 gets full marks, 0.868 gets M1A1A0.
4	(b)	$X - 0.6Y$ (or $0.6Y - X$, oe)	M1	3.1a	Consider this or equivalent single linear RV, e.g. $5X - 3Y$ or $\frac{5}{3}X - Y$ Allow for $0.6X - Y$ etc, but *not* $5V - 4.2W$.
		~ N(8.4, ...	A1	1.1	Or N(–8.4, …). Can be scaled depending on alternative $X - 0.6Y$, e.g. $(5X - 3Y) \sim N(42, 2133)$, or $\frac{5}{3}X - Y \sim N(14, 237)$
		..., 85.32) or $\frac{2133}{25}$	A1	1.1	Can be scaled: (√Var) ÷ mean should equal 1.0996… Variance 507.24 from $5^2\times3^2 + 0.6^2\times7^2\times4^2$: (M1A1)A0A0 Allow 9.24 (= σ) if answer implies that 9.24^2 is meant, e.g. 0.818) Withhold if correct variance seen but different variance/SD used, e.g. 85.32/5
		P(< 0) = 0.181(57) **BC**	A1 [4]	1.1	In range [0.181, 0.182] Answer 0.461 is from σ = 85.32: M1A1A1A0. 0.355 is from N(8.4, 507.24): M1A1A0A0 SC: If no working seen, 0.182 gets full marks, 0.818 gets B2

Question		Answer	Marks	AO	Guidance
5	(a)	The sample size 12 is too small for CLT to apply *or* it is not known that the distribution is normal.	**B1** **[1]**	**2.4**	Needs to refer to small sample and CLT, or "not known population normal", but allow "*n* too small". *Not* "too small to approximate data". No wrong extras. Numerical comparison must be with 20 or 25 or 30.
5	(b)	H_0: $m = 1.52(\times 10^5$ km), H_1: $m > 1.52$ where m is the population median of the lifespan of new tyres	**B1**	**1.1**	Needs context. Can be in words; allow "median lifespan the same", etc. If m or "median", allow no mention of population. Allow μ or "mean" only if "population" stated. *Not* "evidence that ..."
		Ranks –7, –5, –3, 1, 2, 4, 6, 8, 9, 10, 11, 12	**M1**	**1.1**	Attempt to rank absolute differences from 1.52 and attach signs 1+2+3 = 6: max (B1)M0B1. 6+8+10 = 24: max (B1)M1A0B1A1M0A0.
		$\Sigma Q = 15$	**A1**	**1.1**	Correct test statistic, allow P and Q interchanged if correct
		$\Sigma P = 63$ so use ΣQ	**B1ft**	**1.1**	Both ΣQ and ΣP ($= 78 - \Sigma Q$) considered (independent of previous A1)
		$15 \leq$ CV 17	**A1**	**1.1**	Smaller signed rank sum (≤ 39) explicitly compared with 17. Allow <.
		Reject H_0. Significant evidence that the new make produces an improvement/median lifespan is greater than 1.52×10^5.	**M1** **A1ft** **[7]**	**1.1** **2.2b**	FT on *their* 15 and on CV 13, if first M1 gained, but *not* other CVs Contextualised, not too assertive (needs "evidence" or equivalent). *Not* "may have" improved. 3 and 9 (sign test): max B1M0B0M0 FT on their 15 provided both M1s gained.
5	(c)	Wilcoxon uses more information/magnitude of differences	**B1** **[1]**	**2.4**	OE. Allow "differences from median/mean".

5(b) exemplars: ***Hypotheses:***

	Their hypotheses	Comments	Mark
i	H_0: there is evidence that ...	Not "evidence" in hypotheses	B0
ii	H_0: new tyres haven't improved the lifespan, H_1: they have improved it	Needs some reference to parameter	B0
iii	H_0: average lifespan of new tyres is 1.52×10^5, H_1: average lifespan $> 1.52\times 10^5$	Not "average"	B0
iv	H_0: $\mu = 1.52$, H_1: $\mu > 1.52$, where μ is the average lifespan of new tyres	Not μ + average	B0
v	H_0: $\mu = 1.52$, H_1: $\mu > 1.52$, where μ is the population mean lifespan of new tyres	Needs "population" if μ used	B1
vi	H_0: $m = 1.52$, H_1: $m > 1.52$, where m is the average lifespan of new tyres	BOD	B1
vii	H_0: median lifespan = 1.52, H_1: median lifespan > 1.52	Correct	B1
viii	H_0: new tyres have same distribution as old, H_1: they don't	Wrong: that's for the rank-sum test	B0
ix	H_0: $m_d = 0$, H_1: $m_d > 0$, where m_d is the difference in median lifespans	BOD	B1
x	H_0: median lifespan of new tyres is the same, H_1: it's greater		B1

Question		Answer	Marks	AO	Guidance
6	(a)	Would result in 0 degrees of freedom	B1 [1]	2.3	Or "there would be nothing to compare", "test is for difference between these variables", OE. *Not just* "only one row" – more needed.
6	(b)	Expected frequencies in one of the top-row cells is 3.75 (or 2.8125)	M1	3.1b	Find at least one relevant expected frequency (*not* observed frequency). Not for just *stating* "one value less than 5" (see next mark).
		which is less than 5	A1 [2]	2.4	3.75 or 2.81 or better, and at least one stated as < 5 SC: State "one <u>expected</u> frequency is less than 5", no working: B1
6	(c)	H_0: no association between type of article and background of author; H_1: there is association	B1	1.1	Context needed. Allow "type of article and background independent", but not "no correlation between ..."
		Expected frequencies: 8.4375, 6.5625, 27.5625, 21.4375	M1	3.3	Evidence for correct calculation method, e.g. $p = 0.147$ or 0.0806 from no or wrong Yates. *Not* from wrong method for expected frequencies. No working (common): allow M1 *only if* one of these ΣX^2 seen: 1.33, 2.10, 2.13, 2.25 or 3.057, or corresponding p. Can get M1 even if 0.5 wrong, e.g. $[(6 - 8.4375)^2/8.4375 - 0.5] + ...$
		X^2 0.4449, 0.5720, 0.1362, 0.1751 = $\frac{961}{2160}$, $\frac{961}{1680}$, $\frac{961}{7056}$, $\frac{961}{5488}$			
		So $\Sigma X^2 = 1.328(237)$ or $p = 0.249$ BC	A1	1.1	ΣX^2, awrt 1.33, or p ($\Sigma X^2 = 2.1022$ from no Yates is M1A0).
		$\Sigma X^2 < 2.706$ or $p > 0.1$	B1	3.4	Correct comparison between *their* 1.328 and 2.706 or *their* 0.249 and 0.1, like-with-like (e.g., *not* 1.328 > 0.1). Must be recognisable attempt at ΣX^2.
		Do not reject H_0. Insufficient evidence of association between type of article and background of author	M1	1.1	FT on wrong ΣX^2 provided $1.3 \le \Sigma X^2 \le 3.06$, *or* if correct working seen for first M1, but needs CV 2.706 or 3.841 (or 0.1). *Allow* from combining first two columns (if clearly seen) *Not* from omitting a column, or from just 2 cells combined.
			A1ft	2.2b	Contextualised, not too assertive, *not* "evidence of no association". "Insufficient evidence that they are not independent" is correct
			[6]		SC: combine first two columns: B1M0A0B1M1A1 SC: combine two cells only (not columns): B1M1A0B1M0A0 SC: not combined, compare with 4.605: B1M0A0B0M1A1

Question		Answer	Marks	AO	Guidance
7	(a)	H_0: $\rho_s = 0$, H_1: $\rho_s > 0$, where ρ_s is the population SRCC between the competitors (in all races of which these two are samples) *Or:* H_0: there is no correlation between (ranks of) competitors' positions, H_1: there is positive correlation between them	**B1**	**1.1**	Some context. Needn't define ρ_s or ρ, but not r_s or r unless fully defined. Allow in words: H_0: there is no agreement between the finishing positions, H_1: there is agreement. ("Agreement" implies "positive".) If "association/correlation", H_1 must say "positive". *Not* "data". Allow "H_0: positions are independent", but H_1 must be clearly 1-tailed.
		CV 0.8286	**B1**	**1.1**	Only this. SC: H_1 is 2-tailed (including "there is association"): give B1 for CV 0.8857, B0 for 0.8286
		0.771 < 0.8286 so do not reject H_0.	**M1**	**1.1**	0.8857 used: can get M1A1. Any other CV: M0A0.
		Insufficient evidence of agreement between the finishing positions.	**A1** **[4]**	**2.2b**	Contextualised, not too assertive, *not* "significant evidence of no agreement". Needn't include "positive" here.
7	(b)	Possible rankings, against 123, are 123, 132, 213, 231, 312, 321	**M1**	**3.1a**	At least 4 needed. Allow from 6 competitors. Allow directly from values of d only if they are (unordered) (2 0 2), (2 1 1), (0 0 0), (0 1 1).
			A1	**1.1**	All of these 6 and no others, *not* directly from values of d
		Values of Σd^2 are 0, 2, 2, 6, 6, 8	**M1**	**1.1**	Find Σd^2 for *their* rankings, independent of previous marks
		Only 4 possible values of Σd^2 (so only 4 possible values of r_s)	**A1**	**3.2a**	All 4 correct different values, no others. Allow if all 4 seen even if not all 6 combinations considered. No statement needed.
		Corresponding values if r_s are 1, ½, –½, –1	**A1** **[5]**	**2.2a**	CWO (i.e., needs all 6 combinations and no others). SC: If Σd^2 not seen, give max M1A1 M0A0B1 if all four r_s correct www.

7(b) ***Exemplars:***

i	Possible ranks 1 2 3, 1 3 2, 3 2 1, 3 1 2 $\Sigma d^2 = 0, 2, 8, 6$ $r_s = 1, 0.5, –1, –0.5$	M1A0 M1A1 A0 cwo
ii	4 possible differences: (2 2 0), (2 1 1), (0 0 0), (0 1 1) $\Sigma d^2 = 8, 6, 0, 2$ $r_s = –1, –0.5, 1, 0.5$	M1A0 M1A1 A0

iii	Possible differences are 0, 1 or 2 so Σd^2 could be 0, 1, 2, 3, 4, 5, 6 or 8 (or 9 or 12) r_s = (probably only 4 of) 0, ±½, ±¾, ±1	M0 A0 M1A0A0
iv		

Question		Answer	Marks	AO	Guidance
8	(a)	$\int_0^1 (k+1)x^k \mathrm{d}x = \left[x^{k+1}\right]_0^1$	M1	3.1a	Attempt to integrate general f(x), limits 0 and 1 seen somewhere
		$= 1$	A1	1.1	Correctly obtain 1, no conclusion needed. SC: "F(1) = 1": B1.
		f(x) ≥ 0 for all $0 \le x \le 1$ (and for all $k > 0$)	B1 [3]	2.4	OE, stated, no conclusion needed. Allow "F(0) = 0 and F(x) increases". Allow "f(x) > 0". *Not* "k must be positive as otherwise f(x) could be negative"
8	(b)	E(X) = $\int_0^1 4x^4 \mathrm{d}x = \frac{4}{5}$ or 0.8 BC	M1 A1	3.3 1.1	Either this or integral expression for E(X^2) correct, soi, limits 0 and 1 seen Correct answer, exact only, allow $(k + 1)/(k + 2)$
		E(X^2) = $\frac{2}{3}$ BC	A1	1.1	Exact or awrt 0.667, allow $(k + 1)/(k + 3)$. "Var(X) = $\frac{2}{3}$" gets M1A1.
		Var(X) = E(X^2) – [E(X)]^2	M1	2.1	Used, allow if no limits used, e.g. for $\frac{2}{3}x^6 - \frac{16}{25}x^{10}$
	Or	Var(X) = $\int_0^1 4x^3(x - \frac{4}{5})^2 \mathrm{d}x$	M1		Correct limits, *their* $4x^3$, *their* $\frac{4}{5}$
		$= \int_0^1 4x^5 - \frac{32}{5}x^4 + \frac{64}{25}x^3 \mathrm{d}x$	A1		Or exact equivalent, can be implied by correct answer
		= $\frac{2}{75}$ or 0.0266...	A1 [5]	3.4	Exact or awrt 0.0267
8	(c)	$\int_0^{0.8203} (k+1)x^k \mathrm{d}x = 0.5$	M1	3.1b	Correct limits seen somewhere. Allow if $(k + 1)$ omitted.
		$0.8203^{k+1} = 0.5$ and solve	M1	2.1	Equation of form $0.8203^r = 0.5$ and find solution, any method
		$k = 2.5$ (2.4992...)	A1	1.1	Awrt 2.50, allow for $k + 1 = 3.50$
		$m^{3.5} = 0.7$	M1	1.1	$m^{\textit{their } 2.5 + 1}$. Also allow for $m^{2.5}$, $m^{4.5}$ etc.
		$m = 0.903(11...)$ or $0.903(09...)$	A1 [5]	2.2a	Awrt 0.903, CWO NB: SC: $0.5^{k+1} = 0.8203 \Rightarrow k + 1 = 0.2857 \Rightarrow 0.7^{k+1} = 0.903$. This gets 0. Use of normal distribution (which may give 0.906) is M0. MR 0.823, giving $k + 1 = 3.558$ and $m = 0.9046$: M1M1A0M1A1

Question		Answer	Marks	AO	Guidance
9	(a)	Poisson would have E(X) = Var(X)	M1	1.2	Stated or implied, allow if sample values implied. Allow $\hat{\sigma}^2 = 3.59$.
		Either: Close so Poisson (fairly) consistent *Or:* Not very close so Poisson (fairly) inconsistent	A1	2.2b	Assessment and single nuanced conclusion, allow "Closer than 12.28 and 3.51 so may be consistent", etc. *Not* from just "4.04 ≠ 3.5184", even if "could be modelled approximately". "May/may not": A0A1
		Geometric would have $1/p = 4.04$ and $q/p^2 = 3.5184$ *or* $1/p = 4.04 \Rightarrow p = 0.2475 \Rightarrow$ variance = 12.28 OE	M1	1.1	Use both formulae, e.g. $p = 0.2475$ from mean and 0.4096 from variance (0.4065 from unbiased estimate)
		E.g. $p \approx 0.25$ (0.2475) so $q/p^2 \approx 12$(.28) which is not close to 3.5 (or 3.51, 3.59) so unlikely to be Geometric	A1 [4]	2.2b	Correct calculation, "not close" OE, and "Geometric unlikely" oe. Allow "not consistent with ...". *Not* from just "0.2475 ≠ 12.28" etc.
	Or	Var/mean^2 = q = 0.2156 ⇒ p = 0.7844, so estimate mean = 1.28 (and var = 0.3584), not close to data, so unlikely to be Geometric	M1 A1		Use both formulae Correct calculation, comment and conclusion as above
	(b)	Use Poisson distribution to find e.g. 50×Po(4.04) or Po(4)	M1*	3.3	Or other Poisson. No marks for using sample mean/variance. *Or*: Poisson increases then decreases, or maximum close to mean: M1M0 (*not* "symmetric", but allow "roughly symmetric")
		Po(4): 0.88, 3.55, 7.18, 9.67, 9.77, 7.89, 5.31, 3.07, 1.55, 1.13 Po(4.04): 0.92, 3.66, 7.33, 9.77, 9.77, 7.81, 5.21, 2.98, 1.49, 1.07 which are fairly close to data	depM1	3.4	Compare at least 2 probabilities or frequencies from Po(4) or Po(4.04) with data, like-with-like, and comment on closeness. Withhold if numbers clearly wrong.
		Geometric probabilities (or frequencies) should decrease, so unlikely to be geometric *Or:* Geometric expected frequencies (0), 12.38, 9.31, 7.01, 5.27, 3.97, 2.99, 2.25, 1.69, 5.14 which are not close to the observed frequencies	M1	3.5a	Reason for very probably not Geometric (*not* "not geometric") E.g. calculate 50×probabilities and compare at least 2 non-zero, or e.g. from two solving equations of the form $(1-p)^{n-1}p$ = freq/50 Allow "consistent with", "valid" or "can be modelled by" as sufficiently nuanced. No marks for sample mean/variance.
		Distribution could be Poisson, unlikely to be geometric	A1 [4]	3.5a	Poisson chosen but nuanced, needs consideration of geometric as well, at least 2 of the previous 3 marks.
		SC can't be Poisson as mean ≠ variance M1A0 Geometric mean and variance M1A1 as in **(a)** Find Geometric expected frequencies M1 Reason for not geometric, so probably neither M1A0			(If omitted, M0 but can get final M1) Max 5/8
		Ignore statement that from Geo, P(0) = 0			No marks for carrying out a chi-squared test. "Consistent for some values, not others": max M0, M1M1A0.

9(a): ***Exemplars***

i	$1/p = 4.04 \Rightarrow p = 0.2475$, $(1-p)/p^2 = 3.5184 \Rightarrow p = 0.410$. $0.2475 \neq 0.410$ so probably not geometric *or* not consistent with geometric $4.04 \neq 3.5184$ so probably not Poisson *or* not consistent with Poisson	M1 A0 M1A0
ii	$1/p = 4.04 \Rightarrow p = 0.2475 \Rightarrow \text{Var}(x) = (1-p)/p^2 = 12.28$ $5.5184 \neq 12.28$ so not close enough to be geometric $4.04 \neq 3.5184$ so close enough to be Poisson	M1 A1 M1A1

9(b): ***Exemplars***

i	Anything using only means and variances	0
ii	Geometric frequencies/probabilities decrease so not consistent with geometric Poisson probabilities roughly symmetrical so consistent with Poisson (Same for "Poisson probabilities increase then decrease")	M1 M1bod M0A1
iii	Geometric frequencies/probabilities decrease so not consistent with geometric Poisson probability greatest close to mean so consistent with Poisson	M1 M1M0 A1
iv	Geo(0.2475): P(1) = 0.2475, not close to 0.08. P(> 8) = 0.103, not close to 0, so can't model with geometric. Po(4.04): P(1) = 0.088, close to 0.08. P(> 8) = 0.009, closer to 0 Can be modelled by Poisson	M1 M1M1 A1
v	Geometric: $(1-p)p = 0.14$, $(1-p) = 0.08$ so $p = 0.571$ From Geo(0.571), $(1-p)^2p = 0.105$ which is not close to 0.1 so geometric unlikely Poisson: $e^{-\lambda}\lambda = 0.08$, $e^{-\lambda}\lambda^2/2 = 0.14$ so $\lambda/2 = 1.75$ and $\lambda = 3.5$. From Po(3.5), $e^{-\lambda}\lambda^3/6 = 0.216$ which isn't too far from 0.1 so may be consistent with Poisson	 M1 M1 M1A1

Acceptable conclusions: Poisson: is consistent with, is valid, can be modelled by, a better model; Geometric: is not consistent with, etc
Not acceptable: It is Poisson, it is probably Poisson, it isn't Geometric, etc.

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